ISSN: 0212-8799
187
Volume 35(5)
September - October 2018

Archivos de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

ORIGINALS

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Correspondencia:
Ap. de correos 1207
31080 Pamplona (España)

Publicidad
ESMON PUBLICIDAD
Tel. 93 2159034

Publicación bimestral
Un volumen por año

Depósito Legal
Pamplona. NA 123. 1984

ISSN
0212-8799

Soporte válido
Ref. SVR 389

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

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

Archivos de medicina del deporte

Revista de la Sociedad Española de Medicina del Deporte

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

Archivos
de medicina del deporte

Volumen 35(5) - Núm 187. September - October 2018 / *Septiembre - Octubre 2018*

Summary / Sumario

Editorial

Combining exercise and diet to prevent and treat non-communicable chronic diseases

La combinación de ejercicio y nutrición en la prevención y tratamiento de enfermedades crónicas no transmisibles

Marcela González-Gross

Catedrática de Nutrición Deportiva y Fisiología del Ejercicio de la Universidad Politécnica de Madrid. Responsable del grupo de investigación ImFINE. Vicepresidenta de la Sociedad Española de Nutrición. Tesorera de la red EXERNET. Manager científico de Exercise is Medicine Spain.

An increase in life expectancy and non-communicable chronic diseases (obesity, type-2 diabetes, heart disease, cancer, dementia, depression) has heightened the prominence of both Sport Sciences and Nutritional Sciences in terms of research and Public Health. Yet the lack of connection and collaboration between these two fields has meant that the majority of scientific studies carried out analyse aspects separately. The current state of scientific knowledge appears to indicate that the correct path to follow is to address these issues together, though, clearly, new questions would arise by combining them both. Exploring all of them would divert from the objective and there is not enough space available in this editorial to do so, but we will cover some brief points that can be transposed to the rest.

When it comes to preventing obesity, most studies performed on all age groups conclude that regular physical exercise leads to lower fat mass and greater lean fat percentages, regardless of quality of diet. If we analyse the relationship between intake and expenditure, more active individuals tend to have a lower body fat percentage and ingest more Kcal than inactive individuals, as we demonstrated in the group of adolescents in the HELENA study (Cuenca-Garcia *et al.* 2014), and in the group of adults in the PHYSMED study (Aparicio-Ugarriza *et al.* 2018), data that has been supported by others. Regrettably, very few nutritional studies include information about physical activity and energy expenditure, as we have seen in a review we are carrying out (González-Gross *et al.* unpublished data). Among the studies that do include physical activity (PA) measurements, the majority do not include this data when making conclusions. Similarly, a study carried out in Finland concluded that the adults that followed a traditional Scandinavian diet more closely displayed a lower abdominal fat percentage, though the fact that this group was also more physically active was not taken into account (Kanerva *et al.* 2012). Therefore, it makes no sense to allege that a certain food or even a type of diet "leads to weight gain" without considering the energy expenditure and the type of exercise carried out by an individual or a group of subjects. Likewise, a reduction in energy intake generally leads to a reduction of PA, both EAT and NEAT, and therefore the output, reducing the possible effect on the energy balance.

With regards to treating obesity, particularly in the early stages, physical exercise should not be recommended/prescribed unless the response that this exercise is going to have on the subject's hunger and appetite is known. Many studies indicate that in its acute state, exercise inhibits appetite-stimulating hormones such as ghrelin, and stimulates appetite inhibitors such as PYY or GLP-1 (Schubert *et al.* 2014), delaying post-exertion meals but not affecting the energy intake. However, there are studies that reveal contrary findings. In the long term, it is suggested that the relationship between PA and appetite is J-shaped, though the data is not conclusive. Proposals by authors such as Blundell are particularly interesting, suggesting that the responders and non-responders should be differentiated, both in terms of diet and exercise. In some studies, some subjects even gain weight. Here once again we must emphasise the improvement of scientific methodology, as many studies use the BMI as an indicator even though it has been proven that the fat % should be used, as a loss of fat mass and lean fat gain is usually accompanied by weight gain, rendering the BMI figure invalid. Here is it also worth mentioning the loss of lean fat associated with weight loss. In a recent systematic review, it is even questioned whether physical exercise can be used as a way of increasing appetite among older demographics, but the authors conclude that there is

Correspondence: Marcela González-Gross
E-mail: marcela.gonzalez.gross@upm.es

not enough data to back up this hypothesis (Clegg and Godfrey, 2018). The hunger-appetite-exercise relationship undoubtedly requires more research, though a quick look on MedLine indicates that work is being carried out on both high performance demographics and the general public. The inclusion of information differentiating age, sex and level of training is an essential requisite.

Today, it is estimated that after 5 years, 90% of patients that have followed a weight-loss diet, even with exercise, recover the weight lost. Research on the type and intensity of the exertion, along with an optimum dietary combination, is a challenge that will no doubt help improve statistics in the post-weight-loss maintenance phase. A recent publication from the DIOGenes study indicates that the amount and type of protein consumed may be relevant in managing cardio-metabolic and obesity risk factors during this maintenance phase. A lack of data about PA is preventing advances from being made in the interaction in question.

The physiological processes associated with ageing are also driving lines of research in to how to halt, slow down or even prevent these processes from occurring. Sarcopenia is defined by the European Work Group on Sarcopenia in Older People (EWGSOP) as decreased muscle mass associated with less exertion and performance. It is a stimulus for research in both nutrition and the physiology of exercise. In the field of nutrition, studies are being carried out on the quality and quantity of protein that should be ingested to avoid or to revert sarcopenia, as well as how this intake should be distributed throughout the day, and even how it should be combined with other foods and drinks. Likewise, supplementary research is being conducted that could contribute to maintaining muscle mass better throughout the ageing process. In Sports Sciences, research is being carried out on exercise protocols that best preserve muscle mass and strength, as well as on the metabolic mediators and biochemical processes that occur when exercise is performed, or when a sedentary life-style is followed. A 2014 review by the EWGSOP group outlined the need for diet and/or exercise intervention studies, from which we have highlighted the need for combined studies. Sarcopenic obesity, weight gain during the menopause, vitamin D deficiency and osteoporosis, among others, are additional factors to take into account.

In a Doctoral Thesis defended recently in our ImFINE research group, with which we aimed to further investigate the relationship between PA, physical condition and nutrition, adults aged 55 with better physical condition revealed an intake of macro and micro nutrients that adhered more closely to recommended levels compared to those in worse physical condition (Aparicio-Ugarriza *et al.* 2018). We also observed a better hydration pattern among those that carried out regular physical exercise and that were not sedentary.

Current Public Health nutritional guidelines, such as cutting down salt, sugar, kilocalories and fats, principally target sedentary demographics, which in turn are receiving guidelines to reduce sedentary behaviour and to increase physical activity. We are concerned about the impact that these guidelines will have on the physically active population. In this respect, authors such as Koenders *et al.* (2006) conclude that general recommendations regarding salt reductions cannot be appropriate for athletes, particularly for those in hot climates. In that particular study performed on runners, a sodium-poor diet led to worse sodium-plasma concentrations, a higher heart rate and body temperature compared to higher intakes. It is also concerning how the salt-reduction recommendation will affect the nutritional state of iodine, as iodised salt has been key to reducing this endemic deficiency (EUFIC, 2011). The myopathy associated with hypothyroidism, among other things, causes intolerance to exercise and muscle cramps, possibly even resulting in closing the circle mentioned above. The consumption of red meat is related to a higher risk of colon cancer and regularly performing physical exercise seems to be a protective factor against this kind of cancer. Therefore, the interaction between diet and exercise remains to be discovered, as well as if the positive effect of exercise counteracts the possible negative effect of the food type. Epidemiological data indicates that exercise may act as a mitigating factor. Furthermore, the recommendation to reduce the intake of red meat affects iron contributions, a mineral that is usually deficient in athletes and in the general public, as well as others, such as zinc, selenium and proteins with high biological value, fundamentally, among other aspects, for muscle quality and functionality. Any other recommendation to reduce or limit the intake of foods entails a possible risk of malnutrition in a kind of domino effect, and guidelines must include alternative foods that are good sources of these same nutrients so as to avoid falling into the deficiency, and among other effects, reducing the physical and mental performance of the population. Moreover, combined research topics emerge such as nutrigenetics, nutrigenomics, epigenetics, microbiota, allergies and food intolerances, in which the intermediation of exercise *per se* is not known, not referring to types, intensities and frequencies.

We can conclude that we need to perform more research in the relationship between exercise and nutrition. Currently, for most chronic illnesses, we do not know if the effects are synergic, antagonic or attenuating. Men and women of the 21st century live in different environmental, social and working conditions, with different access to food and drink, and with a different response to stimuli. An optimum combination of both, adapted to the physiological and pathophysiological aspects of ageing and chronic illnesses, is a challenge that we are passionate about, and one for which a scientific response should be given.

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Original article

Analysis of hydration patterns of elite gymnasts. Intervention to improve performance

Julen Fernández de Landa[1], Robert Strunk[1], Jorge Fernández[1], Sergio Jiménez[2], Nieves Palacios[1]

[1]Centro de Medicina del Deporte. AEPSAD. Consejo Superior de Deportes.
[2]Universidad Europea de Madrid.

Received: 17.01.2018
Accepted: 29.01.2018

Summary

Introduction: Male artistic gymnastics is a sport practiced individually with 6 different apparatus. It is a modality of high intensity and impact. Adequate hydration is important to avoid a decrease in performance and to reduce the risk of fatigue injuries.
Material and method: The hydration patterns of the Spanish artistic gymnastics team are analyzed during training, their individual liquid requirements are calculated, and a personalized hydration is prescribed, with the aim of improve performance. In the research, 9 male elite gymnasts participated. Each one completed 2 equal workouts separated by one week; the first with his usual hydration pattern (HAB) and the second one with an individualized hydration, according to the calculation of their needs with sport drink (POW). All were weighed, and measured the specific gravity and osmolality of urine, before and after training; At the end of each session a rated perceived exertion questionnaire (RPE) was passed and a performance test was carried out.
Results: It is observed that: i) POW significantly increased the drink intake in comparison to HAB during training (HAB: 0.57 ± 0.2 L, POW: 0.90 ± 0.2 L), ii) POW increased the number of pull-ups and total repetitions (HAB: 67.13 ± 4.9 repetitions, POW: 72.63 ± 5.7 repetitions), iii) HAB reduced body mass significantly after training iv) POW presented lower values of urine specific gravity after training and the% of body mass lost was negligible (HAB: 0.44 ± 0.2%, POW: 0.01 ± 0.1%), v) There were no differences in the urine osmolality, the PSE, the number of repetitions in hanging pikes and handstand push-ups between HAB and POW.
Conclusion: Individualized hydration for each athlete with the appropriate drink improves performance during training.

Key words:
Dehydration. Drink. Exercise. Water balance.

Análisis de los patrones de hidratación de gimnastas de élite. Intervención para mejorar el rendimiento

Resumen

Introducción: La gimnasia artística masculina es un deporte practicado de forma individual con 6 aparatos diferentes. Es una modalidad de alta intensidad e impacto. Una correcta hidratación es importante para evitar la disminución del rendimiento y reducir el riesgo de lesiones por fatiga.
Material y método: Se analizan los patrones de hidratación de deportistas de la selección española de gimnasia artística durante el entrenamiento, se calculan sus requerimientos individuales de líquido, y se pauta hidratación personalizada, con el objetivo de mejorar el rendimiento. En la investigación han participado 9 gimnastas de élite varones. Cada uno completó 2 entrenamientos iguales separados por una semana; el primero con su pauta habitual de hidratación (HAB) y el segundo mediante una hidratación individualizada, según el cálculo de sus necesidades con bebida para el deportista (POW). A todos se les pesó, y midió la densidad y osmolaridad de orina, antes y después del entrenamiento; al final de cada sesión se pasó un cuestionario de percepción subjetiva del esfuerzo (PSE) y se realizó un test de rendimiento.
Resultados: Se observa que: i) POW aumentó significativamente la ingesta de bebida respecto a HAB durante el entrenamiento (HAB: 0,57±0,2 L, POW: 0,90±0,2 L), ii) POW aumentó el número de dominadas y el total de repeticiones (HAB: 67,13±4,9 repeticiones, POW: 72,63±5,7 repeticiones), iii) HAB redujo la masa corporal de forma significativa después del entrenamiento iv) POW presentó valores inferiores de densidad de orina tras el entrenamiento y el% de pérdida de masa corporal fue insignificante (HAB: 0,44±0,2%, POW: 0,01±0,1%), v) No hubo diferencias en la osmolaridad de orina, la PSE, el número de repeticiones en flexiones de tronco y flexiones verticales entre HAB y POW.
Conclusión: La hidratación individualizada para cada deportista con la bebida adecuada mejora el rendimiento durante el entrenamiento.

Palabras clave:
Deshidratación. Bebida. Ejercicio. Equilibrio hídrico.

Accesit a la Mejor Comunicación Oral presentada en las VII Jornadas Nacionales de Medicina del Deporte. Zaragoza, 24-25 novbre 2017

Correspondence: Julen Fernández de Landa
E-mail: Julenfdl@hotmail.com

Introduction

Men's artistic gymnastics is an individual sport performed with 6 different apparatus: floor, pommel horse, rings, vault, parallel bars and horizontal bar[1]. Each exercise lasts between 6 (vault) and 60 (floor) seconds[2], and the execution of each is crucial to the score obtained[1]. It is a high intensity, high impact sport which involves a great risk of injury[3]. This is a problem for these athletes, because they suffer approximately 2 injuries per year[3], causing them to lose many hours of training. The prevention of these injuries, therefore, especially those to the upper limbs4, is of paramount importance to the continuity of the training needed for maximum performance.

Many factors are responsible for the injuries incurred by those who practise this sport, the most relevant being incorrect technique in the execution of certain movements, the lack of protection available to the gymnast and fatigue[5,6].

Hydration status and fatigue are inversely related, meaning that it is vitally important to stay well hydrated during both training and competition in order to avoid a drop in physical performance and reduce the risk of injury[7,8].

Arnaoutis *et al.*[9] calculated the dehydration produced during training in five different sports: artistic gymnastics, swimming, canoeing, basketball and running, artistic gymnasts being those who finished training the most dehydrated, with a loss of 1.7 ± 0.07% body mass.

Water serves different functions during exercise: it cools the body, helping to release the excess heat produced, supplies nutrients to the muscle cells, eliminates waste products and lubricates the joints[10].

Furthermore, it is an essential nutrient as it is involved in practically all the functions of the human body and, at about 60% of the body mass of adult males[11], represents its main component. So adequate water intake is essential.

Body water balance is maintained when the loss of water is offset by water and food intake plus endogenous water production by the metabolism[12], as shown in Table 1.

Dehydration can impair sports performance, with impairment intensifying the higher the % body mass loss during the activity[13], as shown in Table 2.

Table 1. Daily water consumption and loss in a sedentary person[12].

Daily water consumption (mL)		Daily water excretion (mL)	
Drinks	1500	Urine	1500
Food	1000	Faeces	200
Metabolic water	300	Lungs	350
		Skin (sweat)	750
Total	2800	Total	2800

Table 2. Symptoms of dehydration, according to the dehydration percentage[13].

% dehydration	Symptoms
	1% Thirst.
5%	Malaise, fatigue, loss of appetite.
7%	Difficulty salivating and swallowing.
>10%	Difficulty walking, lack of coordination and spasticity.
15%	Delirium, dry skin, difficulty drinking water.
>20%	The skin cracks and bleeds. Over this, death.

Table 3. Hydration status by urine density and osmotic concentration[21].

	Well hydrated	Euhydrated	Hypohydrated
Urine density	<1.013	1.013-1.029	>1052
Urine osmotic concentration (mOsm/Kg)	<442	442-1052	>1029

Although the effect of dehydration on performance in some types of sport has been measured[14-17], the consequences that a hydration status below optimal levels may have on artistic gymnastics has yet to be studied.

The objective of drinking during exercise is to prevent excessive dehydration (> 2% body mass) and alterations in electrolyte balance which may affect athletic performance[18].

Hydration status can be evaluated by calculating the change in body mass, the most realistic method[19], and analysing urine density and osmotic concentration, among other procedures[20]. Table 3 shows hydration status using the latter methods.

For athletes, sports drink is the most suitable liquid to prevent dehydration during exercise[21]. According to the consensus on drinks for athletes[22] of the Spanish Federation of Sports Medicine (FEMEDE), these should contain more than 80 Kcal/L and a maximum of 350 Kcal/L, with at least 75% of calories from high-glycaemic-index carbohydrates (glucose, sucrose, maltrodextrin). The concentration of carbohydrates should not be greater than 9% (90 g/L) and that of sodium should be between 460 mg/L (20 mmol/L) and 1150 mg/L (50 mmol/L).

Sodium intake is of great importance, because a decrease in blood sodium during physical exertion may lead to hyponatremia of the utmost gravity[22]. It also helps to improve hydration because it increases the sensation of thirst, meaning that the athlete keeps on drinking, and, moreover, it increases the amount of water retained in the body[11]. Meanwhile, carbohydrates help to maintain blood glucose levels and, therefore, help to save muscle glycogen, delaying the onset of fatigue[22].

The amount of fluid to ingest depends on the individual's sweat rate, the intensity and duration of exercise, the sports clothes worn, air movement and humidity, among other factors[19].

For all these reasons, it was considered important to carry out a study of the influence of hydration on performance in artistic gymnastics.

Objective

The objective of this study was:

- To analyse the hydration patterns of competition-level artistic gymnasts.
- To assess specific individual requirements in order to enhance sports performance.

Hypothesis

The hypothesis of this study was to verify that:

- Artistic gymnasts do not hydrate properly.
- Gymnasts improve their performance in training sessions with proper, individualised hydration, consuming sports drinks.

Material and method

The study involved 9 male sportsmen from the Spanish national artistic gymnastics team who train at the Madrid High Performance Centre; with an average age of 18.13±1.96, a height of 1.68±0.07 m, a body mass of 60.04±11.37 kg and 3.25±1.49 years' experience of high-performance training.

All the subjects passed a medical examination which included: medical, sports and dietary history, a clinical examination and blood and urine tests. They were informed about all aspects of the study and signed the consent form to take part in the study. They stated that they did not have any disease which might affect the results of the research.

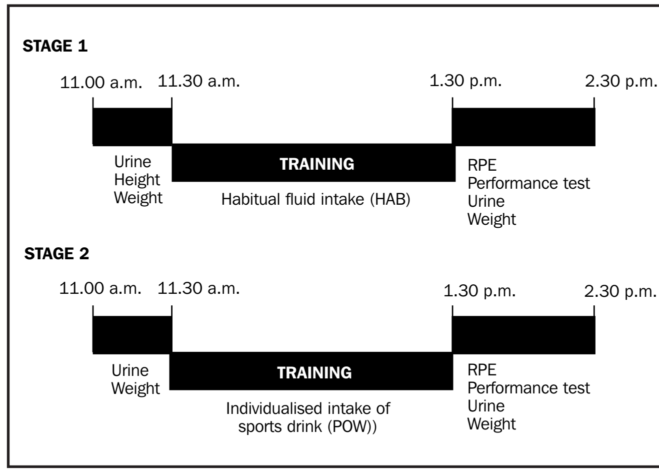
Procedures

The study was conducted using an experimental design with control group and pre-post measurement.

The training sessions for data collection for the study were held one week apart at the same time on the same day of the week. The subjects ate and drank as normal, without any changes, and promised not to start taking nutritional supplements during the study. The research was divided into two different stages, as shown in Figure 1.

- STAGE 1 (HAB): The gymnasts were weighed 30 minutes before training (11 a.m.) with a body composition analyser and a first urine sample was taken. Training began at 11.30 a.m. They were asked not to urinate and to train for 2 hours as normal in terms both of intensity and type and quantity of drink. After training, their rate of perceived effort (RPE) was determined and they completed a sports performance test consisting of three different exercises. A second urine sample was taken and they were weighed again to calculate the percentage of dehydration.

Figure 1. Diagram of the methodology. RPE, rate of perceived effort.



- STAGE 2 (POW): The gymnasts were weighed 30 minutes before training (11 a.m.) with a body composition analyser and a first urine sample was taken. Training began at 11.30 a.m. They were asked not to urinate and to train at their habitual of intensity for 2 hours. They drank a drink specially designed for sportspeople in a quantity calculated on an individual basis according to each athlete's fluid needs (see 2.5 Calculation of fluid needs). The fluid they drank was Powerade® Powder, containing 7% carbohydrates and a sodium concentration (Na^+) of 22.62 mmol/L (520 mg/L). After training, their RPE was determined and they completed a sports performance test consisting of three different exercises. A second urine sample was taken and they were weighed again to calculate the percentage of dehydration.

Measurement of height

Height was measured using a stadiometer (Seca 213) on the first day of the study, before training began.

Urine osmotic concentration and density analysis

A urine sample was taken 30 minutes before the start of training and a second sample was taken in the hour following the end of training. The urine was collected in containers specifically designed for the purpose and these were labelled with the name of the athlete and a control digit.

Osmotic concentration was calculated using the freezing point method with an osmometer (OSMO STATION™ OM-6050). Density was measured using test strips (Combur 10 Test M) with an automatic urine analyser (URISYS 1800).

Dehydration analysis

The subjects were first weighed 30 minutes before starting to train and a second time after completing training. All measurements were taken after urinating, with the least amount of clothing possible (underwear). The dehydration percentage was calculated on the basis of body mass before and after training, using the following formula:

% dehydration= Mass BEFORE - mass AFTER/mass BEFORE x100

Calculating fluid requirements

Fluid requirements were calculated on the basis of the body mass of the athletes before and after training, and fluid intake during training.

The athletes drank from water bottles to make calculation easier. The bottles were weighed before and after training to calculate the difference and arrive at real fluid intake. The number of times the water bottle was refilled was taken into account if any of the athletes filled it up again. The bottles were weighed with an electronic balance (Kern PCB 6000-1). The following formula was used for the calculation:

Fluid requirements = (Mass BEFORE - Mass AFTER)
+ (Drink BEFORE-Drink AFTER)

Rate of perceived effort questionnaire

The scale used for the RPE of the athletes was the 10-point scale modified by Foster *et al.*[23]. This consists of a scale of 0 to 10, where 0 is zero exhaustion and 10 is a state of maximum exhaustion. The questionnaire was answered immediately after finishing training, the athletes pointing at their answers. Given that the two sessions were the same length, the RPE value was determined per session.

Performance analysis

Performance was measured at the end of each training session using a modified version of a specific artistic gymnastics test[24]. A circuit with different exercises (pull-ups, handstand push-ups and leg raises) was completed. Each exercise lasted 30 seconds and the number of repetitions each athlete did was counted. They were asked to carry out as many repetitions as possible using the suitable exercise technique, as shown in Figure 2. The time was calculated using a stopwatch (Geonaute W500) and 2 people observed the tests to count the repetitions.

Leg raises

Start: Hanging.
During: No swaying of the trunk and no bending of legs.
End: Legs parallel to the floor.

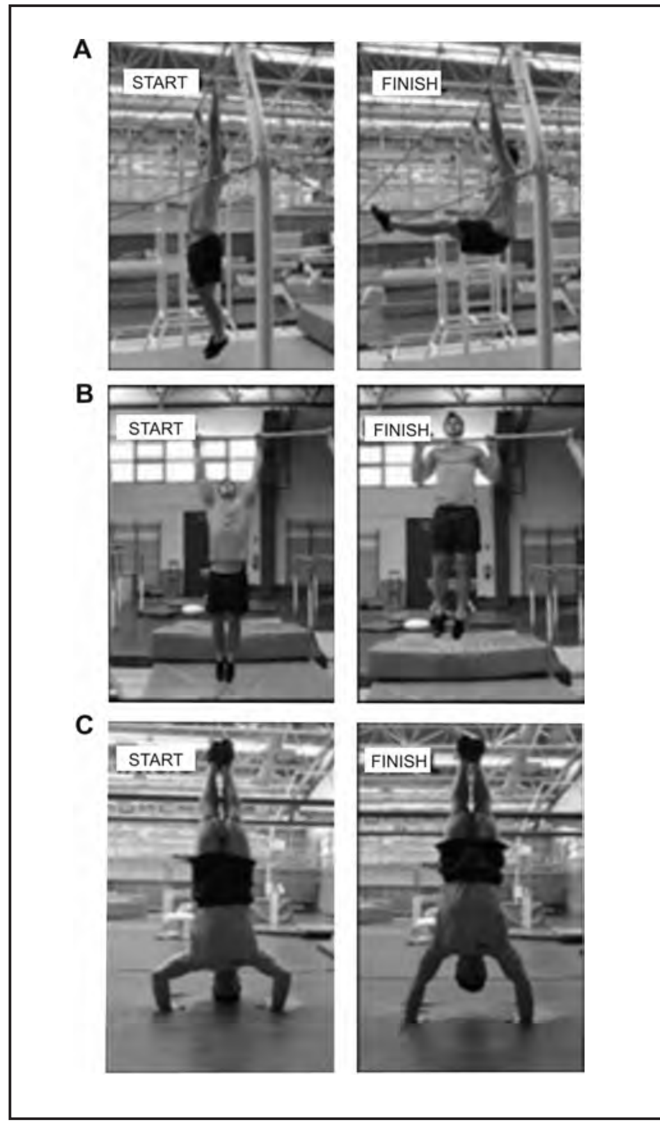
Pull-ups

Start: Hanging from arms.
During: No swaying.
End: The chin passes the bar.

Handstand push-ups

Start: Head touching the floor.
During: No swaying.
End: Fully extended.

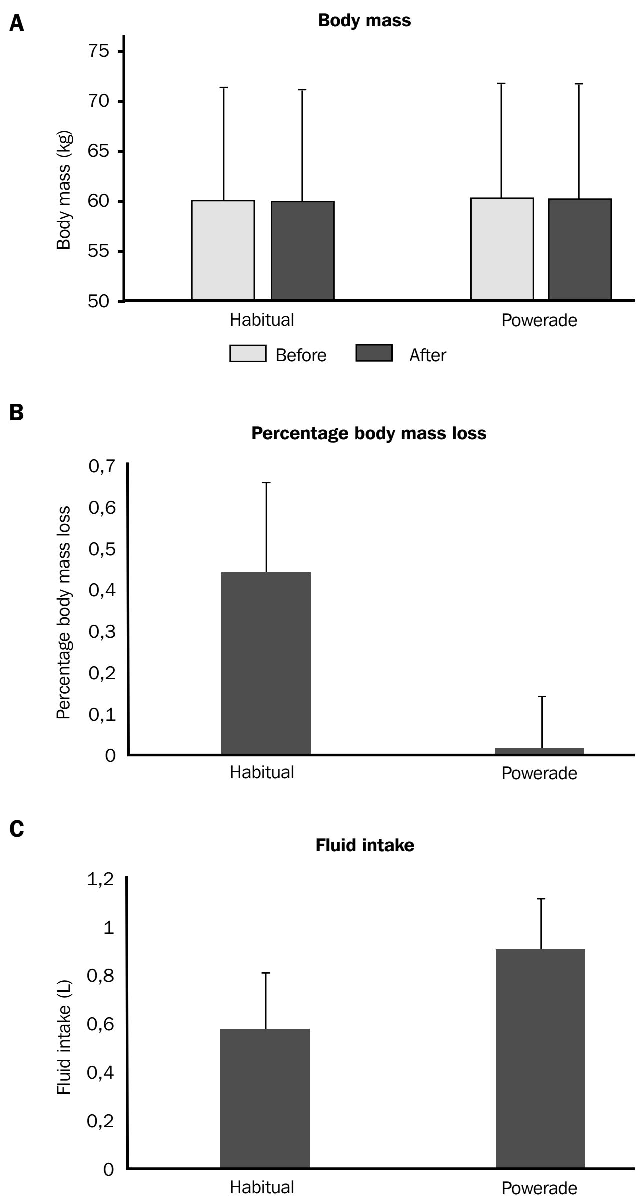
Figure 2. Complete repetition of a leg raise (A), pull-up (B) and handstand push-up (C).



Statistical analysis

The statistical analysis carried out focused on mean and standard deviation (SD) values. Because the number of subjects in the sample for the study was fewer than 30 (Pardo & Ruiz, 2004), a non-parametric statistics approach was chosen. For this reason, the Wilcoxon test for related measurements was used on the different variables of the study. The level of significance was taken as $p < 0.05$. All the statistics were calculated using SPSS software for Windows (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp).

Figure 3. Changes in body mass before and after artistic gymnastics training (A), % body mass loss at the end of training (B), fluid intake during training (C) by the different groups.



The values are means±SD; n=8 subjects. * means statistical difference at $p < 0.05$.

Results

Of the 9 athletes who began the study, one could not attend the tests on the last day. The results correspond to the 8 athletes who completed the entire study.

Body mass

The changes in the gymnasts' body mass on the days of the study are shown in Figure 3a.

During the first stage of the study, with their habitual intake of fluid (HAB), the gymnasts' body mass dropped from 60.04±11.37 to 59.78±11.32 kg after training, with a mass loss of 0.44±0.22%. The difference was significant (p=0.040).

In the second stage, the gymnasts were given the suitable amount and composition of drink (POW), and the figures before and after training were 60.35±11.40 and 60.35±11,41kg, respectively, with a mass loss of 0.01±0.13%. No significant change was registered (p=0.931).

The body mass loss percentage between HAB (0.44±0.22%) and POW (0.01±0.13%) was significant (p = 0.025), and is shown in Figure 3b.

Fluid intake

The amount of fluid ingested was 0.57±0.24 L (HAB) and 0.90±0.22 L (POW). The difference was statistically significant (p = 0.025) and is shown in Figure 3c.

Urine density and osmotic concentration analysis

The changes in urine density on the days of the study are shown in Figure 4a.

The HAB values before and after training were 1.019±0.006 and 1.025±0.013, respectively. The results did not show a statistically significant difference (p = 0.317).

During the POW stage, the athletes' urine density decreased from 1.020±0.003 a 1.018±0.005. This difference did prove to be statistically significant (p=0.046).

The changes in the osmotic concentration of the athletes' urine on the days of the study are shown in Figure 4b.

The HAB values for this variable before and after training were 982.00±151.91 and 966.38±114.15 mOsm/kg, respectively. The results did not show a statistically significant difference (p = 0.674).

In the POW stage, the osmotic concentration of the subjects' urine dropped from 925.75±133.57 to 893.63±96.71 mOsm/kg. Again, the results did not show a statistically significant difference (p = 0.674).

Performance measurements

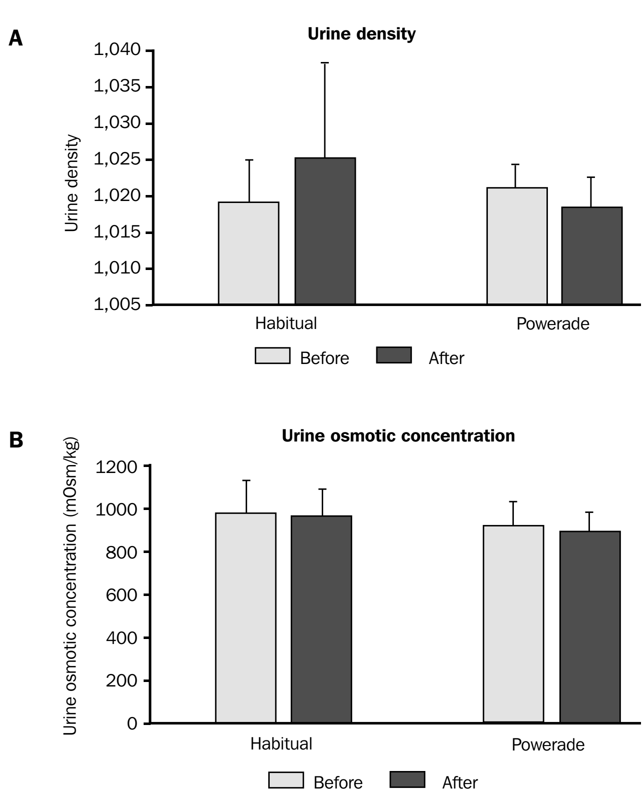
Figure 5a shows the number of repetitions of each exercise completed as a means of measuring performance.

The number of leg raise repetitions was 32.50±1.31 in HAB and 32.63±1.69 in POW. The result was not statistically significant (p=0.914).

The number of pull-up repetitions was 19.13±2.85 (HAB) and 21.88±3.27 (POW). The difference was statistically significant (p = 0.027).

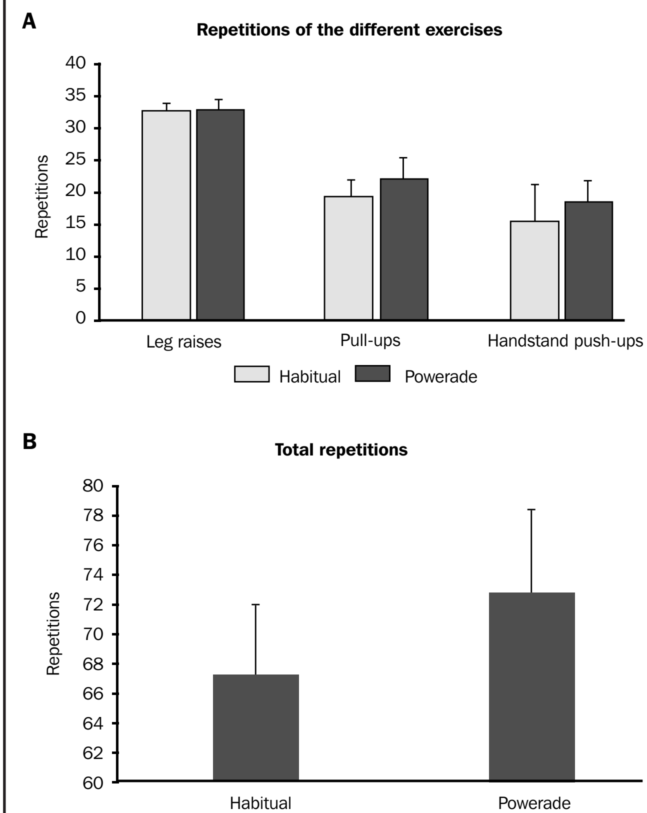
The number of handstand push-up repetitions was 15.50±5.55 in HAB and 18.13±3.60 in POW. The result was not statistically significant (p=0.207).

Figure 4. Urine density (A) and osmotic concentration before and after training in the different groups.



The values are means±SD; n=8 subjects. * means statistical difference at $p < 0.05$.

Figure 5. Repetitions of the different exercises (A) and total repetitions (B) at the end of training in the different groups.



The values are means±SD; n=8 subjects. * means statistical difference at $p < 0.05$.

The total number of repetitions carried out was 67.13±4.91 in HAB and 72.63±5.71 in POW. The difference was statistically significant (p=0.034) and is shown in Figure 5b.

Rate of perceived effort

The rate of perceived effort values were 6.25±1.39 in HAB and 6.75±1.49 in POW. The difference was not statistically significant (p=0.339) and is shown in Figure 6.

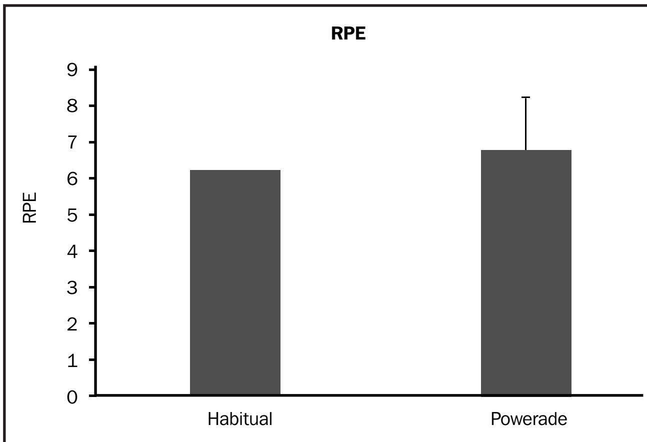
Tables 4 and 5 summarise the data presented above.

Discussion

In this study, we investigated hydration habits during regular training and calculated the right amount of the ideal drink for gymnasts to consume in order to assess any improvement in terms of performance on a second day of training.

The drink used in this study contains 7% carbohydrates and a concentration of Na^+ of 22.62 mmol/L (520 mg/L), fulfilling all the requirements to be called a sports drink according to the consensus of the Spanish Federation of Sports Medicine (FEMEDE)[22].

Figure 6. Rate of perceived effort (RPE) at the end of training by the different groups.



The values are means±SD; n=8 subjects.

Each participant was weighed before and after training to calculate the decrease in body mass during the exercise performed, this being the most realistic way[19] to find out the degree of fluid loss.

Table 4. Variables measured before and after training in the different groups.

Variable	Group	Before training	After training	*p*-value
Body mass (kg)	Habitual	60.04±11.37	59.78±11.32	0.040
	Powerade	60.35±11.40	60.35±11.41	0.931
Urine density	Habitual	1.019±0.006	1.025±0.013	0.317
	Powerade	1.020±0.003	1.018±0.005	0.046
Urine osmotic concentration (mOsm/kg)	Habitual	982.00±151.91	966.38±114.15	0.674
	Powerade	925.75±133.57	893.63±96.71	0.674

N.B.: The values are means±SD; n=8 subjects.

Table 5. Variables measured at the end of training in the different groups.

Variable	Habitual	Powerade	*p*-value
Leg raises (repetitions)	32.50±1.31	32.63±1.69	0.914
Pull-ups (repetitions)	19.13±2.85	21.88±3.27	0.027
Handstand push-ups (repetitions)	15.50±5.55	18.13±3.60	0.207
Total (repetitions)	67.13±4.91	72.63±5.71	0.034
Fluid intake (L)	0.57±0.24	0.90±0.22	0.025
Dehydration (%)	0.44±0.22	0.01±0.13	0.025
RPE	6.25±1.39	6.75±1.49	0.339

N.B.: The values are means±SD; n=8 subjects; RPE, Rate of perceived effort

In the HAB stage of the study, the gymnasts' lost 0.44±0.22% of body mass, meaning that they did not reach an excessive degree of dehydration (>2% body mass). These values are even lower than those described by Arnaoutis *et al.*[9], who cited a mass loss of 1.7±0.07%. The hydration pattern of the athletes taking part in the study was, therefore, acceptable.

Even so, individualised hydration (POW) worked better for the gymnasts than their habitual intake, with a body mass loss percentage of 0.01±0.13% (practically zero), as opposed to 0.44±0.22% in HAB. This result may be due to the greater intake of fluid in POW, 0.90±0.22 L *versus* 0.57±0.24 L in HAB, each gymnast following the personal recommendations given.

The urine density and osmotic concentration values in both HAB and POW before and after training fell within the ranges of euhydration, although were far from the 'well hydrated' values considered in this study.

It should be noted that urine density decreased significantly during training in POW. This may be due to the intake of a greater amount of fluid. Meanwhile, density increased slightly in HAB, without reaching a significant level, probably due to a lower intake of fluid.

Arnaoutis *et al.*[9], who also measured urine density in gymnasts, found that it rose from 1.022±0.004 to 1.024±0.008 after training, probably due to dehydration of 1.7% of body mass. In contrast, while the increase in density in HAB from 1.019±0.006 to 1.025±0.013 was greater, the decrease in body mass was much lower: 0.4%. In both studies, the variable possibly increases due to the decrease in body mass. The difference in the density increase between the two studies may be because there is great variation between individuals.

Although the osmotic concentration and density figures fall within the range of euhydration, both before and after training, they are by no means consistent with adequate hydration. Therefore, hydration during training may not be enough to maintain proper body water balance, meaning that importance should be placed on hydration throughout the day.

The exercises used to analyse the gymnasts' level of performance were taken from Sleeper *et al.*[24]. The three exercises considered the most specific to artistic gymnastics were chosen. The duration of each exercise was cut by half to take into account the fatigue resulting from training.

The total number of repetitions was significantly higher in POW than in HAB. This may be because muscle glycogen was saved in POW as a result of increasing blood glucose through the carbohydrates contained in the drink ingested in this stage.

The performance of gymnasts in a state of dehydration has never been studied, so the results were compared with weight training, given that most of the muscle groups are involved and performance is also measured using the number of repetitions.

Haff *et al.*[25] increased performance through sports drink intake before and during a one-hour session with 16 sets of 10 repetitions involving isokinetic exercise of the hamstrings and quadriceps. In Kraft et al's study[26], 3% dehydration prior to strength training consisting of 3 sets at an intensity of 12 RM to failure and 2 minutes rest between sets, with exercises involving the whole body (bench press, lateral pulldown, military press, bicep curl, tricep extension and leg press), led to significantly fewer repetitions. Therefore, adequate hydration can increase the work performed during training sessions, because the right kind of drink is consumed and dehydration is prevented.

The rate of perceived effort in POW was higher than in HAB, though not sufficiently so as to reveal statistically significant differences, possibly because the athletes did not reach a state of excessive dehydration at any stage.

Carvalho *et al*.[27] compared the RPE of basketball players who drank sports drink or water during training. Those who drank the sports drink felt less fatigue, though not sufficiently so as to yield statistically significant differences, as in this study.

In contrast, in Kraft et al's aforementioned study[26], the RPE of the group which was dehydrated to 3% body mass significantly increased. These data do not coincide with those from this research, possibly because the body mass loss percentage in HAB (0.44±0.22%) was not as high as in this study.

Limitations

- The placebo effect may have come into play when carrying out the performance tests, with the gymnasts feeling motivated as a result of consuming a drink which they were not used to.
- To ratify the results of the study, it would be desirable to prolong the duration of the two stages of the study, taking into account the athletes' hydration throughout the day.

Conclusion

- The habitual hydration pattern of artistic gymnasts during training is acceptable.
- Individualised hydration regimes for each gymnast are the best way to maintain body water balance during training.
- Suitable hydration significantly improves performance in artistic gymnastics.

Practical applications

The data from this study indicate that individualised hydration for gymnasts is the best hydration approach to maintain body water balance and enhance performance.

Therefore, the multidisciplinary team of professionals working with the gymnast should consider this form of hydration, the characteristics of which are quite easy to define using data on body mass loss and fluid intake.

Gymnasts do not tend to be ideally hydrated when they start training. Therefore, the general recommendations for fluid intake before training, which consist of about 5-10 mL/kg body mass, 2-4 hours beforehand[20], should be taken into account. The gymnasts should continue to drink after training, replenishing 125-150% of the fluid lost and ingesting an adequate amount of sodium in order to retain the fluid drunk and stimulate the sensation of thirst[20], always adapting these recommendations to the needs of each individual.

Conflict of interest

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

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Original article

Effect of disease duration on somatotype in a Mexican population with type 2 diabetes mellitus using structural equation modeling

Tomás J. Martínez-Cervantes, Lidia de Jesús Martínez-Martínez, Tomás J. Martínez-Martínez, Antonino Aguiar-Barrera, Ángel González-Cantú, Neri A. Álvarez Villalobos, Oscar Salas-Fraire

Departamento de Medicina del Deporte y Rehabilitación, Facultad de Medicina y Hospital Universitario "Dr. José Eleuterio González", Universidad Autónoma de Nuevo León, Monterrey, México.

Received: 05.09.2017
Accepted: 15.02.2018

Summary

Background: Diabetes mellitus (DM) is a well-known health problem. Nevertheless, its etiology, natural history, and epidemiology are still incomplete. Its prevalence has increased, cases of DM have doubled and its association with body mass index and obesity is high. The objective was to determine the effect of disease duration on somatotype of patients with type 2 DM using structural equation modeling (SEM).
Methods: Two hundred participants underwent anthropometry following the restricted profile of the International Society for the Advancement of Kinanthropometry (ISAK). A database was made using age, height, weight, the other anthropometry measures, the three components of somatotype, and disease duration of DM.
Results: Mean age for men was 58,7 ± 11,1 and for women 56,4 ± 10,7 years; mean body weight for men was 80,0 ± 14,2 and for women 74,8 ± 8,0 kg; mean height for men was 168,3 ± 7,4 and women 154,9 ± 6,0 cm.The median and interquartile interval for the non-parametrical variables in men were endomorphy 4.86 (4.04 to 6.00), mesomorphy 5.82 (4.59 to 7.20), ectomorphy 0.49 (.10 to 1.22) and disease duration 9.00 (4.00 to 17.00); for women, endomorphy 7.52 (6.30 to 8.27), mesomorphy 6.28 (5.05 to 8.15), ectomorphy 0.100 (.10 to.500) and disease duration 9.00 (4.00 to 15.00). A correlation between disease duration and somatotype was found.
Conclusions: Longer disease duration is associated with an increase in endomorphy and mesomorphy; however, ectomorphy decreases. SEM showed that DM disease duration impacts somatotype but this relationship is different in men and women. More research is necessary to understand this relationship. SEM is a feasible technique for modeling disease duration and somatotype.

Key words:
Somatotype. Endomorph. Ectomorph. Mesomorph. Diabetes mellitus. Structural equation model.

Efecto del tiempo de evolución de la enfermedad en el somatotipo de una población Mexicana con diabetes mellitus tipo 2 usando modelamiento de ecuaciones estructurales

Resumen

Introducción: La diabetes mellitus (DM) es un problema de salud bien conocido. Sin embargo, su etiología, historia natural y epidemiología sigue incompleto. Su prevalencia ha aumentado, los casos de DM se han duplicado y su asociación con índice de masa corporal y obesidad es alta. El objetivo fue determinar los efectos de la duración de la enfermedad en el somatotipo de pacientes con DM tipo 2 utilizando modelamiento de ecuaciones estructurales (SEM).
Métodos: Se sometieron a antropometría doscientos participantes siguiendo el perfil restringido de la Sociedad Internacional para el Avance de la Kinanthropometry (ISAK). Se elaboró una base de datos utilizando edad, talla, peso, las medidas antropométricas restantes, los tres componentes del somatotipo y el tiempo de evolución de DM.
Resultados: Edad promedio para hombres fue 58,7 ± 11,1 y para mujeres 56,4 ± 10,7 años; peso promedio de hombres fue 80 ± 14.2 y de mujeres 74,8 ± 18.0 kg. Estatura promedio de hombres fue 168.3 ± 7.4 y de mujeres 154.9 ± 6.0 cm. La mediana y el intervalo intercuartil para las variables no paramétricas en hombres fueron endomorfia 4.86 (4.04 a 6.00), mesomorfia 5.82 (4.59 a 7.20), ectomorfia 0.49 (.10 a 1.22) y duración de la enfermedad 9.00 (4.00 a 17.00) y para mujeres endomorfia 7.52 (6.30 a 8.27), mesomorfia 6.28 (5.05 a 8.15), ectomorfia 0.100 (.10 a.500) y duración de la enfermedad 9.00 (4.00 a 15.00). Se encontró una correlación entre evolución de la enfermedad y somatotipo.
Conclusiones: Mayor tiempo de evolución se asocia con aumento de la endomorfia y la mesomorfia; sin embargo, la ectomorfia disminuye. SEM mostró que la evolución de DM afecta somatotipo, pero esta relación es diferente en hombres y mujeres. Se necesita más investigación para entender esta relación. SEM es una técnica factible para modelar duración de la enfermedad y somatotipo.

Palabras clave:
Somatotipo. Endomorfia. Ectomorfia. Mesomorfia. Diabetes mellitus. Modelo de ecuaciones estructurales.

Correspondence: Tomás Javier Martínez-Cervantes
E-mail: tomas.martinezcr@uanl.edu.mx

Introduction

Diabetes mellitus (DM) is a widespread health problem and a common health disorder known for centuries. Nevertheless, knowledge of its etiology, natural history, and epidemiology is still incomplete1. The global prevalence of diabetes mellitus is rapidly increasing. Over the past three decades, the number of people with diabetes has doubled[2].

An increase in the diagnosis of DM in young people in recent years has been observed, even though the disease has been related to older adults. Type 2 diabetes (T2DM) has a strong genetic component and is associated with obesity and low levels of physical activity[3,4].

People in Mexico have suffered a rapid shift in dietary and physical activity patterns and this has lead to an important increase in obesity and diabetes mellitus with diabetes causing almost 14% of all deaths. Also, the growing prevalence of obesity and metabolic syndrome in children and adults suggests that this situation will worsen in the future[4].

The National Survey on Health and Nutrition 2012 estimated that 9.2% of adults had a previous diagnosis of diabetes mellitus. This was an important increase in contrast to the results observed in 2000, where the proportion was 5.8%, and in 2006, 7%[5].

Somatotyping is a method used to evaluate, study, and appraise body shape and composition in terms of bone dimensions, muscle, and adipose tissue. It is a unique method that was first described by Sheldon *et al.* in 1940[6], and modified by Heath and Carter in 1967[7]. The somatotype is a description of the actual morphological constitution. It is comprised of three numerical variables, consisting of three sequential numbers representing endomorphy, mesomorphy and ectomorphy, respectively[8].

Endomorphy refers to relative fatness and relative leanness, mesomorphy, to relative musculoskeletal development according to height, and ectomorphy, to relative body linearity. It is based largely, but not entirely, on height/cubed root of weight ratio. Ectomorphy evaluates the form and degree of longitudinal distribution of the first and second component[9,10].

The relationship between somatotype and disease was first researched by Sheldon *et al* in 1940[6]. In 2002, Koleva *et al*[11] examined the association between somatotype and its three components, and the prevalence of several chronic diseases. In five disease groups, prevalence was significantly related to a somatotype. Other studies have shown an association between somatotype and other pathologies, such as polycystic ovary syndrome[12].

T2DM is a metabolic disorder that affects and is affected by body composition. It induces changes in body size and shape that adversely affect the prognosis of the disease[13]. Obesity, represented by endomorphy, has a positive correlation with the onset of diabetes and it is a well-known risk factor for cardiovascular disease[14,15]. However, the association between somatotype and diabetes is limited and poorly documented. The aim of this study was to determine the somatotype of T2DM patients in a Mexican population and the effects of disease duration on somatotype.

Material and method

Participants

This was a prospective, quantitative, observational and analytical, multiple correlation study previously approved by the Ethics Committee of the Institution with registration number MD13-001. Patients provided verbal informed consent after being informed about the study procedure and asked if they wanted to participate. All procedures in this study were carried out according to the guidelines of the Declaration of Helsinki. The study group consisted of 200 patients with a previous diagnosis of T2DM who attended the outpatient clinics of the departments of internal medicine, general medicine, and endocrinology. Individuals with complications that could alter their body composition such as lower extremity edema, amputations, hiatal hernia or other situations that limited their ability to stand up, such as fractures or recent surgery, were excluded. A good sample size for SEM is more than 200 considering an estimation of 20 participants for every variable in the model. In this case, there were four variables; therefore, a minimum sample size of 80 was adequate[16,17].

Structural Equation Modeling

Structural equation modeling (SEM) is a set of statistical techniques that systematically analyze multivariate data to measure latent variables and their interrelationships. Latent variables are variables that are observed indirectly or through the effects on observed variables; in this case, somatotype through endomorphy, mesomorphy and ectomorphy.

Anthropometrics

To measure the independent variable, somatotype, measures of weight, height and skinfolds were obtained using the restricted profile of anthropometric measures in accordance with the recommendations of the International Society for the Avancement of Kinanthropometry (ISAK)[18]. The measurements obtained directly were height; body weight; skin folds: triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf; girths of relaxed upper arm and flexed and tensed upper arm; waist (minimum); gluteal (hip); and calf (maximum); biepicondylar breadth of the humerus; biepicondylar breadth of the femur. Two measurements were taken at each site with the mean value being used. All measurements were made by the same measurer. The measurer was a level I ISAK-certified sports medicine physician. The variable disease duration was obtained by direct questioning.

Data Analysis

A database was made using Microsoft Excel 2010. This database was imported to SPSS AMOS version 21.0. Before conducting the statistical analysis, data were evaluated for implausible or error values, abnormalities indexes, and normality. We conducted a descriptive statistical analysis for quantitative variables. Measures of central tendency and dispersion are presented as means ± standard deviation. In the case of qualitative variables, frequencies and percentages were obtained. The validity of several models that explain the relationship between disease duration and somatotype was tested using the following: multivariate normality, and maximum likelihood estimation (MLE) using confirmatory factor analysis.

Results

After eliminating cases with incomplete and missing data, the final sample consisted of 196 patients. The study group was 42.3% male and 57.7% female. The age interval was 27.1 to 85.0 years with a mean of 57.3 ± 10.8. Weight interval from 37.6 to 119 kg with a mean of 76.9 ± 16.6. Height interval from 136.5 to 191 cm with a mean of 160.5 ± 9.3 cm. The characteristics of the general population and gender are shown in Table 1.

The median and interquartile interval (IQI) for the non-parametrical variables in men were endomorphy 4.86 (4.04 to 6.00), mesomorphy 5.82 (4.59 to 7.20), ectomorphy 0.49 (.10 to 1.22) and disease duration 9.00 (4.00 to 17.00) (Table 2); for women, endomorphy 7.52 (6.30 to 8.27), mesomorphy 6.28 (5.05 to 8.15), ectomorphy 0.100 (.10 to.500) and disease duration 9.00 (4.00 to 15.00) (Table 3).

A measurement model was tested to predict the somatotype, based on disease duration by path analysis. This considers disease duration as an independent variable with the dependent variable being somatotype with its endomorphy, mesomorphy and ectomorphy factors (Figure 1). The final estimated model is depicted in Figure 2. The coefficient above each path is AMOS's maximum likelihood estimate of the effect size.

After evaluating the structural model disease duration—somatotype with its indicators, significant parameters were found. As shown in Table 4 in the column critical ratio (CR), all factors are considered loaded and have a significance of 0.05, since all CR values are greater than 1.96. Values greater than 2.58 have a confidence level of 0.01[19]. This means that the structural model between the endogenous variable somatotype and the exogenous variable disease duration is valid. Regarding standardized regression weights (Table 5), disease duration negatively impacts somatotype with a regression of –0.21. In relation to somatotype, endomorphy, with a weighted regression of 0.78, has a positive correlation and high weight. Mesomorphy in relation to somatotype has a weighted regression of 0.76. Ectomorphy in relation to somatotype has a negative weighted regression of –0.80, and a proportion of explained variance of 5.8% for the relationship between somatotype and disease duration. This result is statistically significant.

Table 1. Characteristics of the study group.

Gender	Age (yrs)			Weight (kg)			Height (cm)		
	n	mean	SD	n	mean	SD	n	mean	SD
Female	113	56.38	10.66	113	74.78	17.96	113	154.90	6.01
Male	83	58.71	11.08	83	80.03	14.20	83	168.28	7.37
Total	196	57.37	10.88	196	77.00	16.63	196	160.56	9.36

SD, standard deviation.

Table 2. Endomorphy, mesomorphy and ectomorphy factors in relation to disease duration in female population.

Variable		Endo	Meso	Ecto	Disease duration
N	Valid	111	111	111	111
	Missing	0	0	0	0
Percentiles	25	6.30	5.05	.100	4.00
	50	7.52	6.28	.100	9.00
	75	8.27	8.15	.500	15.00

Endo: endomorphy; Meso: mesomorphy; Ecto: ectomorphy.

Table 3. Endomorphy, mesomorphy and ectomorphy factors in relation to disease duration in male population.

Variable		Endo	Meso	Ecto	Disease duration
N	Valid	85	85	85	85
	Missing	0	0	0	0
Percentiles	25	4.04	4.59	.10	4.00
	50	4.86	5.82	.49	9.00
	75	6.00	7.20	1.22	17.00

Endo: endomorphy; Meso: mesomorphy; Ecto: ectomorphy.

Figure 1. Proposed model to estimate somatotype represented by endomorphy, mesomorphy and ectomorphy (endogenous variable) and disease duration (exogenous variable).

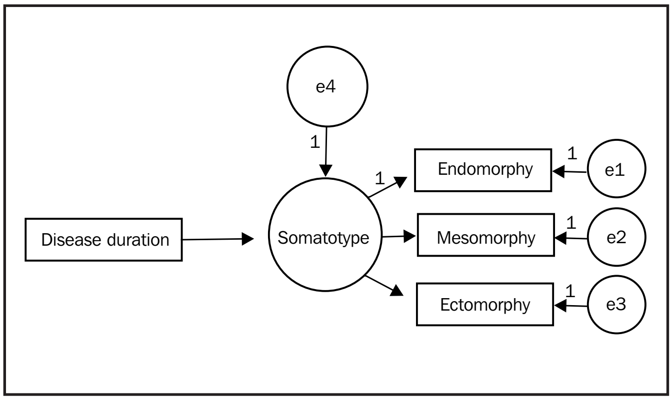

Figure 2. Standardized regression weights of the study group. The coefficient above each path is AMOS's maximum likelihood estimate of the effect size.

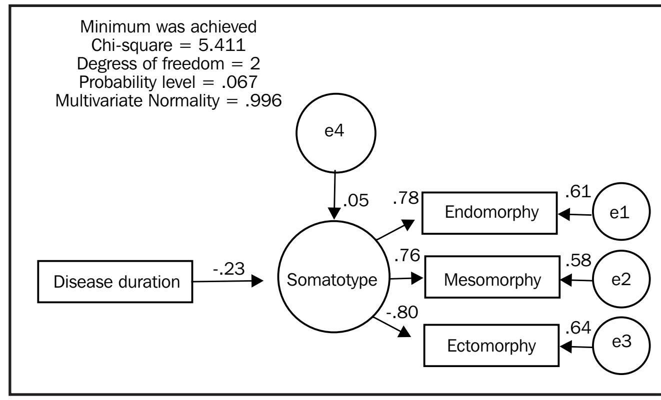

Table 4. Regression Weights (Group number 1 - Default model).

Variable			Estimate	SE	CR	P	Label
Somatotype	<---	Disease Duration	–0.040	.015	–2.67	.008	par_3
Endomorphy	<---	Somatotype	1.000				
Mesomorphy	<---	Somatotype	1.087	.115	9.42	***	par_1
Ectomorphy	<---	Somatotype	–0.386	.040	–9.56	***	par_2

SE: standard error; CR: critical ratio; P: bilateral asymptotic significance.

Table 5. Standardized Regression Weights (Group number 1 - Default model).

Variable		Variable	Estimate
Somatotype	<---	Disease duration	–0.21
Endomorphy	<---	Somatotype	0.78
Mesomorphy	<---	Somatotype	0.76
Ectomorphy	<---	Somatotype	–0.80

Table 6 shows a basic understanding of fit indexes cutoff levels for determining model fit. In general, if the vast majority of the indexes indicate a good fit, a good fit is accepted.

Discussion

The structural model estimated by Maximum Likelihood showed that somatotype (formed by endomorphy, mesomorphy, and ectomorphy) and disease duration were consistent as a construct to explain the effect of disease duration on somatotype. It demonstrated a negative impact on the somatotype of individuals with T2DM when diabetes mellitus duration increases. This means that an increase in disease duration increases the levels of endomorphy and mesomorphy, while ectomorphy decreases. A decrease in ectomorphy is expected since in this population it is known that[20]. What is not expected is an increase in mesomorphy. The changes observed in endomorphy are changes

Table 6. Cutoff Criteria for Several Fit Indexes.

Quality adjustment	Cutting criteria	Model results	Interpretation
Absolute fit			
X^2	Al .05 to 9.49	5.4	Good
X^2/DF	2 to 3.2	2.7	Good
AIC	Close to 0	21.4	Rejected
Comparative fit			
NFI	≥ .95	.97	Good
IFI	≥ .95	.98	Good
TLI	≥ .95	.95	Good
CFI	≥ .95	.98	Good
Parsimonious fit			
PNFI	Between .50 and .90	.32	Rejected
PCFI	Between .50 and .90	.32	Rejected
PGFI	Close to 1	.2	Rejected
Other			
GFI	≥ .95	.99	Good
AGFI	≥ .95	.92	Good
RMR	Close to 0	.39	Acceptable
RMSEA	< .08	.09	Good
HOELTER. 05	> 200	193	Good
HOELTER.01	> 200	296	Good

AIC: Akaike information criterion; NFI: normed fit index; IFI: Incremental fix index; TLI: Tucker-Lewis index; CFI: Comparative fit index; PNFI: Parsimony adjusted NFI; PCFI: Parsimony adjusted CFI; PGFI: Parsimony adjusted GFI; GFI: goodness of fit index; AGFI: adjusted GFI; RMR: root mean square residual; RMSEA: root mean square error of approximation; Hoelter 0.05, Hoelter 0.05 index.

Adapted from Schreiber *et al.* Reporting structural equation modeling and confirmatory factor analysis results: a review. Journal of Educational Research. 2006; 99: 323-337.

in body composition related to age. This combination of a decrease in muscle mass and muscle strength has been recently defined as sarcopenic obesity, a change that may cause an additive effect on insulin resistance in patients with diabetes[21,22]. The changes in ectomorphy can be explained as previously mentioned but not the changes in mesomorphy since we expect a loss of muscle mass not an increase[23,24].

In the study by Baltadjiev[13] mean somatotypes in men in both age groups, 40-60 years and 61-80 years, were endomorph mesomorph: endo, 5.03; meso, 6.57; ecto, 2.01, and endo, 4.14; meso, 5.88, and ecto, 1.64, respectively. In a second study by Baltadjiev[25] of mean woman somatotypes in the 40 to 60-year age group, the dominant somatotype component was endomorphy, while mesomorphy in the 61-80 years age group was mesomorph-endomorph: mean somatotypes were endo, 6.59; meso, 6.09; and ecto, 1.57, while in women 61 to 80 years it was an endomorph-mesomorph somatotype: endo, 5.39; meso, 9.41; ecto, 1.55. In contrast to our study, these results were not compared with disease duration.

Likewise, the results of Yadav *et al*.[14] showed a mesomorph-endomorph somatotype. Values in men in the 49.1–60-year age group were endo, 7.44 ± 1.27; meso, 4.97 ± 1.25; and ecto, 0.62 ± 0.51, while in women they were endo 8.11 ± 0.96; meso, 5.06 ± 1.57; ecto, 0.45 ± 0.48. In both groups, the mesomorph and endomorph components were elevated. These findings are similar to ours with regard to endomorphy but our values of mesomorphy were slightly higher.

Unlike other reports of somatotype in patients with T2DM, our patients, similar to Baltadjiev´s[13,25] over time show a tendency to have high endomorphy and mesomorphy components. As stated by Perna *el al*.[26] these individuals can benefit from this so-called "obesity paradox.". In the study by Mesquita *el at*.[27] obese patients had a lower prevalence of sarcopenia than those who were thin.

Fat and muscle mass are increased in individuals with T2DM. This is important because, in theory, this would represent a favorable somatotype. An increased muscle mass would facilitate control and/or management of diabetes mellitus with regard to exercise programs and also a lower sarcopenia index. However, this increase in mesomorphy may not be entirely associated with disease duration since some authors have mentioned an overestimation of mesomorphy caused by the accumulation of soft tissue which produces an erroneous measurement of the biepicondylar breadth of the humerus and the femur[28]. Herrera *et al*.[29,30] attribute this overestimation of mesomorphy to a centripetal redistribution of subcutaneous fat in the elderly. It is important to take this into consideration when mesomorphy is being interpreted. Maybe more exact methods, such as Dual-Energy-X-ray-Absorptiometry (DEXA), can help discriminate if this overestimation of mesomorphy exists.

Conclusions

This study shows that somatotype changes according to disease duration with a tendency towards increasing muscle mass and not only fat mass. With the findings in this study, we can say that somatotype can be effectively applied to the study of T2DM.

Acknowledgments

We thank Sergio Lozano-Rodriguez, M.D. for his help in translating the manuscript.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Blood glucose response to two intensities of physical exercise in young women during fasting

Juan C. Sánchez-Delgado[1,2], Adriana Angarita-Fonseca[3,4], Clara L. Aguirre-Aguirre[1], Diana M. Aguirre-Rueda[2], Rubén D. Pulgarín-Araque[2], Sandra Pinzón-Romero[5]

[1]Universidad de Santander, Facultad de Ciencias de la Salud, Grupo de Investigación Fisioterapia Integral, Bucaramanga, Colombia. [2]Universidad Santo Tomas, Bucaramanga, Colombia. [3]Universidad de Santander, Facultad de Ciencias de la Salud, Grupo de Investigación Fisioterapia Integral, Grupo de investigación en Manejo Clínico CliniUDES, Bucaramanga, Colombia. [4]University of Saskatchewan, Saskatoon, Canadá. [5]Universidad Autónoma de Manizales (UAM), Manizales, Colombia.

Received: 09.08.2017
Accepted: 26.02.2018

Summary

Introduction: Physical exercise in the fasting state has been a controversial topic; however, some studies have shown a greater loss of body fat and better glycemic control in those who participate in aerobic training when fasting.
Aim: To evaluate the glycemic response after a session of moderate or vigorous physical exercise in young women in the state of fasting.
Material and method: A randomized clinical trial was carried out. Twenty-six women (19 to 22 years old) were randomly assigned to two intervention groups. The first group was trained at an intensity of 70% of maximum heart rate (MHR) for 30 minutes, and the second group at an intensity of 90% MHR for 15 minutes. Height (cm), weight (Kg), body mass index (BMI), fat percentage, and maximum oxygen consumption (VO_{2max}) during a stress test were evaluated. Blood glucose levels were checked before and after the exercise session of each group.
Results: No significant changes were found in post-exercise blood glucose levels in any experimental group, and the existing differences were not statistically significant.
Conclusions: Moderate or vigorous physical exercise during fasting did not show significant variations in blood glucose, which suggests that it is safe for healthy young women to train when fasting.

Key words:
Exercise. Blood glucose. Athletic performance. Body composition.

Respuesta de la glucemia frente a dos intensidades de ejercicio físico realizado en ayunas en mujeres jóvenes

Resumen

Introducción: La práctica de Ejercicio Físico (EF) en estado de ayuno ha sido controvertida; no obstante, algunas investigaciones evidencian mayor pérdida de grasa corporal y mejor control glucémico en quienes participan de entrenamiento aeróbico en estado de ayuno.
Objetivo: Evaluar la respuesta de la glucemia después de una sesión de ejercicio físico de intensidad moderada o vigorosa realizado en ayunas en mujeres jóvenes.
Material y método: Se realizó un ensayo clínico controlado aleatorizado. Veinticuatro mujeres (19 a 22 años) fueron asignadas de manera aleatoria a dos grupos de intervención. El primero fue sometido a una intensidad de ejercicio del 70% de la Frecuencia Cardíaca Máxima (FCM) durante 30 minutos y el segundo a una intensidad del 90% de la FCM durante 15 minutos. Se evaluaron la talla (cm), peso (Kg), índice de masa corporal (IMC), porcentaje de grasa y consumo máximo de oxígeno ($VO_{2máx}$) mediante una prueba de esfuerzo. Los niveles de glucemia fueron determinados antes y después de la sesión de ejercicio de cada grupo.
Resultados: No se encontraron cambios significativos en los niveles de glucosa en sangre post ejercicio en ningún grupo experimental, y las diferencias existentes no fueron estadísticamente significativas.
Conclusión: El ejercicio físico moderado o vigoroso en estado de ayuno no mostró variaciones significativas en la glucemia posterior a su ejecución, lo que sugiere seguridad en el desarrollo del entrenamiento en ayuno en mujeres jóvenes saludables.

Palabras clave:
Ejercicio. Glucemia. Rendimiento atlético. Composición corporal.

Correspondence: Juan Carlos Sánchez-Delgado
E-mail: juancarlossanchezd@gmail.com

Introduction

The recommendations issued by specialised organisations, declare the benefits of physical activity (PA) for health, as mentioned by Cenarruzabeitia[1] *et al* (2003); Cadore[2] *et al* (2005); Bayego[3] *et al* (2012). Key benefits include the control of blood glucose levels, thanks to increased sensitivity to insulin and an increase in the number of non-insulin dependent receptors, which ultimately reduces the risk of suffering from metabolic chronic diseases in the future[4,5]; yet, not everyone recognises these benefits[6,7].

Specifically, physical exercise (PE) performed in the morning is one of the most widely used routines by the general public; it offers additional benefits such as a greater loss of body fat when performed before eating any food. Among the physiological reasons for this phenomenon, mention is made of the low levels of insulin and high levels of plasma epinephrine present during exercise, which is associated with increased lipolysis and peripheral fat oxidation[8-9].

Van Proeyen[8] *et al* (2010) indicate that training while fasting improves the muscle oxidative capacity and increases the use of lipid fuel during aerobic activities, without altering the carbohydrate oxidation (CHO), preventing hypoglycaemia. However, it is important to emphasise the need to eat food the night before, in order to guarantee an appropriate reserve of glucose when starting the training session. Another benefit reported in the literature reviewed, is the one referred to by Stannard[9] *et al* (2010), who concluded that not only does regular exercise reduce the risk of insulin resistance, this is also the case when performed on an empty stomach.

When PE is performed without a full glycogen reserve, due to fasting, then the glycemic values may be balanced by hepatic glycogenolysis or gluconeogenesis, depending on the intensity and duration of the physical activity[8-12]. The carbohydrate energy intake during low intensity effort levels (30% VO_{2max}) is around 10 - 15% and its uptake increases by three to four-fold when maximal or supramaximal activities are performed, where the greatest energy input is derived from phosphagen, blood glucose and muscle glycogen[13].

The percentage of energy provided by the blood glucose at intensities of 25%, 65%, 85% VO_{2max} is around 10% and, apparently, its post-exercise variation is not significant after performing activities at intensities of between 46 to 65% VO_{2max} with a duration of ≤ 120 min[13-15].

Finally, the goal of this investigation is to analyse the glycemic response to PE performed during fasting, taking into account the recommendations for the type of exercise, as well as the recomendations for the "moderate or vigorous" intensities issued by the OMS, the American College of Sports Medicine, the American Heart Association and the British Association of Sport and Exercise Sciences for the young adult population[16-17].

Material and method

A controlled randomized clinical trial was conducted with two parallel intervention groups. An allocation ratio of 1:1 was used.

Participants

The population comprised students from the physiotherapy course at the University of Santander, women, adults, and residents of the metropolitan area of Bucaramanga, who voluntarily agreed to take part in the study, after reading the informed consent. The inclusion criteria were voluntary participation, to be of legal age, no relative or absolute contraindication for PE. For this purpose, use was made of the self-completion questionnaire *Physical Activity Readiness Questionnaire* (PARQ&YOU), of the Canadian Society of Exercise Physiology[18]. The study excluded those participants showing bone and joint pain during the exercise session (n=1), thoracic discomfort (n=1), gastroenteritis (n=1) and for having had breakfast (n=1), (Figure 1).

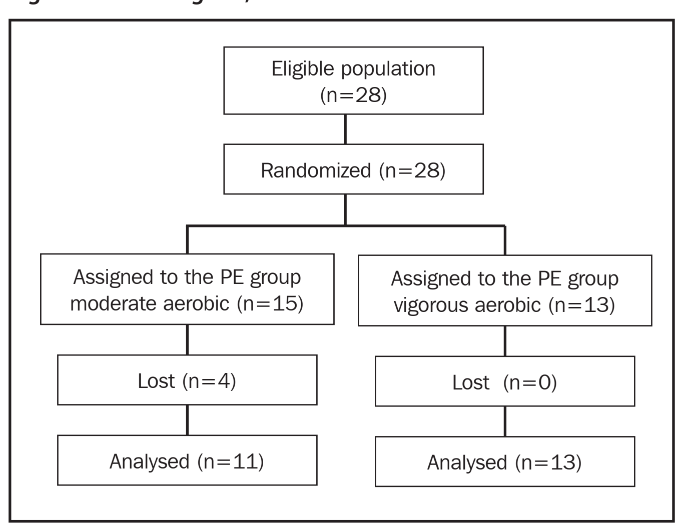
The eligible population were 24 women, who were divided into two groups by simple randomisation, using the Epiinfo 6.04d software. The program allocated 15 women to the moderate aerobic PE (GO) group and 13 to the vigorous PE (G1) group. No masking was performed.

Procedure

The study was divided into three phases:

- During the first week, the goals of the study were communicated, voluntary participation was requested and the informed consent was signed by each of the participants.
- During the second week, the anthropometric assessment was made, and the aerobic physical capacity through the "yo-yo" test[19].
- In the third week, the randomised allocation of the intervention groups was carried out: (G0) and (G1); the intervention was developed, by taking the blood glucose level before and after PE. On the other hand, it is important to clarify that there was no control of the diet on the night and during the week before the intervention.

Figure 1. Flow diagram, data collection



Source: the authors.

Interventions

The 24 participants performed a single physical exercise session, with a continuous run at 6.30 am.. The (G0) included a 5 minute warm up, 30 minutes of exercise at 70% of the Heart Rate Reserve (HRR) according to Karvonen[20], controlled by heart rate monitors (Polar, Sounto, Omrom) and 5 minutes recovery; the GI performed the same process with an exercise intensity of 90% of the HRR according to Karvonen, for 15 minutes.

Measurements

Anthropometric measurement

For the height measurement, a standard height rod was used with a scale in centimetres (cm) and millimetres (mm) and with a reading accuracy of 0.1 cm. The body weight was also recorded with digital weighing scales with an accuracy of 100 grams, in order to finally calculate the body mass index (BMI). Additionally, 6 skin folds were taken (triceps, subscapular, suprailiac, abdomen, anterior thigh, calf) using the Harpenden Skinfold Caliper, with a scale accuracy of 0.2 mm, in order to determine the percentage of body fat, using the Yuhasz equation[21]. All measurements were taken following the ISAK standards.

Quantification of blood glucose levels

2 samples of blood glucose levels were taken, before and after exercise, at the index finger tip, with a blood glucose monitor Fast-Check® (Laboratorios DAI, Colombia). This device does not require code calibration or electronic chips.

Statistical analysis

The data obtained were entered in Excel, the database obtained was exported to Stata 13.0 for subsequent analysis. For the numerical scale, central tendency and dispersion measurements were calculated according to the distribution of the variables and, for the nominal scale measurements, the absolute and relative frequencies were calculated. The difference between measurements was compared between groups using the Student t-test for independent data; while the intra-group comparison of the change in blood glucose levels before and after the intervention was made using the Student t-test for paired data. An alpha level of 5% was considered for the entire analysis.

Ethical considerations

The authors declare that the procedures followed comply with the ethical standards of the committee responsible for human experimentation and in accordance with the World Medical Association and the Declaration of Helsinki.

This study was approved by the investigation committee of the Physiotherapy Program of the University of Santander. The study observed the ethical principles of confidentiality, beneficence, nonmaleficence, autonomy and justice. The authors obtained the informed consent of the patients and/or subjects mentioned in this paper. This document is held by the corresponding author.

Results

As shown in Table 1, the average age of those performing moderate Pe was 20 years, and those performing vigorous aerobic PE was 21 years. The average BMI was 23.4 (kg/m²), the % of fat, 27.5%, the VO_{2max} 35.4 ml.kg min, pre-exercise blood glucose level 89.1 mg/dl and post-exercise 93.1 mg/dl.

By comparing the changes in the pre and post exercise blood glucose levels in the two groups "PE moderate aerobic and PE vigorous aerobic" no statistical significant differences were found in the initial blood glucose level (p=0.701), and the final blood glucose level (p=0.611) nor in the differences between the initial and final blood glucose levels (p=0.673). On the other hand, with regard to the intra-group comparison, no statistically significant differences were found before and after the intervention of the Moderate PE group (p=0.177) or the vigorous PE group (p=0.416) (Table 2).

Table 1. Baseline evaluation of the study population, according to intervention group.

Variable	Moderate PE (n=11)	Vigorous PE (n=13)	Overall (n=24)
Age (IQR)	20 (19-21)	21 (19-21)	20 (19-21)
Height (mt)	1.61 ± 0.1	1.58 ± 0.1	1.59 ± 0.06
Weight (Kg)	62 ± 11.8	58.3 ± 4.5	59.8 ± 8.6
BMI (kg/m²)	23.6 ± 3.8	23.2 ± 2.8	23.4 ± 3.2
% Fat	28 ± 7.9	27.2± 5.1	27.5 ± 6.4
VO_{2max}	35.4 ± 3.9	35.5± 3.1	35.4 ± 3.5
GluPrePE	88.4 ± 5.8	89.6 ± 9.1	89.1 ± 7.6
GluPostPE	95.2 ± 13.3	93 ± 10	93.1 ± 11.6

IQR: Interquartile range. BMI: Body Mass Index. GluPrePE:Blood glucose level pre exercise GluPostPE: Blood glucose level post exercise

Table 2. Blood glucose level before and after exercise in the study population, according to study group.

Variable	Moderate PE n=11	Vigorous PE n=15	*p* Value
Initial blood glucose level (mg/dL)	88.4 ± 5.8	89.6 ± 9.1	0.701*
Final blood glucose level (mg/dL)	95.2 ± 13.3	93 ± 10	0.611*
Difference blood glucose level initial-final(mg/dL)	6.8 ± 15.5	3± 13.1	0.673*
P value (Comparison initial and final evaluation)	0.177**	0.416**	

*t-test for independent samples. **t-test for paired data.
Source: the authors

Discussion

In this study, the type and levels of intensity of the PE were based on the recommendations issued by institutions specialising in exercise sciences for this type of population[16-17]. The results show that PE performed with either moderate or vigorous intensity levels in fasting conditions, does not generate changes in the blood glucose levels immediately after PE, which is consistent with most studies reviewed[21-25].

One of the reasons to account for the limited variation in the post-exercise blood glucose level for the two experimental groups (G0= 6.8±15.5; G1=3±13.1), is argued by the compensation produced by the hepatic glycogenolysis and the gluconeogenesis, which could be promoted by fasting, which causes increases in the release of glycerol considered to be a valuable pioneer in the development of these processes[26-28].

Ferreira A[14] *et al* (2016) and Van Proeyen[29] *et al* (2013) indicate that one of the possible reasons to account for the fact that the glucose blood level does not decrease, is that the PE performed while fasting, stimulates the production of energy through the oxidation of fat, which means that those persons training in this condition reduce their body fat to a greater extent, without significantly affecting the concentration of glucose in the blood. However, it is important to emphasis that, when lipids gain importance in energy production, physical performance tends to decrease[30].

Another possible reason to account for the non-variation in the blood glucose level immediately after exercise performed when fasting, is the low consumption of glucose of all body tissues at that time, except the muscle and liver[12]. It is also important to stress that, although exercise can increase insulin sensitivity and the transport of glucose to the muscle, this effect may be lessened by the above mentioned lipolytic responses, as well as the anti-glycemic hormonal responses caused by the fasting condition, characterised by an increase in catecholamines, cortisol, growth hormone and glucagon, which controls 70% of the production of glucose during exercise, stimulating glycogenolysis, a process which is more important when the glycogen reserves are depleted due to prolonged exercise or in starvation conditions[26,31,32].

It is important to consider that most of the studies published on the subject use exercises with intensities not greater than 70% VO_{2max}, with a duration of less than 120 minutes, therefore the results presented in this study must not be extrapolated as long term effects, where the probability of hypoglycemia could increase[26].

Despite the results of this study and the evidence with regard to the accelerated effect on the oxidation of fat when PE is performed when fasting, it is necessary to clarify that these effects were observed in fit and/or healthy persons. Therefore, precaution should be taken for this type of training for sedentary persons[21,22,26,29].

Conclusion

The non-existence of changes in the blood glucose level following a moderate intensity physical exercise session for 30 minutes or vigorous intensity for 15 minutes, suggests safety in the performance of a training session of this type for young, healthy women.

Limitations

The analysis method used to evaluate the concentration of glucose could be considered to be a limitation in our study, given the fact that the glucometer could have a margin of error of between 10 - 15%. However, its use is understandable, as it was for field work. Despite the fact that most of the studies reviewed evaluate this variable by using venous or arterial blood samples. Finally, other limitations observed were the size of the sample used and the failure to control the food eaten the night or week before. For this reason, it is suggested that, for future analyses, a representative sample is included, the control of the dietary variables and the evaluation of glycomia in the long term, in order to confirm the health benefits or consequences of this type of practice when extended over time.

Acknowledgements

The authors would like to thank the Faculty of Healthcare and the Physiotherapy program of the Univserity of Santander, UDES, for its support and backing during this present investigation.

Conflict of interest

The authors have no conflict of interest whatsoever.

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Original article

Evaluation of the hydration status in professional football players through different body composition assessment techniques

Guillermo Casas Ares[1], Alberto López Moreno[2], Fernando García Oliveri[2], Raquel Blasco Redondo[2]

[1]Universidad de Valladolid. [2]Departamento de pediatría e inmunología, obstetricia y ginecología, nutrición y bromatología, psiquiatría e historia de la ciencia. Universidad de Valladolid.

Received: 09.02.2018
Accepted: 06.03. 2018

Summary

Introduction: The hydration status of the individual during sports is currently one of the most important issues in relation to the practice of physical exercise, especially in hot and long-lasting environments (>1h). In the present study, the hydration status of professional football players, members of Real Valladolid B, is analysed during a training session at different times of the year in order to check their hydration status, as well as to observe in which way the climate influences the aforesaid state. Since a variation in the hydration status, whether dehydration or overhydration, is harmful for the athlete, affecting both his physical performance and health. Thus, in order to maintain an ideal hydration status throughout the physical effort, it will be essential to accomplish a set of regulations and guidelines.
Methods: For this purpose, different hydration assessment techniques are used. These techniques comprise a double weight recording, a bioimpedance analysis before and after training, a cineantropometry before and after training, and, only after training, the measurement of the density of the urine.
Results: the results showed differences regarding the different weight obtained before and after training, as well as a variation in the weight percentage between january and may. Urine density also pointed out the manifestation of a state of post-exercise dehydration. Furthermore, the bioimpedance and anthropometry reflected significant differences and low consistency between them, being anthropometry the most accurate method.
Conclusions: the diversity of results obtained, related to the appearance of a state of dehydration in players at the post-exercise moment, suggests the necessity of advising and raising awareness among the athletes about the compliance of the individualized strategies of hydroelectricity replacement, taking into account the personal characteristics of the individual, as well as those that are external to him.

Key words:
Hydration. Football. Bioimpedance analysis. Cineanthropometry. Hydroelectrolytic replacement.

Estudio del estado de hidratación de futbolistas profesionales mediante diferentes métodos de evaluación de la composición corporal

Resumen

Introducción: El estado de hidratación del individuo durante la práctica deportiva, es uno de los temas más importantes en la actualidad en relación a la práctica de ejercicio físico, sobre todo, en ambientes calurosos y de duración prolongada (>1h). En el presente estudio, se analiza el estado de hidratación de jugadores profesionales de fútbol, integrantes del Real Valladolid B, durante una sesión de entrenamiento en diferentes épocas del año, con el fin de, además de comprobar su estado de hidratación, poder observar de qué manera influye el clima en dicho estado. Dado que una alteración en el estado de hidratación, será perjudicial para el deportista, afectando tanto a su rendimiento físico, como a su salud, el cumplimiento de una serie de normas y pautas existentes será imprescindible para mantener un estado óptimo de hidratación.
Métodos: Se usaron distintos métodos de evaluación de la hidratación. Un registro de doble pesada, una bioimpedanciometría pre y post entrenamiento, una cineantropometría pre y post entrenamiento y la medición de la densidad de orina únicamente post entrenamiento.
Resultados: Los resultados mostraron diferencias significativas en cuanto a la diferencia de peso entre el pre y post entrenamiento, y en el% de variación de peso entre enero y mayo. La densidad de orina indicó también la aparición de un estado de deshidratación postejercicio. La bioimpedancia y la antropometría mostraron diferencias significativas y una concordancia baja entre ellas, siendo la antropometría la más sensible.
Conclusiones: La diversidad de resultados obtenidos, relacionados con la aparición de un estado de deshidratación en los jugadores en el momento postejercicio, sugiere la necesidad de aconsejar y concienciar a los deportistas sobre el cumplimiento de estrategias de reposición hidroelectrolítica individualizadas, teniendo en cuenta las características propias del individuo, así como las externas a este.

Palabras clave:
Hidratación. Fútbol. Bioimpedanciometría. Cineantropometría. Reposición hidroelectrolítica.

Correspondence: Guillermo Casas Ares
E-mail: guicasas2@gmail.com

Introduction

The hydration status of professional sportspeople is a measurable parameter which has now been shown to have an inverse relationship with sports performance and health. Anything, therefore, which prevents athletes from being euhydrated (optimal hydration status) will negatively affect their performance and health[1-3]. According to the American College of Sports Medicine[4], different biological markers can be considered useful for assessing hydration status. See Table 1.

When doing sport, body temperature increases, causing the body to set in motion mechanisms to help lose this heat (thermoregulation): an increase in blood flow in the vessels closest to the skin (peripheral vasodilation) and the secretion of sweat. The latter mechanism is the body's main way of dissipating heat during prolonged exercise, even at submaximal exercise intensity and especially in warm climates[5].

Sweating causes the body to lose both water and electrolytes. Such loss is a determining factor and is not the same in all individuals. Sweat is obtained from both extracellular and intracellular fluids, meaning that the electrolytes and salts most affected by sweat production are sodium and chlorine. Studies published on the subject show that an average of about 3.2 g of salt are lost per litre of sweat and that the normal sweat rate stands at 1-1.5 L per hour of exercise[5].

In order to prevent disruption in sportspeople's hydration status (dehydration or over-hydration) during exercise, the Spanish Federation/ Society of Sports Medicine (FEMEDE/SEMED) has established a consensus on sports drinks, their composition and fluid replenishment guidelines[6], supplying the information needed to keep athletes euhydrated.

Football is a mixed sport which calls for physical strength throughout the entire session and speed at specific moments when explosiveness is required. It is also quite specific regarding hydration, since the players can only drink before and after each match and at halftime. Proper fluid intake in line with each player's needs when doing the sport should, without a doubt, bring numerous benefits in terms of both health and sports performance. According to Monteiro CR *et al*., the mean electrolyte replenishment of players during the activity represents 50% of the loss produced[7].

The general objective of this study was to check the hydration status of sportspeople and to see if it is disrupted during the practice of team sports, in this case football. Its specific objectives were to assess whether there exist differences in hydration status depending on the weather and to verify the reliability of kinanthropometry and bioimpedance analysis as methods through which to measure and evaluate total body water.

Table 1. Biological markers of hydration status according to their usefulness, validity and cut-off point.

Measurement	Practical usefulness	Validity (Acute and chronic change)	Euhydration cut-off point
TBW Low	Acute and	<2% Chronic	
Plasma osmotic concentration	Medium	Acute and Chronic	<290 mOsmol
Specific gravity	High	Chronic	<1020 g/ml
Urine osmotic concentration	High	Chronic	<700 mOsmol
Body weight (Evidence category A)	High	Acute and Chronic	<1% (Excessive dehydration>2%)

TBW: Total body water.
Biological markers of hydration status according to their usefulness, validity and cut-off point. Source: American College Sports of Medicine, Exercise and fluid replacement. Medicine and Science in Sports and Exercise.

Material and method

Type of study

The study was observational, descriptive and longitudinal, without any type of intervention on the study variables. The players drank water on demand during the sessions, as they usually do, and did not consume any drinks other than water. All the subjects in the study were exposed in a similar manner to the study factor: sport during training at a professional level at the same points in the football season and under similar ambient conditions. The effect that physical activity and climate had on their hydration status, and, consequently, on their sports performance and health was evaluated.

The hydration statuses of professional football players belonging to the Real Valladolid B team, which currently plays in Spanish league division 2B, were analysed during training sessions in different weather conditions. Analysis was performed by measuring three variables: total body water, specific gravity of the urine and variation in body weight.

Population

Eighteen players, of whom fourteen successfully completed the study (n=14). All the players were male field players (no goalkeepers) belonging to the same professional football team, Real Valladolid B, who volunteered for the study.

The following inclusion criteria were applied for selection:

- Over 18 years of age.
- No injuries which might affect training.
- Training at the same level of intensity and in the same environmental conditions.
- Not taking any medication which might affect fluid retention or the player's physical condition.
- No metal elements in the body.
- Accepting and signing the informed consent form and consent for the collection of biological samples.

The characteristics of the participants were: age (20.8±1.76), height (180.7±4.6) cm, weight (72.8±4.1) kg and BMI (22.3±1.6) kg/m^2. Because the sample is not representative, the results of the study cannot be generalised to other professional football teams.

In order to be part of the study, the participants necessarily received clear, concise written information on it so that they could understand and accept the procedures, the use of their personal data and the collection and analysis of biological samples. The study was approved by the Clinical Research Ethics Committee of the East Valladolid Health Area, University Clinical Hospital of Valladolid.

Procedures

The study took place at two very important points in the sport season in terms of physical preparation. The mesocycles in which the measurements were taken were:

- In January, during the preparation period. Just after returning from the Christmas break.
- In May, during the last weeks of competition of the football season. (Table 2)

These mesocycles were chosen because they involve similar workloads.

The data provided by the Spanish Meteorological Agency were used to register the ambient temperature and relative humidity. The temperature and relative humidity (RH) were (3.2±2.1) ºC and (76.7±12.4) %RH when the first data were collected in January, and (13.2±6.3) ºC and (59±14.9) %RH when the second set of data were collected in May.

Test weighing and the calculation of %total body water were conducted by bioelectrical impedance analysis using a Tanita BC-601 body composition monitor, strictly observing the measuring protocol regarding the absence of metal elements in the body. Considering that the objective was to carry out an observational study of the changes in body composition produced as a result of the intake or non-intake of fluid and the performance of physical exercise, the restrictive criteria of the measuring protocol relevant to these activities were not respected[8,9].

Formula of %weight variation by test weighing:

[[(Starting weight (kg) - End weight (kg) + Water consumed (L)] / Starting weight] x 100

The anthropometric measurements were taken on the basis of the international consensus, International Society for the Advancement of Kinanthropometry (ISAK 2001)[8], following specific locations based on the texts of Ross and Marfell-Jones (1991), backed by ISAK and in Spain by the Spanish Kinanthropometry Group (GREC)[10], using:

- TANITA BC-601 body composition scales and monitor (accuracy: 0.1 kg).
- Holtain skinfold calliper (accuracy: 0.2 mm).
- Wall measuring rod (accuracy: 1 mm)
- Tape measure: Rosscraft (accuracy: 1 mm), metal, narrow and inextensible.
- Dermographic pencil.

The data were then entered in calculation tables to obtain data for %total body water from the anthropometry. The formulas indicated in Table 3, applying the hydration constant (73%) for fat-free mass, were used for this purpose. This constant was applied because a variation of the constant takes place throughout the exercise, meaning that pre-training can only be calculated assuming the error which not taking into account the small % of water found in the fat mass supposes.

The post-training urine specific gravity (USG) or urine density (UD) was also recorded. Urea (20%), sodium chloride (25%), sulphate and phosphate account for most of the specific gravity of normal urine. Normal adults with an adequate fluid intake produce urine with a specific gravity of 1016-1022 g/ml for a period of 24 hours; however, healthy kidneys are capable of producing urine with a specific gravity which oscillates between 1003 and 1035 g/ml. If a random sample of urine has a specific gravity of 1023 g/ml or more, the concentration capacity can be considered normal. The minimum specific gravity after a standard load of water should be less than 1007 g/ml. Urine with a low specific gravity of less than 1007 g/ml is known as hyposthenuric urine[4,11,12.]

Table 2. Distribution and conditions of the training sessions.

Moment:	Date	Time Pre	Time Post	Amb. temp. Cº	% Rel. hum.
First measurement January					
Sample 1	26/01/2017	09:00	13:00	-3ºC – 6ºC	70
Sample 2	02/02/2017	09:00	13:00	-4ºC – 7ºC	91
Sample 3	09/02/2017	09:00	13:00	-0ºC – 5ºC	69
Second measurement May					
Sample 1	27/04/2017	09:00	13:00	-0ºC – 12ºC	65
Sample 2	04/05/2017	09:00	12:30	-11ºC – 25ºC	42
Sample 3	11/05/2017	09:00	12:30	-10ºC – 22ºC	70

Amb. Temp.: Ambient temperature in degrees Celsius, %Rel. hum.: Relative humidity percentage.

Table 3. Formulas used to calculate body density, fat mass and total body water using the hydration constant of muscle mass.

Durnin/Womersley formula, Body Density, for males aged 20-29:
$1.1631-0.0632* \text{LOG}(\Sigma 4\text{skinfolds})$
Siri's formula for %FM:
$[(4.95/Db) -4.5] \times 100$
Use of the hydration constant for FFM as a method to obtain TBW:
$\dfrac{(100 \times [0\text{-}73 \times (\text{Weight kg} - \frac{\%FM \times \text{Weight kg}}{100})]}{(\text{Weight Kg})}$

%FM: Percentage of fat mass, FFM: Fat-free mass, TBW: Total body water.

Formulas used to calculate body density, fat mass and total body water using the hydration constant of muscle mass.

In general, normal urine density values are:

- 1001 g/ml: Low density.
- 1001 - 1020 g/ml: Normal density.
- 1020 -1030 g/ml: Indicator of dehydration.
- More than 1030 g/ml, not ingesting enough fluids.

The data were collected by inserting Health Mate DUS-10 urine analysis test stick strips into the sterile sample collection containers for 2 seconds and reading them 60 seconds later, as indicated by the protocol. Values of <1020 g/ml were considered normohydration and >1020 g/ml as indicators of hypohydration and/or dehydration[13].

Statistical analysis

The statistical significance used in the study was p<0.05. Statistical analysis was performed with the statistical package IBM SPSS 1.0.0.407 for MAC. The normality of the variables was determined using the Shapiro-Wilk test (n<30).

Given the normality of the variables, Student's t-test for related variables was used to see if there were significant differences between the different variables (weights, total body water). The Wilcoxon test was used for urine density because it did not follow a normal distribution.

The Intraclass Correlation Coefficient (ICC), with a confidence interval of 95%, was used to compare the concordance between the different total body water measurement techniques. Agreement was also expressed graphically with a Bland–Altman plot.

Results

Description of the sample

14 members of the Real Valladolid B football team were selected. Their weight, body water and urine density data for January and May are given in Table 4.

In general terms, it was observed that:

- They consumed more fluid in January than they did in May.
- The %body weight loss was greater in May than it was in January.
- Urine density hardly varied between the two measurements.

Statistical analysis was then performed to check whether the results were significant or not.

Statistical significance

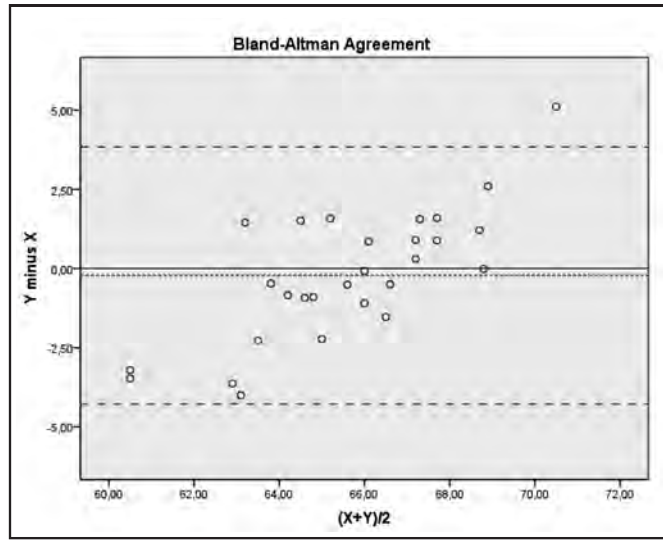
Save urine density, the variables evaluated followed normal distributions.

Weight variable

Statistical analysis of the pre- and post-training weight data showed a significant difference between the two measurements: January (p = 0.000; p < 0.05); and May (p=0.000; p<0.05).

Analysis of the data relating to %weight variation between January and May also showed a significant difference between the two measurements (p = 0.001; p <0.05).

Figure 1. Representation of Bland-Altman for the analysis of concordance between BIA and Cineanthropometry.



Representation of Bland Altman for the qualitative analysis of the agreement between cineantropoemtría (Siri) and bioimpedanciometría as methods for the estimation of Total Body Water. The mean (X axis) and the difference (Y axis) of the measurements are performed to perform the representation.

Table 4. Data of the different variables measured.

Data	January	May
Pre-tr weight (kg)	(72.8±4,1) [65.7-79.8]	(73.4±3.8) [65.7-78.6]
Post-tr weight (kg)	(72.5±4.1) [65.5-79]	(72.5±3.8) [65.1-77.9]
Water intake (ml)	(750.3±281.0) [388-1260]	(586±197.4) [86-975]
%Weight loss (Not counting water)	(0.44±0.55) [-0.71-1.3]	(1.18±0.47) [0.6-2]
%Weight loss (counting water)	(1.47±0.31) [0.94- 2.22]	(1.99±0.55) [1.24- 3.24]
TBW by anthropometry Pre-training (L)	(66.06±1.53) [62.99-68.81]	(65.56±1.66) [61.75-68.03]
TBW by BIA Pre-training (L)	(65.77±2.43) [60.5- 68.90]	(65.41±2.49) [60.5-70.5]
TBW by BIA Post-training (L)	(66.06±3.11) [60.6- 72.5]	(66.39±2.67) [63.3- 71.8]
Post-tr urine density (g/ml)	(102.,5±2.6) [1025-1030]	(1026.8±4.2) [1015-1030]

Pre-tr: Pre-training, TBW: Total body water, BIA: Bioimpedance analysis, Post-tr: Post-training, Data of the different variables measured in January and May. (Me±SD) [Min-Max].

Total body water variable

Statistical analysis of the pre- and post-training TBW data taken in January and May, measured by bioelectrical impedance analysis, did not yield a significant difference in January (p = 0.577; p > 0.05), but did in May (p = 0.003, p < 0.05).

Statistical analysis of the data relating to %TBW variation between January and May did not reveal any significant difference between the two measurements (p = 0.183; p <0.05).

Urine density variable

Both in January (1027.5±2.6 g/ml) and May (1026.8±4.2 g/ml), the UD results obtained were well above the reference euhydration value (1020 g/ml), indicating that the players finished training in a state of dehydration.

Statistical analysis of the post-training urine density data did not show a significant difference between the densities of January and May (p=0.317; p>0.05). Since they did not follow normal distribution, the Wilcoxon test was used.

Concordance analysis

Concordance of TBW measurements (ICC) between BIA and anthropometry:

The pre-training TBW data taken by means of anthropometry and BIA were analysed to see the relationship between them.

The Intraclass Correlation Coefficient (ICC) was used to measure the degree of agreement or consistency between the two measurements.

ICC values fall between 0 and 1, with agreement increasing the closer the value is to 1. The ICC obtained was:

CCI=0.494 with p=0.004

The results show a significant difference and low concordance between the two measurement instruments (anthropometry and BIA). This is represented graphically below with a Bland-Altman plot (Mean (Y-X) = -0.219; CI 95% (-4.277 a 3.838).

Discussion

The principal objective of this study was to check the hydration status of sportspeople and to see if it is disrupted during the practice of team sports, in this case football. Since football matches last 90 minutes, hydration status was evaluated following training lasting a similar period of time. Taking into account that hydroelectrolytic replenishment is easier during training than it is in competitive matches (given the restrictions placed on players both by the rules of game and the availability of drink), the results obtained from training sessions may be better than those obtained during competition.

The results obtained for the change in body weight variable are statistically significant, thereby validating this method of determining players' hydration status[4]. The cut-off point of the state of dehydration taken as a reference[4,11] was a loss of >1%, while >2% would indicate excessive dehydration. The means of the weight variation results obtained were (1.47±0.31) and (1.99±0.55)% weight loss in January and May, respectively.

In both months, the players presented a state of dehydration. It should be noted the % loss approached excessive dehydration in May.

Both Da Silva AI *et al.* in their study of footballers in 2011[14] and Da Silva RP *et al.* in 2012[15] obtained similar results in terms of % weight loss (2±0.2) and (1.6±0.8) during matches lasting 90 minutes. However, Aragon LF *et al*. in 200916 and Duffield R *et al*. in 2012[17] published higher %weight loss results: (3.4±1.1) and (3.4±0.7), respectively. The disparity in the data found in different studies may be due to diverse factors which directly or indirectly influence player hydration[18], such as temperature, relative humidity, fluid intake before and during the activity, the state of the players prior to exercise, ingestion beforehand, the availability of fluid during the sports activity, exertion at that particular moment, etc. In general, however, the studies show that football players end both training and competition matches in a certain state of dehydration, as demonstrated by the %weight loss variable (Table 5).

– Total body water was analysed using two different instruments, kinanthropometry (Siri's formula, applying the hydration constant) and bioimpedance analysis. Kinanthropometry was only used prior to training and so no comparative study was conducted, as indicated in Material and Methods.
– Bioimpedance analysis did not yield significant results in terms of TBW variation during the January session (90 min), but it did in May. This may be due to differences between the two measurements regarding temperature, humidity, clothing worn by the players or other factors.
– Urine density variable. Values indicative of normohydration (<1020 g/ml) and hypohydration and/or dehydration (>1020 g/ml)[4,11] were taken as reference values:
  - January: UD= (1027.5±2.6 g/ml)
  - May: UD= (1026.8±4.2 g/ml)

Both indicate the existence of a state of dehydration at the end of the training session (90 min). The results are consistent with those obtained in previous studies in which it has been demonstrated that football players finish training sessions and matches in a state of dehydration[14-17]. Previous studies have also shown on the basis of urine density data that players present a state of dehydration prior to sporting activity[14-16,19,20]. Pre-training data were not taken in this study, so the state in which the players arrived at training cannot be deduced, only the state in which they finished.

As for the secondary or specific objectives:

– Of the variables measured in the present study, the only one that gave significant results regarding the influence of the weather on hydration status was comparison of the weight difference percentage between January and May. Accordingly, the weather may influence players' hydration status. This is consistent with existing evidence that hot climates have a more significant negative impact on the hydration status of athletes than cold climates[3-5,19,21].
– The second specific objective of the study was to verify the reliability of kinanthropometry and bioimpedance Analysis as methods to measure and evaluate total body water.

The results obtained in the statistical analysis yielded low concordance (ICC=0.494) between the two measuring instruments. These results are similar to those of Portao *et al.*, who analysed concordance between different BIA appliances and the kinanthropometric method

Table 5. Comparison of the study with similar studies.

Estudios	n/Level of players /Sex	Type of activity/duration/ environment	Fluid intake (ml)	Dehydration (% weight variation)
Aragón-Vargas *et al.* 2009	17 professionals	Official match, 90 min/ 35 ± 1ºC, RH = 35 ± 4%	1948 ± 954	3,4 ± 1,1
	Male			
Da Silva & Fernández 2003	6 referees and 6 assistants	Match, 90 min/ 20 ± 1ºC, RH = 77 ± 4%	Referees: 320 ± 60	Referees: 1.6 ± 0.1
	Male		Assistants: 250 ± 90	Assistants: 0.6 ± 0.2
Da Silva *et al.* 2011	10 referees	Match, 90 min/ 23 ± 1ºC, RH = 67 ± 4%	480 ± 90	2,0 ± 0,2
	Male			
Da Silva *et al.* 2012	15 professional youth	Official match, 90 min/ 31 ± 2ºC, RH = 48 ± 5%	1120 ± 390	1,6 ± 0,8
	Male			
Duffield *et al.* 2012	13 professionals	Game simulation, 100 min/ 27 ± 0.1ºC, RH= 65 ± 7%	1166 ± 333	3,4 ± 0,7
	Male			
Gibson *et al.* 2012	34 professional youth	Training practice, 90 min/ 10 ± 3ºC, RH = 63 ± 12%	200 ± 20	0,8 ± 0,7
	Female			
Kiding *et al.* 2009	13 professionals	2 training practices, 90 min each/ T1: 14 ± 1ºC, RH = 71 ± 3%; T2: 6 ± 1ºC, RH = 74 ± 3	T1: 450 ± 250	T1: 0.6 ± 0.5
	Female		T2: 379 ± 142	T2: 0.5 ± 0.5
Maughan *et al* 2007	20 professionals	Friendly match, 90 min/ 6-8ºC, RH = 50-60%	840 ± 470	1.1 ± 0.6
	Male			
Shirreffs *et al.* 2005	26 professionals	Training practice, 90 min/ 32 ± 3ºC, RH = 20 ± 5%	972 ± 335	1.6 ± 0.6
	Male			
Williams & Blackwell 2012	21 professional youth	Training practice, 100 min/ 11 ± 1ºC, RH = 50 ± 3%	807 ± 557	0.5 ± 0.5
	Male			
Casas *et al.* 2018	14 professional youth	Training practice, 90 min/ 3.2 ± 2.1 ºC, RH = 76.7 ± 12.4%	750.3 ± 281	1.47 ± 0.31
	Male			
	14 professional youth	Training practice, 90 min/ 13.2 ± 6.3 ºC, RH = 59 ± 14.9%	586 ± 197.4	1.99 ± 0.55
	Male			

Min: Minutes, %RH: Relative humidity.

Comparison of the study with similar studies on the hydration status of professional football players. Source: Hydration science and strategies in football. Sports Science Exchange[18].

in 2009[18,22,23], their results also failing to reflect concordance between the two methods.

In addition to the concordance analysis performed, observation of the other results obtained shows that measuring skinfolds is more sensitive to changes in body composition and total body water than BIA. The kinanthropometric method, even taking into account the difficulty of implementing it correctly (trained staff and right equipment) and the inherent technical errors of measurement which can be committed, is a benchmark method for estimating body composition and is more sensitive when it comes to detecting changes in the body composition of sportspeople, as seen in previous studies. However, the BIA methods are an alternative to bear in mind when the means, material or qualified personnel to carry out the measurements of the different anthropometric parameters are not available, always bearing in mind the errors in measurement associated with their use, using them under the same conditions and applying the same equations in order to minimise such errors[18,22,24].

The broad range of results obtained in terms of weight variation, total body water and urine density suggest the need to individualise players' hydroelectrolytic replenishment strategies, taking into account the specific characteristics of each individual and factors external to him/her: temperature, relative humidity, duration of exercise, etc.

According to the above, the following conclusions can be reached.

Conclusions

- Incorrect hydration status is common in young professional footballers. This leads to different levels of hypohydration during the 90-minute sports activity they carry out.

- The percentage variation in body weight as a measurement to predict hydration status proved more sensitive to acute changes than measurement of total body water.
- Urine density analysis can be considered a correct, practical way to evaluate a sportsperson's hydration status.
- Hot environments have a negative effect on hydration status.
- It is essential to give footballers suitable guidelines concerning hydroelectrolytic replenishment and raise their awareness about its importance in order to achieve, at minimum, a state of euhydration during their sports activity.
- There is no concordance between bioimpedance analysis and kinanthropometry, the latter proving to be more sensitive. Consequently, the two methods are not comparable to each other.

The appearance of different degrees of hydration in players after exercising suggests the need to advise them as to individualised hydroelectrolytic replenishment strategies which take into account the characteristics of each individual and factors external to him/her, and insist on their importance.

Conflict of interest

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

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Original article

Isokinetic strength and vertical jump test in acrobatic skydivers

Ignacio Martínez González-Moro, Rocío Navalón Alcañiz, María José Paredes Ruiz, José L. Lomas Albaladejo, Vicente Ferrer López

Grupo de Investigación Ejercicio Físico y Rendimiento Humano. Universidad de Murcia.

Received: 03.01.2018
Accepted: 07.03.2018

Summary

Introduction: Knees of the parachutists can suffer injuries during the landing that can be avoided with a correct muscular strength. This strength is posible to be evaluated of direct way with isokinetic dynanometers and indirect methods using the test of vertical jump.
Objective: The aim of this study was to determine and analyze, in professional skydivers, the relationship between the values of isokinetic force of quadriceps and hamstrings with height and time of flight in vertical jumps.
Material and method: We studied the fourteen paratroopers belonging to the (patrol acrobatic jumper of the air force) using an isokinetic dynamometer (60°/s and 180°/s) both for concentric work as eccentric, obtaining the peaks maximum of strength and hamstrings/quadriceps ratios. Evaluate, on a platform of contact, the following vertical jumps: Abalakov Jump and Squat Jump, Counter Movement Jump.
Results: The results indicate that the peaks of maximum strength of flexor and extensor muscles of the knee are greater in eccentric mode, and the men's team. Hamstrings/quadriceps ratios show a predominance of the first. AJ is the jump where greater height and time of flight is achieved. There is a positive correlation between the flight time of all jumps and concentric quadriceps strength. The height of jump by body weight (Work = Kg x m) correlates with the peaks of concentric and eccentric strength of the quadriceps. The ratio is higher in the higher speed. The eccentric strength of hamstrings does not correlate with the height of flight, but the concentric strength.
Conclusions: We can conclude that the knees of the skydivers have a predominance of the hamstrings what is considered positive for the activity carried out, since it helps to improve the stability of the knee and that there are high correlations between the peaks of force isokinetic and the work done in the jumps vertical.

Key words:
Isokinetic dynamometry. Vertical jump. Peak force. Hamstrings/quadriceps ratio. Skydivers.

Fuerza isocinética y test de salto vertical en paracaidistas acrobáticos

Resumen

Introducción: Las rodillas de los paracaidistas pueden sufrir lesiones durante la toma de tierra que se pueden prevenir con una adecuada fuerza muscular. Esta fuerza se puede evaluar de manera directa con dinamómetros isocinéticos y con métodos indirectos mediante el test de salto vertical.
Objetivo: El objetivo del estudio fue determinar y analizar, en paracaidistas profesionales, las relaciones entre los valores fuerza isocinética máxima de cuádriceps e isquiosurales con la altura y el tiempo de vuelo en saltos verticales.
Material y método: Valoramos a los catorce paracaidistas pertenecientes a la Patrulla Acrobática Paracaidista del Ejército del Aire mediante un dinamómetro isocinético (a 60º/s y 180º/s) tanto para el trabajo concéntrico como excéntrico, obteniéndose los picos máximos de fuerza y las ratios isquiosurales/cuádriceps. Evaluamos, sobre una plataforma de contacto, los siguientes saltos verticales: *Squat Jump, Counter Movement Jump* y *Abalakov Jump*.
Resultados: Los resultados indican que los picos de fuerza máxima de la musculatura flexo-extensora de la rodilla son mayores en modalidad excéntrica, y en el equipo masculino. Las ratios isquiosurales/cuádriceps muestran un predominio de los primeros. *Abalakov Jump* es el salto donde mayor altura y tiempo de vuelo se consigue. Existe una correlación positiva entre el tiempo de vuelo de todos los saltos y la fuerza concéntrica del cuádriceps. La altura de salto por el peso corporal (Trabajo = Kg x m) se correlaciona con los picos de fuerza concéntrica y excéntrica del cuádriceps. La relación es mayor en la velocidad más alta. La fuerza excéntrica de isquiosurales no se correlaciona con la altura de vuelo, pero sí la fuerza concéntrica.
Conclusiones: Podemos concluir que las rodillas de los paracaidistas presentan un predominio en la fuerza de los isquiosurales, lo que se considera positivo para la actividad que realizan ya que contribuye a mejorar la estabilidad de la rodilla y que hay altas correlaciones entre los picos de fuerza isocinético y el trabajo realizado en los saltos verticales.

Palabras clave:
Dinamometría isocinética. Salto vertical. Pico de fuerza. Ratio isquiosurales/cuádriceps. Paracaidistas.

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

Introduction

Skydiving is a physical-sporting activity prone to causing both acute and chronic injuries[2]. Recent studies suggest that injuries to the lower limbs are the most frequent, making up 65% of total injuries[3], and within this region knee joint injuries are particularly noteworthy.

Just as in other sports, acute injuries are caused by trauma or sporting accidents; whilst chronic injuries - or overload – are linked to diverse aetiological factors, including abnormal anatomical alignment[4], reduced strength in the hip or thigh muscles[5,6], or faulty mechanism in the lower extremities whilst undertaking specific activities[7].

Identifying and correcting imbalances in lower extremity muscle strength is one of the key components in preventing and treating sporting injuries[8]. To do this, this strength must be quantified and measured using dynamometers and specific protocols. As it is not always possible to measure the muscle strength generated during sporting activity in real situations, these tests are often carried out under controlled laboratory conditions[9]. Of all the different demonstrations of strength, the most frequently used ones for assessing athletes are explosive strength and isokinetic strength. Explosive strength can be assessed using a test and with sporting apparatus, such as the vertical jump on specific platforms[10], whilst isokinetic strength can be measured using functional assessment devices such as specific dynamometres[11].

The isokinetic method is an assessment system that uses information and robotised technology to obtain and process muscle strength in quantitative data, obtaining its maximum values in the entire range of movement and establishing the position in which the strength peak is obtained[12]. This enables it to be measured in both concentric and eccentric activation, and comparisons can be established[13]. The advantage over other methods is the possibility of objectively assessing the dynamic qualities of the muscle group responsible for the movement of a particular joint. It can be applied in fields such as rehabilitation[14], muscle training[15] and biomechanical analysis[16].

Explosive strength as a motor skill, is one of the determining factors in the success of all activities that require high muscle strength expression as quickly as possible, playing a vital role in a wide range of sports linked to jumps and propulsion, which is why it forms part of training in almost all modalities[17]. A very common way of quantifying it is using the well-known jump tests. The first jump tests, which are still used today, were performed without platforms, such as the "Détente Vertical"[18] or the "Sargent test"[19], which reveal the benefits of using the arms whilst jumping. Today, jump and/or strength platforms are used with tests, based on and adapted to Bosco systems, such as the Squat Jump, the Counter Movement Jump and the Drop Jump[20].

Tests based on the vertical jump aim to assess the functional and neuromuscular characteristics of the extensor muscles of the lower limbs depending on the heights obtained in the various tests. These are strictly standardised maximum tests and two phases can be seen: eccentric and concentric[21,22]. Assessing strength and strength training using vertical jumps is known as plyometry[23]. The biomechanical parameters of the lower limbs are the factors that determine the height of the jump, including the use of elastic energy, the shortening cycle, muscle contraction speed and power[24,25].

The landing in manual release-chute skydiving, and more specifically in the sport, is performed standing, with the skydiver taking more or less quick steps from the moment he/she touches the floor until complete standstill (Figure 1). This instant is particularly stressful for the knees as it combines the effect of the forces of action (weight of the skydiver) and reaction (contact with the ground), with the run to stop the movement, on a possibly irregular surface, as well as the likely rotation due to the traction of the parachute in the wind current. Furthermore, in the "precision jump" modality, the skydiver's feet must make contact with a specific point marked on a mat. This leads the skydiver to prioritise precision over stability to achieve the highest score, which leads to awkward contact positions with the consequent risk of injury (Figure 2). At this point the skydiver makes a quadriceps contraction to maintain his/her position and to avoid falling, which causes knee extension and a tendency to displace the tibia over the femur, stretching the anterior cruciate ligament (ACL). The sum of all these elements entails risk factors for ACL injury, which can be controlled using proprioception and muscle strength training, paying particular attention to the muscle balance between quadriceps and the hamstring muscles[26].

Most skydiving injuries occur upon landing[27], which is why the more jumps performed, the greater the possibility of injury. One of the groups to perform the most jumps in Spanish skydiving is the Acrobatic Parachuting Patrol of the Spanish Air Force (PAPEA). Its main activities

Figure 1. Running landing.

Figure 2. Standing landing in a precision jump.

are acrobatic exhibitions and sporting competition in representation of the Air Force. Given their specific training, these skydivers perform 4-5 jumps each day and each skydiver accumulates thousands of jumps. This large number of jumps means that their knees are at a high risk of injury, especially the anterior cruciate ligament, which is why studies and injury prevention activities should be carried out[28].

The publication of results regarding the assessment of knee strength using different techniques is increasingly widespread, and the diversity of methods used makes it difficult to compare findings in terms of strength peaks and their possible application as predictors of sporting or motor skills[29-31], which is why we consider it to be particularly interesting to see the relationships between both measurements.

As such, our aim is to establish and analyse the isokinetic strength parameters of the flexor-extensor muscles of the knee involved in injury prevention among teams of professional acrobatic skydivers, and the relationship between height and the time spent in flight in different vertical jumps.

Material and method

Participants

In this study, all the members of the PAPEA were analysed: nine males and five females, comprising the male and female teams. Exclusion criteria included the presence of an acute injury or discomfort to the lower limb, which impeded the development of maximum strength during the tests. The military authorities granted permission, and the Research Ethics Commission of the University of Murcia gave approval.

Procedure

Our study is descriptive, transverse and observational.

All the subjects were informed about the study objectives and method and they all signed the corresponding informed consent document. After accepting the conditions, an anamnesis was carried out, in which subjects gave information about any previous injuries, personal data (age) and information about their skydiving experience.

The isokinetic dynamometer used was the Chattanooga KIN-COM AP, with the software provided by the manufacturer to calculate the strength peak, both in concentric and eccentric contractions. The dynamometer allows a maximum strength peak of 2000 Newton and a maximum speed of 250º/s.

To assess the vertical jump, the GLOBUS Ergojump contact platform was used. This apparatus works like a stopwatch, which is activated when the athlete, with both feet positioned on the platform, jumps up, and which stops when the subject lands back on the platform. It measures the flight time of the jump and immediately calculates the equivalent height of the jump.

Before performing the tests, a quantitative measurement was made of height and weight using the SECA 813 weighing scale and the SECA 213 height measuring device. After a five-minute warm up on a cycle ergometer, the isokinetic assessment was carried out following the protocol used by our group[32]. A week later, to avoid the effects of fatigue, three jumps were performed, detailed in the Bosco protocol on a contact platform: Squat Jump (SJ), Counter Movement Jump (CMJ) and the Abalakov Jump (AJ).

Assessment and isokinetic variables

Both extremities were analysed with the subject in seated position. The order for carrying out the test was random, depending on the initial provision of the machine. The subjects were attached to the seat and to the backrest of examination seat the using adjustable straps. The thigh was kept next to the seat using a suitable support. The arm rotation axis of the dynamometer was positioned laterally to the external femoral epicondyle, and the mobile end was attached to the middle part of the leg, 22 cm from the rotation axis (Figure 3). The muscle groups examined were the quadriceps and hamstrings using both concentric and eccentric flexor-extensor movements of the knee. The range of motion was between 80º and 10º of knee flex (0º = complete extension), and the speeds of 60º/s and 180º/s were examined. The type of register used is called "overlay" or contraction to contraction. Valid movements are considered to be those in which the greatest strength is achieved (with a minimum of three maximum attempts), requesting sub-maximum efforts to reach the greatest possible, by following the strength/angular position curves.

The isokinetic variables have been described for the dominant (D) and non-dominant (ND) sides, both for the quadriceps (Q) and the hamstrings (H), the speed (60º/s and 180º/s) and the strength peaks in concentric (con) and eccentric (ecc) modality of the assessed limb. The conventional quotients - or ratios - were obtained by dividing the concentric strength of the hamstrings by that of the quadriceps (Hcon/Qcon), and the functional ratios were obtained the same way but using the eccentric strength of the hamstrings (Hecc/Qcon)[33].

Figure 3. Position for the isokinetic assessment.

Execution and assessment of the vertical jumps

The following jumps were carried out: Squat Jump, Counter Movement Jump, and Abalakov Jump. SJ consists in jumping from a 90º knee-flex, avoiding a countermovement so as not to accumulate elastic energy. The trunk must be straight and hands positioned on the hips during the test. During the flight phase the legs must be extended, and when the feet come back into contact with the platform the first point of contact must be the metatarsal and then the back part, the calcaneal. The CMJ is performed the same way as the SJ, but with the subject starting from an upright position, so that during the eccentric phase to reach a 90º knee-flex, the potential elastic energy is stored in the spring elements in series, enabling them to be reused as mechanical work during the concentric phase. The Abalakov Jump (AJ) is performed the same way as the CMJ but with the upper limbs released to be used in coordination and synchronisation with the flexor-extension action of the legs to achieve maximum flight.

To establish the plyometric variables, the time (T) and flight height (H) must be considered in each of the jumps. The work has been obtained from the product between the weight of the subject and the height achieved.

Statistical analysis of the data

With the data obtained, an Excel sheet was drawn up in which each line is a subject (case) and each column is a variable. From here, the data was exported to an SPSS v.19 statistics package. The quantitative variables were described using minimum and maximum values (range), average, typical deviation, and variation coefficient. The qualitative variables were described using absolute and relative frequencies (percentages). The normal distribution of the initial characteristics of the sample was checked using the Saphiro-Wilk test, and the equality of the variances using the Levene test. The comparison of averages for independent variables was performed using the T-student test. The comparison of the averages of related variables was performed using the T-paired study. The correlation between variables was established using the Pearson test. Statistical significance was considered to be present when $p \leq 0.05$.

Results

The average age of participants is 34.4 years for the male team and 35 for the female team. The anthropometric characteristics and skydiving experience are displayed in Table 1, separated by team. Significant differences ($p \leq 0.05$) can be seen in all the variables apart from age.

The results of the isokinetic assessment of the strength peaks of the quadriceps and hamstrings are displayed in Table 2, in concentric and eccentric modality, at the speeds of 60º/s and 180º/s separated by sex. It is worth noting that strength in eccentric modality exceeds that of concentric, for the two speeds assessed and for both teams. In all the strength pairs there is significant difference between men and women ($p \leq 0.05$), with higher figures displayed in the male teams. There are no bilateral differences. The ratios between the hamstrings and the

Table 1. Anthropometric variables and skydiving experience of each team.

	Male Team (n=9)		Female Team (n=5)	
	$\bar{X} \pm \sigma$	Mín – Máx	$\bar{X} \pm \sigma$	Mín – Máx
Age (years)	34.44 ± 4.36	29-41	35 ± 2.64	32-39
Height (cm)	173.6 ± 6.73	162.5-182	158.3 ± 6.135	152.4-168.5
Weight (Kg)	77.18 ± 7.45	65-87	55.8 ± 5.917	48.6-64.7
BMI (Kg/m^2)	25.61 ± 1.93	23.3-28.4	22.24 ± 1.702	19.3-23.7
Fat percentage	20.48 ± 3.92	14-26.2	27.18 ± 2.40	24.5-30.3
Years in PAPEA	8.55 ± 5.59	3-20	5.6 ± 2.88	2-8
No. jumps	3944 ± 2781	1200-10000	2060 ± 1212	600-3200

$\bar{X} \pm \sigma$: Average and typical deviation; Min: minimum; Max: Maximum.

Table 2. Comparison of the isokinetic strength peaks (Newtons) of the quadriceps and hamstrings and conventional and functional ratios between teams and sides.

Speed	Team	Dominant Side		Non-Dominant Side		P
		$\bar{X} \pm \sigma$	p	$\bar{X} \pm \sigma$	p	
Q 60º/s con	Male	763.22 ± 135.91	0.002**	760.77 ± 159.28	0.003**	0.965
	Female	501.2 ± 105.19		478.33 ± 181.58		0.215
Q 60º/s ecc	Male	1232.77 ± 245.28	0.009**	1048.44 ± 167.6	0.02*	0.035*
	Female	862.8 ± 141.27		804.66 ± 276.92		0.280
Q 180º/s con	Male	616.88 ± 89.61	0.0001***	592.22 ± 159.78	0.018*	0.601
	Female	364.2 ± 66.61		396.66 ± 57.36		0.866
Q 180º/s ecc	Male Male	1186.66 ± 203.04	0.026*	1273.33 ± 177.85	0.003**	0.194
	Female	885.8 ± 185.53		862 ± 267.3		0.358
H 60º/s con	Male	604.33 ± 124.27	0.001**	589.22 ± 116.06	0.033*	0.653
	Female	392 ± 35.34		423 ± 90.94		0.375
H 60º/s ecc	Male	741.44 ± 146.81	0.002**	802.22 ± 141.26	0.020*	0.281
	Female	520.2 ± 63.2		566 ± 123.66		0.343
H 180º/s con	Male	536 ± 128.61	0.015*	540.66 ± 48.07	0.001**	0.914
	Female	353 ± 83.67		427.33 ± 44.63		0.442
H 180º/s ecc	Male	735.87 ± 165.16	0.004**	799 ± 115.58	0.008**	0.105
	Female	494.2 ± 28.14		587.33 ± 145.52		0.376
60º/s Hcon/Qcon	Male	0.80 ± 0.16	0.956	0.78 ± 0.09	0.136	0.729
	Female	0.81 ± 0.19		0.96 ± 0.18		0.052
180º/s Hcon/Qcon	Male	0.88 ± 0.21	0.420	0.97 ± 0.27	0.508	0.375
	Female	0.98 ± 0.25		1.06 ± 0.05		0.272
60º/s Hecc/Qcon	Male	0.98 ± 0.17	0.441	1.09 ± 0.26	0.196	0.182
	Female	1.07 ± 0.28		1.31 ± 0.25		0.088
180º/s Hecc/Qcon	Male	1.17 ± 0.28	0.189	1.45 ± 0.23	0.863	0.089
	Female	1.38 ± 0.24		1.50 ± 0.16		0.306

Q = Quadriceps; H = Hamstrings. con = Concentric; ecc Eccentric; X: Average deviation; σ: Typical deviation; Maximum. Statistical significance: * p ≤ 0.05; ** p ≤0.01; *** p<0.001

quadriceps reveal a predominance of the hamstrings, with conventional ratio values exceeding 0.80 and functional ratios greater than 1.

Table 3 displays the average values of time and flight height in the three jump modalities, separated by sex. Slightly higher values can be observed in all the jumps for the male team, though significant differences were only found in the SJ. As foreseen, AJ is the jump in which the greatest height and flight time is achieve in both teams.

To analyse the relationship between the flight times in each jump and the strength peaks, the values from both sides have been added together and have been correlated to the seconds of flight. As such, a positive and significant correlation is only obtained for the quadriceps at 180º/s with the flight time of males in the three jumps: SJ r=0.738 (p=0.023); CMJ r=0.873 (p=0.002) and AJ r=0.910 (p=0.001). Upon analysing the demographic as a whole, we can see that there is a positive correlation between the flight time in all the jumps and the concentric strength of the quadriceps, being the most significant at 180º/s. Upon correlating the jump height to body weight (Work = Kg x m) with the strength peaks, a positive correlation is obtained with the concentric and eccentric strength peaks of the quadriceps, also higher at the highest speeds. The strength peaks of the hamstrings are positively related in its concentric form with the three jumps, but not in its eccentric form (Table 4).

Discussion

We have assessed the isokinetic strength of the quadriceps and the hamstrings both concentrically and eccentrically in all members of the PAPEA – an elite group of international skydivers. Their strength and power in vertical jumps has also been quantified using three tests. There are no studies that describe this kind of strength in skydivers, and few that relate both modalities in other sporting modes. In 2002, Tsionakos *et al*[34], performed a study on young physical education students, and

Table 3. Times (s) and flight height (m), by teams in vertical jumps.

	Male team			Female team			p
	$\bar{X} \pm \sigma$	cv	Mín – Máx	$\bar{X} \pm \sigma$	cv	Mín – Máx	
SJ (s)	0.5 ± 0.05	9.79	0.45-0.5	0.44 ± 0.03	7.62	0.39-0.48	0.041*
SJ (m)	0.31 ± 0.06	20.04	0.25-0.31	0.24 ± 0.04	15.16	0.19-0.29	0.048*
CMJ (s)	0.52 ± 0.04	8.28	0.45-0.52	0.47 ± 0.04	8.19	0.41-0.51	0.051
CMJ (m)	0.33 ± 0.05	16.46	0.25-0.33	0.28 ± 0.05	16.95	0.21-0.32	0.103
Abalakov (s)	0.57 ± 0.06	10.01	0.48-0.57	0.52 ± 0.03	6.63	0.48-0.57	0.132
Abalakov (m)	0.4 ± 0.08	20.06	0.29-0.4	0.34 ± 0.04	13.22	0.28-0.4	0.13

$\bar{X}$: Average deviation; σ: Typical deviation; cv: Variation coefficient; Min: Minimum; Max: Maximum; SJ: Squat Jump; CMJ: Counter Movement Jump; Statistical significance: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Table 4. Pearson's correlation and significance (p) between the time in the air (s) and the work performed in the vertical jumps (Kg x m) with quadriceps and hamstring strength peaks at both speeds.

	Quadriceps		Hamstrings	
60º/s	**Concentric**	**Eccentric**	**Concentric**	**Eccentric**
SJ (s)	0.568 (0.034)*	0.557 (0.038)*	0.418 (0.155)	0.301 (0.318)
SJ (Kg x m)	0.731 (0.006)**	0.689 (0.006)	0.576 (0.039)*	0.499 (0.083)
CMJ (s)	0.611 (0.020)*	0.470 (0.090)	0.428 (0.144)	0.289 (0.338)
CMJ (Kg x m)	0.786 (0.001)**	0.658 (0.011)	0.597 (0.031)*	0.518 (0.070)
AJ (s)	0.616 (0.019)*	0.478 (0.084)	0.500 (0.082)	0.352 (0.238)
AJ (Kg x m)	0.767 (0.001)**	0.660 (00.10)	0.633 (0.020)*	0.545 (0.054)
180º/s				
SJ (s)	0.781 (0.002)**	0.541 (0.056)	0.513 (0.073)	0.361 (0.225)
SJ (Kg x m)	0.912 (0.000)***	0.717 (0.006)**	0.684 (0.010)*	0.474 (0.102)
CMJ (s)	0.774 (0.002)**	0.487 (0.092)	0.462 (0.112)	0.233 (0.444)
CMJ (Kg x m)	0.920 (0.000)***	0.737 (0.004)**	0.684 (0.010)*	0.436 (0.137)
AJ (s)	0.835 (0.000)***	0.636 (0.020)*	0.462 (0.112)	0.318 (0.289)
AJ (Kg x m)	0.944 (0.000)***	0.774 (0.002)**	0.682 (0.010)*	0.465 (0.109)

Statistical significance: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

like us, they discovered a solid relationship between the isokinetic strength of the quadriceps and that obtained in the jump, especially when it was calculated depending on body weight (work). They only used concentric values, whilst we also discovered this with eccentric values. This relationship has also been described in young football players by Lehnert *et al*[13], but indications show that it differs throughout the season and is higher at greater speeds.

The average age of our demographic is higher than that of the majority of studies published about athletes, which generally oscillates between 16[13] and 27[35] years of age. This is because skydiving is a sport that is performed at adulthood, and there are no junior categories. As the female and male teams belong to the same military unit, and as they follow the same training routine, the effects of training can be compared and the same physical preparation principles can be adopted.

Isokinetic strength has been measured at both extremities, looking for differences or asymmetries. We did not find any in either team. Likewise, González-Ravé *et al*[35], with a study of handball players, also failed to find any significant differences between the dominant and non-dominant side, whilst Menzel *et al*[36] do describe differences. Although the majority of authors prefer to use the "the moment" or torque as the physical magnitude to assess isokinetic strength, we preferred to use "strength" as we have used a constant distance between the point of application of strength and the axis of the joint, which is why this factor does not have an influence when calculating the ratios and the differences, and what truly makes a difference in the muscles is the strength used, regardless of where it is executed.

In alignment with Alemdaroğlu[37], we have used two speeds for the isokinetic assessment – 60º/s and 180º/s – and a jump test for anaerobic power, finding that the strength values at the high speed are lower than at the low speed, though this author did not find any relationship with the jump height, whereas we did find one.

We have proven, just like other authors, that eccentric strength exceeds concentric strength in all cases, and including its determination in assessing the knee, it allows us to obtain useful information to understand its development and function[38], and to calculate functional ratios[33]; in other words, the relationship between the maximum concentric strength of the quadriceps to maintain a standing position, and that of the hamstrings in eccentric movement to slow down the hyperextension movement and the anterior displacement of the tibia.

Using hamstring/quadriceps ratios we observe that there is a predominance of the hamstrings over the quadriceps, which indicates that the knees, especially the anterior cruciate ligament (ACL) are protected as the agonist action of this muscle with the ACL[33] prevails over the activity of the quadriceps and avoids the distension of the ACL with the rapid displacement of the tibia over the femur upon landing and possible breakage. The individual study of each skydiver using these ratios enables us to customise their physical preparation, focusing on preventing injuries caused by landing and the predisposing factor of muscle imbalance[39]. Having powerful hamstrings in eccentric mode contributes to slowing down this displacement and protects the ligament[26].

We only carried out a bilateral assessment of the vertical jump, whereas Laudner *et al*[40] also performed a unilateral assessment, which is why we have added the isokinetic strength of both extremities to correlate it with the flight heights. According to studies, the most used jumps to carry out plyometric assessment and to establish a posterior correlation with the isokinetic measurement, are the CMJ[36,40,41], and the SJ[34,36,37]. Of all the studies consulted, we only found one that used the Abalakov Jump as we did, which was used alongside the CMJ[35]. We did not find any studies in which all three jumps were compared with the isokinetic measurement. We believe that analysing the three is of particular interest when verifying the influence of elastic energy accumulation during the jump, as well as the collaboration of the upper body, as these are determining factors in most sporting movements. Other authors use the Drop Jump from different heights, allowing the muscles to act depending on the shorten-stretch cycle[41].

In our study we have assessed and compared both concentric and eccentric work, and the relationship between this and the vertical jump, in contrary to most authors consulted, who have only related the vertical jump to concentric strength[35-37] or to isometric stength[42]. Following the Bosco concept[20], we believe that it is more interesting to also study eccentric work because via the reflex activated by the eccentric phase, a reinforced innervation is obtained which can strengthen the elastic characteristics of the muscle-tendon system and lead to a more important activation of the concentric phase. This can generate greater levels of strength than an isolated concentric contraction[43]. Furthermore, it is the eccentric strength of the hamstrings that is taken into account to calculate the functional ratio related to the balance of the knee and ACL protection[33].

The highest strength peaks were obtained during eccentric work on both teams. As foreseen, our data reveals that males generate more isokinetic strength than women in all modalities, a fact analysed many times with similar outcomes in previous studies[36,40,44]. On the contrary, the only jump test in which the males jump higher than women is the SJ, in the others there are no significant differences. This may be due to the fact that having to overcome the resistance of body weight relativizes the strength exercised by the extremities. Upon analysing the work and multiplying height by weight, the differences between men and women reappear.

We found higher correlations in eccentric work at 180º/s than at 60º/s. These correlations are clearer between the eccentric isokinetic strength of the quadriceps and the work performed in the vertical jump than with the flight height. Wilheim *et al*[41] refer to a correlation of height in the CMJ with the strength of the quadriceps of $r=0.513$, $p<0.001$, similar to our findings ($r=0.659$, $p=0.010$).

All the jump modalities analysed maintain a high correlation with the strength peak of the quadriceps. The highest relationship that we found is between concentric strength at the speed of 180º/s and the work of the CMJ and AJ ($r>0.9$ $p<0.001$). This data coincides with that found by Lehnert *et al*[13], who also indicate that the maximum relationship is established at higher angular speeds, specifically at 180º/s for the CMJ and at 180º/s and 360º/s for the AJ. These two jump modalities were also related to isokinetic strength by Alemdaroğlu[37], who found a significant correlation with the same angular speeds as in our study.

With regards to the work of the hamstring muscles, our data reflects a relationship between the strength peak in concentric mode and the three jumps, but expressed in the form of work (height achieved by body weight) and not just upon analysing the flight time, the correlation is also greater at the highest isokinetic speed. In vertical jumps the activity of the hamstring muscles can be considered as secondary, as the main action falls upon the quadriceps. The presence of these correlations reflects the importance of preventive work of knee flexors to maintain the muscular balance of the knees and to contribute to protecting the anterior cruciate ligament.

The relationship between both types of test is considered useful for assessing strength and functional capacity in subjects with anterior cruciate ligament injuries[40], and can be useful for rehabilitation follow-up. We would add that this would be more useful if there were values available taken prior to the injury that reveal the presence of asymmetries between antagonist muscles and between sides.

Overall, the data from our demographic coincides with those referenced, indicating that the maximum strength peaks of the knee muscles present higher values in the eccentric modality than in the concentric modality in both muscle groups, and that they are greater in the male team. The influence of upper body participation and accumulated elastic energy significantly affect the height and time achieved in the different jumps. We can also affirm that the correlation between the characteristics of isokinetic strength on the knee with the vertical jump performance is higher between the strength peaks of the extensors during the concentric work at a faster speed.

On the other hand, a significant relationship has not been objectified in any of the parameters corresponding to the vertical jump test with the eccentric strength of the hamstrings, on any team or at any speed. For this reason, the jump tests cannot substitute isokinetic assessment in the determination of ACL injury risk factors, though they are useful for displaying the strength of the quadriceps among skydivers.

For all the above, we conclude that skydivers' knees reveal a predominance in hamstring strength, which is considered positive for the activity they undertake, as it improves the stability of the knee and can help prevent ACL injuries. The isokinetic strength of the hamstrings in eccentric modality has no correlation with the work carried out in vertical jumps, whilst the concentric and eccentric strength of the quadriceps and the concentric strength of the hamstrings do correlate.

Acknowledgements

To PAPEA, the Air Army Acrobatic Skydiving Patrol.

Conflict of interests

The authors claim to have no conflict of interests whatsoever.

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The isometric muscle contraction tasks or repetitive movements to evaluate the effects of fatigue. A systematic review

Diego Peinado Palomino[1], Marta Torres Pareja[1], Laura Mordillo Mateos[2], Nuria Mendoza Láiz[1]

[1]Universidad de Castilla-La Mancha. Toledo. [2]Grupo de investigación FENNSI del Hospital Nacional de Parapléjicos. Toledo.

Received: 19.02.2018
Accepted: 30.05.2018

Summary

Fatigue has been defined as a phenomenon related to the time of decrease of the maximum capacity of generation of force, expressing itself, generally, as a deterioration in the maximum voluntary contraction (CMV). The appearance of fatigue in skeletal muscle during an effort has long been of interest to physiologists, especially because fatigue is a limiting factor in athletic performance or in the performance of any task. The aim of the article is to analyze the literature and provide a systematic review on fatigue induced by muscle contraction tasks, caused by isometric contractions or by finger tapping. To this end, an investigation was carried out based on the PRISMA methodology (Articles of preferred reports for systematic reviews and meta-analyzes). Conducting a search of articles in the PubMed, Medline, Science Direct and Google Scholar databases, between the months of June and November of 2017 after the year 2000. Of the 315 studies initially identified, only 12 complied with the established selection criteria. The methodological variability of the different studies allows to observe how through the tapping tasks (repetitive movements of fingers), or through isometric contraction tasks, it is possible to determine the different parameters of fatigue that are evaluated in each study, being a very used to address that topic. Muscle fatigue has been predominantly studied when induced by isometric tasks, with a greater number of investigations using this type of methodology, since, although finger tapping is a reliable procedure to evaluate the underlying neurophysiological mechanisms of fatigue, It has been explored.

Key words:
Isometric contraction. Finger tapping. Fatigue. Contractile force.

Las tareas de contracción muscular isométricas o de movimientos repetitivos para evaluar los efectos de la fatiga. Una revisión sistemática

Resumen

La fatiga es definida como un fenómeno relacionado con el tiempo de disminución de la capacidad máxima de generación de fuerza, expresándose, como un deterioro en la contracción máxima voluntaria (CMV). La aparición de la fatiga en el músculo esquelético durante un esfuerzo ha sido de interés para los fisiólogos, especialmente porque la fatiga es un factor limitante, tanto en el rendimiento deportivo como en la realización de cualquier tarea. El objetivo del artículo es analizar la literatura y proporcionar una revisión sistemática sobre la fatiga inducida por tareas de contracción muscular, provocadas por contracciones isométricas o mediante tapping de dedos. Para ello se realizó una investigación basada en la metodología PRISMA (Artículos de informes preferidos para revisiones sistemáticas y metanálisis). Llevando a cabo una búsqueda de artículos en las bases de datos PubMed, Medline, Science Direct y Google Scholar, entre los meses de junio y noviembre de 2017 con fecha posterior al año 2000. De los 315 estudios identificados inicialmente, sólo 12 cumplieron con los criterios de selección establecidos. La variabilidad metodológica de los distintos estudios permite observar como a través de las tareas de tapping (movimientos repetitivos de dedos), o mediante tareas de contracción isométrica se pueden determinar los distintos parámetros de la fatiga que se evalúan en cada estudio, siendo un instrumento muy utilizado para abordar dicho tema. La fatiga muscular se ha estudiado predominantemente cuando es inducida por tareas isométricas, habiendo un mayor número de investigaciones que utilizan este tipo de metodología, ya que, aunque el tapping de dedos sea un procedimiento fiable para evaluar los mecanismos neurofisiológicos subyacentes de la fatiga, apenas se ha explorado.

Palabras clave:
Contracción isométrica. Tapping de dedos. Fatiga. Fuerza contráctil.

Correspondence: Diego Peinado Palomino
E-mail: diego_peinado2@hotmail.com

Introduction

The onset of skeletal muscle fatigue during exertion has long been a source of interest to physiologists, particularly because fatigue is a limiting factor in sport performance or for carrying out any task[1]. Fatigue has been defined as a phenomenon related to the decrease over time of the maximal ability to produce force[2], generally expressed as a deterioration in the maximal voluntary contraction (MVC). According to the force-fatigability relationship[3], the greater the force exerted by a muscle, the faster it will fatigue and reach the point of failure (inability to maintain the required force).

The voluntary contraction of a muscle to produce force or movement, according to Taylor *et al.*[4], involves a series of events that start in the brain and end in the muscle. The processes leading to muscle fatigue commence when a person makes repetitive or sustained contractions of the muscle. Therefore, muscle fatigue can be defined as an exercise-induced loss of ability to produce force with a muscle or muscle group[5]. This condition is temporary and reversible with rest, except for chronic fatigue pathologies. As a chronic symptom, fatigue is a well-known manifestation of a series of somatic disorders, including cancer, multiple sclerosis (MS), Parkinson's disease (PD) and cerebrovascular disorders.

The term fatigue is used both to describe the condition of a specific localised group of muscles and to refer to a situation in which tiredness is generalised and affects the entire body. Frequently, fatigue is not located in a group of muscles or in an individual physiological process within the muscle, instead, it involves a number of processes acting in parallel, including the muscle and the structures continuing through the entire neural axis[5]. Due to its multifactorial nature, the mechanisms responsible for fatigue are still imprecise. Consideration is given to muscle level factors, causing neuromuscular or peripheral fatigue, and factors above the neuromuscular junction, generating central fatigue[6].

Muscle fatigue has primarily been studied when it is induced by isometric tasks (iso), however the underlying neuropsychological mechanisms of fatigue during rapid repetitive movements known as finger tapping have barely been explored, while the tapping test is a reliable procedure used throughout the world to evaluate the physiological and pathological mechanisms of repetitive movements[7].

It has been demonstrated how, with voluntary contraction, the motor-evoked potential (MEP) increased in size in comparison to the evoked motor potentials obtained from the relaxed muscles, and how this reflected greater cortical and spinal excitability[8,9]. Fatiguing exercise can reduce cortical excitability, as already demonstrated by Brasil-Neto *et al.*[10] where, immediately after the subjectively fatiguing exercise, the MEP amplitude increased in size while the silent period increased in duration with muscle fatigue.

It is widely accepted that there is no single cause for fatigue, the physiological mechanisms behind the reduction in the ability to produce force, prohibiting the indefinite performance of tasks, are specific to the task demands (in other words, the contraction intensity, duration,mode, muscle group, joint angle, limb posture and stabilisation). In general, it has been shown that the failure of the nervous system to maintain sufficient activation of the muscle is an important contributor to task failure in sustained submaximal contractions in comparison to maximal contractions[11].

To our knowledge, very few studies have reviewed the different methods of inducing fatigue and what this involves. Therefore, the purpose of this study is to analyse the literature and to provide a systematic review of fatigue induced by muscular contraction tasks, caused by isometric contractions or finger tapping.

Methodology

A theoretical analysis was conducted with a systematic review of the literature available on intervention studies made through isometric contractions or finger tapping, in accordance with the PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analyses methodology (Figure 1).

The articles in this review were obtained through a search in the electronic databases of PubMed, Medline, Science Direct and Google Scholar. The descriptor terms or key words for the search were as follows: muscle fatigue, finger tapping, muscle contraction and repetitive movements. For the correct use of terminology, we consulted the descriptor terms of the Medical Subject Headings, making a review of peer-reviewed journal articles between the months of June and November 2017, in English, Spanish and Portuguese, dated later than the year 2000.

The following method was used for the bibliographic search:

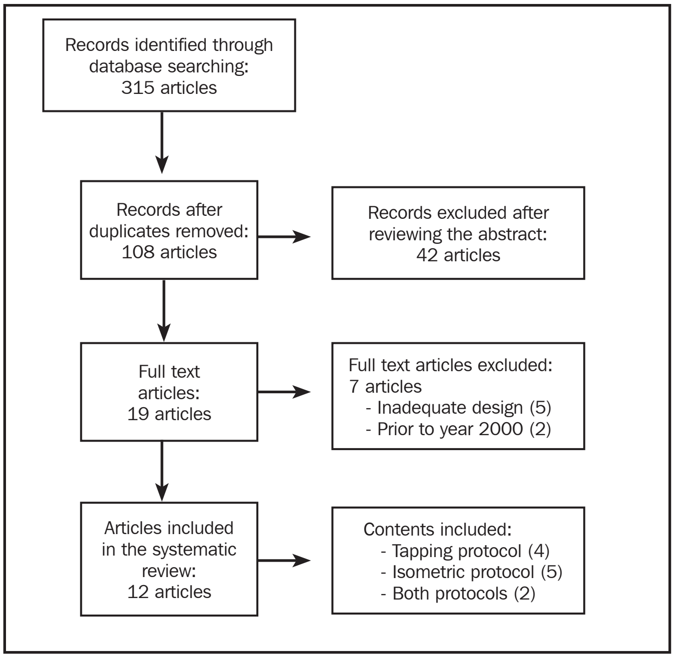
- Studies analysing fatigue by isometric or isotonic contractions, making it possible to extract the most relevant information from each investigation.
- Synthesis of information, making it possible to sort and combine the information obtained, and to make a comparative analysis between studies on contractions through Tapping or maximal voluntary contraction (MVC).
- Once the search had been completed, we then determined which articles were to be included in the review. To do so, it was necessary to consider the value and relevance of the subject studied, as well as to analyse the applicability of the results to the subject of study.

Articles written in English, Spanish or Portuguese were included if the protocols were based on tasks in which isometric contraction or finger tapping tasks were used to induce fatigue.

Studies were excluded if the methodology or design was considered not to comply with the above mentioned protocols, if they were summaries of conferences, papers or news items, or if they were prior to the year 2000, in order to base the review on up-to-date investigations.

The initial search process identified 315 articles, of which 207 duplicate articles were eliminated. The remaining 108 articles were selected in order to determine their relevance, based on their title and abstract. This resulted in the elimination of a further 66 studies, leaving a total of 42 studies, examining the complete text of 19 of these. Finally, 12 texts

Figure 1. Flow diagram of the PRISMA methodology showing the identification, screening and selection of relevant studies for this systematic review.



met the established selection criteria, following the critical reading of the entire document (Figure 1).

The validity of the articles selected was given by the level of evidence demonstrated, the recommendations of the article and the applicability to our context.

Results

The methodological variability of the different studies is explained below. These studies discuss how, through fatigue induced by repetitive finger tapping tasks or by isometric contraction tasks, it is possible to determine the different fatigue parameters evaluated in each study.

For this purpose, we started by looking at the studies based on the use of contraction tasks (Table 1), where Klass *et al.*[9] compared the selected inputs with the groups of motor neurons of the elbow flexor muscles during the performance of force and position tasks. The force task consisted in performing a fatiguing contraction at 20% of MVC for as long as possible, ending when it was not possible to maintain the torque level required during 5-10 s. The position task consisted in maintaining the elbow joint at a right angle while supporting an inertial load equivalent to 20% of the MVC, sustaining this position for as long as possible and ending when the elbow angle declined by 10º from the target during 5-10 s. Both tasks required a sustained isometric contract with the elbow flexor muscles.

Williams *et al.*[11] compared the facilitatory and inhibitory supraspinal adjustments.and the voluntary drive of the motor cortex for force-matching and position-matching tasks. Subjects needed to perform two fatiguing tasks. One task consisted in sustaining a force equivalent to 15% MVC for as long as possible, pulling against a force transducer tied to a chair. The length of the transducer prevented the elbow from flexing more than 90º. The second test consisted in maintaining, until task failure, the position of the elbow joint at 90º, supporting a free weight equivalent to 15% of the MVC force.

Butler *et al.*[14] performed a sustained maximal voluntary effort (MVC) of the right elbow flexors for 120 sec to determine whether the motoneurons were inhibited during a maximal isometric contraction. The elbow was flexed to 90° strapped to an isometric myograph. Before the test contraction, a series of brief MVCs were performed (for 2-3 sec.) at 1 min intervals. Following the test contraction, some brief MVCs were performed.

In order to compare the behaviour of short-latency reflexes (H reflex) and long-latency reflexes (LLR), Duchateau *et al.*[15] conducted 3 sessions. A fatiguing contraction performed at 25 % MVC and sustained until the endurance limit. In the second session, the subject performed an intermittent contraction (6 s contraction, 4 s rest) at 25% MVC for the same duration as the sustained contraction at 25 % MVC. For the third session, the subject performed a contraction sustained at 50% MVC until the endurance limit. The sustained contractions (25 and 50% MVC) ended when the subject was unable to maintain the required level of force during 5 s.

By five isometric maximal voluntary flexions of the elbow (1, 2 s) separated by one minutes rests, Taylor, *et al.*[16] examined the development of the supraspinal component of central fatigue. The patterns used were 5 s at 50% of MVC and 5 s rest. 12, 15 s contractions at 60% of MVC and 10 s rest. 12, 15 s contractions at 75% of MVC and 5 s rest. And 6, 30 s contractions at 86% of MVC and 5 s rest. Finally, subjects performed a series of brief MVCs at 15 s, 30 s, and 1, 2, and 3 min after the series of fatiguing contractions. During each brief contraction, a single transcranial magnetic stimulus was given.

Finally, Maluf and Enoka[17] compared the physiological adjustments that occur when two similar fatiguing contractions are performed to failure. To do so, 2 different tasks were performed. In the force task, , the limb was attached to a restraint and the subject was required to sustain a constant force (15–20% of maximum) for as long as possible. In the other task, the position task, the subject supported an inertial load that was equivalent to the force exerted during the force task and was required to maintain a constant joint angle for as long as possible. The criterion for task failure was an inability to sustain the target force or position for at least 5 s.

Based on the use of tapping tasks (Table 2), Arias *et al.*[7] evaluated cortico-spinal fatigue between three groups; one group of subjects with Parkinson's, one group of elderly subjects and a group of young people.. The subjects were seated comfortably with their forearms resting on a table, their elbows bent at 90º. They were asked to perform tapping tasks with their index finger by flexing-extending the metacarpophalangeal joint. Two modes were included: tapping tasks (FT) at their fastest rate

Table 1. Articles related to the use of isometric contraction tasks.

Author	Sample	Objective	Results
Klass *et al.* 2008	11 subjects (6 male and 5 female) aged between 22 and 41 years (29.4 ± 6.0 years)	Compare the selected inputs with the groups of motor neurons of the elbow flexor muscles during force and position tasks. The comparisons involve MEP in response to the TMS and the Hoffmann reflex induced by the electrical stimulation of the brachial plexus at Erb's point.	The study revealed how the MVC mean torque before the fatiguing contraction was similar for the force session and the position task session. The aEMG for the biceps brachii during the MVC of the elbow flexor decreased immediately after the fatiguing contraction in the force and position tasks.
Williams, Hoff-man, and Clark. 2014	10 healthy right-handed subjects (5 male, 5 female), mean age of 24 years. The subjects identified themselves as highly active (n=2, 1 male, and 1 female,) moderately active (n=5, 3 male, 2 female), or low active (n=3, 1 male, 2 female).	Compare the supraspinal, facilitatory and inhibitory adjustments and the voluntary drive of the motor cortex, measured with TMS, in relation to force-matching and position-matching tasks.	The study showed how the level of corticospinal excitability (MEP and SP induced MEP) increased throughout the performance of the fatiguing task while the CMEP in SP decreased. Furthermore, the intracortical inhibition ratio within the motor cortex either decreased or was maintained during the performance of the fatiguing task.
Butler, Taylor and Gandevia. 2003	2 groups: Experimental with 8 subjects (5 male and 3 female) who were studied on two occasions. And Control, with 8 subjects (4 male and 4 female) 3 of the subjects performed both the main and control experiments. The subjects were healthy and ranged in age from 30 to 58 years	To determine whether motoneurons were inhibited during a sustained fatiguing contraction of the elbow flexor muscles and whether this inhibition was caused by the discharge of group III and IV muscle afferents.	During the sustained MVC, there were changes in the size of the responses in brachioradialis and biceps brachii produced both by corticospinal stimulation and brachial plexus stimulation, revealing a decrease in the size of the muscle response to corticospinal tract stimulation during fatigue. Decreasing the excitability of motoneurons, contributing to the decline of the discharge rate of motor units and the development of central fatigue that occurs with sustained MVCs.
Duchateau *et al.* 2002	13 healthy volunteers, 3 female and 10 male, aged 21 to 46 years.	To compare the behaviour of the short-latency (H reflex) and long-latency (LLR) reflexes in the APB during contractions sustained at 25 % and 50 % MVC and during sustained and intermittent contractions at 25 % MVC.	Both showed a reduction in absolute amplitude, with no significant change in the H reflex or the LLR amplitude. The MVC force declined at the end of the sustained 25% MVC and 50% MVC tests. The averaged EMG associated with the MVC was reduced after the sustained contractions at 25 % and 50 % MVC but not for the intermittent contractions.
Taylor *et al.* 2000	9 healthy volunteers, 5 male and 4 female, aged 25 to 46 years.	Examine whether the development of the supraspinal component of central fatigue was similar during exercise protocols with differing levels of activity.	They demonstrated how the silent period lengthened, and the MEP increased in size. At the end of the fatiguing protocol after a total 3 minutes of contraction, the prolongation of the silent period varied between 20 ms with the 50% duty cycle and 0.75 ms with the 30 s MVC and 5-s rest.
Maluf and Enoka. 2005	16 subjects, 8 male and 8 female, aged 27 ± 4 years.	To compare the physiological adjustments that occur when two similar fatiguing contractions are performed to failure, it is possible to identify mechanisms that limit the duration of the more difficult task.	It was observed how the time to task failure was consistently less for the position task (702 ± 582 s) compared with the force task (1.402-768s). However, the amount of fatigue experienced by the subjects during both tasks was similar, as indicated by comparable ratings of perceived exertion at failure and the reductions of 28 –35% in MVC force immediately after each fatiguing contraction.

(FAST) and tapping at their comfortable rate (COMFORT). The complete protocol consisted in 3 series of 50 cycles at COMFORT and 3 series of 50 cycles at FAST. This was repeated twice, with a one week interval. Recordings were made by an electronic system which included a metal plate and a metal ring adapted to the finger.

Anwar *et al.*[12] used tapping tasks that included simple finger taping tasks (FT), simple finger sequences (SFS) and complex finger sequences (CFS) to check the connectivity of the sensorimotor network. By conducting a block design whereby the subjects performed finger movement tasks for 30 s followed by 30 s of rest. Ten complete blocks were performed for each finger movement task, 10 minutes per task. With 2 minutes' rest between each movement task.

The investigation of Lutz *et al.*[18] consisted in evaluating the hand used (dominant *vs* non-dominant) to determine the amount of the

Table 2. Articles related to the use of Tapping tasks.

Author	Sample	Objective	Results
Arias *et al*. 2012	3 different groups (17 subjects with Parkinson's average age of 69.47 years, 20 elderly healthy controls average age of 70.55 years, and 21 young healthy control subjects, average age of 23.90 years.	To evaluate the validity of the finger tapping test (FT) to detect alterations in rhythm formation.	The results demonstrated how the finger tapping of the group of young people was significantly faster than the Parkinson's and elderly groups. While no sign of fatigue appeared in the Parkinson's and elderly groups, the group of young people showed an evident decrease in the tapping frequency.
Anwar *et al.* 2016	9 healthy subjects, 5 female and 4 male with an average age of 27 years (range 21-38 years)	To apply the Granger causality analysis to the EEG, fMRI and fNIRS signals in order to determine the effective connectivity of contralateral cortico-cortical sensorimotor network during simple and complex finger movement tasks.	The tapping tasks were associated with increased activity in the SMC, PMC and DLPFC.
Lutz *et al*. 2004	9 healthy subjects (3 female, 6 male) 4 right-handed and 5 left-handed aged from 22 to 34 years.	To evaluate the extent to which the hand used (dominant vs. sub-dominant) determines the amount of the pattern of activation in the contralateral primary motor cortex, measured through magnetic resonance, during FT at own rate and at maximum speed.	There was a greater increase in the cortical activations of the right motor cortex, when right-handed subjects tapped with their left hand in comparison with the opposite hand. Differentiating the maximum tapping rate between hands, with shorter inter-tapping intervals for the dominant hand (130 to 180 ms) than for the non-dominant hand 8160 and 200 ms).
Teo *et al*. 2011	10 healthy right-handed subjects, 5 male and 5 female, aged 21-32 years.	To investigate the changes in the ECM and SICI following a 10 second MVR test of the index finger, comparing self-paced and external movements. In order to determine whether the central effects were specific to the MVR task, a comparison was made with kinetically sustainable slower movements.	The results show how the performance of an MVC rhythmic tapping task rapidly decreases and is followed by a decline in the ECM. A similar post-exercise depression also occurs when the task is performed at slower, sustainable rates. With each of these tasks, the reduction in excitability is accompanied by an increase in the short interval intracortical inhibition (SICI) which is greater following the slower tasks than the MVR task.

Table 3. Articles related to the use of both tasks (contraction and tapping).

Author	Sample	Objective	Results
Arias *et al.* 2015	2 groups. The TMS group with nine right-handed healthy subjects (eight males and one female, with an age range of 22 to 38 years), and the CMS group with 12 right-handed healthy subjects, all males with an age range of 18 to 41 years.	To observe the differences in the motor-evoked potential and the changes in excitability of the cortical and spinal circuits, between the maximal FT and ISO tasks.	It was seen how the force decreased at the end of the session for both tasks. For the FT task, the maximal voluntary contraction force decreased right at the end. While, for the ISO task, we observed an accumulation of fatigue expressed in the decrease in MVC force.
Rodrigues, Mastaglia, and Thickbroom. 2009	10 healthy volunteers, 4 male and 6 female, aged 25 to -51 years.	To investigate the change in the movement rate and amplitude in healthy subjects performing repetitive finger flexion–extension in a maximal voluntary movement or tapping task.	The maximum rate of movement was maintained for a few seconds, showing a constant decline throughout the task, while the amplitude of movement remained unchanged. The subjects were unable to sustain the tapping at a maximum rate for more than a few seconds, leading to a constant decline in frequency with no change in amplitude. There were no changes to the isometric MVC force following the MVR task, with no loss of the force generation capacity.

pattern of activation in the contralateral primary motor cortex. Measured through magnetic resonance, during FT at own rate and at maximum speed. An arrow to the right or left indicated the hand to be used for the tapping, the colour of the arrow indicated the tapping rate (green, own rate and red, maximum rate). 4 sessions divided into 6, 20 s tapping blocks, followed by a 20 s rest.

To finalise, Teo *et al.*[19] investigated the changes occurring in corticomotor excitability (CME) and short interval cortical inhibition (SICI) when performing finger tapping. Participants performed three series of 10-second cyclic flexion-extension movements (starting with the neutral position in relation to the metacarpophalangeal joint (MCP) at different rates.

With regard to the investigations using both action protocols (Table 3), it can be observed how in the investigation conducted by Arias *et al.*[13] the subjects underwent two sessions in order to observe the differences in the motor-evoked potential and the changes in excitability of the cortical and spinal circuits, between the maximal FT and isometric tasks. One session in which the subjects performed tapping with their index finger on a metal plate mounted on a force sensor. And, in the second session, a continuous isometric test, also pressing the goniometer.

Finally, Rodrigues *et al.*[20] investigated the change in amplitude and in the movement rate when performing finger tapping. The maximal voluntary contraction (MVC) force was measured through a force transducer, performing a maximal voluntary flexion of the finger for 3 s, brief pause and then a maximum voluntary extension of the finger for 3 s. In order to obtain the force generating capacity of the index finger flexors and extensors, the rates of the ballistic flexion and extension movements were measured. For the task of the repetitive voluntary movement (RVM), continuous flexion-extension movements were performed with the index finger, as quickly as possible, maintaining the maximum rate for a period of 20 s.

Discussion

The purpose of this investigation was to provide a systematic review of fatigue induced by muscle contraction tasks, triggered by isometric contractions or by finger tapping.

The studies using isometric contractions to induce muscle fatigue[9,11,14-17] have differing objectives, since this type of methodology permits a wide range of investigations. Through the application of isometric contractions to compare force tasks (performing a fatiguing contraction by maintaining constant force over a period of time) and position tasks (maintaining the position of a joint for as long as possible while supporting an inertial load) it has been possible to compare the selected inputs with the groups of motor neurons of the elbow flexor muscles9. As well as the physiological adjustments that occur when two similar fatiguing contractions are performed to failure, it is possible to identify mechanisms that limit the duration of the more difficult task[17]. In addition to defining the contribution of the mechanisms provoking supraspinal failure of the task during sustained submaximal contractions, comparing the specific differences of the task in the adjustments in cortical and spinal excitability[11].

Studies based on the application of maximal voluntary contractions also have a wide scope of action, such as checking motoneuronal excitability [14]. A comparison of the behaviour of short-latency reflexes (H reflex) and long-latency reflexes (LLR)[15]. The study by Taylor *et al.*[16] examined whether the development of the supraspinal component of central fatigue was similar during four, three-minute exercise protocols with differing levels of activity (5 s MVC, 5 s recovery). 15 s MVC, 5 s recovery. 15 s MVC, 10 s recovery and 30 s MVC, 5 s recovery), demonstrating a supraspinal component of central fatigue produced by a series of intermittent MVCs.

The finger tapping test is a basic tool for evaluating rythmic movement patterns. It is commonly used in clinical assessments and as part of investigation protocols, including brain imaging studies[21,22] and neurophysiological examinations[23,24]. With regard to the studies that conducted tapping tasks to induce fatigue[7,12,18,19], it has been possible to examine the validity of this protocol by two different modes, Fast and Comfort, for different groups (young, elderly and persons with Parkinson's disease) and to re-evaluate some methodological aspects of its use[7].

This type of methodology has also been used to determine the effective connectivity of the contralateral cortico-cortical sensorimotor network during simple and complex finger movement tasks, by applying the Granger causality analysis to the EEG, fMRI and fNIRS signals. Lutz *et al.*[18] aimed to demonstrate the extent to which the hand used (dominant vs non-dominant) determines the amount of the pattern of activation in the contralateral primary motor cortex at maximum rate and comfort rate, given that a number of brain imaging studies consistently demonstrated increased cortical activation (indexed by an increase in haemodynamic responses) as a function of the increase in the finger tapping frequency in the primary motor cortex, the cerebellum and partly in other motor areas[25,26].

This type of protocol was also used to investigate changes in corticomotor excitability and the short-interval cortical inhibition following a 10 s tapping task of the index finger, comparing self-paced and external movements. In order to determine whether the central effects were specific to the task, a comparison was made with kinetically sustainable slower movements.

Finally, there were also studies that included the use of isometric contraction tasks and also finger tapping in their protocol to induce fatigue. Such as the study by Arias *et al.*[13] which compared the neurophysiological signs of fatigue induced by tapping with those induced by isometric contraction tasks, in order to analyse the underlying neurophysiological mechanisms of fatigue during fast repetitive movements (tapping). In order to thereby determine the contribution of some spinal and supraspinal motor circuits to the production of fatigue during short-lasting repetitive movements (finger touching), if performed at the fastest possible rate. Furthermore, studies of the maximum isometric or isotonic movements of the finger have shown a possible relation between speed and amplitude[27]. For this reason, Rodrigues *et al.*[20] aimed to investigate the change in the rate of movement and amplitude in healthy subjects performing a repetitive finger flexion-extension task at maximal voluntary rate.

Conclusion

This systematic review was addressed in order to provide information about fatigue induced by muscle contraction tasks, observing how the majority of investigations use isometric contractions, in comparison to those using the finger tapping methodology.

Muscle fatigue has predominantly been studied when it is induced by isometric tasks (iso), however the underlying neuropsychological mechanisms during rapid repetitive finger tapping have scarcely been considered, while the tapping test is a reliable procedure to evaluate repetitive physiological and pathological mechanisms.

The methodology search considered in this review (isometric contractions and tapping) makes it possible to address the subject of fatigue, particularly when investigating how fatigue can affect the performance of individuals, as well as in the daily lives of patients suffering from pathologies in which fatigue is a chronic symptom.

The performance of maximal isometric contractions leads to the progressive failure of voluntary activation, causing subjects to be unable to fully activate the muscles, thereby demonstrating the appearance of central fatigue.

Intermittent fatiguing contractions, as already demonstrated for sustained voluntary contractions, cause changes in the responses of the muscle electromyography (EMG) to transcranial magnetic stimulation, extending the silent period and increasing the size of the MEP more quickly, recovering more slowly than the extension of the silent period.

The tapping task produces a constant decrease in the speed at which the movement is made, exhibiting similar effects on excitability and inhibition, both after exercise and after an fatiguing isometric MVC task, causing decreased performance due to the fact that it is not possible to sustain the demands in the motor control.

When addressing different objectives, the variety provided by the use of this type of methodology makes it a highly utilised instrument by investigators considering the wide range of subjects in the area of fatigue.

Conflict of interest

The authors have no conflict of interest whatsoever.

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Methods of evaluating the force-velocity profile through the vertical jump in athletes: a systematic review

Guido Contreras-Diaz[1], Daniel Jerez-Mayorga[2], Pedro Delgado-Floody[3], Leónidas Arias-Poblete[2]

[1]Departamento de Salud. Universidad de los Lagos. Puerto Montt. Chile. [2]Escuela de Kinesiología. Laboratorio de Ciencias de la Rehabilitación. Universidad Andrés Bello. Santiago. Chile. [3]Universidad de La Frontera. Temuco. Chile.

Received: 10.04.2018
Accepted: 05.06.2018

Summary

Introduction: In the world of sport, the ability of humans to develop maximum muscular power (Pmax) is directly related to performance and sporting success. For this, the measurement of the force- velocity profile (F-v) plays a key role in the evaluation of the athlete. At present, there are different methodologies and technologies to assess this profile, with sprint and vertical jump being the most used forms. The objective of this review is to identify and analyze different methods and tools for assessing F-v profile through the vertical jump.
Methods: A search was carried out on the following databases, PubMed, SPORTDiscus, and Web of Science, of papers published between January 2010 and August 2017. The search terms were as follows: strength, speed, profile, vertical jump, squat jump (SJ), countermovement jump (CMJ), sports, strength training, resistance training, and all possible combinations of the above. Methodological quality was assessed using the PEDro scale.
Results: Nine out of a total of 254 articles met the criteria for inclusion: six of them evaluated the F-v profile using a force platform, while three used the photocell system. Analysis of their evaluation methods revealed that of the six studies using the force platform, one used the SJ as an assessment measure, two used the CMJ and three used both methods; all three studies using the photocell system used the SJ as the method of assessment.
Conclusion: The instruments most often used to evaluate the F-v profile are the force platform and the photocell system. Nevertheless, other new and interesting technologies exist that are capable of evaluating the vertical jump. for example, through mobile applications.

Key words:
Muscular power. Assesing force-velocity. Vertical jump.

Métodos de evaluación del perfil fuerza-velocidad a través del salto vertical en deportistas: una revisión sistemática

Resumen

Introducción: En el mundo del deporte, la capacidad que tiene el ser humano para desarrollar la máxima potencia muscular (Pmáx) está directamente relacionada con el rendimiento y éxito deportivo. Para ello, la medición del perfil fuerza velocidad (F-v) cumple un rol clave dentro de la evaluación del deportista. En la actualidad existen diversas metodologías y tecnologías para valorar este perfil, siendo el sprint y el salto vertical las formas más utilizadas. El objetivo de esta revisión es identificar y analizar diferentes métodos e instrumentos de evaluación del perfil F-v a través del salto vertical.
Método: La búsqueda se realizó en las siguientes bases de datos: PubMed, SportDiscus y Web of Science, entre enero del 2010 hasta agosto del 2017. Los términos de búsqueda fueron los siguientes; Fuerza, velocidad, perfil, salto vertical, Squat Jump (SJ), Countermovement Jump (CMJ), deportes, entrenamiento de fuerza, entrenamiento de resistencia y sus posibles combinaciones. La calidad metodológica fue evaluada a través de la escala PEDro.
Resultados: Nueve de los 254 artículos encontrados cumplieron con los criterios de inclusión al estudio, de los cuales, 6 evaluaron el perfil F-v a través de una plataforma de fuerza y 3 mediante el sistema de fotocélulas. En el análisis de los métodos de evaluación, de los 6 estudios que evaluaron el perfil F-v con plataforma de fuerza, uno lo hizo a través del SJ, dos a través del CMJ y tres utilizaron ambos métodos, mientras que de los tres estudios que valoraron el perfil F-v con el sistema de fotocélulas, todos usaron el SJ como método de evaluación.
Conclusión: Los instrumentos más utilizados para la evaluación del perfil F-v son; Plataforma de fuerza y fotocélulas, sin embargo, existen nuevas tecnologías capaces de evaluar el salto vertical, por ejemplo, a través de aplicaciones móviles.

Palabras clave:
Fuerza Muscular. Evaluación. Fuerza-Velocidad. Salto Vertical.

Correspondence: Daniel Jerez-Mayorga
E-mail: daniel.jerez@unab.cl

Introduction

The vertical jump is an important factor in sports performance, due to its ballistic and explosive character.[1] The object of this rapid, high speed movement is to accelerate an internal or external mass in the least possible time.[2] The acceleration of body mass depends on the ability of the neuromuscular system to generate power,[3] which in turn is understood as the combined product of maximum strength and speed to generate movement through muscle contraction.[4] This relationship is known as the force-velocity profile (F-v),[5] and has three variables: maximum theoretical force at zero speed (F0), maximum theoretical velocity at zero load (V0), and maximum power (Pmax). These three variables represent the maximum capacity of the lower extremities to develop strength, power, and velocity.[6]

An F-v profile shows the balance that exists between the force and speed (SFV) of an athlete, and is tested by jumping with loads to reveal either optimal balance (Sfvopt) or imbalance (FVimb) between both variables.[7] Both results are determined by the slope of the F-v.[8]

In both cyclical and acyclic sports, the ability to generate high levels of mechanical power during the jump and sprint plays a determining role in the performance of the athlete.[9] The ability to generate power is determined by a series of mechanical, morphological, and neural factors that are related to each other.[6] Of particular importance are type of muscular action[10,11] execution time,[12,13] interaction between elastic-contractile components,[14,15] stretch reflex,[16] type of muscle fiber,[13,17] cross-section area,[11] recruitment of motor units,[18-20] firing frequency,[20-23] and intermuscular coordination.[24-26] However, in addition to knowing the level of mechanical power it is important to determine the F-v profile; this reveals the FVimb, through which it is possible to identify an athlete's mechanical deficits in order to schedule training and/or rehabilitation to reduce the FVimb and achieve Sfvopt.[7]

A wide range of methods, evaluation techniques, and tools are used to evaluate the Pmax of the F-v profile through the vertical jump, the gold standard being the force platform.[27,28] At the same time there are other instruments, such as the photocell system,[29,30] contact mats,[28,31,32] and now mobile applications,[33-35] not to mention other methods such as the sprint.[36]

F-v and Pmax are evaluated through the vertical jump since it is one of the most common actions performed in sport.[28,37] Irrespective of the method used, the important thing is that the measuring device is valid and trustworthy.[38]

The problem is that many of the technologies and methods used to evaluate athletes are unaffordable for the vast majority of professionals working in the field. Therefore, the objective of this review is to identify and analyze different methods and tools for assessing the F-v profile of sports people through the vertical jump, in order to clarify and identify effective assessment tool options for use in sports performance, injury prevention, and/or rehabilitation and reintegration.

Methods

Literature Search Strategy

To carry out the review, the following databases were used: PubMed, SPORTDiscus and Web of Science. The keywords used during the search were: Force, Velocity, Profile, Vertical Jump, Squat Jump, Countermovement Jump, Sports, Strength training, resistance training, and all possible combinations.

Selection criteria

The inclusion criteria were as follows: a) clinical papers published between January 01, 2010 and August 31, 2017; b) subjects were men and/or women older than 18 years who participate in cyclic or acyclic sports, regardless of whether or not they are prominent sports people; c) interventions include any type of method or instrument for evaluating the profile F-v through the vertical jump; d) articles are written in the English language.

Interventions that used the sprint to measure F-v profile were excluded, as were chapters of books, summaries of congress papers, and doctoral theses.

Evaluation of methodological quality

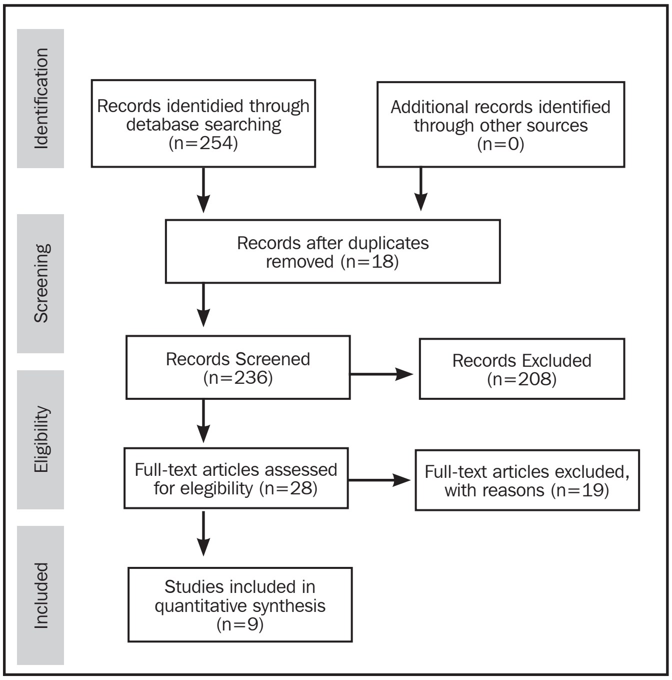
The methodological quality of the studies was assessed using the PEDro scale (Table 1), which uses 11 criteria to determine the internal

Table1. Classification of methodological quality.

Study	1	2	3	4	5	6	7	8	9	10	11	Total
Giroux *et al.*[39]	1	0	0	1	0	0	0	1	1	1	1	6
Jiménez-Reyes *et al.*[40]	1	0	0	1	0	0	0	1	1	1	1	6
Samozino *et al.*[8]	1	0	0	1	0	0	0	1	1	1	1	6
Jiménez-Reyes *et al.*[41]	1	0	0	1	0	0	0	1	1	1	1	6
Jiménez-Reyes *et al.*[42]	1	0	0	1	0	0	0	1	1	1	1	6
Cuk *et al.*[43]	1	0	0	1	0	0	0	1	1	1	1	6
Feeney *et al.*[44]	1	0	0	1	0	0	0	1	1	1	1	6
Garcia Ramos *et al.*[45]	1	0	0	1	0	0	0	1	1	1	1	6
Hansen *et al.*[46]	1	1	1	1	1	0	0	1	1	1	1	9

1. Eligibility criteria were specified; 2. Subjects were randomly allocated to groups ; 3. Allocation was concealed; 4. The groups were similar at baseline regarding the most important prognostic indicators ; 5. There was blinding of all subjects; 6. There was blinding of all therapists who administered the therapy; 7. There was blinding of all assessors who measured at least one key outcome; 8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; 9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"; 10. The results of between-group statistical comparisons are reported for at least one key outcome ; 11. The study provides both point measures and measures of variability for at least one key outcome.

Figure 1. Diagram of the selection of articles for review.



validity of clinical trials. From those articles identified as being potentially eligible by this search strategy, the authors (GCD and DJM) then made a further selection on the basis of article titles and summaries.

Results

Search Results

The search process allowed us to identify 254 potentially eligible articles (PubMed, N = 44, Web of Science, N = 150, SPORTDiscus, N = 60). An initial analysis revealed 18 duplicates, which were removed to leave 236 articles. Of these, 208 were excluded after reading the title and summary, leaving [28]. A further 19 were excluded after reading the complete text, leaving nine relevant articles according to the eligibility criteria (Figure 1).

Photocell system

In three studies the F-v profile was measured using the Optojump® device. The first, by Giroux *et al.*[39], evaluated SJ in 95 elite athletes (38 women and 57 men) from different sports (cycling, fencing, taekwondo, and athletics), using seven different loads based on the percentage of one maximum repeat (1RM) (0, 10, 20, 30, 40, 50, and 60% of 1RM). Fifteen active control group subjects (7 women and 8 men) were also assessed. The authors found significant differences ($p < 0.05$) in the Sfv and Sfvopt between the control subjects (men and women), fencers (men and women), and Taekwondo athletes (men and women). In the second study, Samozino *et al.*[8] studied the F-v profile of 48 national and international athletes (31 soccer players, 11 sprinters, and six rugby players) using the SJ method with five additional loads (0, 25, 50, 75, and 100%) in relation to the body weight of each athlete. Their results showed a loss in individual performance as a result of FVimb (6.49 ± 6.25%). Finally, Jiménez-Reyes *et al.*[40] evaluated 84 trained athletes (semi-professional football and rugby players) divided into three groups: optimized group (n = 46), non-optimized group (n = 18), and control group (n = 20), using the SJ with five to eight loads ranging from 17 to 87 kg. They found large (Effect Size (ES) = 1.21-100/0/0) and moderate (ES = 0.73 100/0/0) differences in FVimb and height of leap in favor of the optimized group compared with the non-optimized group.

Force platform

In six studies the F-v profile was measured using the force platform measuring instrument. In a study by Jiménez-Reyes *et al.*[41] which evaluated the SJ and the CMJ of 54 trained subjects (jumpers and sprinters) with five to eight loads ranging from 17 to 87 kg, significantly different values ($p < 0.001$) were found for SJ and CMJ, except for displacement of the center of mass from the beginning of the concentric phase until takeoff (hPO), sfv and FVimb ($p > 0.05$). In a more recent study, Jiménez-Reyes *et al.*[42] assessed the CMJ of 16 subjects (runners and jumpers) with five different loads (17 to 87 kg), using a force platform versus a simple method to determine F-v profile. They obtained high reliability (Intraclass Correlation Coefficients (ICC) > 0.980 and Coefficient of Variation (CV) < 1.0%) for all variables between the two methods of evaluation. Cuk *et al.*[43] studied the F-v profile of 30 subjects (divided into three groups: strength group, active group, and sedentary group) through SJ and CMJ with 10, 20, and 30% of body weight using the force platform. They reported coefficients ranging from r = 0.949-0.995 ($p < 0.01$) in the averages of the F-v relations between the participants of every group, and found that the force group obtained better results on F0 and Pmax compared with the other groups. Feeney *et al.*[44] studied the F-v relationship in ten physically active subjects through the CMJ with loads of 0 to 40% of body weight, using the force platform and an isokinetic device for evaluating knee extension. Their results showed a strong and linear F-v relationship (the coefficients of individual interrelations ranged between 0.78 and 0.93) and a moderate to highly reliable relation (0.67 < ICC < 0.91) between the slopes of force and speed. Garcia Ramos *et al.*[45] determined the F-v profile of 23 physically active subjects using the SJ and CMJ with six different loads (0, 17, 30, 45, 60, and 70 kg), and found a linear interrelation in all F-v relations ($r > 0.98$) when participants data were divided equally and when considered individually (r = 0.94-0.98). Finally, Hansen *et al.*[46] evaluated the F-v profile of 18 elite rugby players through SJ without external load (with body weight) and with three external loads (20, 40, and 60 kg). The group was then divided into two, with each new group receiving a different type of training (traditional training group and cluster training group). The results showed a significant increase ($p = 0.05$) in post-training F0 in both groups, the increase being greater ($p = 0.05$) for the traditional training group (Table 2).

Discussion

The objective of this review was to identify and analyze instruments and methods for evaluating F-v profile through the vertical jump in

Table 2. Results of the evaluations and interventions to determine force-velocity profile.

Study	Description of Subjects	Design of Study	Evaluation Instrument F-V profile	Evaluation Protocol	Outcomes	Test Results
Giroux *et al.*[39]	Study Group: N = 95 Age: 23.6 ± 4.0 Height:176.2 ± 5.3 cm Weight: 70.4 ± 7.8 kg Group Control: N = 15 Age: 25.1 ± 2.1 Height: 172.5 ± 5.7 cm Weight: 68.6 ± 7.2 kg	Experimental design, Cohort study Evaluated Group: Squat Jump (SJ) (n = 95)	Optojump Next (Microgate, Bolzano-Bozen, Italy)	SJ: 0, 10, 20, 30, 40, 50, 60% of 1 RM.	F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power F0th: Maximum optimum strength V0th: Optimum maximum speed	Sprinters and cyclists present values of F0 > than other groups. F0 < F0th for Female Fencers, Group Control, Sprinters, Fencers and Male Taekwondo. V0 > V0th for Female Fencers, Control Group, Sprinters, Fencers and Male Taekwondo.
Jiménez-Reyes *et al.*[40]	Study Group: N = 84 Age: 23.1± 4.4 Weight: 75.5 ± 8.5 kg Height: 1.79 ± 0.046 m	Longitudinal experimental design Evaluated Group: All groups performed Squat Jump Optimized Group: - Force deficit Group (FD) - Speed deficit Group (VD) - Well-balanced group (WB) Non-optimized group Control Group	Optojump (Microgate, Bolzano, Italy)	SJ without load and with loads ranging between 17 and 87 kg.	F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power Sfv: Slope Force-Velocity profile Sfvopt: Optimum slope Force-Velocity profile FvIMB: Force-Velocity imbalance	Optimized group: FD, VD, and WB, all subjects show improvements in jump height and a decrease in FVimb compared with non-optimized group and control group, who show varying results.
Samozino *et al.*[8]	Study Group: N=48 Age: 20.9 ± 4.4 Weight: 75.8 ± 12.0 kg Height: 1.79 ± 0.06 m	Experimental design. Evaluated Group: Squat Jump (SJ) (n = 48)	Optojump (Microgate, Bolzano, Italy)	SJ: 0, 25, 50, 75, and 100% of subject's body weight.	F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power Sfv: Slope Force-Velocity profile Sfvopt: Optimum slope Force-Velocity profile FvIMB: Force-Velocity imbalance	Loss of individual performance, due to FVimb (6.49 ± 6.25%)
Jiménez-Reyes *et al.*[41]	Study Group: N= 54 Age: 23 ±4.4 Height: 1.80 ± 0.06 m Age: 77.9 ± 6.0 kg	Randomized clinical trial. Evaluated Group: Squat Jump (SJ) and Countermovement Jump (CMJ) (n = 54)	Smith Machine (Multi-power Fitness Line) Force platform (Bertec, type 4060-15)	SJ and CMJ: with 5 to 8 additional loads ranging between 17 and 87 kg.	SJ and CMJ: F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power Jump height Sfv: Slope Force-Velocity profile Sfvopt: Optimum slope Force-Velocity profile FvIMB: Force-Velocity imbalance	SJ vs. CMJ F0 > CMJ V0 > CMJ Pmax > CMJ Jump Height > CMJ Sfv > CMJ Sfvopt > CMJ FVimb > SJ
Cuk *et al.*[43]	Study Group: N = 30 Age: 24. 4 ± 2.3 Height: 182.4 ± 6.2 cm Weight: 80.2 ± 7.0 kg Body Mass Index (BMI): 24.1 ± 2.1 kg/m Muscular Mass: 40.7± 5.0 kg Body fat: 11.5 ± 5.7% 1 RM Squat: 139.6± 44.9 kg Maximum Voluntary Contraction (MVC) 884 ± 174	Experimental design Evaluated Group: 1 RM Squat MVC Knee Extenders (n = 30	MVC: Isokinetic Dynamometer (Kin-com) Squat Jump (SJ) + Countermovement Jump (CMJ) (Force platform, AMTI, USA)	Warm up: 5 minutes of trot + Dynamic Stretches. SJ and CMJ with 10, 20, and 30% of subject's body weight.	F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power Force-Velocity profile	Pmax: Force Group > Active group and Sedentary group

(continue)

(continuation)

Study	Description of Subjects	Design of Study	Evaluation Instrument F-V profile	Evaluation Protocol	Outcomes	Test Results
Jiménez-Reyes *et al.*[42]	Study Group: N = 16 Age: 23.1± 4.1 Weight: 76.3 ± 6.4 kg Height 1.81 ±0.06 m	Cross-cutting experimental design Evaluated Group: Countermovement Jump (CMJ) (n = 16)	Smith Machine (Multi-power Fitness Line, Peroga, Spain) Force platform (Bertec, Tipo 4060-15, USA)	Warm-up: 10 minutes of trot on tread-mill+ Dynamic Stretches + Preparatory Vertical Jumps. CMJ jumps without load and with 5 different loads (17-87 kg) on force platform and on soil (simple method).	F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power Force-Velocity profile	Variables calculated by a simple method show high reliability: ICC < 0.980 CV > 1.0%
Feeney *et al.*[44]	Study Group: N = 10 Age: 21.9 ±3.2 Weight: 72.2 ± 5.4 kg Height: 1.78 ± 0.12 m Body Mass Index (BMI): 22.8± 1.2 kg/m	Experimental cross-sectional design Evaluated Group: Knee Extensions against Resistance and Countermovement Jumps (CMJ) (n = 10)	Isokinetic Dynamometer Kin-com (Chatex corp, Chattanooga, USA) Force platform (Bertec FIT, Columbus, OH, USA).	Warm Up: 5 Minutes of Stationary Bike + Dynamic Stretches. CMJ with loads of 0-40% of body weight. Knee extensions in isokinetic device.	F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power Force-Velocity relation	Coefficients of individual correlation of strength and velocity of 0.78-0.93. The relation between the slopes of Force and Velocity are from moderate to highly reliable (0.67 < ICC < 0.91)
García Ramos *et al.*[45]	Study Group: N = 23 Age: 23.1 ± 3.2 Weight: 74.7 ± 7.3 kg Height: 177.1 ± 7.0 cm	Experimental Design Evaluated Group: Squat Jump and Countermovement Jump (n = 23)	Force platform (Dinascan/IBV Institute of Biomechanics of Valencia)	10 minutes warm-up: Joint Mobility and Dynamic Stretches SJ and CMJ with loads: 0, 17, 30, 45, 60, and 70 kg.	F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power Force-Velocity relation	There is a linear relationship in all force-velocity relationships: r > 0.98.
Hansen *et al.*[46]	Study Group: N = 18 Age: 26.8 ± 4.5 Weight: 103.5 ± 8.6 kg Height: 1.89 ± 0.1 m	Experimental design Group traditional training (TT) (n = 9) Cluster Group training (CT) (n = 9) (Total n = 18) Both groups received force and potency training on the lower extremities twice per week.	Force platform (Accupower, AMTI, Watertown, MA, USA)	Squat Jump with body weight and 3 external loads: 20, 40, and 60 kg.	F0: Theoretical maximum force V0: Theoretical maximum velocity Pmax: Maximum power	↑ in maximum force in the TT and CT Groups.

Theoretical maximum force (F0), Theoretical maximum speed (V0), Maximum power (Pmax), Slope Force-Velocity profile (Sfv), Optimum slope Force-Velocity profile (Sfvopt), Force-Velocity imbalance (FvIMB) Squat Jump (SJ), Countermovement Jump (CMJ).

athletes. The main finding is that most of the studies in this review used the force platform as the sole instrument of evaluation. Other studies have considered other methods. For example, García-Ramos *et al.*[47] Correlated, compared, and determined the reliability of F0, V0, and Pmax values obtained using a force platform and a linear encoder during jumps with loads (25, 50, 75, and 100% of body weight). They found a high correlation ($p < 0.0001$) between both evaluation methods, suggesting that the linear Encoder is a valid tool for measuring F-v profile. This study is consistent with that of Padulo J. *et al*.[48], who used a linear Encoder to evaluate the F-v profile of ten sports people across two types of movement (squat and leg press). Other authors have also searched for an evaluation method of similar validity to that of the force platform. Balsalobre-Fernández *et al*.[33], for example, analyzed the validity and reliability of a mobile application (My Jump®) for measuring vertical jump and F-v profile, and found almost perfect agreement between the height of jump as measured by the application and that measured using a force platform, thus demonstrating another valid and easily accessible option for evaluating F-v profile. Finally, Jiménez-Reyes, *et al*.[42] validated a simple method of evaluating F-v profile through the CMJ using three parameters; body mass, height of jump, and distance of propulsion. A comparison of these results and those obtained using a force platform showed strong interrelations between the F-v profile variables of both methods, thereby providing another assessment option.

While it is the case that the objective of this review was to evaluate the F-v profile through the vertical jump, other methods do exist. Samozino *et al*.[49] studied the F-v relationship using an ergometer fitted with a car seat, in which horizontal movement is enabled through ballistic push with the aim of quantifying the bilateral force deficit (BLD) associated with mechanical alterations of the F-v profile. On the other hand, Dobrijevic *et al.* [50], evaluated the F-v profile using an ergometric tape with an indicator connected to the subject by means of a belt. In addition, Romero-Franco *et al*.[51] examined the validity and reliability of the results of sprints measured using a mobile application (My Sprint) compared with existing methods (photocell and radar gun), and obtained an almost perfect correlation between the times, F0, V0, and Pmax measured with the mobile application and the photocell system.

As Samozino *et al*.[5] concluded, regardless of the method and instrument of evaluation, sports performance during a jump or race is not based exclusively on the Pmax but rather on the balance that exists within the F-v. Therefore, it is vital to measure this profile in order to improve the training and rehabilitation of sports people.[7]

Practical Applications

Is necessary to emphasize the importance of evaluating sports people, and to consider the methods most appropriate to meet the requirements of sports and the valid and reliable instruments that can give accurate evaluations and results. Doing so will allow the correct training loads to be prescribed and adjusted that will favor optimum performance with the lowest incidence of injuries.

On the basis of this review it is suggested that future investigations are undertaken with mobile applications and other more accessible instruments, comparing their ability to determine the F-v profile of sportsmen with that of the Gold Standard or the photocell system with the aim of facilitating and enhancing the work of sports science and health professionals to the benefit of athletes and the field of sport generally.

Conclusions

The methods and instruments for evaluating the F-v profile identified and included in this review are based primarily on the force platform or photocell system. Nevertheless, there are other methods that are more accessible to the majority of sports science professionals. It is therefore necessary to investigate whether these other measurement options are as valid and trustworthy as more commonly used instruments.

This research suggests that mobile applications may be a valid option for studying the F-v profile in sports people submitted to jump and sprint evaluations, allowing FVimb to be determined.

Conflict of interest

The authors do not declare a conflict of interest.

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ANATOMÍA DEL ENTRENAMIENTO PLIOMÉTRICO

Por: Derek Hansen y Steve Kennelly
Edita: Ediciones Tutor-Editorial El Drac.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf. 915 599 832 – Fax: 915 410 235
E-mail: info@edicionestutor.com Web: www.edicionestutor.com
Madrid 2018, 264 páginas, P.V.P: 29,95 euros

Los deportistas y entrenadores de alto nivel utilizan el entrenamiento pliométrico para mejorar la potencia, la agilidad, la velocidad, la fuerza, el control corporal, el equilibrio y el rendimiento deportivo en general. Con esta guía acreditada sobre el entrenamiento pliométrico, se pueden aprender los ejercicios más eficaces y mejorar los resultados. En total se describen con detalle 94 ejercicios pliométricos, además de 78 variantes que suponen un aumento de la dificultad para continuar mejorando a lo largo del tiempo. En este se recoge todo: ejercicios bilaterales, unilaterales, para el core y ejercicios pliométricos combinados.

Lo más interesante es que se puede ir más allá de las instrucciones para realizar un ejercicio y ver los músculos en acción. Cada ejercicio se ilustra con dibujos anatómicos detallados que muestran cómo los músculos interaccionan con las articulaciones y otras estructuras esqueléticas adyacentes. Se pueden aprender cómo las variantes, progresiones y secuencias de ejercicios afectan a la mejora y la recuperación y, por tanto, al rendimiento.

EL DESARROLLO DE LA POTENCIA

Por: National Strength and Conditioning Association (NSCA)
Edita: Ediciones Tutor-Editorial El Drac.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf. 915 599 832 – Fax: 915 410 235
E-mail: info@edicionestutor.com Web: www.edicionestutor.com
Madrid 2018, 288 páginas, P.V.P: 25 euros

Avalado por la NSCA, este libro es el recurso definitivo para el desarrollo de la potencia deportiva. Se incluyen: protocolos de evaluación para probar saltos, lanzamientos y ejercicios balísticos; instrucciones paso a paso de ejercicios de potencia para el tren superior, inferior y todo el cuerpo; orientación de cómo agregar progresiones con seguridad y efectividad para un desarrollo continuado; múltiples métodos de entrenamiento, como el entrenamiento explosivo con pesas, los levantamientos olímpicos y la pliometría; y programas para 12 de los deportes más populares.

El lector encontrará recomendaciones basadas en las investigaciones de los principales expertos mundiales sobre la materia y también los ejercicios, programas y protocolos que están utilizándose en los más altos niveles del deporte y el rendimiento.. La NSCA cuenta con más de 30.000 miembros en 72 países y es líder en investigación y formación de profesionales en entrenamiento de fuerza y acondicionamiento físico.

LA CIENCIA DEL CICLISMO

Por: Mikel Zabala y Stephen S. Cheung
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
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Madrid 2018, 656 páginas, P.V.P: 49,95 euros

Por fin ha llegado la fuente autorizada que los ciclistas serios llevan tanto tiempo esperando. La mezcla perfecta de principios científicos y su aplicación práctica. Este libro introduce al lector en este deporte, tanto en la sala de entrenamiento como en el laboratorio de investigación, el circuito, la pista o la carretera. Es una obra colectiva dirigida por los doctores Mikel Zabala y Stephen Cheung, científicos especializados en este deporte; y es la guía más conveniente para comprender los principios científicos y tecnológicos en que se sostiene la práctica ciclista.

Incluye: colaboraciones de 43 destacados científicos y entrenadores de ciclismo de todo el mundo; las últimas ideas sobre el interfaz ciclista-máquina, incluidos temas tales como ajuste de la bicicleta, aerodinámica, biomecánica y técnica de pedaleo; información sobre los factores ambientales estresantes, como el calor, la altitud y la contaminación atmosférica; una visión sobre problemas de salud tales como la nutrición durante la práctica ciclista y en el resto de la vida del deportista, lesiones comunes, fatiga, sobreentrenamiento y recuperación; ayuda en la planificación de programas de entrenamiento, incluidos el empleo de potenciómetro, gestión de los datos ciclistas, entrenamiento complementario, estiramientos específicos para ciclismo y entrenamiento mental; y las últimas técnicas de entrenamiento y competición, como teorías sobre establecimiento de ritmos y estrategias para pruebas de carretera, pista, BTT, BMX y ultradistancia.

2018		
55º Congreso Argentino de Ortopedia y Traumatología	1-4 Noviembre Rosario-Santa Fe (Argentina)	web: http://congresoaaot.org.ar/
VII Congreso Asociación Hispanoamericana de Médicos del Fútbol	3-4 Noviembre Lima (Perú)	web: http://hispamef.com/
2as Jornadas Nacionales SETRADE	8-9 Noviembre Vitoria	web: www.setrade.org
7º Congreso Mundial del Deporte Escolar, Educación Física y Psicomotricidad	8-10 Noviembre A Coruña	web: www.sportis.es/congresos
XVIII Congreso latinoamericano de Nutrición (SLAN) 2018	11-15 Noviembre Guadalajara (México)	web: www.slaninternacional.org
CIENMEDE 2018 - Ciencias Aplicadas a la Medicina del Deporte	12 -15 Noviembre La Habana (Cuba)	web: www.cienmedecuba.com/
6th Medica Medicine + Sports Conference	13-14 Noviembre Dusseldorf (Alemania)	web: www.medicine-and-sports.com
4th International Conference on Sports Medicine and Fitness	14-16 Noviembre Edimburgo (Reino Unido)	web: https://sports.conferenceseries.com/
50 Congresso Brasileiro de Ortopedia e Traumatologia	15-17 Noviembre Rio de Janeiro (Brasil)	http://cbot2018.com.br/
X Congreso de la Asociación Española de Ciencias del Deporte	21-23 Noviembre La Coruña	web: www.aecdcoruna2018.com
XII World Congress on Mountain Medicine	21-24 Noviembre Kathmandu (Nepal)	web: http://ismm2018.org/
XVII Congreso Nacional de la SEMED-FEMEDE	29 Noviembre-1 Diciembre Toledo	web: www.femede.es
5th International Conference of Physical Education and Sports Science	4-6 Diciembre Cappadocia (Turquía)	web: https://icpess2018.nevsehir.edu.tr/
2nd International Conference on Sports Medicine & Sports Sciences	5-7 Diciembre Nueva Delhi (India)	E-mail: saicon2delhi2018@gmail.com
XXV Congreso Mexicano de Física y Rehabilitación y el 2º Congreso Internacional "Actualización en Rehabilitación" 2018	5-8 Diciembre Cancún (México)	web: http://congresorehabilitacion2018.mx/
2019		
I Congreso Internacional de Ciencias de la Actividad Física y el Deporte, "Retos actuales y futuros de la Actividad Física y el Deporte"	24-26 Enero Torrent (Valencia)	web: https://www.ucv.es/
BKAM 2019: Barcelona associated Knee Meeting	6-9 Febrero Barcelona	web: www.bkam.info
9th Annual Sports Medicine Winter Summit	6-10 Marzo Park City, Utah (EEUU)	web: https://www.cmxtravel.com/conferences/sports-medicine-summit-2/

XVI Congreso Nacional de Psicología de la Act. Física y del Deporte	13-16 Marzo Zaragoza	web: www.psicologiadeporte.org
7th International Conference & Exhibition on Physiotheraphy & Physical Rehabilitation	25-26 Marzo Roma (Italia)	web: https://physiotherapy.annualcongress.com/
8th World Congress on Physical Medicine and Rehabilitation	25-26 Marzo Sidney (Australia)	web: https://rehabilitation.conferenceseries.com/
XXXVI Congresso FMSI: "Età biologica, età anagrafica"	27-29 Marzo Roma (Italia)	web: www.fmsi.it/
XVII Congreso de la Asociación Argentina de Traumatología del Deporte	11-12 Abril Buenos Aires (Argentina)	web: http://aatd.org.ar/
2019 AMSSM Annual Meeting	12-17 Abril Houston (EEUU)	web: https://www.amssm.org/
XIII Congreso de SETRADE	25-26 Abril Palma de Mallorca	E-mail: sanicongress@setrade.org web: http://www.setrade.org/
XXVIII Isokinetic Medical Group Conference: "Football Medicine meets the universe of sport"	27-29 Abril Londres (Reino Unido)	web: http://www.footballmedicinestrategies.com/en/2019-wembley/3988/482/
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1er Congreso Internacional de Podología Deportiva	10-11 Mayo Plasencia (Cáceres)	web: www.sepod.es
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12th Biennial ISAKOS	12-16 Mayo Cancún (México)	web: www.isakos.com
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XL Juegos Mundiales de la Medicina-International Sports Medicine Symposium	22-29 Junio Budva (Montenegro)	web: http://www.medigames.com
VIII Congreso Iberoamericano de Nutrición	3-5 Julio Pamplona	web: http://www.academianutricionydietetica.org/congreso.php?id=7#
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13th Congreso Mundial de la International Society of Physical and Rehabilitation Medicine	9-13 Julio Kobe (Japón)	web: http://www.isprm.org
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26th TAFISA World Congress	13-17 Noviembre Tokyo (Japón)	web: www.icsspe.org/sites/default/files/e9_TAFISA%20World%20Congress%202019_Flyer.pdf
2021		
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UCAM Universidad Católica San Antonio de Murcia

Campus de los Jerónimos,
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