Archivos de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

ISSN: 0212-8799

194

Volume 36(6)

November - December 2019

ORIGINALS

REVIEWS

ANALIZADOR de
CETONAS
en SANGRE
eBketone
eBketone
Blood Ketone Monitoring System
For in vitro diagnostic use
eBketone
Blood Ketone Test Strips
For in vitro diagnostic use
10 Test Strips
Seconds
Resultados en 10 segundos
0.5 µL Volumen de muestra capilar
Sencillo e intuitivo
PRODUCTOS de:
BIOLaster
www.biolaster.com
ANALIZADOR PORTÁTIL de
LACTATO
Lactate Scout 4
- Volumen de muestra: 0.2 µl.
- Resultados en 10 segundos
- Calibración automática
- Conexión PC vía Bluetooth
- Software de análisis Lactate Scout Assistant
(en presentaciones Start y Maletín)
Nuevas Características
- Compatible con las tiras reactivas actuales.
- Memoria de hasta 500 resultados
- Nueva pantalla para facilitar la visualización
- Diseño más pequeño, más ligero, más robusto
- Gran Conectividad:
- Conexión a monitores de ritmo cardíaco
compatibles
- App Android disponible próximamente
Lactate Scout 4
OK
T. 943 300 813 | M. 639 619 494

Sociedad Española de Medicina del Deporte

Sociedad Española de Medicina del Deporte

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

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

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), Índice SJR (SCImago Journal Rank), y SCOPUS

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


Laktate
www.laktate.com
ANALIZADOR de LACTATO
LACTATE PLUS
CÓMODO
El analizador Lactate Plus no necesita calibración
RÁPIDO
Tiempo de medición de 13 segundos.
Sólo requiere 0.7 microlitros de sangre
PRECISO
Numerosos estudios demuestran la exactitud del Lactate Plus
ECONÓMICO
Coste por Análisis significativamente más bajo que en otras marcas
619 284 022
Hemoglobin
www.hemoglobin.eu
ANALIZADORES PORTÁTILES de HEMOGLOBINA
DiaSpect Tm
- Resultados en tan solo 1 segundo aproximadamente
- No necesita calibración adicional
- Volumen de la muestra: >10 µL
- Conexión mediante Bluetooth (opcional)
Hemo Control
- Resultados de hemoglobina y estimación del hematocrito de una muestra en 25-60 segundos
- Volumen de muestra de 8µL
- No necesita mantenimiento. Autocomprobación automática
- Almacena hasta 4.000 resultados
- Conexión al PC mediante cable USB
Quo-Lab®
- Medidor de Hemoglobina Glicosilada
- Se requiere 4 µL de sangre total capilar o venosa
- Resultados en 4 minutos
- Almacena hasta 7.000 resultados
- Puerto USB

Archivos
de medicina del deporte

Volumen 36(6) - Núm 194. November - December 2019 / *Noviembre - Diciembre 2019*

Summary / Sumario

The responsibility of the dead and almost-dead in sport

La responsabilidad de los muertos y casi-muertos en el deporte

Pedro Manonelles Marqueta

Presidente de la Sociedad Española de Medicina del Deporte (SEMED).

Experience tells us that media events must to happen in order to have an impact on society.

They say that " every cloud has a silver lining", but it is a pity to have to apply this saying in a subject of the transcendence of death that happens in people who practice sport and, nowadays and given the recent events, of those who, might have passed away, have not done so because of the fortunate intervention of a savior.

It is a shame that these situations have to hold a media dimension in order to have some kind of beneficial outcomes for athletes.

We have been trying for 25 years, in the Spanish Society of Sports Medicine, to convince authorities and athletes of the need for medical examinations for sports fitness. Little has been achieved by means of reasoning and the attempt to convince them of the need for it, so we are convinced that it is necessary to make it compulsory, especially keeping in mind that the number of athletes is, fortunately, increasing... which also increases the number of these unfortunate events.

However, we will continue trying to convince those people and we propose two reflections. How many deaths and near-deaths are necessary for those responsible for the registration of athletes (of all athletes) in competitions to take effective measures?

And this one goes to athletes, millions of popular athletes who buy their shoes or bicycles, spend a fortune on supplements, sports materials, travel, etc., but who do not consider visiting a specialist to see if they are fit to practice sport. Have you thought about what happens when an athlete goes out to practice his sport, have a good time, compete or enjoy one of his favorite activities, and has the misfortune of suffering a cardiovascular incident, sometimes deadly? What will happen to the people who are waiting for him at home, with life projects underway, with economic needs to cover, with mortgages to pay, with children who will remain...?

Doctors have a responsibility to society. We have an obligation to take care of sick and healthy people. In the latter case, by doing our job of prevention.

Is it so much to ask to those responsible for sporting activities and, especially to those who are most interested, which are the sportsmen and sportswomen, to share this responsibility?

Correspondence: Pedro Manonelles Marqueta
E-mail: pmanonelles@femede.es

Peak running velocity predicts 5-km running performance in untrained men and women

Cecília Segabinazi Peserico[1], **Danilo Fernandes da Silva**[2], **Fabiana Andrade Machado**[1]

[1]Department of Physical Education. State University of Maringá. Brazil. [2]University of Ottawa, U. Ottawa, Canadá.

Received: 12.07.2018
Accepted: 02.01.2019

Summary

Objective: The aim of the present study was to examine the relationship between 5-km running performance and peak running velocity (V_{peak}) in untrained men and women and propose sex-specific equations for performance prediction based on V_{peak}.
Methods: Fifty young and untrained participants (20 female and 30 male) aged between 20 and 35 years participated in this study. Firstly, they performed a continuous incremental test on treadmill to determine V_{peak}; the second test was a 5-km running performance performed in 400 m outdoor track. V_{peak} test started with a velocity of 8 km•h^{-1} and increased by 1 km•h^{-1} between each successive 3-minute stage until participants reached volitional exhaustion. The 5-km time trial running performance for each participant were recorded and registered by the evaluator to determine the test duration (t_{5km}). The comparisons between female and male were performed using Student´s *t* test for independent samples; the relationship between V_{peak} and 5km running performance was examined using Pearson correlation coefficient (r), adjusted coefficient of determination (R^2) and standard error of estimate (SEE). Simple linear regression analyses were used to generate predictive equations for t_{5km} from V_{peak}.
Results: The V_{peak} and 5-km performance (t_{5km} and M_{V5km}) were significant higher for the male group compared to the female group ($P < 0.001$). In addition, both female and male presented high correlations values for the association between V_{peak} and t_{5km}.
Conclusion: V_{peak} is a good predictor of 5-km endurance running performance in untrained men and women. In practical application, V_{peak} could be used to prescribe and control running training in beginners in running practice.

Key words:
Exercise test. Peak treadmill velocity. Performance prediction. Time trial. Untrained runners. Sex difference.

La velocidad máxima predice el rendimiento en la prueba de 5 km en hombres y mujeres no entrenados

Resumen

Objetivo: El objetivo del presente estudio fue examinar la relación entre el rendimiento en la carrera de 5 km y la velocidad máxima (V_{peak}) en hombres y mujeres no entrenados y proponer ecuaciones específicas de acuerdo con el sexo para la predicción del rendimiento basada en la V_{peak}.
Métodos: Cincuenta participantes jóvenes y no entrenados (20 mujeres y 30 hombres) con edades comprendidas entre 20 y 35 años participaron en este estudio. Primero, realizaron una prueba incremental continua en la cinta rodante para determinar la V_{peak}; la segunda prueba fue una prueba de 5 km realizada en una pista de 400 m al aire libre. La prueba para determinar la V_{peak} comenzó con una velocidad de 8 km·h^{-1} y aumentó en 1 km·h^{-1} entre cada etapa sucesiva de 3 minutos hasta que los participantes alcanzaron el agotamiento volitivo. El rendimiento de cada participante fue registrado por el evaluador para determinar la duración de la prueba (t_{5km}). Las comparaciones entre mujeres y hombres se realizaron utilizando el Student's *t* test para muestras independientes; la relación entre V_{peak} y el rendimiento en la prueba de 5 km se examinó utilizando el coeficiente de correlación de Pearson (r), el coeficiente de determinación ajustado (R^2) y el error estándar de estimación (SEE). Se utiliza el análisis de regresión lineal simple para generar ecuaciones predictivas para t_{5km} desde la V_{peak}.
Resultados: V_{peak} y 5-km (t_{5km} y M_{V5km}) fueron significativamente mayores para el grupo masculino en comparación con el grupo femenino ($P <0.001$). Además, tanto hombres como mujeres presentaron altos valores de correlaciones para la asociación entre V_{peak} y t_{5km}.
Conclusión: V_{peak} es una buena predictora del rendimiento em la prueba de 5-km en hombres y mujeres no entrenados. En la aplicación práctica, V_{peak} puede utilizarse para prescribir y controlar el entrenamiento de carrera en principiantes en la práctica de correr.

Palabras clave:
Prueba de ejercicio. Velocidad máxima en la cinta rodante. Predicción del rendimiento. Prueba de 5.000 m. Principiantes en la práctica de correr. Diferencias entre sexos.

Correspondence: Cecília Segabinazi Peserico
E-mail: ceciliapeserico@gmail.com

Introduction

Peak running velocity (V_{peak}) is the highest velocity attained during a maximal incremental test that reflects the maximal aerobic speed and an important advantage in using this variable is that its determination does not depend on highly expensive equipment, such as gas analyzers[1-3]. V_{peak} is related to the speed associated with VO_{2max} (vVO_{2max})[3] and has been considered one of the most useful aerobic indices for running training prescription, with various application in different models of aerobic training sessions[4,5].

Previous studies demonstrated that V_{peak} is a good predictor of endurance running performance, in which high correlation values were found between V_{peak} and 5-km, 10-km, and 1-h time trials[1-3,6]. It is important to emphasize that V_{peak} is also a great tool for practical application[4,5], and its use ranges from submaximal continuous training (*e.g.,* light-intensity continuous training, moderate-intensity continuous training)[7], high-intensity interval training at V_{peak} (also known as long high-intensity interval trainings)[5] to supramaximal (*i.e.,* above V_{peak}) interval training (also known as short high-intensity interval training)[8].

However, these previous studies evaluated a specific sample of recreational[1-3,6] or trained runners[4], and the relationship between V_{peak} and endurance running performance in untrained individuals was unknown. More participants (including subjects not engaged in systematic running training programs) have been investigated for endurance running races[9], and as these numbers increase, the need for tools with great practical application also increases. Given its extremely low cost of determination[1-3] and high correlation with performance[1], V_{peak} has gained attention of being this potential tool. It may become a better option to individualize and optimize training outcomes and race performance, as results related to training application were highly positive[3,4,7]. Furthermore, in the majority of studies, only male runners were evaluated, and data on female participants are scarce. Sex-related differences in physical performance should be taken into account, given that men consistently present greater endurance performance than women of the same training level[10,11].

Given this, both performance level and differences between sexes may influence the prediction equation of running performance based on V_{peak}, which reinforces the need for reporting sex-specific equations in the same study with similar sample training level and procedures to determine exercise tests. Thus, we aimed to examine the relationship between 5-km running performance and V_{peak} in untrained men and women and propose sex-specific equations for performance prediction based on V_{peak}. Our hypothesis is that 5-km running performance is highly associated with V_{peak} in untrained men and women.

Material and method

Participants

Fifty young and untrained participants (20 female and 30 male) aged between 20 and 35 years participated in this study. We considered untrained runners as those who had never engaged in a systematic running training program (*i.e.,* with a coach, specific tests and individualized running training prescription). Volunteers were excluded if they use regular pharmacological agents or nutritional supplements; were smoking or have diabetes, hypertension, asthma, and/or present any cardiovascular disorder; have a body mass index ≥ 30 $kg{\cdot}m^{-2}$; and were engaged in systematic running training. Prior to testing, written informed consent was obtained from all participants and all procedures and test protocols were explained individually for each participant. The protocol was approved by the Local Human Research Ethics Committee (#623.581/2014; #409.162/2013) and appropriate standards for human experimentation have been followed.

Experimental overview

The participants performed two running tests after familiarization with the protocols to improve prediction power. Initially, in the first visit, the anthropometric measures were obtained in the laboratory. Subsequently, they performed a continuous incremental test under laboratory conditions (temperature = 20–22 °C and relative humidity = 50–60%) on a motorized treadmill (Super ATL; INBRAMED®, Porto Alegre, Brazil) to determine V_{peak}. The second was a 5-km running performance test performed in an outdoor track (temperature = 18–26 °C; relative humidity = 60–80%; air speed = 7-11 $km{\cdot}h^{-1}$).

To minimize circadian variations in performance, all evaluations were performed at the same period of the day, between 06:00 and 8:00 h p.m., due to availability of participants and the fact that the performance is better during the night[12]. These evaluations were performed in a maximum period of 7 days and had an interval of 48 h to ensure the recovery of the participants[13]. Participants were instructed to attend the testing sessions well rested, nourished, hydrated, and wearing comfortable clothing. Furthermore, were also instructed to avoid eating 2 h before the tests, to abstain from caffeine and alcohol, and to refrain from strenuous exercise for 24 h before testing.

Anthropometric measurements

All the anthropometric measures were obtained in the laboratory before the incremental test and were made by a single researcher to minimize possible inter-tester errors. Body mass (BM) and height were measured using standardized procedures. Body mass was measured to the nearest 0.05 kg using a Filizola® scale with a capacity of measuring 150 kg. Subjects were wearing light clothes and no shoes. Height was measured with a Seca® stadiometer to the nearest 0.05 cm and capacity of measuring 2 m. Participants were positioned in anatomic position and the reference being the distance between vertex and the plantar aspect of the foot. Skinfold measures were used to calculate body fat percentage using a Harpenden® skinfold caliper at seven sites: pectoral, triceps, abdominal, thigh, subscapular, suprailiac and midaxillary. Measures were taken at each site three times, adopting the average of these values as final value. Body density (BD) was determined using the seven skinfolds protocol of Jackson and Pollock[14]. Subsequently, body fat percentage (%BF) was calculated from BD using Siri's equation[15].

Incremental exercise test to determine peak velocity (V_{peak})

After a warm-up, comprised walking at 6 km•h^{-1} for three minutes, the continuous protocol started with a velocity of 8 km•h^{-1} and increased by 1 km•h^{-1} between each successive 3-minute stage until participants reached volitional exhaustion, with the gradient set at 1%[1,2]. This protocol was chosen because we previously demonstrated that this incremental rate and stage duration presented the highest correlations with endurance running performance and has been suggested as a tool for endurance running training prescription[4,5]. The V_{peak} of the incremental test was calculated as the velocity of the last complete stage added to the completed fraction of the incomplete stage[16], calculated according to the equation $V_{peak} = V_{complete}+t/T$, in which $V_{complete}$ is the running velocity of the last complete stage, t the time in seconds sustained during the incomplete stage, and T the time in seconds required to complete a stage. During the test (*i.e.*, 15 seconds before the end of each stage) the HR (Polar RS800sd; Polar®, Finland) and rating of perceived exertion (RPE)[17] were monitored and the maximal HR (HR_{max}) and maximal RPE (RPE_{max}) were defined as the highest (*i.e.*, 100%) HR and RPE values, respectively, obtained during the test. The percentage of age-predicted maximum heart rate (%APMHR) was calculated using the HR_{max} obtained during the incremental test and the age-based equation proposed by Tanaka *et al.*[18] ($HR_{max} = 208 - 0.7 \times age$).

5-km running performance

The 5-km time trial running performance was performed on a 400 m outdoor track and preceded by a self-determined warm-up of 10 min. Participants freely choose their pacing strategy during the performance. Based on the incremental test result, experienced running coaches provided suggestion of pace to avoid participants to start the race too fast or too slow. All of the participants were encouraged to give their best performance. Participants performed the tests with more runners on the track; however, they started the race at different times.

The 5-km time for each participant were recorded and registered by the evaluator to determine the test duration (t_{5km}) and to calculate the mean velocity (MV_{5km}). This result was considered the running performance of the participant.

Statistical analysis

The Shapiro-Wilk test was used and confirmed the normality of the data distribution. Data are presented as means ± standard deviations (SD) and were analyzed using the Statistical Package for the Social Sciences 17.0 software (SPSS® Inc., USA). The comparisons between female and male were performed using Student´s *t* test for independent samples. The relationship between V_{peak} and 5km running performance was examined using Pearson correlation coefficient (r), adjusted coefficient of determination (R^2) and standard error of estimate (SEE). Simple linear regression analyses were used to generate predictive equations for t_{5km} from V_{peak}. Statistical significance was set at $P < 0.05$.

Results

A total of 50 participants (20 female and 30 male) completed the study. There was no age difference between groups (Female = 25.9 ± 3.8 years, Male = 27.4 ± 4.5 years; $P = 0.247$). However, the anthropometric measures were different: height (m): Female = 1.7 ± 0.1, Male = 1.8 ± 1.0, $P < 0.001$; body mass (kg): Female = 61.8 ± 10.8, Male = 79.7 ± 8.7, $P < 0.001$; body mass index (kg•m^{-2}): Female = 22.7 ± 4.1, Male = 25.4 ± 2.7, $P = 0.014$; body fat (%): Female = 26.1 ± 3.5, Male = 17.4 ± 5.4, $P < 0.001$. The results obtained during the incremental test and 5-km running performance are presented in Table 1. The V_{peak} and 5-km running performance (t_{5km} and MV_{5km}) were significantly higher in the male group compared to that in the female group ($P < 0.001$). In addition, % V_{peak} referring to the mean 5-km running velocity, was different between groups ($P < 0.001$).

Table 2 presents the relationship between V_{peak} and 5-km running performance and the prediction equations for the indirect determina-

Table 1. Comparison between groups for variables obtained during the performance tests.

Variables	Female (n = 20)	Male (n = 30)	Total (n = 50)
V_{peak} (km·h^{-1})	10.5 ± 1.1	13.4 ± 1.1*	12.2 ± 1.8
HR_{max} from V_{peak} test (bpm)	195 ± 8.8	194 ± 9.9	195 ± 9.4
RPE_{max} from V_{peak} test (6-20)	19.8 ± 0.4	19.7 ± 0.7	19.7 ± 0.6
%APMHR	102.7 ± 4.5	102.9 ± 5.1	102.8 ± 4.8
t_{5km} (min)	38.7 ± 4.2	27.3 ± 3.1*	31.9 ± 6.6
MV_{5km} (km·h^{-1})	7.8 ±0.8	11.1 ± 1.3*	9.8 ± 2.0
% V_{peak} of MV_{5km}	75.1 ± 3.9	82.9 ± 4.2*	79.8 ± 5.6

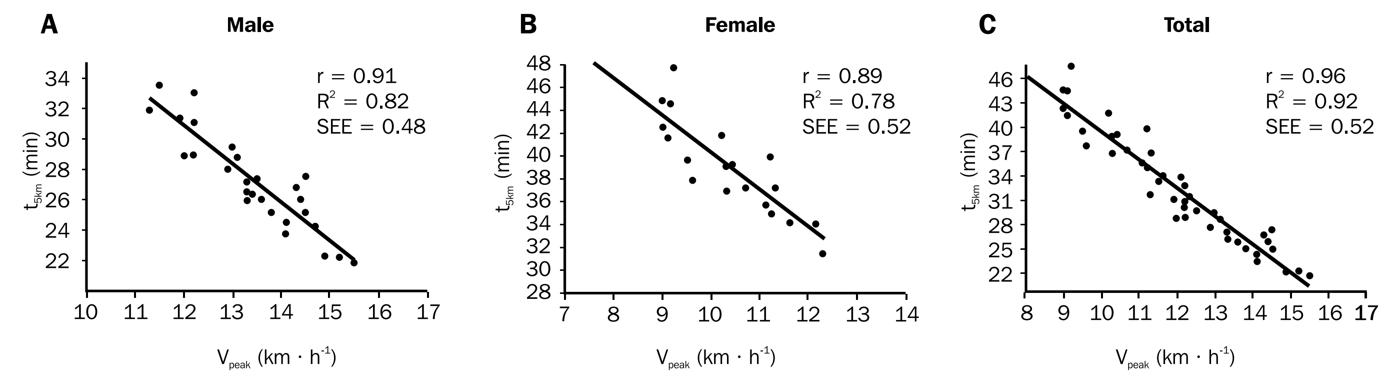
Note: V_{peak}: peak velocity; HR_{max}: maximal heart rate; RPE_{max}: maximal rating of perceived exertion; %APMHR: percentage of age-predicted maximum heart rate; t_{5km}: 5-km time; MV_{5km}: mean 5 km running velocity; % V_{peak}: referring to the mean 5-km running velocity. *$P < 0.05$ compared to female group.

Table 2. Relationship between peak velocity (V_{peak}) and 5-km time (t_{5km}) for different gender.

Protocols	r (95% CI)	Adjusted R^2	SEE (km•h^{-1})	Regression equation
Female (n=20)	0.89* (0.74–0.96)	0.78	0.52	$t_{5km} = 73.04 - 3.28 * V_{peak}$
Male (n=30)	0.91* (0.82–0.96)	0.82	0.48	$t_{5km} = 60.80 – 2.50 * V_{peak}$
Total (n=50)	0.96* (0.93–0.98)	0.92	0.52	$t_{5km} = 74.32 – 3.47 * V_{peak}$

CI: confidence interval; r: Pearson product-moment correlation coefficient; R^2: coefficient of determination; SEE: standard error of estimate in km•h^{-1}; V_{peak}: peak velocity; t_{5km}: 5-km time. *$P < 0.05$.

Figure 1. Correlation between peak velocity (V_{peak}) and 5-km time (t_{5km}).



A: for male; B: for female; C: for all participants (total).

tion of 5-km time. Figure 1 illustrates these relationships. Both the female and male groups presented high correlation values for the association between V_{peak} and t_{5km}.

Discussion

The present study aimed to examine the relationship between 5-km running performance and V_{peak} in untrained men and women and propose sex-specific equations for performance prediction based on V_{peak}. The main finding was that V_{peak} is a good predictor of 5-km running performance for both untrained men and women.

It is important to highlight that V_{peak} is a performance variable with high reliability[19] that should be determined during an incremental running test with initial speed of 8 km•h^{-1}, with 3 min stage duration and 1 km•h^{-1} speed increment[1,2,6]. We used this design because previous studies[1,2,6] found that the V_{peak} values obtained were better correlated with endurance running performance than other protocols tested.

The correlation values in our results for the association between V_{peak} and 5-km were 0.89 and 0.91 for female and male participants, respectively. Our results are similar to others studies that investigated the relationship between V_{peak} and endurance running performance with different distances in male[1,2,6,20] and female[21-23] runners and demonstrated high association. However, it is important to mention that Machado *et al.*[1] (r = 0.95 with 5-km), Alves *et al.*[6] (r = 0.92 with 10-km) and Noakes *et al.*[20] (r = 0.94 with 10-km) demonstrated higher correlation values with runners compared to our data. In contrast, other studies reported the same correlation values[22,24] or lower correlation values[21] (r = 0.83 for male and 0.80 for female). Thus, based on these results, it appears that performance level does not largely influence the relationship between V_{peak} and endurance running performance.

It is important to note that, specifically with 5-km running performance, few studies determined this association[1,21,24]. Machado *et al.*[1] in a sample of 27 male recreational runners determined V_{peak} using the same protocol as that in the present study and found a high association between V_{peak} and 5-km running performance with a correlation value of 0.95, SEE of 0.57 and R^2 of 0.91, which was similar to our findings.

The other two studies also demonstrated this association in those defining V_{peak} during an incremental test for VO_{2max} determination[21,25]. Stratton *et al.*[25] demonstrated similar results with those in our study, in which they found that final treadmill velocity was the best predictor (among other physiological variables) of 5-km performance in untrained (r = 0.89) and trained states (r = 0.83) (*i.e.*, pre and post six weeks of running training); in addition, a stepwise multiple regression analysis of the full pretesting data set revealed that, in the untrained state, 77.8% of the variance in 5-km performance could be explained by V_{peak} alone. Scott and Houmard[21] investigated a group of highly trained male and female distance runners and found that V_{peak} was related to 5-km time trial performed on treadmill in both men (r = 0.83) and women (r = 0.80) and when the data of both groups were combined (r = 0.94). It is important to mention that the correlation values determined by Scott and Houmard[21] were lower compared to those in our study; however, it is important to emphasize that the differences between protocols to determine V_{peak} influence these results[1,2,3], mainly because in the study of Scott and Houmard[21] both maximal oxygen consumption (VO_{2max}) and V_{peak} were determined using the same incremental protocol. Moreover, it is expected that trained subjects present lower coefficient of variation in the sample than untrained subjects, which was observed in our study compared to Scott and Houmard[21]. This higher homogeneity could play a role in reducing the correlation values.

To our knowledge, this is the first study to associate V_{peak} determined in a protocol without use of a gas analyzer and 5-km running performance in untrained participants. Moreover, only study of Machado *et al.*[1] on recreational runners proposed a prediction equation of running performance based on V_{peak}. These equations have high practical application and can help coaches to combine V_{peak} assessment with training prescription and performance prediction[4,5].

In addition, women are poorly investigated in this context compared to men[26], although there are evidences that women are adhering more to endurance running races[9] and consequently to running training programs in previously untrained subjects.

The reasons in separating women and men are related to different factors, including social, psychological, and physiological. However, due to the association between V_{peak} significance and physiological factors, they play an important role in defining equations specifically for men and women[12]. Joyner[26] recently suggested that from the key factors related to endurance performance (*i.e.*, VO_{2max}, lactate threshold, and running economy), it seems that VO_{2max} is the main differential variable between sexes. Men present larger muscle cross-sectional area[27] and lower percentage body fat and higher red cell mass for a given body weight[26,27]. Additionally, there are some evidences that women have smaller lungs relative to their body size and are more prone to arterial desaturation during intense exercise[26,28,29].

The $\%V_{peak}$ referring to the mean 5-km running velocity were 75.1 ± 3.9% and 82.9 ± 4.2% in women and men, respectively. These values were significantly different between groups and may be explained by the physiological differences between men and women discussed previously, such as larger muscle cross-sectional area[27], lower percentage body fat, and higher red cell mass for a given body weight[26,27]. These physiological advantages should contribute to the higher percentages of V_{peak} observed in male participants[26].

It is important to emphasize that, although incremental test led participants to exhaustion (based on RPE_{max}, HR_{max} and the %APMHR), this information was not obtained in the track test. However, both men and women performed 5-km running in similar percentages of V_{peak} with that in the study of Scott and Houmard[21]. It is also important to point out that participants were encouraged to give their best in the track test.

The Vpeak test (*i.e.*, incremental test) is highly applicable than 5-km running performance in training routines of different level runners, including untrained ones[1,2,4,5]. In our perspective, it is very useful to provide prediction equations to obtain 5-km running performance with V_{peak} as it will add one more practical benefit for this variable besides all the possibilities related to a more individualized training prescription. V_{peak} can be applied to a variety of training sessions (*e.g*., long high-intensity interval training, short high-intensity interval training, moderate-intensity continuous training, light intensity continuous training, and race pace[4,5,7,8] and presents very high correlation values with different running performance distances (*e.g.,* from 1.5 to 90 km)[1,20].

Therefore, we concluded that V_{peak} is a good predictor of 5-km running running performance in untrained men and women. In practical application, in agreement with previous studies that demonstrated the importance of this variable[4,5], V_{peak} could be used to prescribe and control training in beginners in running practice since its determination is simple and does not require expensive equipment or invasive techniques.

Conflicts of interest

The authors declare no conflict of interests.

Bibliography

1. Machado FA, Kravchychyn AC, Peserico CS, da Silva DF, Mezzaroba PV. Incremental test design, peak 'aerobic' running speed and endurance performance in runners. *J Sci Med Sport*. 2013;16:577-82.
2. Peserico CS, Zagatto AM, Machado FA. Evaluation of the best-designed graded exercise test to assess peak treadmill speed. *Int J Sports Med*. 2015;36:729-34.
3. da Silva DF, Simões HG, Machado FA. vVO_{2max} versus V_{peak}, what is the best predictor of running performances in middle-aged recreationally-trained runners? *Sci Sports*. 2015;30:e85-92.
4. Manoel FA, da Silva DF, de Lima JRP, Machado FA. Peak velocity and its time limit are as good as the velocity associated with VO_{2max} for training prescription in runners. *Sports Med Int Open*. 2017;1:E8-15.
5. da Silva DF, Ferraro ZM, Adamo KB, Machado FA. Endurance running training individually-guided by HRV in untrained women. *J Strength Cond Res*. 2017 [Epub ahead of print].
6. Alves JCC, Peserico CS, Nogueira GA, Machado FA. Influence of continuous and discontinuous graded exercise tests with different initial speeds on peak treadmill speed. *Sci Sports*. 2017;32:e15-22.
7. Buchheit M, Chivot A, Parouty J, Mercier D, Haddad AH, Laursen PB, *et al*. Monitoring endurance running performance using cardiac parasympathetic function. Eur J Appl Physiol. 2010;108:1153-67.
8. Esfarjani F, Laursen PB. Manipulating high-intensity interval training: Effects on VO_{2max}, the lactate threshold and 3000 m running performance in moderately trained males. *J Sci Med Sport*. 2007;10:27-35.
9. Cushman DM, Markert M, Rho M. Performance trends in large 10-km road running races in the United States. *J Strength Cond Res*. 2014;28:892-901.
10. Lopes TJA, Simic M, Alves DS, Bunn PS, Rodrigues AI, Terra BS, *et al*. Physical performance measures of flexibility, hip strength, lower limb power and trunk endurance in healthy Navy cadets: normative data and differences between sex and limb dominance. *J Strength Cond Res*. 2018; ahead of print.
11. Dada EO, Anderson MK, Grier T, Alemany JA, Jones BH. Sex and age differences in physical performance: a comparison of army basic training and operational populations. *J Sci Med Sport*. 2017;20:S68-73.
12. Cruz R, Melo BP, Manoel FA, Castro PHC, Da Silva SF. Pacing strategy and heart rate on the influence of circadian rhythms. *J Exerc Physiol Online*. 2013;16:24-31.
13. Mourot L, Boyhaddi M, Tordi N, Rouillon JD, Regnard J. Short- and long-term effects of a single bout of exercise on heart rate variability: comparison between constant and interval training exercises. *Eur J Appl Physiol*. 2004;92:508-17.
14. Jackson AS, Pollock ML. Practical assessment of body composition. Phys. *Sportsmed*. 1985;13:76-90.
15. Siri WE. *Tecniques for measuring body composition*. Washington DC: National Academy Press; 1961.
16. Kuipers H, Rietjens G, Verstappen F, Schoenmakers H, Hofman G. Effects of stage duration in incremental running tests on physiological variables. *Int J Sports Med*. 2003;24:486-91.
17. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exer*. 1982;14:377-81.
18. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*. 2001;37:153-6.
19. Peserico CS, Zagatto AM, Machado FA. Reliability of peak running speeds obtained from different incremental treadmill protocols. *J Sports Sci*. 2014;32:993-1000.
20. Noakes TD, Myburgh KH, Schall R. Peak treadmill running velocity during the VO_{2max} test predicts running performance. *J Sports Sci*. 1990;8:35-45.
21. Scott BK, Houmard JA. Peak running velocity is highly related to distance running performance. *Int J Sports Med*. 1994;15:504-7.
22. McLaughlin JE, Howley ET, Bassett DR, Thompson DL, Fitzhugh E. Test of the classic model for predicting endurance running performance. *Med Sci Sports Exerc*. 2010;42:991-7.
23. Machado FA, de Moraes SM, Peserico CS, Mezzaroba PV, Higino WP. The Dmax is highly related to performance in middle-aged females. *Int J Sports Med*. 2011;32:672-6.
24. Slattery KM, Wallace LK, Murphy AJ, Coutts A. Physiological determinants of three-kilometer running performance in experienced triathletes. *J Strength Cond Res*. 2009;20:47-52.
25. Stratton E, Obrien BJ, Harvey J, Blitvich J, Mcnicol AJ, Janissen D, *et al*. Treadmill velocity best predicts 5000-m run performance. *Int J Sports Med*. 2009;30:40-5.
26. Joyner MJ. Physiological limits to endurance exercise performance: influence of sex. *J Physiol*. 2017;595:2949-54.
27. Kanehisa H, Ikegawa S, Fukunaga T. Comparison of muscle cross-sectional area and strength between untrained women and men. *Eur J Appl Physiol Occup Physiol*. 1994; 68:148-54.
28. Sterkowicz-Przybycien K, Almansba R. Sexual dimorphism of anthropometrical measurements in judoists *vs* untrained subject. *Sci Sport*. 2011;26:316-23.
29. Harms CA, McClaran SR, Nickele GA, Pegelow DF, Nelson WB, Dempsey JA. Exercise induced arterial hypoxaemia in healthy young women. *J Physiol*. 1998;507:619-28.

Impact of the vertical sleeve gastrectomy on oxygen consumption kinetics among women post bariatric surgery

Claudia Miranda-Fuentes[1], Paulina Ibacache Saavedra[1,2], Pedro Delgado-Floody[3], Marcelo Cano-Cappellacci[4], Daniel Jerez-Mayorga[1], Edgardo Opazo Diaz[4]

[1]Universidad Andres Bello. Escuela de Kinesiología. Facultad de Ciencias de la Rehabilitación. Chile. [2]Facultad de Ciencias de la Salud. Universidad de Las Américas. Sede Viña del Mar. Chile. [3]Departamento de Educación Física. Universidad de La Frontera. Temuco. Chile. [4]Departamento de Kinesiología. Universidad de Chile. Chile.

Received: 15.11.2018
Accepted: 18.02.2019

Summary

Introduction: Obesity is considered one of the main health problems of modern society, there are several treatments to reverse it, being bariatric surgery (BS) the most effective method in cases of severe obesity. Cardiorespiratory fitness (CRF) is an aspect of physical condition assessed through maximum oxygen consumption (VO_{2max}); the kinetics of VO_2 is a less studied aspect of CRF; it has been described that this variable allows estimation of the CRF without high physical efforts in comparison with other forms of evaluation; In spite of the above, there is no information regarding the impact that sleeve gastrectomy (SG) has on the CRF evaluated through this variable.
Objective: To determine the impact of SG on the VO_2 kinetics of women with obesity.
Material and method: Quasi-experimental study, 15 women with an age of 32,9 ± 10,3 years and an initial BMI of 35,2 ± 3,9 kg/m^2 participated. The sample is non-probabilistic through a group of volunteers evaluated at three times: before surgery (*pre*), 30 and 90 days post vertical gastrectomy (30*post* and 90*post* respectively). Body weight, body mass index (BMI), waist circumference (WC), VO_{2peak} and VO_2 kinetics were evaluated.
Results: After surgery, the variables body weight, CC and BMI reported a significant decrease (p <0,001) compared to the pre-surgery moment. The relative VO_{2peak} (ml/kg/min) increases between 30*post* and 90*post* (p <0,001); the absolute VO_{2peak} (L/min) decreased between the pre moments with 30*post* and *pre* with 90*post* (p <0,05); the kinetics of VO_2 showed an increase in time at 30*post* (p <0,05).
Conclusion: The VO_2 kinetics is increased in obese women undergoing SG at 30*post* surgery, which shows a deterioration of this capacity.

Key words:
Obesity. Oxygen consumption. Bariatric surgery.

Impacto de la gastrectomía vertical sobre la cinética de consumo de oxígeno en mujeres post cirugía bariátrica

Resumen

Introducción: La obesidad es considerada uno de los principales problemas de salud de la sociedad moderna, existiendo variados tratamientos para revertirla, siendo la cirugía bariátrica (CB) el método más efectivo en los casos de obesidad severa. La capacidad cardiorrespiratoria (CCR) es un componente de la condición física valorada a través del consumo máximo de oxígeno (VO_{2max}); la cinética del VO_2 es un aspecto poco estudiado de la CCR; se ha descrito que esta variable permite estimar la CCR sin elevados esfuerzos físicos en comparación con otras formas de evaluación; a pesar de lo anterior, no existe información respecto del impacto que tiene la gastrectomía vertical (GV) sobre la CCR evaluada a través de esta variable.
Objetivo: Determinar el impacto de la GV en la cinética del VO_2 de mujeres con obesidad.
Material y método: Estudio de tipo cuasi experimental, participaron 15 mujeres con edad de 32,9±10,3 años y un IMC inicial de 35,2±3,9 kg/m^2. La muestra es de tipo no probabilística a través de grupo de voluntarios evaluados en tres momentos: previo a la cirugía *(pre)*, 30 y 90 días post gastrectomía vertical (30*post* y 90*post* respectivamente). Se evaluó peso corporal, índice de masa corporal (IMC), circunferencia cintura (CC), VO_{2peak} y cinética del VO_2.
Resultados: Post cirugía las variables peso corporal, CC e IMC reportan disminución significativa (p<0,001) respecto del momento pre cirugía. El VO_{2peak} relativo (ml/kg/min) aumentó entre 30*post* y 90*post* (p<0,001); el VO_{2peak} absoluto (L/min) disminuyó entre los momentos pre con 30*post* y *pre* con *90post* (p<0,05); la cinética del VO_2 presentó un incremento del tiempo a los 30*post* (p<0,05).
Conclusión: La cinética del VO_2 se ve incrementada en mujeres obesas intervenidas con GV a los 30 días post cirugía, lo que evidencia un deterioro de la capacidad cardiorrespiratoria.

Palabras clave:
Obesidad. Consumo de oxígeno. Cirugía bariátrica.

Correspondence: Claudia Miranda Fuentes
E-mail: cmiranda@unab.cl

Introduction

According to the World Health Organisation (WHO), obesity is defined as the abnormal or excessive accumulation of fat that can deteriorate health, and is considered to be one of the main problems faced by modern society[1]. In Chile, according to the National Health Survey (NHS) 2016-2017, the prevalence of obesity was 31.2% (28.6% among men and 33.7% among women), the main cause considered to be lifestyle in terms of unhealthy eating habits, a lack of physical activity and sedentary behaviour, in addition to genetic, physiological, psychological, social, economic and educational factors[2]. Treatments to combat obesity currently focus on reversing poor eating habits, increasing levels of physical activity, providing psychological support and administering pharmaceutical drugs[3]. In severe cases of obesity, or when the previously mentioned interventions have not had the desired effect, treatment moves on to Bariatric Surgery (BS)[4], considered the most effective treatment in reducing weight in the long term, and proving highly effective for weight loss, leading to a considerable reduction in the associated co-morbilities[4]. Vertical Sleeve Gastrectomy (VSG) is the most used BS in the world, comprising 45.9%[5] of all surgeries of this kind, and in Chile, it constitutes 70.8% of all BS[6].

Physical condition is a combination of physical attributes related to the capacity to perform a task, and may or may not be related to health[7]. Cardio-Respiratory Capacity (CRC) is a component of this condition, used as a health and life-expectancy indicator, demonstrated through maximum oxygen consumption (VO_{2max})[8]. Assessing this variable requires the maximum CRC of the subject, a situation that may be high risk in some cases9. In obese patients, the assessment of this variable is generally sub-maximum, and the term VO_{2peak} is used to denominate the amount of oxygen consumed at the moment the test is stopped, expressed in absolute values (L/min) or values related to body weight (ml/kg/min).

One of the aspects that is rarely addressed regarding VO_2, is its kinetic at the start of the constant load exercise, represented by the tau measurement (τ), which consists in the time response of the VO_2, quantifying stabilisation after a constant load exercise lasting 6-10 minutes, representing the overall function of cardiovascular, pulmonary and muscular-skeletal system activity[10]. Three phases can be discerned for the reaction of the increase of VO_2 in these conditions[11], with the τ value corresponding to the time in seconds in which 63% of the maximum VO_2 plateau is obtained with sub-maximum load in phase II, which has been proven to be sensitive to changes in CRC in subjects with cardio-respiratory pathologies12 and type II diabetes *mellitus*[13], with the reduction of τ linked to an improvement in this capacity.

There is currently limited literature available describing the behaviour of τ in obese adult patients treated with VSG[14]. For this reason, the aim of this study was to describe the impact of VSG on the VO_2 kinetics of obese women.

Material and method

This study is quasi-experimental, with the participation of 15 women aged 32.9 ± 10.3 years of age; weight, height and starting BMI of 90.2 ± 10.49 kg; 1.6 ± 0.1 m and 35.2 ± 3.9 kg/m^2 respectively. The sample is non-probabilistic, with a group of volunteers, who were assessed at three different points in time: before surgery (pre), as well as 30 and 90 days after surgical intervention (30 post and 90 post respectively). The inclusion criteria correspond to: BMI ≥ 30 kg/m^2, having fulfilled the surgical and anaesthetic criteria in order to undergo BS, and that the mentioned intervention is BS. Excluded patients were all those with previous BS, those with medical co-morbidities such as: chronic respiratory disease, heart disease, chronic liver disease or kidney failure, patients that used beta blockers, smokers, post-menopausal women, and patients that presented muscular-skeletal pathology that prevented them from performing the tests. Research and its protocols were aligned with the guidelines indicated in the 2013 Helsinki Declaration, approved by the Ethics Committee for Research on Humans at the University of Chile Medicine Faculty, Project No. 149-2014; all participants signed a previously informed consent form when their details were taken.

Procedures

Upon arriving at the laboratory, each subject had been previously required to fast for 4 hours and not to perform intense physical activity within the 24 hour period before assessment. The CC was assessed with a ROSSCRAFT® adult tape measure graduated in centimetres, to establish the middle point between the iliac crest and the lowest part of the ribs. Weight and height were measured with a DETECTO 439 (Detecto, Webb City, United States) graduated weighing scale/height measure. BMI was measured to estimate the degree of obesity (kg/m^2).

To measure the cardio-respiratory variables, Metalyzer 3b equipment, Cortex (CORTEX Biophysik, Leipzig, Germany) and a Monark 915E cycle-ergometer (Monark Exercise AB, Vansbro, Sweden) were used. To obtain VO_2 and VO_{2peak} kinetic data, the protocol consisted in the measurement of 2 minutes resting base cardio-respiratory parameters on the cycle-ergometer, then whilst pedalling at a speed of 60 rpm at a constant load of 0.5 watts per kilogram of body weight (W/kg) for 6 minutes to obtain the tau data. After this, to obtain the VO_{2peak} values, the load was increased at steps of 20 or 25 W (depending on the level of physical activity) every two minutes until exhaustion or to the point of reaching a respiratory quotient (RER) ≥ 1.1, perceived exertion ≥ 7 on the modified Borg Scale, or until the subject presented muscle fatigue that prevented the pedal speed from remaining at 60 rpm[15]. Following this, pedalling without load was performed for 3 minutes to cool down. Tau values were established following the protocol described by Poole[16], in which the value was obtained from the 6 first minutes on the cycle-ergometer exercise test. The VO_2 by ventilation values were transformed to obtain values with the 1Hz frequency, to be modelled mathematically in accordance with the equation that defines the VO_2 response, at a constant load and at moderate intensities, described below (Figure 1):

Figure 1. Formula to calculate the oxygen consumption kinetics.

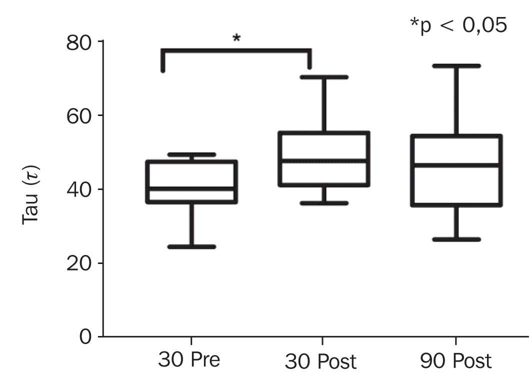
$$\dot{V}O_2(t) = \dot{V}O_2 \text{ basal} + \text{amplitud}\left(1 - e^{-\frac{t-TD}{\tau}}\right)$$

Where $VO_2(t)$ is the VO_2 at any time t, base VO_2 is the VO_2 before starting the exercise, range is the "stable state" towards which the VO_2 is projected, TD is the time delay that precedes the increase in muscular VO_2 and τ is the time constant that describes the rate at which VO2 increases to a stable state[16].

Statistical analysis

The statistical analysis was performed using IBM® SPSS® Statistics software, version 24.0 (Chicago, USA). The continuous variables were expressed as average and standard deviation prior to an analysis of data normality using the Shapiro-Wilk test. Quantitative variable comparisons were established using the ANOVA test of a factor of repeated measures and post-hoc analysis of Bonferroni. The p<0.05 values were considered to be statistically significant.

Figure 2. Oxygen consumption kinetics in pre and post vertical sleeve gastrectomy conditions on obese women.



Results

The women presented type II obesity in the assessment prior to surgical intervention (BMI 35.2 ± 3.9 kg/m²), shifting to a condition of pre-obesity (28.5 ± 3.4 kg/m²) three months later[17]; significant reductions were reported 30 and 90 days post surgery, in body weight, CC and BMI variables, as well as between *30 post* and 90 post (p<0.001) (Table 1).

In relation to relative VO_{2peak} (ml/kg/min), this displayed significant changes between the pre and 90 post periods (p<0.001), and in turn, the absolute VO_{2peak} value (L/min) reduced between the pre and *30 post* moments (p<0.001) and 90 post (p<0.002) (Table 1). In turn, the VO_2 kinetic presented significant differences between the pre and *30post* periods (p<0.05) (Figure 2).

Discussion

The aim of this study was to describe the impact of BS on VO_2 kinetic. First off, it is relevant to highlight that in this study, a detailed body composition assessment was not taken into account, whereby the researchers consider it pertinent to express the changes in the CRC values obtained in their absolute form (VO_{2peak} absolute (L/min) as opposed to normalising them by body weight; as such it is brought to light that just 30 days post surgical intervention are enough to present significant deterioration of this capacity; the results obtained are similar to those put forward by Browning *et al*. who analysed the parameters of this variable in obese subjects intervened with BS, affirming an average reduction of 2.6 L/min to 2.4 L/min at 3 months post intervention18. The aforementioned can be explained by the loss of lean mass and not fat mass[19]; on the other hand, significant body weight loss has been verified, associated specifically to predominantly fat mass in the first months following this kind of surgery[20].

With regards to the results of the VO_2 kinetic obtained in this research, it is important to highlight that this variable describes the dynamic response of this gas to sudden changes in the external work rate, proving to be dependent upon the intensity of the exercise when this exceeds the gas exchange threshold[21,22]. The results obtained of the VO_2 kinetic reveal that 30 days after BS, a significant increase can be seen in the stabilisation response time of this variable to the work load imposed by the activity, which indicates a slower fundamental component in the VO_2 kinetic, determining a greater oxygen deficit during the transition of resting to exercise. The results obtained can be compared to those put forward by Neunhaeuserer et al. who also refer to an increase in this variable among obese subjects who have undergone VSG BS[23].

Table 1. Effect of the vertical sleeve gastrectomy on the physical capacities of obese women.

Variables	Evaluations				Bonferroni *(Post hoc)*		
	pre	*30post*	*90post*	*p value*	*pre vs. 30post*	*pre vs. 90post*	*30post vs. 90post*
Weight (kg)	91.5 ± 11.0	82.2 ± 11.2	74.2 ± 9.9	<0.001	9.3 (<0.001) **	17.3 (<0.001) **	8.0 (<0.001) **
BMI (kg/m²)	35.2 ± 3.9	31.6 ± 3.9	28.5 ± 3.5	<0.001	3.6 (<0.001) **	6.6 (<0.001) **	3.0 (<0.001) **
CC (cm)	109.5 ± 6.7	102.5 ± 7.1	94.9 ± 7.9	<0.001	7.1 (<0.001) **	14.5 (<0.001) **	7.4 (<0.001) **
VO_{2peak} (L/min)	1.9 ± 0.2	1.6 ± 0.3	1.6 ± 0.2	<0.001	0.2 (<0.001) **	0.2 (<0.005) *	-0.05 (0.402)
VO_{2peak} (ml/kg/min)	21.0 ± 3.6	19.6 ± 2.6	22.5 ± 2.8	<0.001	1.3 (0.077)	-1.4 (0.099)	-2.8 (<0.001) **
Tau (τ)	39.8 ± 6.8	48.8 ± 9.5	46.1 ± 12.4	<0.001	-9.0 (<0.005) *	-6.3 (0.124)	2.7 (1.00)

The data is presented as averages and standard deviation, p value, ANOVA Test and Bonferroni Test. Tau (τ): Oxygen consumption kinetics; BMI: Body Mass Index. *p <0.05 **<0.001.

This results highlights that this kind of intervention negatively influences tolerance to exercise, suggesting that an increase in this variable (τ) slows down oxidative muscular metabolism activation[24], which is a possible cause of a lower energy expenditure per activity faced with a reduction of body weight post BS. On the other hand, Simoneau and Kelley highlighted that in subjects with health conditions associated to poor nutrition through overeating, there is a reduced activity of oxidative enzymes and a disproportionate increase of the activity of glycolytic enzymes, which could explain the τ results obtained in this research[25]. In the same sphere, literature has revealed τ values close to ~10 seconds in healthy individuals with a high level of physical training[26] and between 20 to 60 seconds in healthy adults[27]; the publications displayed have described that the increase of oxygen capture at the start of exercise demonstrates the circulatory adjustments to the metabolic modifications induced by this activity, where the oxygen contribution is not a limiting factor of performance during sub-maximum exercise, which reflects efficient muscular bioenergy and an effective tissue-level oxygen diffusion[28], conditions that are not present in subjects with obesity[15]. On the other hand, literature has also revealed τ behaviour in obese adults (without surgical intervention), with data discovered close to 58.7 ± 35.8 seconds[23]; subjects with pulmonary vascular disease 74 ± 16 seconds[29] and with type II diabetes *mellitus* 55.7 ± 20.6 seconds[30]; attributing the increase of this variable to the intensity of physical exercise employed and the capacity of the cardio-respiratory system to respond to the greater demand of this activity. Other antecedents have reported that obese subjects present muscular-skeletal changes both structurally (associated mainly to the higher proportion of type IIb muscle fibres[31]) and to the amount of muscle compared to normal-weight subjects[32], which entails the consequent incapacity to increase the oxidation of fats during β-adrenergic stimulation in exercise, with the subsequent increase of intramuscular fat storage[33]. In turn, with regards to the functioning of the respiratory system, information has been found stating that these subject present a lower flow value upon performing physical exercise, which must be compensated for by increasing the respiratory frequency, accelerating the start of the ventilatory threshold, speeding up the appearance of the slow VO_2 component, infringing upon tolerance of effort and adaptation to physical effort[34].

Conclusion

It is suggested that the VO_2 kinetic increases in obese women intervened with BS 30 days post surgery, therefore, the time needed to stabilise the cardio-respiratory response to work load imposed is slower. The latter is highly useful in clinical terms for the treatment of subjects with this health condition, as it is relevant when it comes to planning physical exercises guidelines for this particular demographic.

Conflict of Interest

The authors claim to have no conflict of interest whatsoever.

Bibliography

1. World Health Organization. Obesity and overweigth 2017 [cited 2018 May 31]. Disponible en: http://www.who.int/es/news-room/fact-sheets/detail/obesity-and-overweight.
2. Ministerior de Salud, Gobierno de Chile. Encuesta Nacional de Salud 2016-2017 Primeros resultados 2017 [cited 2018 January 29]. Disponible en: http://web.minsal.cl/wp-content/uploads/2017/11/ENS-2016-17_PRIMEROS-RESULTADOS.pdf.
3. Yarborough CM, 3rd, Brethauer S, Burton WN, Fabius RJ, Hymel P, Kothari S, *et al*. Obesity in the Workplace: Impact, Outcomes, and Recommendations. *J Occup Environ Med.* 2018;60(1):97-107.
4. le Roux CW, Heneghan HM. Bariatric Surgery for Obesity. *Med Clin North Am.* 2018; 102(1):165-82.
5. Plamper A, Deitel M, Rheinwalt KP. Letter to the Editor: Bariatric Surgery and Endoluminal Procedures: IFSO Worldwide Survey 2014. *Obesity Surgery*. 2018;28(1):249-50.
6. Angrisani L, Santonicola A, Iovino P, Formisano G, Buchwald H, Scopinaro N. Bariatric Surgery Worldwide 2013. *Obesity surgery.* 2015;25(10):1822-32.
7. Castillo-Garzon MJ, Ruiz JR, Ortega FB, Gutierrez A. Anti-aging therapy through fitness enhancement. *Clin Interv Aging*. 2006;1(3):213-20.
8. Lee DC, Sui X, Ortega FB, Kim YS, Church TS, Winett RA, *et al.* Comparisons of leisure-time physical activity and cardiorespiratory fitness as predictors of all-cause mortality in men and women. *Brit J Sport Med.* 2011;45(6):504-10.
9. Mezzani A, Agostoni P, Cohen-Solal A, Corra U, Jegier A, Kouidi E, *et al.* Standards for the use of cardiopulmonary exercise testing for the functional evaluation of cardiac patients: a report from the Exercise Physiology Section of the European Association for Cardiovascular Prevention and Rehabilitation. *European journal of cardiovascular prevention and rehabilitation: official journal of the European Society of Cardiology, Working Groups on Epidemiology & Prevention and Cardiac Rehabilitation and Exercise Physiology.* 2009;16(3):249-67.
10. Grassi B. Oxygen uptake kinetics: old and recent lessons from experiments on isolated muscle in situ. *Eur J Appl Physiol.* 2003;90(3-4):242-9.
11. Grassi B, Poole DC, Richardson RS, Knight DR, Erickson BK, Wagner PD. Muscle O2 uptake kinetics in humans: implications for metabolic control. *J Appl Physiol.* 1996;80(3):988-98.
12. Borghi-Silva A, Beltrame T, Reis MS, Sampaio LMM, Catai AM, Arena R, *et al*. Relationship between oxygen consumption kinetics and BODE Index in COPD patients. *Int J Chronic Obstr.* 2012;7:711-8.
13. Brandenburg SL, Reusch JEB, Bauer TA, Jeffers BW, Hiatt WR, Regensteiner JG. Effects of exercise training on oxygen uptake kinetic responses in women with type 2 diabetes. *Diabetes Care.* 1999;22(10):1640-6.
14. Neunhaeuserer D, Gasperetti A, Savalla F, Gobbo S, Bullo V, Bergamin M, *et al.* Functional Evaluation in Obese Patients Before and After Sleeve Gastrectomy. *Obesity surgery.* 2017;27(12):3230-9.
15. Littleton SW. Impact of obesity on respiratory function. *Respirology*. 2012;17(1):43-9.
16. Poole DC, Jones AM. Oxygen uptake kinetics. *Compr Physiol.* 2012;2(2):933-96.
17. World Health Organization. Obesity and overweigth - 10 facts about obesity 2017 [cited 2019. Disponible en: https://www.who.int/es/news-room/fact-sheets/detail/obesity-and-overweight.
18. Browning MG, Franco RL, Herrick JE, Arrowood JA, Evans RK. Assessment of Cardiopulmonary Responses to Treadmill Walking Following Gastric Bypass Surgery. *Obesity Surgery.* 2017;27(1):96-101.
19. Muñoz R, Hernández J, Palacio A, Maiz C, Pérez G. El ejercicio físico disminuye la pérdida de masa magra en pacientes obesos sometidos a cirugía bariátrica. *Rev Chil Cir.* 2016;68:411-6.
20. Chaston TB, Dixon JB, O'Brien PE. Changes in fat-free mass during significant weight loss: a systematic review. *Int J Obes (Lond).* 2007;31(5):743-50.
21. McNarry MA, Kingsley MI, Lewis MJ. Influence of exercise intensity on pulmonary oxygen uptake kinetics in young and late middle-aged adults. *Am J Physiol Regul Integr Comp Physiol.* 2012;303(8):R791-8.
22. Miranda C, Ibacache P, Opazo E, Rojas J, Cano M. Uso de la cinética del consumo de oxígeno para la evaluación de la capacidad cardiorrespiratoria en pacientes con obesidad. *Rev Med Chile.* 2018;146:15-21.
23. Neunhaeuserer D, Gasperetti A, Savalla F, Gobbo S, Bullo V, Bergamin M, *et al.* Functional Evaluation in Obese Patients Before and After Sleeve Gastrectomy. *Obes Surg.* 2017;27(12):3230-9.

24. Grassi B. Oxygen uptake kinetics: Why are they so slow? And what do they tell us? *J Physiol Pharmacol.* 2006;57 Suppl 10:53-65.

25. Simoneau JA, Kelley DE. Altered glycolytic and oxidative capacities of skeletal muscle contribute to insulin resistance in NIDDM. *J Appl Physiol* (1985). 1997;83(1):166-71.

26. Koppo K, Bouckaert J, Jones AM. Effects of training status and exercise intensity on phase II VO_2 kinetics. *Med Sci Sports Exerc.* 2004;36(2):225-32.

27. Whipp BJ, Rossiter HB, Ward SA. Exertional oxygen uptake kinetics: a stamen of stamina? *Biochemical Society transactions*. 2002;30(2):237-47.

28. Ba A, Bregeon F, Delliaux S, Cisse F, Samb A, Jammes Y. Cardiopulmonary response to exercise in COPD and overweight patients: relationship between unloaded cycling and maximal oxygen uptake profiles. *Biomed Res Int*. 2015;2015:378469.

29. Sietsema KE. Oxygen uptake kinetics in response to exercise in patients with pulmonary vascular disease. *Am Rev Respir Dis*. 1992;145(5):1052-7.

30. Regensteiner JG, Bauer TA, Reusch JE, Brandenburg SL, Sippel JM, Vogelsong AM, *et al.* Abnormal oxygen uptake kinetic responses in women with type II diabetes *mellitus. J Appl Physiol* (1985). 1998;85(1):310-7.

31. Pattanakuhar S, Pongchaidecha A, Chattipakorn N, Chattipakorn SC. The effect of exercise on skeletal muscle fibre type distribution in obesity: From cellular levels to clinical application. *Obes Res Clin Pract.* 2017;11(5s1):112-32.

32. Ciolac EG, Greve JA. Exercise-induced improvements in cardiorespiratory fitness and heart rate response to exercise are impaired in overweight/obese postmenopausal women. *Clinics.* 2011;66(4):583-9.

33. Blaak EE. Basic disturbances in skeletal muscle fatty acid metabolism in obesity and type 2 diabetes *mellitus*. *Proc Nutr Soc.* 2004;63(2):323-30.

34. Arena R, Cahalin LP. Evaluation of cardiorespiratory fitness and respiratory muscle function in the obese population. *Prog Cardiovasc Dis.* 2014;56(4):457-64.

Original article

Obesity *vs*. Whole-body-fat and myocardial infarction risk prediction. Body fat percentage is better indicator

Ángel Martín Castellanos[1,2], Pedro Martín Castellanos[1,3]

[1]Centro de Medicina Deportiva. Cáceres. [2]Departamento de Anatomía. Grupo de Investigación en Bio-Antropología y Ciencias Cardiovasculares. Universidad de Extremadura. Facultad de Enfermería y Terapia Ocupacional. Cáceres. [3]Centro de Atención Primaria. Cáceres.

Received: 19.09.2018
Accepted: 21.12.2018

Summary

Objective: Our aim was to realize an anthropometric analysis to identify both the association and plausibility of measurements and indicators of general obesity and whole-body fat on the risk prediction for myocardial infarction (MI) in men.
Material and method: A case-control study in 244 European men aged 30-74 years was conducted. We measured weight, height, waist and hip perimeters and skinfolds: triceps, subscapular and supraspinale, according to standardized protocols. We calculated the areas under the ROC curves, the odds ratios and correlations for indicators.
Results: Body mass index (BMI) [AUC: 0.687, 95% CI (0.619-0.715); OR: 3.5]. Waist circumference (WC) [AUC: 0.742, 95% CI (0.679-0.805); OR: 5.9]. Waist-to-height ratio (WHtR) [AUC: 0.780, 95% CI (0.721-0.839); OR: 8.4]. Endomorphy [AUC: 0.721, 95% CI (0.656-0.785); OR: 2.4]. Body fat percentage (%BF) [AUC: 0.774, 95% CI (0.714-0.834); OR: 10.2]. Lean body mass (LBM) [AUC: 0.490, 95% CI (0.413-0.568); OR: 1]. BMI correlated with %BF (0.84), endomorphy (0.80), WC (0.69), WHtR (0.72) and LBM (0.65). WHtR correlated with WC (0.97), %BF (0.92), endomorphy (0.62) and LBM (0.32). %BF correlated with WC (0.86) and endomorphy (0.78). The correlations between WHtR and body fat-associated indicators were strong (all $r \geq 0.62$, $p < 0.001$).
Conclusions: In MI men, body fat-associated indicators show different discriminative ability. BMI-defined obesity presents moderate discrimination and anthropometric association bias that do not lent support their suitability as risk predictor. Abdominal adiposity and whole-body fat percentage show the highest discriminative abilities and robust anthropometric reasons related with the true biological risk. We defend the use of WHtR as concept of risk volume and individual visceral adiposity for the early identification of adult men at risk of myocardial infarction.

Key words:
Obesity. Myocardial infarction. Anthropometric indicator. Body fat. Cardiometabolic risk. Risk prediction.

Obesidad *vs*. grasa corporal total y predicción de riesgo de infarto. El porcentaje de grasa corporal es mejor indicador

Resumen

Introducción: Nuestro objetivo era realizar un análisis por antropometría para identificar la asociación y plausibilidad de mediciones e indicadores de obesidad general y grasa corporal total en la predicción de riesgo de infarto en varones.
Material y método: estudio caso-control en 244 varones de 30 a 74 años de edad. Medimos peso y talla, perímetros de cintura y cadera, y pliegues de triceps, subescapular y supraespinal, según protocolos estandarizados. Obtuvimos las áreas bajo la curva ROC y las *odds ratios* para la asociación de indicadores.
Resultados: índice de masa corporal (IMC) [ABC: 0,687, 95% CI (0,619-0,715); OR: 3,5]. Circunferencia de cintura (CC) [ABC: 0,742, 95% CI (0,679-0,805); OR: 5,9]. Índice cintura-talla (ICT) [ABC: 0,780, 95% CI (0,721-0,839); OR: 8.4]. Endomorfia [ABC: 0,721, 95% CI (0,656-0,785); OR: 2,4]. Porcentaje de grasa corporal (GC%) [ABC: 0,774, 95% CI (0,714-0,834); OR: 10,2]. Masa magra (MM) [ABC: 0,490, 95% CI (0,413-0,568); OR: 1]. IMC correlacionó con GC% (0,84), endomorfia (0,80), CC (0,69), ICT (0,72) y MM (0,65). ICT correlacionó con CC (0,97), GC% (0,92), endomorfia (0,62) y MM (0,32). GC% correlacionó con CC (0,86) y endomorfia (0,78). Las correlaciones entre ICT y los indicadores asociados a la grasa corporal fueron fuertes (todas $r \geq 0{,}62$, $p < 0{,}001$).
Conclusiones: En los varones infartados, los indicadores asociados a la grasa corporal muestran diferente capacidad discriminativa. El IMC presenta moderada discriminación y sesgos de asociación antropométrica que no avalan su idoneidad como predictor de riesgo. La obesidad abdominal y el porcentaje de grasa corporal muestran las mayores capacidades discriminativas y robustas razones antropométricas relacionadas con el verdadero riesgo biológico. Nosotros defendemos el uso del índice cintura-talla como concepto de volumen de riesgo y adiposidad visceral individual para la temprana identificación de varones adultos en riesgo de infarto de miocardio.

Palabras clave:
Obesidad. Infarto de miocardio. Indicador antropométrico. Grasa corporal. Riesgo cardiometabólico. Predicción de riesgo.

Work awarded with the Accésit for the Best Oral Communication presented to the XVII Congress International of Spanish Society of Sports Medicine. Toledo november 29 to december 1, 2018.

Correspondence: Ángel Martín Castellanos
E-mail: angelmartincastellanos@gmail.com

Introduction

Obesity is a public health problem with high prevalence in Spain and worldwide[1,2]. Adiposity is associated with several diseases, including cardiovascular disease as the leading cause of morbidity and mortality worldwide[2]. Coronary heart disease represents 31.2% of cardiovascular mortality in Spanish men[3]. Body mass index (BMI) has been associated with myocardial infarction (MI) in Europe and worlwide[4-7] but in spite of its wide use does not provide accurate information on the whole-body fat percentage (%BF) and fat distribution. Thus, accurate estimation of the body fat distribution is highly relevant from a public health perspective, an aspect that has been endorsed by the American Heart Association Obesity Committee[8]. Technological methods for assessing whole-body fat such as dual-energy X-ray absorptiometry (DXA) can support the criterion of a more accurate evaluation; however, it is impractical in clinical settings. The diagnosis of BMI-defined obesity is the failure to considerer the impact of real adiposity on MI risk prediction[5-7]. Further, BMI has been found as a worse index than %BF to diagnose obesity in patients with coronary disease or acute coronary syndrome[9,10]. Evidence is accumulating in support of the anatomical distribution of adipose tissue as strong indicator of coronary heart disease and mortality[11-13]. Equally, our study previously published supports the anatomical distribution of adipose tissue as strong indicator of risk in proving the different biological risk for both visceral and subcutaneous adipose tissue[14]. From the INTERHEART and Norwegian studies, waist-to-hip ratio (WHR) is confirmed as a strong indicator to explain MI and risk attributable to obesity[5,6]. However, we have revealed statistical error bias for WHR-associated risk if the cutoff were not biologically equivalents with other indicators such as waist circumference (WC) and waist-to-height ratio (WHtR)[14]. Equally, we have described the anthropometric reasons that do not lent support WHR-associated risk unlike WHtR[7,10,14]. Additionally, in the same study of body composition by somatotyping we have warned about the spurious risk attributed to both BMI and WHR, being very important to know that in the MI-associated risk the role of each component as metabolic mediator is well different for each one[14].

Although a wide variety of anthropometric methods to estimate body composition in adults has been developed without taking into account hip dimension[15], WHR derived from cross-sectional and prospective larger studies[5,6] is still very considered even without keeping in mind our revelations[7,14]. In addition, WHtR has been described as the best predictor of %BF and visceral adipose tissue mass (by DXA) in Caucasian individuals[16], and in a recent study, relative fat mass (RFM) as new indicator of %BF, foundated on WHtR inverse, also has been validated by DXA in European-American adult individuals[17]. We know that BMI-defined obesity is associated to MI beyond other cardiovascular risk factors but provide poor discriminative performance[5-7,14]. Maybe this indicator used as proxies of obesity may not have the validity relative to use of a standard method of reference to assess real adiposity of risk.

Our aim was to assess the relative importance of measurements, general obesity, relative fatness, %BF and other classic indicators on the MI risk prediction in a sample of European men. We evaluated the discriminative ability by comparing the Receiver Operating Curves (ROC). Furthermore, we determined the correlations between anthropometric indicators in differentiating those that estimate body fat-associated risk by measuring total body weight, subcutaneous and visceral adipose tissue, and %BF.

Material and method

Study participants were recruited from a Hospital Complex in the Health Area of Caceres in Spain. Cases were selected from a post-myocardial infarction Cardiac Rehabilitation Program. The minimum sample size for calculating was of 91 cases and at least 1 control per case, with an obesity exposition for adult population of 22%, a level of safety of 0.99 and a statistical power of 0.99. The odds ratio (OR) to detect was of 3. A sample of 244 subjects, men of Europid ethnicity, aged 30-74 years, from 2012 database and new additions during 2018 was evaluated. Cases data were collected in the first fitting days after hospital diagnosis. Exclusion criteria were nonage, physical disability or any chronic disease. One control age-matched (± 5 years) was recruited per case at two Health Centers (60%), a wellness center (20%) and a department of workers of the State General Administration (20%). Exclusion criteria for controls were identical to those described for cases, with the additional criterion that controls had no previous diagnosis of coronary disease or history of exertional chest pain.

All subjects signed an informed consent approved by the Ethical Committee of the Hospital, according to the principles of the Declaration of Helsinki and Data Protection.

Anthropometric measures

Measurements were made according to standard international protocols[18,19]. Weight was measured (kg) wearing light underwear. Height was measured (cm) without shoes and the head was positioned in the Frankfort plane. Skinfolds (mm): triceps, subscapular and supraspinale were measured on the right side. WC and hip circumference were measured to the nearest 0.1 cm. WC was determined in a horizontal plane in the perimeter passing through the navel and just above the uppermost lateral border of the right iliac crest at the midaxillary line, and at the end of a normal expiration. HC was measured at the maximum perimeter around the buttocks with feet together and without gluteus contraction. Technical error of measurement for each dimension with an anthropometric tolerance for skinfolds about 5%, for perimeters 1%, and for height and weight 0.5%, was calculated.

BMI dividing body weight by square height (kg/m^2), WHR and WHtR (waist, hip and height in cm) were calculated. BMI ≥25-29.9 was defined as overweight and ≥30 as general obesity. Endomorphy rating was calculated according to the Heath-Carter Instruction Manual[20]. The equation to calculate endomorphy was:

$$\text{Endomorphy} = -0.7182 + 0.1451\,(X) - 0.00068\,(X^2) + 0.0000014\,(X^3).$$

Where X = (sum of triceps, subscapular and supraspinale skinfolds) x (170.18/height).

Rating on endomorphy component of 0.5 to 2.5 was considered low, 3 to 5 were moderate, and 5.5 to 7 were high. RFM as %BF was calculated according to the formula from Woolcott and Bergman for men: 64 - (20 * height (m)/WC (m))[17]. Lean body mass (LBM) was calculated by subtracting body fat mass (BFM) of total body weight: LBM= weight – BFM (kg). BFM is the transformation from %BF to unit of mass = RFM*100/weight (kg).

Statistical analysis

Data were computed using SPSS® software (version 20.0 IBM for Windows). Descriptive statistics as means, standard deviations are provided. Normal distributions were assessed using Kolmogorov Smirnov test. Student -test as parametric and Chi-square as no parametric test were applied to establish differences. Bivariate analysis was used for calculating Pearson´s correlation coefficients (r). Sensitivity and specificity by ROC analysis were assessed. The total area under the curve (AUC) was tested with no parametric differences and their values were used for identifying the strength of association for each indicator. The cutoff were defined there where sensitivity plus specificity was the highest. The odds ratio (OR) of prevalence of indicators according to different cutoff was calculated by using contingency tables and binary logistic regression analysis. The confidence interval was set at 95% in all cases. A value of p <0.01 was considered significant.

Table 2. Analysis ROC for the association of anthropometric indicators in myocardial infarction men.

Anthropometric variables	AUC	Error	95% CI	p
BMI	0.687	0.034	0.619-0.715	<0.001
BFM	0.721	0.033	0.657-0.785	<0.001
WC	0.742	0.033	0.679-0.805	<0.001
WHtR	0.780	0.030	0.721-0.839	<0.001
Inverse WHtR	0.220	0.030	0.161-0.279	<0.001
LBM	0.490	0.039	0.413-0.568	0.808
Endomorphy	0.721	0.033	0.656-0.785	<0.001
%BF	0.774	0.030	0.714-0.834	<0.001

AUC: Area under the curve; BF: Body fat; BFM: Body fat mass; BMI: Body mass index; LBM: lean body mass; WC: waist circumference; WHtR: Waist-to-height ratio. p: Significance level.

Results

Baseline anthropometric indicators are shown in Table 1. The main anthropometric indicators present significant differences. Both indicators of general obesity and abdominal obesity show strongly differences with level of significance. Indicators measured by skinfolds (endomorphy) as well as %BF also show significant differences. Only LBM and HC do no show anthropometric differences (p = 0.8, *p*= 0.2 respectively).

The AUC to establish the differences between groups were calculated according to sensitivity and specificity at each point of the ROC curve (Table 2). It is worth noting that an inferior limit less than 0.5 included in the confidence interval would indicate lack of association.

The cut-off point, sensitivity, specificity, OR and confidence interval for risk indicators are shown (Table 3). The different ROC curve patterns are plotted in Figure 1 and 2. The correlation coefficients for the main variables in MI men are given in Table 4. BMI correlated with endomorphy, LBM and %BF (0.80, 0.65 and 0.84 respectively). The correlations for WHtR with WC, endomorphy, LBM and %BF were 0.97, 0.62, 0.32 and 0.92 respectively. WHtR was notably correlated with body fat-associated risk indicators. LBM correlated strongly with BMI and weakly with both skinfold and central obesity variables (all r <0.5).

Discussion

Our study shows that indicators proxies of adiposity are associated to MI men with different discriminative ability. Previous studies have shown the association of both general and abdominal obesity with MI although BMI-defined obesity and WHR have presented statistical error bias on their predictive ability[4-7,14]. In addition, statistical association for any indicator is not the same as epidemiological causality and implicit risk. Therefore, some anthropometric indicators could show confusing in its true putative risk[14]. To our knowledge, the anthropometric risk associated to MI would depend on body fat-associated risk rather than the indicators may be responsible for all or much of the statistical association. In this line, BMI does not discriminate between musculoskeletal

Table 1. Baseline anthropometric indicators of the study participants.

Variable	MI (n=122)	95% CI	Control (n=122)	95% CI	p
Age (years)	53.8 ± 9.8	52.07 – 55.5	51.7 ± 9.5	50.1– 53.5	0.09
Height (cm)	169.4±7.3	168.1 – 170.7	173.5 ± 6.8	172.3 – 174.8	<0.01
HC (cm)	99.1 ± 13.1	96.8 – 101.5	97.5 ± 6.4	96.3 – 98.6	0.21
BMI (kg/m^2)	28.5 ± 4.0	27.7 – 29.2	25.2 ± 3.4	25.6 – 26.8	<0.01
WC (cm)	101.6 ± 20.7	97.9 – 105.3	91.3 ± 10.2	89.4 – 93.1	<0.01
WHR	1.02 ± 0.13	0.9 – 1.04	0.93 ± 0.06	0.92 – 0.95	<0.01
WHtR	0.60 ± 0.12	0.57 – 0.62	0.52 ± 0.06	0.51 – 0.53	<0.01
Endomorphy	4.6 ± 1.2	4.3 – 4.8	3.6 ± 0.9	3.4 – 3.8	<0.01
%BF	29.8±4.6	28.9¬ – 30.6	25.5±4.0	24.8 – 26.3	<0.01
BFM (kg)	36.8±5.1	35.8 – 37.7	32.6 – 4.8	31.7 – 33.4	<0.01
LBM (kg)	45.0±16.4	42.1 – 48.0	46.4±14.5	43.8 – 49	0.8

Abbreviations: BF: Body fat; BFM: Body fat mass; BMI: Body mass index; HC: Hip circumference; LBM: Lean body mass; MI: Myocardial infarction; WC: waist circumference; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio. p: Significance level.

Table 3. Cut-off points, sensitivity, specificity and odds ratio for the association between anthropometric indicators and myocardial infarction men.

Variables	Cut-off point	Sensitivity	Specificity	OR	95% CI	p
BMI (kg/m^2)	≥30	0.322	0.918	3.5	2.3-10.3	<0.001
WC (cm)	≥94.4	0.711	0.605	5.9	3.4-10.3	<0.001
WHtR	≥0.54	0.777	0.746	8.4	4.7-15.1	<0.001
LBM	45.5	0.492	0.459	1	0.6-1.2	<0.001
%BF	27.2	0.769	0.754	10.2	5.7-18.5	0.8
Endomorphy	≥3.9	0.682	0.581	2.4	1.4-4.2	<0.001
BFM	33.3	0.694	0.607	3.9	2.3-6.8	<0.001

BF: Body fat; BFM: Body fat mass; BMI: Body mass index; LBM: Lean body mass; WC: Waist circumference; WHtR: Waist-to-height ratio; p: significance level.

Table 4. Correlations between anthropometric variables of European men with myocardial infarction (N = 122).

Variables	BMI	WC	WHR	WHtR	Endo	%BF	LBM
BMI	1	0.69(*)	0.69(*)	0.72(*)	0.80(*)	0.84(*)	0.65(*)
WC	0.69(*)	1	1	0.97(*)	0.59 (*)	0.86(*)	0.49(*)
WHR	0.52(*)	0.76(*)	0.76(*)	0.75(*)	0.48 (*)	0.79(*)	0.24(*)
WHtR	0.72(*)	0.97(*)	0.97(*)	1	0.62(*)	0.92(*)	0.32(*)
Endo	0.80(*)	0.59 (*)	0.59 (*)	0.62(*)	1	0.78(*)	0.45(*)
%BF	0.84(*)	0.86(*)	0.86(*)	0.92(*)	0.78(*)	1	0.30(*)
LBM	0.65(*)	0.49(*)	0.49(*)	0.32(*)	0.45(*)	0.30(*)	1

Data are correlation coefficients.
BF: Body fat; BMI: Body mass index; Endo: Endomorphy; LBM: Lean body mass; WC: Waist circumference; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio;
*Correlation is significant at the .01 level.

Figure 1. Graph representing of the ROC curves for calculated indicators. AUC denotes area under the curve, BF body fat, BMI body mass index, LBM lean body mass and WHtR waist-to-height ratio.

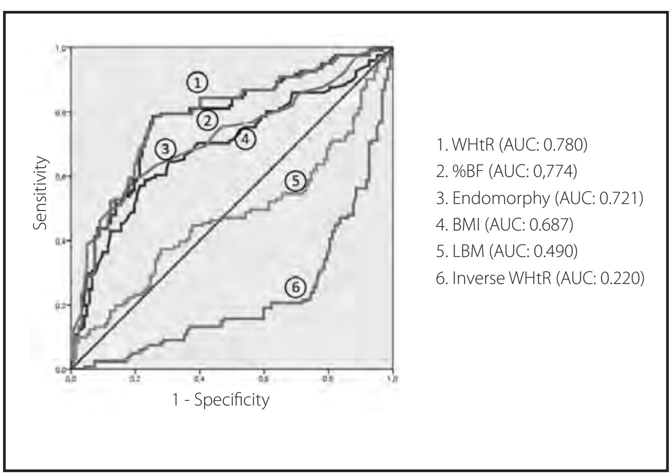
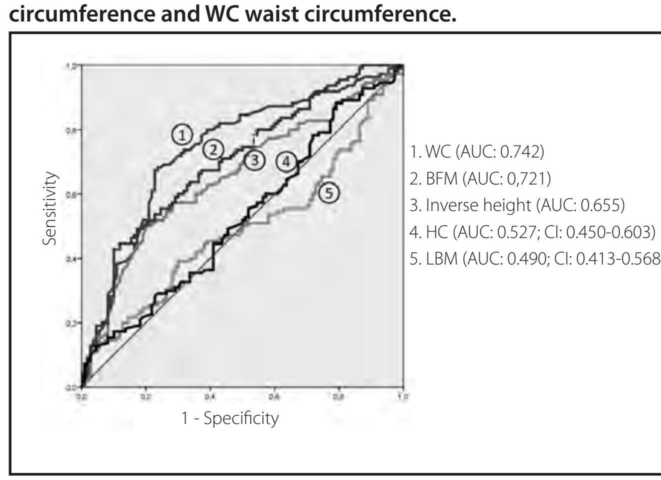


Figure 2. Graph representing of the ROC curves for simple indicators and others represented by units of mass. AUC denotes area under the curve, BFM body fat mass, LBM lean body mass, HC hip circumference and WC waist circumference.



component and body fatness in attributing partially a spurious risk to mesomorphy component[14]. Thus, BMI in depending on various components (muscle, bone, fat and residual mass) it underestimates abdominal obesity risk. Moreover, whether LBM does not show discriminative ability BMI provides an association bias beyond of BFM-associated risk. Our study is in agreement with previous study about body composition by somatotyping[14], and we can prove the different discriminative association between BMI-defined obesity and %BF by measuring WC and height. Equally, relative body fatness (expressed by endomorphy) in measuring three skinfolds, shows moderate discrimination according to somatotype of MI patients[7,14]. These observations could confirm the different biological risk for both visceral and subcutaneous fat depots what is in agreement with body composition and high prevalence of %BF-defined obesity in coronary disease men[9,10,14]. Additionally, in the Spanish thesis from the Complutense University of Madrid[10], %BF estimated from four skinfold thickness (method of Durnin-Womersley)[15] presented clear higher prevalence than BMI-defined obesity. In this study, %BF mean value (27.4 ±4.5) was lesser than RFM mean of the present study. This is important, since subcutaneous adipose tissue is less deleterious than intra-abdominal fat accumulation, which influences cardiometabolic processes and atherosclerotic coronary events risk[5-7,9,11-14,21-25].

Our study supports the anatomical distribution of adipose tissue as notable risk predictor although all variables with WC measurements shown higher discrimination than indicators with skinfolds distribution or body fat associated to body weight. In strict anthropometric sense WC as proxy of abdominal obesity is the true focal component of risk to relate adiposity and coronary risk and mortality in European men[11-14,21,23-28]. At time, in a recent research, WC has been found as the only metabolic syndrome component independently associated with left ventricular global longitudinal strain impairment[29]. Strain by echocardiography is an advanced cardiological technique that seems to be an independent predictor long-term risk of cardiovascular morbidity and mortality[30]. In this line, we have exposed the role of WC and height as physical dimensions in relation to a body volume index through WHtR[7,14]. Thus, our data strengthen the ability of WHtR to predict MI risk actually being WC and height measurements the foundated anthropometric basis for estimating %BF[17]. In our results, %BF shows the same discriminative power as WHtR actually drawing inverse WHtR the same reciprocal ROC curve as %BF but associated to status of healthy controls. The question is the scientific deduction, %BF comes from equations of statistical models and WHtR provides an index of biological risk volume by unit of height, with too little - too much dependence on LBM – visceral adiposity[7,14]. To our knowledge, this is the first time that anthropometrically-predicted %BF provide a clear discriminative association by using ROC analysis.

On the other hand, the differences of associated risk between simple measurements or unit of measure (e.g. length, mass) such as WC, height, HC, and body weight, BFM and LBM are the fundamental anthropometric key for the understanding of the true risk for each compound indicator. Our findings are in agreement with previous studies[7,14] and it strengthen statistical bias in research for BMI and WHR. Both indicators depend at time on peripheral body fat (with lesser discriminative risk) and LBM (without associated risk) in underestimating abdominal obesity. Anthropometric evidence supports that HC does not influence body composition but vice versa and WHR in showing a spurious risk would be misleading on the risk association[14].

According to our reasoning, the validity for any indicator depends on strength of their formula to reflect body fat-associated risk although keeping in mind the discriminative ability as well as epidemiological causality and real risk equivalence from each biological measurement[14]. Therefore, anthropometric evaluation will have more strength with those formulas that properly may translate a higher, verifiable, and plausible biological risk. In our results, WHtR and %BF show the highest real discriminative abilities although conceptually are different. We have proposed WHtR as risk volume concept where WC and inverse height (associated risk factors) always would be proportional to the individual biological risk[14]. However, %BF in spite of being a more intuitive concept, in depending on other statistical numerical variables could not translate the whole and true biological risk.

Lastly, our results provide critical perspectives on cardiovascular research related with obesity classification criteria. In MI risk prediction, we defend WHtR-associated risk as the best classification criteria, at least in adult men. Anyway, a pending question in research is to determine validated geographic region-specific and ethnicity-specific cutoff values for both WHtR and anthropometrically predicted %BF.

One limitation of our study is that the cross-sectional design did not allow showing long-term epidemiological causality between MI and associated risk indicators. Another limitation is that our results cannot be generalized by the sample size. Despite this, thousands of subjects are not needed for the interpretation about an anthropometric profile similar to those of other from large studies. The new data referenced help to better understanding a profile related with obesity and %BF on MI risk prediction. The relevance of these results extends the knowledge for the large number of infarcted people whose degree of BMI-defined obesity or %BF measured by anthropometry could be very close to our values. Future studies should confirm this possibility.

Conclusions

In MI men, body fat-associated indicators show different discriminative ability. BMI-defined obesity presents moderate discrimination and anthropometric association bias that do not lent support their suitability as risk predictor. Abdominal adiposity and whole-body fat percentage show the highest discriminative abilities and robust anthropometric reasons related with the true biological risk. We defend the use of WHtR as concept of biological risk volume and individual visceral adiposity for the early identification of men at risk of myocardial infarction.

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. WHO. Obesity and overweight; 2014 [updated June 2016]. [Web page]. http//www.who.int/mediacentre/factsheets/fs311/en. Accessed Feb 12, 2018
2. Aranceta-Batrina J, Pérez-Rodrigo C, Alberdi-Aresti G, Ramos-Carrera N, Lázaro-Masedo S. Prevalencia de obesidad general y obesidad abdominal en la población adulta española (25-64 años) 2014-2015: estudio ENPE. *Rev Esp Cardiol.* 2016; 69: 579-87.
3. Instituto Nacional de Estadística. Causas de defunción. 2016. Madrid: INE; 2017. Available in: http://www.ine.es/inebase/index.html. Accessed Mar 15, 2018
4. Lassale C, Tzoulaki I, Moons KGM, Sweeting M, Boer J, Jhonson L, *et al.* Separate and combined associations of obesity and metabolic health with coronary heart disease: a pan-European case-cohort analysis. *Eur Heart J.* 2018;39(5):397-406.
5. Yusuf S, Hawken S, Ounpuu S, Bautista L, Franzosi MG, Commenford P, *et al.* Obesity and the risk of myocardial infarction in 27,000 participants from 52 countries: a case-control study. *Lancet.* 2005;366;1640-9.
6. Egeland GM, Igland J, Vollset SE, Sulo G, Eide GE, Tell GS. High population attributable fractions of myocardial infarction associated with waist-hip ratio. *Obesity.* 2016;24 (5):1162-9.
7. Martín-Castellanos A, Cabañas-Armesilla MD, Barca-Durán FJ, Martín-Castellanos P, Gómez-Barrado JJ. Obesity and risk of Myocardial Infarction in a Sample of European Males. Waist To-Hip-Ratio Presents Information Bias of the Real Risk of Abdominal Obesity. *Nutr Hosp*. 2017;34(1):88-95.
8. Cornier MA, Després JP, Davis N, Grossniklaus DA, Klein S, Lamarche B, *et al.* Assessing adiposity: a scientific statement from the American Heart Association. *Circulation.* 2011; 124(18):1996–2019. Available in: https://doi.org/10.1161/CIR.0b013e318233bc6a. Accessed 14 Sep 2018.
9. Romero-Corral A, Somers VK, Sierra-Johnson J, Jensen MD, Thomas RJ, Squires RW, *et al.* Diagnostic performance of body mass index to detect obesity in patients with coronary artery disease. *Eur Heart J.* 2007;28(17):2087-93.
10. Martín-Castellanos A. Estudio sobre el perfil antropométrico, la composición corporal y el somatotipo en pacientes con síndrome coronario agudo en el área de salud de Cáceres. Tesis doctoral. Universidad Complutense. Madrid, España, 2014. https://ucm.on.worldcat.org/oclc/1026112318.
11. National Cholesterol Education Program (NCEP). Executive Summary of the Third Report of the National Cholesterol Education Program. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel

III). Expert Panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III) final report. *Circulation.* 2002;106:3143-421.

12. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Doanto KA, *et al.* Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation.* 2009;120(16):1640-5.

13. Brown JC, Harhay MO, Harhay MN. Anthropometrically-predicted visceral adipose tissue and mortality among men and women in the third national health and nutrition examination survey (NHANES III). *Am J Hum Biol.* 2017;29:e22898.

14. Martín-Castellanos A, Cabañas MD, Martín-Castellanos P, Barca-Durán FJ. The body composition and risk prediction in myocardial infarction men. Revealing biological and statistical error bias for both general obesity and waist-to-hip ratio. *Card Res Med.* 2018; 2: 13-20. Available in: http://www.globalaccesspub.com/journals/cardiovascular_research_and_medicine_articles_in_press. Accessed 30 Aug 2018

15. Alvero JR, Cabañas MD, Herrero A, Martínez L, Moreno C, Porta J. Protocolo de valoración de la composición corporal para el reconocimiento médico-deportivo. Documento de consenso del Grupo Español de Cineantropometría (GREC) de la Federación Española de Medicina del Deporte (FEMEDE). Versión 2010. *Arch Med Deporte.* 2010; XXVII (139): 330-44.

16. Swainson MG, Batterham AM, Tsakirides C, Rutherford ZH, Hind K. Prediction of whole-body fat percentage and visceral adipose tissue mass from five anthropometric variables. *PLoS One.* 2017;12(5):e0177175.

17. Woolcott OO, Bergman RN. Relative fat mass (RFM) as a new estimator of whole-body fat percentage. A cross-sectional study in American adult individuals. *Scientific Reports.* 2018;8(1):10980.

18. Stewart A, Marfell-Jones M, Olds T, De Ridder H. International standards for anthropometric assessment. International Society for the Advancement of Kinanthropometry. ISAK. Lower Hutt, New Zealand; 2011. pp. 50-3, 83-85.

19. National Health and Nutrition Examination Survey (NHANES). Anthropometry procedures manual 2007. Available in: http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf.

20. Carter JEL. The Heath-Carter Anthropometric Somatotype Instruction Manual. Department of Exercise and Nutritional Sciencies. San Diego State University: San Diego CA; 2002. p.15.

21. Gruson E, Montaye M, Kee F, Wagner A, Bingham A, Ruidavets JB, *et al*. Anthropometric assessment of abdominal obesity and coronary heart disease risk in men: the PRIME study. *Heart.* 2010;96(2):136-40.

22. Zeng Q, Dong S-Y, Sun X-N, Xie J, Cui Y. Percent body fat is a better predictor of cardiovascular risk factors than body mass index. *Braz J Med Biol Res*. 2012;45(7):591-600.

23. Ashwell M, Gunn P, Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. *Obes Rev.* 2012;13(3):275-86.

24. Estruch R, Ros E, Salas-Salvadó J, Covas MI, Corella D, Arós F, *et al.* PREDIMED Study Investigators. Primary Prevention of Cardiovascular Disease with a Mediterranean Diet. *N Engl J Med*. 2013;368(14):1279-90.

25. Gavriilidou NN, Pihlsgard M, Elmstahl S. Anthropometric reference data for elderly Swedes and its disease related pattern. *Eur J Clin Nutr*. 2015;69(9):1066-75.

26. Guasch-Ferré M, Bulló M, Martínez-González MÁ, Corella D, Estruch R, Covas MI, *et al.* Waist-to-Height Ratio and Cardiovascular Risk Factors in Elderly Individuals at High Cardiovascular Risk. *PLoS ONE*. 2012;7(8):e43275.

27. Savva SC, Lamnisos D, Kafatos AG. Predicting cardiometabolic risk: waist-to-height ratio or BMI. A meta-analysis. *Diabetes Metab Syndr Obes.* 2013;6:403-19.

28. Song X, Jousilahti P, Stehouwer CD, Söderberg S, Onat A, Laatikainen T, *et al.* Comparison of various surrogate obesity indicators as predictors of cardiovascular mortality in four European populations. *Eur J Clin Nutr.* 2013;67(12):1298-302.

29. Cañón-Montañez W, Santos ABS, Nunes LA, Pires JCG, Freire CMV, Ribeiro ALP, *et al.* Central obesity is the key component in the association of metabolic syndrome with left ventricular global longitudinal strain impairment. *Rev Esp Cardiol (Engl Ed).* 2018; 71(7):524-30.

30. Biering-Sørensen T, Biering-Sørensen SR, Olsen FJ, Sengeløv M, Jørgensen PG, Mogelvang R, *et al.* Global longitudinal strain by echocardiography predicts long-term risk of cardiovascular morbidity and mortality in a low risk general population: The Copenhagen City Heart Study. *Circ Cardiovasc Imaging*. 2017;10:e005521.

Parasympathetic recovery following exercise as a measure of training load

José F. Ruso Álvarez, Claudio Nieto

Universidad Pablo de Olavide. Sevilla.

Received: 20.09.2018
Accepted: 21.12.2018

Summary

In the Heart Rate Variability (HRV), the RMSSD (root mean square of the successive differences between adjacent RR intervals in ms) is the most used indicator of parasympathetic activity in sport. Its recovery after an effort can be a good indicator of workload but there is some controversy about how to use it and its relationship with intensity or volume.
After a maximum stress test to determine ventilatory thresholds (VT1 and VT2), 14 physically active men performed two separate tests for 48-72 hours. In the first one, subjets ran for 20 minutes to VT1 speed. In the second one, subjets ran to VT2 speed a time in which the product of intensity per duration was the same as VT1 (5 minutes warming-up). In both sessions, we measured the HRV during 10 minutes at rest and up to 10 minutes after the exercise, in a sitting position, with a Polar V-800 device. The subjective perception of effort on the Borg scale was recorded.
The RMSSD was calculated obtaining the slope formed by the values of the 10 minutes of recovery (Slope-10).
During the exercise, there was an identical and very significant fall ($p < 0.001$) of RMSSD in both tests. All recovery values remained significantly below those at rest, being higher in VT1 compared to VT2. Slope-10 values were 1.51 at VT1 and 0.34 at VT2, inversely correlating with the Borg scale ($r = -0.63$).
The parasympathetic reduction produced by any workload is independent of the type of work performed. The recovery of the parasympathetic system is inverse to the intensity of the work done. The recovery slope of the RMSSD is a good indicator of internal load.

Key words:
Heart rate Variability.
Workload. RMSSD.

La recuperación parasimpática tras el esfuerzo como medida de carga de trabajo

Resumen

En la variabilidad de la frecuencia cardiaca (VFC), la RMSSD (raíz cuadrada de la media de las diferencias de la suma de los cuadrados entre intervalos RR adyacentes) es el indicador de actividad parasimpática más utilizado en el deporte. Su recuperación tras un esfuerzo puede ser un buen indicador de carga de trabajo, pero existe cierta controversia sobre cómo utilizarla y sobre su relación con la intensidad o el volumen.
Tras una prueba de esfuerzo máxima para determinar umbrales ventilatorios (VT1 y VT2), 14 hombres físicamente activos realizaron dos pruebas separadas por 48-72 horas. En la primera, corrieron durante 20 minutos a velocidad de VT1. En la segunda, corrieron a velocidad de VT2 un tiempo en el que el producto de intensidad por duración fuese el mismo que el VT1 (calentamiento 5 minutos). En las 2 sesiones, medimos la VFC durante 10 minutos en reposo y hasta 10 minutos posterior al ejercicio, en posición sentado, con un dispositivo Polar V-800. Se registró la percepción subjetiva del esfuerzo en escala de Borg.
Se calculó la RMSSD obteniendo la pendiente formada por los valores de los 10 minutos de recuperación (Slope-10).
Durante el ejercicio, se produjo una caída muy significativa ($p<0,001$) de la RMSSD idéntica en ambas pruebas. Todos los valores de recuperación se mantuvieron significativamente por debajo de los de reposo, siendo superiores en VT1 respecto a VT2. Los valores de Slope-10 fueron de 1,51 en VT1 y 0,34 en VT2, correlacionando inversamente con la escala de Borg ($r = -0.63$).
La reducción parasimpática producida por una carga de trabajo es independiente del tipo trabajo realizado. La recuperación del sistema parasimpático es inversa a la intensidad. La pendiente de recuperación de la RMSSD es un buen indicador de carga interna.

Palabras clave:
Variabilidad de la frecuencia cardíaca.
Carga de trabajo. RMSSD.

Work awarded with the Best Oral Communication Award presented to the XVII International Congress International of Spanish Society of Sports Medicine.
Toledo november 29 to december 1, 2018.

Correspondence: José F. Ruso Álvarez
E-mail: joserusoalvarez@gmail.com

Introduction

The use of heart rate variability (HRV) in the field of sports and physical activity has grown in recent years as it provides a non-invasive tool to assess sympathetic and parasympathetic modulation[1,2].

The control of the training load (TL) in athletes[3] is currently one of the main challenges in training research and several authors advance HRV as a valid method for assessing individual responses to such loads[4,5]. However, there are still too many methodological discrepancies and conflicting results to draw any clear conclusions which can easily be applied to control training.

The method most commonly used is the measurement of HRV immediately after exercise to assess the way in which the values are recovered. But there is no work methodology, there only existing laboratory studies[6-9] and studies which evaluate complete training sessions[4,5,10,11] or sessions designed specifically in the field[12].

Nor is there uniformity in the variables measured: some authors use time-domain variables[6,10,13], others use frequency-domain variables[14] and others use both[15-17].

When analysing the HRV response after an exercise load, most studies focus on the effects of intensity[14,16-18], although some studies show changes related to the duration of the exercise[19] and others centre on both aspects[7].

In summary, although agreement is not absolute and no uniform methodology exists, the predominant idea in the literature would seem to be that: a) time-domain variables generate fewer discrepancies than frequency-domain variables[20]; b) exploring various exercise intensities is more useful[7,16,17]; c) immediate recovery of the parasympathetic variables (especially RMSSD or its natural logarithm) depends primarily on the intensity of the exercise[1].

In the literature reviewed, however, these variables (intensity and volume) are not adjusted to make the load obtained the same, so there is no information on the behaviour of HRV against TL as a whole.

Moreover, no useful indexes which can easily be applied to control responses to training loads on a daily basis have been extracted from the behaviours observed following exercise. Although some indexes have been described[6,8], their application does not throw up consistent data and they have not been used on an everyday basis.

This study, therefore, centres on analysing the RMSSD response in two tests of different intensity and duration, but with the same TL, in order to design a recovery index based on RMSSD which may prove useful when assessing athletes.

Materials and methods

14 physically active, healthy, male non-smokers (age: 20.93 ±1.38 years old; weight: 75.34 ± 10.07 kg; height 178.04 ± 5.83 cm; VO_2max 49.33 ± 3.93 ml · kg^{-1} · min^{-1}) took part in the study.

Following the general Task Force recommendations[2], all the subjects were told not to drink alcohol or caffeine-based drinks and to refrain from physical activity during the 24 hours prior to each test.

Each participant was subjected to an anamnesis to ensure that they were not under treatment or had any cardiovascular or other type of disorder which might affect or alter the state of the autonomic nervous system. All the subjects were informed about the procedure and gave their written consent to participate in the experiment. The Ethics Committee approved the study, which respected all the principles expressed in the Declaration of Helsinki.

The experiment lasted a total of 2 weeks and consisted of three sessions separated by 48-72h at about the same time of day 10 a.m. (± 2 h), maintaining stable environmental conditions (temperature and humidity).

In the first session, each subject filled in a background questionnaire and his height and weight were recorded. An incremental and maximum cardiopulmonary exercise test was conducted on an Ergo Run Medical 8 treadmill (Daum Electronic; Fürth, Germany), following a staged protocol with an initial load of 7 km/h at an inclination of 1% for 3 minutes with 1 km/h increases every minute until exhaustion. The test was performed with a BreezeSuite CPX ergospirometer (Medical Graphics, St. Paul, Minnesota, USA) calibrated before each measurement. The breath data were obtained breath by breath using a differential pressure flowmeter and the inspired and expired fractions of O_2 and CO_2 were obtained using a galvanic cell sensor and an infrared sensor, respectively.

For the purposes of this study, the positions of the ventilatory thresholds (VT1 and VT2) were determined following each test using the ventilatory technique proposed by Skinner and McLellan[21], and the speed corresponding to each threshold was recorded. VO_2max and maximum aerobic speed (MAS) were also determined for reference purposes.

In the second session, each subject ran constantly for 20 minutes at the VT1 speed and, given the low intensity, without warming up.

In the third session, each subject ran constantly at the VT2 speed for a time set so that the product of intensity by duration was the same as at VT1. This test was preceded by a 5 minute warm-up at 60% of each subject's VAS.

This ensured that both tests involved the same TL, which was calculated in each session as the product of intensity (speed) by volume (time)[20]. By expressing speed in km/h and time in hours, the TL was expressed as the distance travelled in kilometres.

In sessions 2 and 3, a Polar V800 pulse watch with H10 HR sensor chest strap (Polar Inc., Kempele, Finland) was worn from 10 minutes before the test until 10 minutes after completion of the test to measure HRV. All pre- and post-exercise measurements were taken seated in a calm and quiet environment. In all the sessions, the subject had to sit down immediately on completing the test (without active recovery) to measure recovery.

The RR interval time series were exported via the Polar FlowSync application (version 2.6.2) for analysis with Kubios HRV software (Version 2.1, University of Eastern Finland, Kuopio, Finland).

In each session, the last 5 minutes of the recording at rest (rest) and during exercise (exer.) were taken. In the case of the 10 minutes of recovery, the measurements were divided into two 5-minute periods (rec. 5 and rec. 10).

In order to develop a simple method which would be easy to use in real situations in which athletes are assessed, we chose to use a single variable of parasympathetic state for analysis. In accordance with the literature, RMSSD was calculated in the time domain[2], this being the tool most used to assess parasympathetic activity[20,22].

Each recording analysed was previously examined to detect the possible presence of artifacts and abnormal heartbeats, proceeding, when necessary, to apply the appropriate filters.

In each exercise session, the Borg scale 1-10 was used to subjectively rate perceived effort[23].

To compare with these algorithms, and in order to advance a recovery index based on HRV, we calculated the recovery slope of the RMSSD values over the 10 minutes based on the final value of the exercise for each of the intensities used in the experiment (VT1 and VT2). In this way, we devised an index called Slope-10 which could be applied without difficulty in real assessment situations.

Statistical analysis

First, descriptive statistics were calculated to present all the data through mean and standard deviation. Then hypothesis tests were conducted. First of all, the Kolmogorov-Smirnov test was used to test the normality of the distributions. Then Levene's test was used to assess the equality of variances and, there being more than two independent distributions, an ANOVA test was applied with a Games-Howell post-hoc test. To rule out the null hypothesis, a significance level of $p < 0.05$ was used for a confidence level of 95%.

To analyse the relationship between the slopes proposed and other load variables, a Pearson correlation analysis was run.

Statistical analysis was conducted using SPSS version 15.0 for Windows (SPSS Inc, Chicago, IL).

Results

Table 1 shows the data for intensity (speed), duration and TL, and the Borg scale values for the two tests.

Table 2 shows the RMSSD values measured at rest in the last 5 minutes of exercise and throughout recovery. The p-values are shown comparing each datum with the at rest value and those of recovery with exercise.

There were no significant differences in baseline HRV between tests. Significant differences were observed in RMSSD in every minute of recovery at the 2 intensities compared to at rest.

Figure 1 shows a comparison of the RMSSD data and their evolution during the two tests conducted. In this figure, the p-values show the differences between the two exercise intensities. No differences between the two tests can be observed in the RMSSD values during either rest or exercise. However, there were significant differences ($p < 0.05$) between the two tests throughout recovery.

Table 3 shows the mean, minimum and maximum Slope-19 values for both exercise loads.

Table 1. Characteristics of the tests.

	VT1	VT2
Speed (km/h)	10.24 ± 1.44	13.71 ± 0.89
Time (h)	0.33 ± 0	0.22 ± 0.05
TL (km)	3.43 ± 0.48	3.43 ± 0.88
Borg (1-10)	3.93 ± 0.92	7.57 ± 1.74

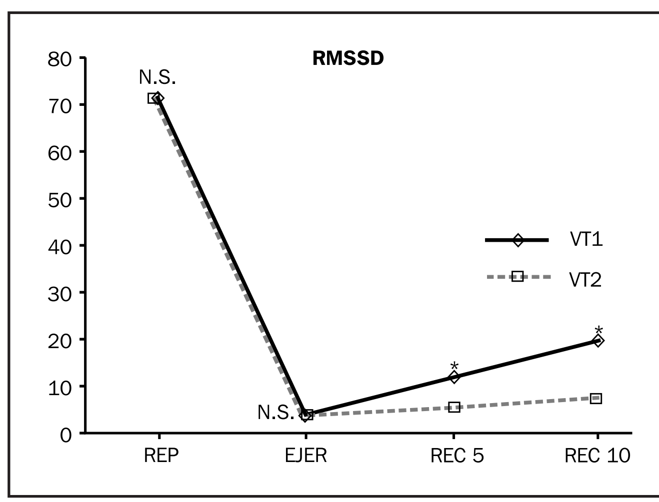
VT1: first ventilatory threshold; VT2: second ventilatory threshold; TL: training load.

Table 2. RMSSD values in the tests.

		RMSSD	
		VT1	VT2
REST	Mean	71.24	71.15
	SD	31.22	21.69
EXER.	Mean	3.92	4.26
	SD	1.11	0.83
	p (rest)	0.000	0.000
REC. 5	Mean	12.21	5.15
	SD	7.77	2.02
	p (rest)	0.000	0.000
	p (exer.)	0.025	0.782
REC. 10	Mean	19.56	7.69
	SD	10.33	4.58
	p (rest)	0.001	0.000
	p (exer.)	0.001	0.184

RMSSD: root mean square of the successive differences in ms; VT1: first ventilatory threshold; VT2: second ventilatory threshold; Rest: at rest; Exer: exercise; Rec: recovery; SD: standard deviation.

Figure 1. Evolution of the RMSSD values in the tests.



RMSSD: root mean square of the successive differences in ms; VT1: first ventilatory threshold; VT2: second ventilatory threshold; Rest: at rest; Exer: exercise; Rec: recovery. NS: not significant.

The Slope-10 index has a Pearson correlation coefficient (r) of 0.37 with TL, -0.63 with the Borg scale, -0.16 with VO_{2max} at VT1 and -0.11 with VO_{2max} at VT2.

Table 3. Values of the RMSSD recovery slope.

	Slope-10 Min	Mean	Max
VT1	0.64	1.51	2.49
VT2	0.10	0.34	0.72

RMSSD: root mean square of the successive differences in ms; VT1: first ventilatory threshold; VT2: second ventilatory threshold; MIN: minimum; MEAN: mean; MAX: maximum.

Discussion

The main finding of this study is that the reduction in parasympathetic stimulation produced by the same training load is independent of the type of exercise performed, while recovery of the autonomic nervous system depends on exercise intensity.

RMSSD suffers a significant drop in its values regardless of the intensity and duration of the exercise (Figure 1). Therefore, we can say that the suppression of parasympathetic stimulation during physical exertion is total regardless of the intensity, provided that the TL is the same. However, once recovery starts, a progressive increase in RMSSD values can be seen which is significantly faster when the intensity is lower (VT1). Other studies also find that RMSSD recovery is much quicker at lower intensities[1,6,14,16,17].

Nevertheless, these studies do not measure intensities according to thresholds but as percentages of HR_{max}; nor is intensity adjusted to duration[7,19] as we have done with the VT1 and VT2 loads to obtain the same TL.

Since RMSSD recovers faster, the lower the intensity and this results in a different slope for each situation, we understand that the numerical value of that slope could be a good indicator of the ease of recovery and, therefore, the internal load that the exercise supposes. That is to say, the steeper the recovery slope, the less the internal load. For our purpose, we assessed the slope in the first 10 min of recovery (SLOPE-10) trying to find an indicator easy to measure in real situations after training.

When these slopes were compared with the Borg scale, which is another common internal load indicator, they were found to correlate well and inversely (r = -0.63). Table 3 shows the Slope-10 values to be expected as a reference for each of the intensities studied.

In conclusion, reduction in parasympathetic stimulation is independent of the type of exercise performed and its recovery depends on the intensity of the exercise. The RMSSD recovery slope would seem to be a good indicator of the internal training load.

Conflict of interest

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

Bibliography

1. Stanley J, Peake JM, Buchheit M. Cardiac parasympathetic reactivation following exercise: Implications for training prescription. *Sport Med*. 2013;43:1259–77.
2. Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology. Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. *Eur Heart J*. 1996;17:354–81.
3. Bourdon PC, Cardinale M, Murray A, Gastin P, Kellmann M, Varley MC, *et al.* Monitoring Athlete Training Loads: Consensus Statement. *Int J Sports Physiol Perform*. 2017;12:161–70.
4. Pichot V, Roche F, Gaspoz JM, Enjolras F, Antoniadis A, Minini P, *et al.* Relation between heart rate variability and training load in middle-distance runners. *Med Sci Sports Exerc*. 2000;32:1729–36.
5. Kiviniemi AM, Hautala AJ, Kinnunen H, Tulppo MP. Endurance training guided individually by daily heart rate variability measurements. *Eur J Appl Physiol*. 2007;101:743–51.
6. Goldberger JJ, Le FK, Lahiri M, Kannankeril PJ, Ng J, Kadish AH, *et al.* Assessment of parasympathetic reactivation after exercise. *Am J Physiol Circ Physiol.* 2006;290:2446–52.
7. Kaikkonen P, Hynynen E, Mann T, Rusko H, Nummela A. Can HRV be used to evaluate training load in constant load exercises? *Eur J Appl Physiol.* 2010;108:435–42.
8. Saboul D, Balducci P, Millet G, Pialoux V, Hautier C. A pilot study on quantification of training load: The use of HRV in training practice. *Eur J Sport Sci*. 2016;16:172–81.
9. Kaikkonen P, Hynynen E, Mann T, Rusko H, Nummela A. Heart rate variability is related to training load variables in interval running exercises. *Eur J Appl Physiol.* 2012;112:829–38.
10. Plews DJ, Laursen PB, Kilding AE, Buchheit M. Heart Rate Variability and Training Intensity Distribution in Elite Rowers. *Int J Sports Physiol Perform*. 2014;9:1026–32.
11. Schumann M, Botella J, Karavirta L, Häkkinen K. Training-load-guided vs standardized endurance training in recreational runners. *Int J Sports Physiol Perform*. 2017;12:295–303.
12. Seiler S, Haugen O, Kuffel E. Autonomic recovery after exercise in trained athletes: Intensity and duration effects. *Med Sci Sports Exerc*. 2007;39:1366–73.
13. de Oliveira TP, de Alvarenga Mattos R, da Silva RBF, Rezende RA, de Lima JRP. Absence of parasympathetic reactivation after maximal exercise. *Clin Physiol Funct Imaging.* 2013;33:143–9.
14. Kaikkonen P, Nummela A, Rusko H. Heart rate variability dynamics during early recovery after different endurance exercises. *Eur J Appl Physiol.* 2007;102:79–86.
15. Buchheit M, Gindre C. Cardiac parasympathetic regulation: respective associations with cardiorespiratory fitness and training load. *Am J Physiol Heart Circ Physiol.* 2006;291:451–8.
16. Michael S, Jay O, Halaki M, Graham K, Davis GM. Submaximal exercise intensity modulates acute post-exercise heart rate variability. *Eur J Appl Physiol.* 2016;116:697–706.
17. Casonatto J, Tinucci T, Dourado AC, Polito M. Cardiovascular and autonomic responses after exercise sessions with different intensities and durations. *Clinics.* 2011;66:453–8.
18. Cottin F, Médigue C, Leprêtre PM, Papelier Y, Koralsztein JP, Billat V. Heart Rate Variability during Exercise Performed below and above Ventilatory Threshold. *Med Sci Sports Exerc.* 2004;36:594–600.
19. Michael S, Jay O, Graham KS, Davis GM. Longer exercise duration delays post-exercise recovery of cardiac parasympathetic but not sympathetic indices. *Eur J Appl Physiol.* 2017;117:1897–906.
20. Halson SL. Monitoring Training Load to Understand Fatigue in Athletes. *Sport Med.* 2014;44:139–47.
21. Skinner JS, McLellan TH. The Transition from Aerobic to Anaerobic Metabolism. *Res Q Exerc Sport.* 1980;51:234–48.
22. Buchheit M, Laursen PB. Parasympathetic reactivation after repeated sprint exercise. *Am J Physiol Circ Physiol.* 2007;293:133–41.
23. Borg GAV. Phychophysical bases of perceived exertion. *Med Sci Sports Exerc.* 1982; 14:377–81.

Original article

Anthropometric profile and estimation of competition weight in elite judokas of both genders

Alicia S. Canda

Servicio de Antropometría. Centro de Medicina del Deporte. AEPSAD. Consejo Superior de Deportes.

Received: 23.01.19
Accepted: 18.02.19

Summary

Introduction: The aim of the research is to define the anthropometric profile of judokas by gender and weight categories and to estimate the most suitable competition weight according to their physical constitution using regression equations.
Methods: An cross-sectional retrospective anthropometric study was carried out on three hundred and eighteen judokas when their weight was no more than 5% over the limit stipulated for their category, 187 males and 131 females, in all seven weight categories; mean age was 22.5±3.4 years (18-37 years). The anthropometric profile included forty-two direct variables. Their body composition was assessed by estimating the percentage of fat, muscle mass and theoretical minimal weight (TMW) and somatotype. Multiple linear regression equations were developed with each type of variable (lengths, breadths, girths) and in combination as predictors of body weight.
Results: Significant differences ($p<0.05$) were established in the anthropometric profile between the male and female samples and between the different weight categories whithin each gender. Only 2.4% of the judokas were at their TMW at the moment of the study. In males, height and 4 breadths (A-P chest, biiliocristal, femur and bimalleolar) explained 86.8% of the weight variation and 98.3% when girths were added, with an SEE of 4.2 and 1.5 kg, respectively. Among women, height and 3 breadths (A-P chest, biacromial and femur) gave 87.3% and, with girths, 97.9%, with an SEE of 3.3 and 1.3 kg, respectively.
Conclusions: In competition, judokas do not reduce the percentage of fat to the minimum and will lose weight at the expense of lean component. The regression equations developed may be useful to advise the most suitable weight category according to the anthropometric characteristics.

Key words:
Judo. Weight loss. Minimal weight. Anthropometry. Regression analysis.

Perfil antropométrico y estimación del peso de competición en judocas de elite de ambos sexos

Resumen

Introducción: Definir el perfil antropométrico del judoca por sexos y categorías de peso y estimar el peso de competición más adecuado según la constitución física mediante ecuaciones de regresión.
Métodos: Se realizó un estudio retrospectivo del control antropométrico de trescientos dieciocho judocas cuando su peso no excedía al 5 % del estipulado para su categoría, incluyendo 187 varones y 131 mujeres, de las siete categorías de peso, edad media de 22,5±3,4 años (18-37 años). El perfil antropométrico incluyo cuarenta y dos variables directas. Se valoró la composición corporal, estimándose el porcentaje de grasa, la masa muscular y el peso mínimo teórico (PMT) y el somatotipo. Se desarrollaron las ecuaciones de regresión lineal múltiple con cada tipo de variable (longitudes, diámetros, perímetros) y en combinación como variables predictoras del peso corporal.
Resultados: Se establecieron diferencias significativas ($p<0,05$) en el perfil antropométrico entre las muestras masculina y femenina y dentro de cada sexo entre las diferentes categorías de peso. Sólo el 2,4% de los judocas se encontraba en el PMT en el momento del estudio. En varones, la talla y 4 diámetros (A-P de tórax, biiliocrestal, fémur y bimaleolar) explicaron el 86,8% de la variación del peso y añadiendo perímetros el 98,3%, con un Se de 4,2 y 1,5 kg respectivamente. En las mujeres, talla y 3 diámetros (A-P de tórax, biacromial and fémur) el 87,3% y con perímetros el 97,9 %, con un Se de 3,3 y 1,3 kg respectivamente.
Conclusiones: El judoca en competición no baja al porcentaje de grasa mínimo y perderá peso a expensas del componente magro. Las ecuaciones de regresión desarrolladas pueden servir para aconsejar según las características antropométricas la categoría de peso más adecuada.

Palabras clave:
Judo. Pérdida de peso. Peso mínimo. Antropometría. Análisis de regresión.

Correspondence: Alicia S. Canda
E-mail: alicia.canda@aepsad.gob.es ; acandamoreno@yahoo.es

Introduction

Weight categories have been established in combat sports in order to promote balanced competition for athletes of different sizes and to ensure the safety of participants. The athletes wish to lower their body weight as far as possible to compete in a lower weight category and thus have an advantage. Because of this, very serious health problems sometimes arise, as the fast weight loss methods to reach that minimum often use different techniques that produce dehydration and consequential hyperthermia.

In the United States, following three cases of deaths among wrestlers in 1977, the National College Athletics Association (NCAA)[1], began a programme involving professionals at all levels. The measures adopted include the establishment, at the start of the season, of the weight category in which each wrestler can compete according to their physique.

In judo, competitions are divided into seven weight categories, with differences in both functional capacity and body composition as well as in technical-tactical aspects between competitors in different categories[2-4]. Effective bout time is 4 minutes, with predominance of the oxidative system, although decisive actions will depend on the anaerobic system[5-7]. Their physical condition will require high values of maximum strength, aerobic and anaerobic capacity[3,8,9].

The body composition of judokas is of great importance not only to achieve those functional capacities but also to conform to the most suitable weight category. In judo competition is, the official weigh-in takes place the day before the bout, and random controls may be carried out subsequently, at which up to 5% more than the wait for the category is allowed[10]. In principle, this would give more margin for athletes to think about the possibility of compensating their dehydration and the loss of energy deposits and facilitate fast weight loss practices. In 2010, Artioli *et al.* proposed a regulation for judo similar to that of wrestling (NCAA) incorporating a hydration test at the official weigh-in prior to the bout[11].

The aim of our study was to define anthropometric profiles of judokas for each weight category, both males and females, and to develop regression equations in order to estimate body weight based on anthropometric variables in order to provide guidance about the most suitable weight category according to their physique.

Material and method

A retrospective study was conducted on the judokas attending for assessment between 1993 and 2016, including Caucasians over 18 years of age. For each judoka, the control at which his or her body weight was closest to the competition category weight was chosen. Subsequently, we excluded those with the body weight more than 5% above that of the category. The sample finally comprised 318 athletes, 187 males (V) and 131 females (M), with a mean age of 22.5 ±3.4 years (18 37 years), in training for 12.2±5.1 years for 5.4±0.8 days a week and 3.2±1 hours a day at the moment of the study. Their distribution by categories was as follows: males < 60 kg (V1, n=28), < 66 kg (V2, n=33), < 73 kg (V3, n=42), < 81 kg (V4, n=32), < 90 kg (V5, n=25), < 100 kg (V6, n=14), > 100 kg (V7, n=13); females: < 48 kg (M1, n=24), < 52 kg (M2, n=19), < 57 kg (M3, n=18), < 63 kg (M4, n=30), < 70 kg (M5, n=23), < 78 kg (M6, n=8), >78 kg (M7, n=9).

The protocol included 42 variables: general measurements (weight, height, sitting height and arm span), girths (head, neck, shoulders, chest, waist, hip, arm relaxed, arm flexed and tensed, forearm, wrist, thigh, mid-thigh, calf and ankle), bone breadths (biacromial, A-P chest depth and transverse chest, biiliocrestal, bitrochanteric, bi-styloid wrist, biepicondylar humerus, biepicondylar femur, bimalleolar ankle), lengths (upper arm, forearm, hand, thigh, tibial height, and foot) and skinfolds (pectoral, iliac crest, supraspinal, abdominal, subscapular, biceps, triceps, front thigh and medial calf).

The material used was: scales, Seca brand; stadiometer, measuring table for seated position, bone calibrator and body fat calliper, Holtain brand; large calliper with curved arms and anthropometer from GPM Siber Hegner Machinery Limited; and an anthropometry tape, Rosscraft brand. The anthropometrist, qualified to level III by the ISAK (International Society for the Advancement of Kinanthropometry), observed this society's standards[12], except for the variables of shoulders[13] and mid-thigh girth[14].

The body composition was assessed by means of: skinfold profile; sum of 8 skinfolds (all those in the protocol except for the pectoral skinfold); percentage of fat estimated using modified equations by Lohman[15] (males), Slaughter[16] (females) and Withers[17] (both samples), fat weight; lean or fat-free weight; muscle mass using Lee's equation[14] (% and kg/m^2); and muscular cross-sectional areas (CSA), arm, thigh and calf, using Heymesfield equations[18]. The theoretic minimal weight (TMW)[19] was estimated and set, in males, for a 7% fat percentage according to Lohman's equation and 14% in females using Slaughter's equation. The somatotype was calculated using the Heath-Carter method[20].

Prior to the study, athletes signed an informed consent form and the work was conducted in accordance with the ethical standards of the Helsinki Declaration.

In order to determine the difference between genders, the Mann-Whitney U test was applied. Comparison between weight categories was by ANOVA (Tukey HSD subsets). The correlation and linear regression (stepwise method) was analysed for each gender between the weight and the rest of the anthropometric variables, excluding athletes in the last category (>78 kg and >100 kg). Values were considered statistically significant with a $p \leq 0.05$. The software used was Excel and SPSS Statistics.

Results

Body composition and somatotype are shown in Tables 1 and 2. Male judokas have a lower value for the skinfold profile, sum of skinfolds, percentage of fat and fat weight; and a larger height, weight, lean and muscular component both in percentage terms and in kg/m^2 than the females ($p = 0.015$ in subscapular skinfold, $p = 0.002$ in pectoral skinfold and $p < 0.0001$ in the rest of the variables).

In the comparison by weight categories for both the male and the female samples, there are significant differences $p < 0.0001$ in body composition. In terms of skinfolds, the greatest differences between groups were established in the supraspinal and abdominal skinfolds of males; and the least difference was seen in the medial calf. In the case of the women, however, the differences established were smaller due to the greater range in each category, with those in M7 always showing higher values that significantly differentiated them from the rest (except with V6 in the whole profile and V5 in the values for the lower limbs). In terms of fat percentages, four sub-groups can be established among the males (V1-V4, V3-V5, V6, and V7) and three among the women (V1-V4, V4-V6, and V7). In terms of lean weight, there are as many subgroups defined as there are weight categories in both the male and female samples. And with respect to muscle weight kg/m^2, three subgroups existed in males (V1-V3, V3-V6, V7) and in females (V1-V5, V3-V6, V6-V7).

Muscle development at the level of the arm, thigh and calf (CSA) was greater in males ($p < 0.0001$) compared to females. By weight category, the CSA also gave significant differences ($p < 0.0001$) in each sample. The CSA values in males indicate that judokas in one category may have similar values to those of the category immediately below them. In women, however, there is more overlap between groups, with coincidences in more than two categories.

The mean somatotype for judokas was dominant mesomorphic located in balanced mesomorph in males and in endomorphic mesomorph in females. Males had a lower endomorphic component and a larger mesomorphic component than females ($p < 0.0001$), with similar levels of ectomorphism. By weight categories, the judoka somatotype is fundamentally different if the extreme categories are compared. In males, endomorphism was greater in V6 V7; mesomorphism was lower in V1 V3; and ectomorphism was less in V4 V7 and greater in V1 V2. Three categories were classified as balanced mesomorph (V1, V3 and V4), two as ectomorphic mesomorph (V2 and V5) and two as endomorphic mesomorph (V6 and V7). Among the females, endomorphism and mesomorphism were greater in V7; and ectomorphism lower in V6 V7. Endomorphic mesomorph occurred in five categories (V1, V4 V7) and balanced mesomorph in two (V2 and V3). The somatocharts (Figure 1) represent the mean somatotype and the somatotype for each weight category in both samples.

Table 3 shows the estimated TMW if the judokas had the theoretical minimum body fat percentage and maintained their current lean weight; and the difference in this value with its real weight, in absolute terms (kg) and as a percentage.

The correlation between the bodyweight and the rest of the direct variables was significant with $p<0.0001$, except for pectoral skinfold (0.05) and biceps (0.01) in the women. The greatest correlation in lengths was height (R♂= 0.840 and R♀= 0.847). In bone breadths, biepicondylar femur (R♂= 0.800 and R♀= 0.826). In girths, hip girth (R♂= 0.913 and R♀= 0.910). Lastly, in skinfolds, the coefficients are lower with the largest among males being abdominal (R♂= 0.590) and triceps among women (R♀= 0.470).

If we estimate bodyweight by simple regression exclusively on the basis of height (in cm), weight (kg) is found to be equal to:

Males: (height*1.230) - 141.250 (R^2=0.706, SEE=6.2 kg).

Females: (height*1.004) - 104.187 (R^2=0.718, SEE=4.8 kg).

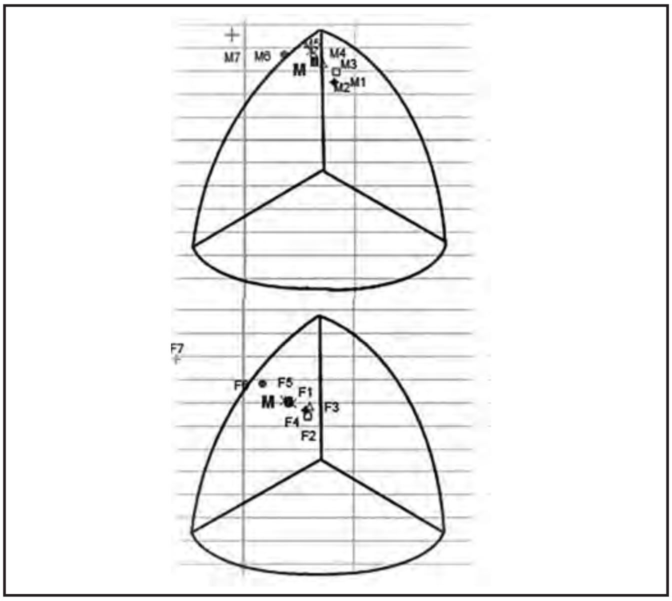
Tables 4 and 5 show the different multiple linear regression models, first independently with each type of variable (lengths, breadths, girths) and then combining them by selecting those with the lowest estimation

Table 1. Body composition and somatotype in the total male sample and by weight categories (m±SD).

	Total n =187	-60 kg n= 28	-66 kg n = 33	-73 kg n = 42	-81 kg n =32	-90 kg n =25	-100 kg n =14	+100 kg n =13
Weight (kg)	78.9±15.7	60.9±1.2	66.9±1.2	73.5±1.9	80.6±1.9	90.1±2	98.4±3	118.7±8.4
Height (cm)	177.6±8.6	166.5±4.2	172.5±5.6	175.2±3.5	178.8±3.6	185.4±3.6	188.7±4.6	191.9±4.3
Profile Skinfolds (mm)								
Chest	5.2±2.2	4.2±0.7	4.1±0.7	4.7±0.9	4.8±0.9	5.4±1.4	6.3±1.4	10.6±4.4
Iliac crest	10.3±6.1	7.4±2.2	7.1±1.9	8.7±2.4	9.3±2.8	10.6±3.1	15.4±5.9	26.5±8.9
Supraspinale	7.8±4.4	5.8±1.2	5.6±1.0	6.4±1	7±1.6	7.9±2.5	11.1±4	20±7.3
Abdominal	10.6±7.2	6.9±2.0	6.8±1.9	8.2±2.6	9.3±2.9	11.4±5.1	16.9±6.6	30.9±7.3
Subscapular	9.9±3.9	8.2±1.6	7.8±1.7	8.6±1.5	9.3±1.2	10.1±2.2	13.6±3.1	20±6.1
Biceps	3.7±1.3	3.2±0.5	3.1±0.4	3.4±0.5	3.6±0.4	3.9±0.6	3.8±0.5	7.2±2.8
Triceps	7.8±3.5	6.3±1.4	6.1±1.4	7±1.6	7.5±2	7.6±1.5	10.6±3.1	16.2±6.2
Front thigh	10.3±4.6	8.1±1.8	8.2±1.9	9.1±2.5	9.5±2.3	11.2±3	13.4±3.6	21.7±8.1
Medial calf	7.1±4.1	5.6±1.2	5.6±1.5	5.8±1.3	6.5±1.8	6.8±2.1	9.2±4	17.4±8.7
∑ 8 Skinfolds (mm)	67.5±32.3	51.6±9.8	50.3±9.2	57.2±10	61.9±12.2	69.7±16.8	93.8±22.3	160±44.5
% fat by E. Lohman	10.9±4.1	8.9±1.3	8.6±1.3	9.6±1.5	10.3±1.7	11.2±2.4	14.8±3.2	22.5±4.7
Minimum weight from the Lohman (kg)	75±11.6	59.6±1.4	65.7±1.5	71.4±2.1	77.8±2.4	86±2.8	90.2±4.4	98.7±6.1
% fat by E. Withers	10.1±4.7	7.9±1.3	7.7±1.3	8.6±1.4	9.3±1.8	10.4±2.4	13.8±3.1	23.6±7
Fat weight by E. Withers (kg)	8.6±6.6	4.8±0.8	5.1±0.9	6.3±1.1	7.5±1.4	9.4±2.2	13.5±3.1	28.3±10
Lean weight by E. Withers (kg)	70.3±10.7	56.1±1.3	61.7±1.3	67.2±1.9	73.1±2.3	80.8±2.6	84.9±4	90.4±7.4
Muscle mass. % by E. Lee	46.6±3.3	49.6±2.0	48.4±2.1	47.5±2	46.5±1.9	45.3±1.7	43.3±2.4	39.8±4.4
Muscle mass. kg/m^2 by E. Lee	11.5±1.0	10.9±0.7	10.9±0.9	11.4±0.8	11.7±0.6	11.9±0.7	12±0.9	12.8±1.6
Cross-sectional areas (cm^2)								
CSA Arm	67.8±13.5	53.1±5.5	57.2±6.6	65.3±7	71.1±7.7	78.7±6.1	81.2±10	90.9±15.2
CSA Thigh	205.1±33.4	171.2±15.0	182.6±16.7	196.2±16.7	209.8±14	225.8±19.4	238.6±23.4	276.4±33
CSA Calf	103.7±16.0	86.7±8.3	93.6±8.2	99±8	108.1±8.1	114.6±8	119±10.7	132.6±21.8
Somatotype								
Endomorphy	2.4±1.0	2±0.5	1.8±0.5	2.1±0.4	2.2±0.5	2.3±0.6	3.2±0.8	4.9±1.3
Mesomorphy	6.4±1.0	5.7±0.7	5.9±1.0	6.2±0.9	6.6±0.7	6.7±0.7	6.8±0.9	8±1.2
Ectomorrphy	1.9±0.9	2.4±0.7	2.5±1.0	2±0.6	1.7±0.5	1.7±0.6	1.4±0.6	0.5±0.4

Significant between-group differences, $p < 0.0001$.

Figure 1. Somatochart. M, sample mean. Distribution from seven weight categories: M1-M7 males and F1-F7 females.



error. In the male sample, height and 4 breadths (A-P chest, biiliocristal, femur and bimalleolar) explain 86.8% of the variation in weight and 98.3% when girths are added, with an SEE of 4.2 and 1.5 kg respectively.

In the female sample, height and 3 breadths (A-P chest, biacromial and femur) explain 87.3% and 97.9% when girths are added, with an SEE of 3.3 and 1.3 kg respectively.

Discussion

The study has been conducted on a wide sample of male and female judokas representing the different weight categories, all members of high-level Spanish teams and while they were at competition weight. The sample included finalists from the Olympic Games, World and European Championships[21]. The anthropometric profile for the valuation of judokas by genders and weight categories is provided as a reference. There is sexual dimorphism and intra-category dimorphism in the anthropometric characteristics of judokas as has been mentioned by other authors. Furthermore, these differences are reflected both in the competition and in judo fitness tests[22-26].

As judo is a sport in which competitors are divided by weight categories, it is necessary to identify the most appropriate weight for each participant. In practice, the tendency is to choose the lowest possible bodyweight in order to maximize the advantages potentially provided by a greater physique and muscle mass. In judo, methods for fast weight loss are extremely prevalent[27-30] and may affect both health and performance[31-34]. In order to determine the athletes' weight category, use is often made of the theoretical minimal weight (TMW)

Table 2. Body composition and somatotype in the total female sample and by weight categories (m±SD).

	Total n =131	-48 kg n= 24	-52 kg n = 19	-57 kg n = 18	-63 kg n =30	-70 kg n =23	-78 kg n =8	+78 kg n =9
Weight (kg)	62.4±12.1	48.8±1.1	52.8±0.9	57.2±1.2	63±1.6	70.5±1	78.4±1.8	92.6±5.5
Height (cm)	164.3±7.7	154.1±3.4	158.6±4.3	162.9±3.6	166.3±3	171.7±5	173.8±5.1	172.5±3.4
Profile Skinfolds (mm)								
Chest	5.8±2.4	4.8±1.1	5±1.7	5.3±1.5	5.5±1.4	5.6±1.4	6±1	12.2±3.2
Iliac crest	12.2±6.0	9.2±2.6	9.3±3.4	9.4±3.2	12.3±3.6	12.5±4.4	14.9±4.6	28.3±5.4
Supraspinale	9.3±5.0	7.1±1.7	7.1±2.2	7.3±2.2	8.5±3	9.6±3.5	11.1±3.1	23.7±5.7
Abdominal	13.5±7.4	9.7±3.4	10.3±3.8	10.7±4.4	12.6±4.7	15.2±7.3	16.7±6.9	31±7.2
Subscapular	11.1±5.5	9.2±3.1	8.7±2	8.5±1.4	10.7±2.2	11.1±3.1	12.8±3.7	27.2±7.6
Biceps	5.0±2.2	4.2±1.3	4.5±1.3	4.4±1	4.9±1.2	4.4±1	6.2±2.7	10.2±4
Triceps	13.7±5.6	10.8±3.2	11.2±3.7	11.2±2.5	13.4±2.7	14.4±4	16.6±5.3	28.1±6.2
Front thigh	20.7±7.6	16.4±5.6	18.2±5.3	17.4±4	20.6±4.3	22.7±5.9	23±7.3	38±9.4
Medial calf	12.7±5.8	9.7±3.4	10.5±3.7	10.1±2.5	12.1±2.8	13.6±4.4	16.1±5.7	26.7±8.1
∑ 8 Skinfolds (mm)	98.2±39.9	76.2±17.7	79.8±22.4	79±14	95.2±15.8	103.4±22.8	117.3±33	213.3±40.6
% fat by E. Slaughter	21.8±6.6	18.6±3.5	18.5±4	18.5±2.7	21.8±2.8	22.5±4.3	25±5.3	39.9±7.1
Minimum weight from the Slaughter (kg)	56.1±7.5	46.2±2	50±2.4	54.2±2.2	57.3±2.3	63.5±3.5	68.3±3.8	64.5±6.1
% fat by E. Withers	18.7±4.8	15.9±3	16.1±3.6	16.2±2.3	18.8±2.2	19.7±3.6	21.8±4.3	31±3.2
Fat weight by E. Withers (kg)	12.1±5.7	7.8±1.5	8.5±2	9.2±1.3	11.9±1.5	13.9±2.6	17.1±3.6	28.8±4.4
Lean weight by E. Withers (kg)	50.3±7.3	41.1±1.6	44.3±1.8	47.9±1.7	51.2±1.8	56.6±2.6	61.3±2.4	63.8±2.9
Muscle mass % by E. Lee	40.9±3.6	44±2.4	41.8±2.9	42.8±1.9	41.1±1.9	39.2±2.5	37.9±2.5	33±2.4
Muscle mass kg/m² by E. Lee	9.3±0.7	9.1±0.7	8.8±0.5	9.2±0.6	9.4±0.8	9.4±0.7	9.8±0.4	10.3±0.7
Cross-sectional areas (cm²)								
CSA Arm	46.4±9.1	38.5±4.3	38.9±6	45.1±5.7	47.5±7.8	51.4±7	58.3±5.9	58.6±7.3
CSA Thigh	156.5±25.1	135.2±13.9	136.1±10.8	152.0±14.1	158.6±17.1	163.4±14.5	193.1±9.1	208.3±19.7
CSA Calf	81.7±12.3	70.4±7.7	70.6±7.4	79.2±7.9	85.4±7.2	90.0±10.2	91.3±9.7	97.6±11.8
Somatotype[18]								
Endomorphy	3.5±1.3	3.0±0.7	2.9±0.9	2.9±0.6	3.4±0.7	3.5±0.9	4.0±1.1	7.0±1.2
Mesomorphy	5.2±1.1	4.8±0.7	4.5±0.7	4.9±0.9	5.2±0.8	5.2±0.9	5.8±1.1	7.8±1.2
Ectomorrphy	2.0±0.9	2.3±0.6	2.4±0.8	2.4±0.7	2.0±0.6	1.9±0.8	1.3±0.9	0.3±0.3

Significant between-group differences, $p < 0.0001$.

Table 3.Theoretical minimal weight (mean±SD).

Weight categories	n	TMW kg	Difference BW – TMW kg (%)	range (kg)
M 1 - 60 kg	28	59.6±1.4	1.2±0.9 (2)	-0.3 ; 3.4
M 2 - 66 kg	33	65.7±1.5	1.2±1.0 (1.8)	0.0 ; 3.7
M 3 - 73 kg	42	71.4±2.1	2.0±1.2 (2.8)	0.3 ; 6.2
M 4 - 81 kg	32	77.8±2.4	2.8±1.4 (3.5)	0.8 ; 5.9
M 5 - 90 kg	25	86.0±2.8	4.1±2.4 (4.5)	0.7 ; 8.9
M 6 -100 kg	14	90.2±4.4	8.3±3.4 (8.3)	2.8 ; 13.7
F 1 - 48 kg	24	46.2±2.0	2.6±2.0 (5.4)	-0.6 ; 6.6
F 2 - 52 kg	19	50.0±2.4	2.8±2.4 (5.3)	-1.0 ; 8.4
F 3 - 57 kg	18	54.2±2.2	3.0±1.8 (5.3)	0.1 ; 6.1
F 4 - 63 kg	30	57.3±2.3	5.7±2.1 (9.1)	1.1 ; 9.5
F 5 - 70 kg	23	63.5±3.5	7.0±3.5 (10.0)	-0.6 ; 12.1
F 6 - 78 kg	8	68.3±3.8	10.1±5.0 (12.9)	0.6 ; 17.1

M: males; F: females; TMW: theoretical minimal weight; BW: body weight.
The estimate of minimal weight through percent fat. In males, the modified Lohman equation (7%); and in females, the Slaughter equation (14%).

defined as the bodyweight at which the fat percentage is as close to the minimum possible without harmful effect on health[35]. This is calculated by performing a body composition study in which the fat-free component is assumed to remain stable compared to a fatty component that will be reduced to the minimum required. However, TMW is rarely achieved with the percentage of fat with which it was estimated as only some athletes in fact come down to those body fat ranges (5-7% in males; 12-14% in females)[19] therefore, after that weight is achieved, if we were to determine the body composition, we would verify that the lean component has also been diminished. In our sample, only one male (0.6%) obtained values of less than 7% of fat and only six women (4.9%) less than 14%. The most frequent percentage falls between 7 and 11% of fat among males and between 18 and 22% in females. For this reason, it is common in judo to be above the TMW, with this difference increasing as athletes move up through weight categories, and larger among the female sample.

Another way to determine weight was proposed by Tcheng and Tipton[36] in 1973 and was subsequently modified by Oppliger and Tipton[37]. These authors developed anthropometric equations to estimate TMW in wrestlers, relating their weight to height along with bone breadths ($R^2 = 0.852$, SD = 4.04 kg) or adding thigh girth ($R^2 = 0.953$, SEE = 2.36 kg). For our study on judokas, we have included additional anthropometric variables (forty-one compared to the fifteen of the previous authors), and have obtained lower estimation errors.

Bone structure as determined by height, lengths and bone breadths in both the trunk and the limbs after growth has finished in an adult athlete conforms the frame size and this does not change through training, therefore estimation equations based on this will give us an initial approach about judokas' competition weight, explaining around 87% of its variability. In men, the estimated weight is more related to the width of the pelvis and in women with the width of the shoulders. And in both genders with the depth of the thorax and the width of the knee.

The equations developed with inclusion of girths are the ones that determine the bodyweight of judokas with fewest errors. There is some discussion as to whether the girth is a measure that includes subcutaneous fat and this might be overvalued in the case of athletes with a greater adipose panicles, which might be lost in order to reduce weight.

Table 4. Multiple stepwise regressions to estimate body weight. Males.

Variables	Weight	R^2	SEE
L	-141.915 + (Tibial height 1.416) + (Sitting height 0.987) + (Foot length 2.268)	0.764	5.6
B	-130.229 + (A-p chest depth 1.846) + (Bimalleolar 5.736) + (Biiliocristal 1.444) + (Humerus 4.094) + (Biacromial 0.730) + (Femur 2.611)	0.844	4.6
G	-149.672 + (Hip 0.665) + (Chest 0.177) + (Calf 0.767) + (Wrist 1.281) + (Head 0.495) + (Waist 0.283) + (Shoulders 0.219) + (Armflexed and tensed 0.454)	0.949	2.6
H,B	-145.285 + (Height 0.512) + (A-P Chest 1.862) + (Biiliocristal 1.160) + (Bimalleolar 4.515) + (Femur 2.661)	0.868	4.2
H,G	-164.304 + (Height 0.493) + (Waist 0.345) + (Mild-Thigh 0.400) + (Forearm 0.787) + (Hip 0.213) + (Chest 0.180) + (thigh 0.264) + (Calf 0.276) + (Head 0.298)	0.983	1.5
H,B,G	-164.610 + (Height 0.479) + (G. waist 0.340) + (G. thigh 0.335) + (G. Forearm 0.748) + (G. Mid-thigh 0.370) + (G. Chest 0.177) + (G. Hip 0.149) + (G. Calf 0.287) + (G. Head 0.308) + (B. Bitrochanteric 0.223)	0.983	1.5

L: length; B: breadth; G: Girth; H: Height; R^2: coefficient of determination; SEE: standard error of estimate; $p<0.0001$.

Table 5. Multiple stepwise regressions to estimate body weight. Females.

Variables	Weight	R^2	SEE
L	-118.030 + (Height 0.156) + (Sitting height 0.796) + (Arm spam 0.306) + (Foot length 1.382)	0.764	4.5
B	-110.85 + (Femur 5.509) + (A-P chest depth 1.372) + (Biacromial 0.948) + (Bimalleolar 5.699) + (Biiliocristal 0.901)	0.856	3.5
G	-121.536 + (Hip 0.304) + (Calf 0.759) + (Shoulders 0.312) + (Waist 0.226) + (Wrist 1.603) + (Thigh 0.397) + (Head 0.567)	0.948	2.1
H,B	-116.688 + (Height 0.456) + (Femur 5.565) + (A-P chest 1.424) + (Biacromial 0.694)	0.873	3.3
H,G	-118.433 + (Height 0.455) + (Waist 0.448) + (Mild-Thigh 0.591) + (Hip 0.248) + (Forearm 0.785)	0.977	1.4
H,B,G	-118.313 + (Height 0.447) + (G. Mid-thigh 0.597) + (G. waist 0.398) + (G. Hip 0.219) + (G. Forearm 0.817) + (B. A-P chest 0.352) +	0.979	1.3

L: length; B: breadth; G: Girth; H: Height; R^2: coefficient of determination; SEE: standard error of estimate; $p<0.0001$.

However, when in good physical condition, the value of the skinfold in comparison to the total value of the girth is proportionally small. The problem lies in athletes who are still growing or those who have not yet achieved suitable muscle development and therefore their estimated weight would be undervalued with respect to what they would obtain after full development of their muscular and skeletal system.

After reviewing the percentiles of our general population[38], we have confirmed that the weights established in the respective categories 1 to 7 by the official organizations correspond to percentiles 10, 25, 50, 75-80, 90, 98 and > 98 in both samples. While the mean of the heights by categories would be in a somewhat lower range: percentiles 3 (V1), 20 (V2), 25-50 (V3), 50 (V4), 85 (V5), 90-97 (V6) and 98 (V7) in males and percentiles 3 (M1), 15-20 (M2), 25-50 (M3), 50-75 (M4), 85 (M5) and 90 (M6, M7 and M8) in females. Moreover, the weights in the different categories coincide with the independent subsets that can be established, while the heights in some of the categories overlap or, to put it another way, a judoka with a particular height may belong to one or another adjacent category, except those in V1 and M1.

The female sample presents a greater adipose panicle and greater variability, their higher weight categories are fundamentally due to having a larger fatty component, whereas the lean component increases in all categories for males. In both samples, the lean component is what classifies a sample into as many groups as there are weight categories established, confirming that this component is the determining factor, although the increase in lean weight is more marked in males than in females as we move up through the weight categories since, as mentioned above, the fatty component also increases markedly in female judokas in higher categories. The categories are also more clearly defined for males with regard to muscle mass compared to height than in females, where there is more overlap.

If general rules are adopted internationally and strictly enforced, then, on the one hand, there would be an end to techniques that are dangerous for health and, on the other hand, competition would be fairer. The safest method, as Artioli[20] proposes, would be to determine urine density by refractometer on the day of the competition together with the official weigh-in, thus confirming that the judokas is normohydrated at competition weight.

Conclusion

There is sexual dimorphism and intra-category dimorphism in the anthropometric characteristics of judokas. The anthropometric profile for the valuation of judokas by genders and weight categories is provided as a reference for the individualized assessment of athletes.

In competition, judokas do not come down to the minimum fat percentages and that their bodyweight estimated in this way will be undervalued, obliging them to lower it at the expense of the lean component. The regression equations proposed may be useful as tools for athletes to adapt to the most suitable weight category according to their anthropometric characteristics.

Acknowledgments

The author would like to thank the judokas who came for a sports medical follow-up and took part in this study and the staff of the Anthropometric Department for their help in everyday work.

Conflict of interest

The authors do not declare a conflict of interest.

References

1. Loenneke JP, Wilson JM, Barnes JT, Pujol TJ. Validity of the current NCAA minimum weight protocol: a brief review. *Ann Nutr Metab.* 2011;58:245–9.
2. Callister R, Callister RJ, Staron RS, Fleck SJ, Tesch P, Dudley GA. Physiological characteristics of elite judo athletes. *Int J Sport Med.* 1991;12:196–203.
3. Franchini E, Del Vecchio FB, Matsushigue KA, Artioli GG. Physiological profiles of elite judo athletes. *Sports Med.* 2011;41(2):147-66.
4. Franchini E, Sterkowicz-Przybycien K, Takito MY. Anthropometrical profile of judo athletes: comparative analysis between weight categories. *Int J Morphol.* 2014;32(1):36-42.
5. Amtmann J, Cotton A. Strength and Conditioning for Judo. *Strength Cond J.* 2005; 27(2):26–31.
6. Julio UF, Panissa VLG, Esteves JVDC, Cury RL, Agostinho MF, Franchini E. Energy System Contributions to Simulated Judo Matches. *Int J Sports Physiol Perform*. 2017;(5):676-83.
7. Sterkowicz-Przybycien K, Fukuda DH. Sex differences and the effects of modified combat regulations on endurance capacity in judo athletes: A meta-analytic approach. *J Hum Kinet.* 2016;51:113-20.
8. Azoury J. A descriptive study of Australian elite Judo players. *J Sci Med Sport.* 2002;5(4):36.
9. Ghrairi M, Hammouda O, Malliaropoulos N. Muscular strength profile in Tunisian male national judo team. 2014;4(2):149-53.
10. International Judo Federation (Sport Commission). Sport and Organization Rules of the International Judo Federation 2018. [Cited 2018 July 10]. Available from: https://www.ijf.org/ijf/documents/.
11. Artioli GG, Franchini E, Nicastro H, Sterkowicz S, Solis MY, Lancha AH Jr. The need of a weight management control program in judo: a proposal based on the successful case of wrestling. *J Int Soc Sports Nutr.* 2010;7:15.
12. Norton K, Whittingham N, Carter L, Kerr D, Gore C, Marfell-Jones M. Measurement Techniques in Anthropometry. In Norton K, Olds T. *Anthropometrica: a textbook of body measurement for sports and health courses*. Sydney, University of New South Wales Press; 1996. p. 25-75.
13. Lohman TG, Roche AF, Martorell R. *Anthropometric Standardization Reference Manual.* Champaign, IL: Human Kinetics Books; 1988. p. 42-43.
14. Lee RC, Wang Z, Heo M, Ross R, Janssen I, Heymsfield SB. Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models. *Am J Clin Nutr.* 2000;72(3):796-803.
15. Thorland WG, Tipton CM, Lohman TG, Bowers RW, Housh TJ, Johnson GO, et al. Midwest wrestling study: prediction of minimal weight for high school wrestlers. *Med Sci Sports Exerc.* 1991;23(9):1102-10.
16. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan MD, *et al.* Skinfold equations for estimation of body fatness in children and youth. *Hum Biol.* 1988;60(5):709-23.
17. Norton K. Anthropometric Estimation of Body Fat. In: In Norton K, Olds T. *Anthropometrica: a textbook of body measurement for sports and health courses.* Sydney, University of New South Wales Press; 1996. p. 172-198.
18. Heymsfield SB, McManus C, Smith J, Stevens V, Nixon DW. Anthropometric measurement of muscle mass: revised equations for calculating bone-free arm muscle area. *Am J Clin Nutr.* 1982;36(4):680-90.
19. Oppliger RA, Case HS, Horswill CA, Landry GL, Shelter AC. American College of Sports Medicine position stand. Weight loss in wrestlers. *Med Sci Sports Exerc.* 1996;28(10):135-8.
20. Carter JEL, Heath BH. *Somatotyping - Development and Applications*. Cambridge, Cambridge University Press; 1990. p. 374-5.
21. Gutiérrez C, Santos L, Montero-Carretero C, Escobar-Molina, R. Éxitos del judo español a nivel internacional: una perspectiva histórica. *Revista de Artes Marciales Asiáticas.* 2018;13(2s):3-8.
22. Casals C, Huertas JR, Franchini E, Sterkowicz-Przybycien K, Sterkowicz, S, Gutierrez-Garcıa C, *et al*. Special judo fitness test level and anthropometric profile of elite spanish judo athletes. *J Strength Cond Res.* 2017;31(5):1229-35.
23. Torres-Luque G, Hernández-García R, Escobar-Molina R, Garatachea N, Nikolaidis PT. Physical and Physiological Characteristics of Judo Athletes: An Update. *Sports (Basel).* 2016; 4:20.
24. Ceylan B, Gurses VV, Akgul MS, Baydi B, Franchini, E. Anthropometric Profile, Wingate Performance and Special Judo Fitness Levels of Turkish Olympic Judo Athletes. *J Martial Arts Anthrop*. 2018;18(3):15-20.

25. Martins FP, Pinto de Souza LSC, de Campos RP, Bromley SJ, Takito MY, Franchini E. Techniques utilised at 2017 Judo World Championship and their classification: comparisons between sexes, weight categories, winners and non-winners. *J Martial Arts Anthrop.* 2019;19(1): 58-65

26. Franchini E, de Moura C FD, Shiroma SA, Humberstone C, Julio UF. Pacing in judo: analysis of international-level competitions with different durations. *Int J Perform Anal Sport.* 2019;1–10.

27. Artioli GG, Gualano B, Franchini E, Scagliusi FB, Takesian M, Fuchs M, *et al.* Prevalence, magnitude, and methods of rapid weight loss among judo competitors. *Med Sci Sports Exerc*. 2010;42(3):436-42.

28. Malliaropoulos N, Rachid S, Korakakis V, Fraser SA, Bikos G, Maffulli N, *et al*. Prevalence, techniques and knowledge of rapid weight loss amongst adult british judo athletes: a questionnaire based study. *Muscles Ligaments Tendons J.* 2017;7(3):459–66.

29. Mazzoccante RP, Sousa IC, Mendes LCV, Mendes MCV, Asano RY. Comparação da prevalência de métodos de perda de peso pré-competição em judocas de diferentes categorias. *Rev Bras Ciênc Esporte.* 2016;38(3):297-302.

30. Reale R, Slater G, Burke LM. Weight Management Practices of Australian Olympic Combat Sport Athletes. *Int J Sports Physiol Perform*. 2018;13(4):459-66.

31. Koral J, Dosseville F. Combination of gradual and rapid weight loss: Effects on physical performance and psychological state of elite judo athletes. *J Sports Sci.* 2009;27(2):115-20.

32. Franchini E, Brito CJ, Artioli GG. Weight loss in combat sports: physiological, psychological and performance effects. *J Int Soc Sports Nutr.* 2012;9:52.

33. Fortes LS, Costa BDV, Paes PP, Cyrino ES, Vianna JM, Franchini E. Effect of rapid weight loss on physical performance in judo athletes: is rapid weight loss a help for judokas with weight problems? *Int J Perform Anal Sport*. 2017;17(5):763-73.

34. Morales J, Ubasart C, Solana-Tramunt M, Villarrasa-Sapiña I, González LM, Fukuda D, *et al.* Effects of Rapid Weight Loss on Balance and Reaction Time in Elite Judo Athletes *Int J Sports Physiol Perform.* 2018;13(10):1371-7.

35. Lohman TG. Advances in Body Composition Assessment. Champaign, IL: Human Kinetics Publishers;1992. p.109-118.

36. Tcheng TK, Tipton CM. Iowa Wrestling Study: anthropometric measurements and the prediction of a "minimal" body weight for high school wrestlers. *Med Sci Sports.* 1973;5(1):1-10.

37. Oppliger RA, Tipton CM. Iowa wrestling study: cross-validation of the Tcheng-Tipton minimal weight prediction formulas for high school wrestlers. *Med Sci Sports Exerc.* 1988;20(3):310-6.

38. Carrascosa A, Fernández JM, Fernández C, Ferrández A, López-Siguero JP, Sánchez E, et al. Estudio transversal español de crecimiento 2008. Parte II: valores de talla, peso e índice de masa corporal desde el nacimiento a la talla adulta. *An Pediatr.* 2008; 68(6):552-69.

Effect of caffeine as an ergogenic aid to prevent muscle fatigue

Elena Barceló Cormano[1], Raquel Blasco Redondo[2], Mar Blanco Rogel[1], Anna Bach-Faig[3]

[1]Universitat Oberta de Catalunya. Barcelona. [2]Unidad de Medicina Interna y Nutrición del Centro Regional de Medicina Deportiva de la Junta de Castilla y León. Departamento de Nutrición y Bromoterapia. Facultad de Medicina. Universidad de Valladolid. [3]Grupo de Investigación FoodLab. Universitat Oberta de Catalunya. Barcelona.

Received: 12.04.2019
Accepted: 09.09.2019

Summary

Caffeine, one of the most widely used psychoactive substances worldwide, has been linked to the delay in the appearance of neuromuscular fatigue and the reduction in the effort perception during physical activity. As a result of a progressive increase in the consumption of food supplements to improve the sports performance, we decided to review the ergogenic effect of caffeine on muscle fatigue at central and peripheral levels. A bibliographic search was conducted between january 2008 and may 2018, identifying studies published in electronic databases (PubMed, SciELO, Dialnet) and documents from national and international organizations (EFSA, AECOSAN, SEMED/FEMEDE, AIS, EUFIC, WADA) about caffeine and its effect on muscle fatigue. The mechanism of action of caffeine in strength and endurance sports is analyzed, as well as the optimal dosage, routes of administration and posology guidelines. We also review other aspects such as toxicity, doping and the current legislation that regulates the labeling of food supplements containing caffeine.

Key words:
Caffeine. Ergogenic effect. Muscle fatigue. Muscle strength. Performance-enhancing effect.

Efecto de la cafeína como ayuda ergogénica para evitar y prevenir la fatiga muscular

Resumen

La cafeína, una de las sustancias psicoactivas de mayor consumo a nivel mundial, se ha relacionado con el retraso en la aparición de la fatiga muscular y la disminución en la percepción del esfuerzo durante la actividad física. Debido al aumento progresivo en el consumo de complementos alimenticios para mejorar el rendimiento deportivo, decidimos realizar esta revisión con el objetivo de sintetizar la evidencia disponible sobre el efecto de la cafeína como ayuda ergogénica en la fatiga central y periférica, examinando los mecanismos de acción y especificando las dosis y la forma de administración idóneas para obtener el efecto ergogénico deseado. Para ello se realizó una búsqueda bibliográfica entre enero de 2008 y mayo de 2018, identificando estudios publicados en bases de datos electrónicas (PubMed, SciELO, Dialnet) y documentos de organismos nacionales e internacionales (EFSA, AECOSAN, SEMED/FEMEDE, AIS, EUFIC, WADA) sobre la cafeína y su efecto sobre la fatiga muscular. Se analiza el mecanismo de acción de la cafeína en deportes de fuerza y resistencia, así como las dosis, vías y pautas de administración óptimas. Se revisan además otros aspectos como la toxicidad, el dopaje y la normativa actual que regula el etiquetado de los complementos alimenticios que contienen cafeína.

Palabras clave:
Cafeína. Efecto ergogénico. Fatiga muscular. Fuerza muscular. Mejora del rendimiento.

Correspondence: Elena Barceló Cormano
E-mail: elenabarceloc@gmail.com

Introduction

Physical activity is an essential strategy to maintain a healthy lifestyle, and it is also recommended for the prevention and treatment of numerous pathologies.

The importance of nutrition on physical performance has long been recognised, not only at competition level but also among those who engage in leisure sports and weight training activities. In order to achieve sporting success, training must be accompanied by the best and most suitable diet for each sports activity. However, given that muscle fatigue is one of the most important causes of the appearance of sports injuries, studies have found a progressive increase in the consumption of ergogenic aids by athletes at different levels and disciplines[1,2] for the purpose of minimising central and peripheral fatigue alike[3,4].

The "Australian Institute of Sport", based on scientific evidence and on criteria considering the safety, legality and effectiveness of sports performance, classifies caffeine (together with ß-alanine, sodium bicarbonate, creatine, beetroot juice and glycerol) within the group: *Ergogenic Aid Supplements / Ingredients with evidence level A*[5].

In chemical terms, caffeine (1,3,7-trimethylxanthine) is an alkaloid of the group of xanthenes, which are substances derived from the purines that are naturally found in tea plants, coffee, mate, cacao, chocolate, guarana and cola nut. Together with the theobromine from the cacao plant and theophylline from black and green tea, caffeine is one of the most consumed psychoactive substances in the world[6]. Products are also available (energy drinks, gels, chewing gums, some medicines) that offer additional concentrations of caffeine to increase physical or psychological performance, also producing effects on other physiological functions such as emotional state, mood, sleep or pain[4].

The capacity of caffeine to improve muscle work has been widely studied over the years, with investigations even dating back to the early 20th century. However the use of caffeine by athletes as an ergogenic aid did not become apparent until the 1970s -1980s[4]. Given that this is an almost ubiquitous substance in the normal human diet, the study of its effect on the human body is of great interest. In this regard, one of the aspects that has generated the most curiosity is its influence on the appearance of fatigue when engaged in sports activities.

This review aims to summarise the evidence available on the effect of caffeine as an ergogenic aid for central and peripheral fatigue, by examining the action mechanisms and specifying the ideal doses and route of administration in order to obtain the desired ergogenic effect.

Methodology

A literature search was conducted on the ergogenic effect of caffeine on muscle fatigue, by consulting electronic databases (PubMed, SciELO, Dialnet), basically selecting systematic reviews, meta-analyses and specific articles by experts, published between January 2008 and May 2018 and following the "snowball" strategy in order to obtain as much information as possible. A review was also made of documents from national and international organisations: EFSA, AECOSAN, SEMED/FEMEDE, AIS, EUFIC, WADA (Table 1).

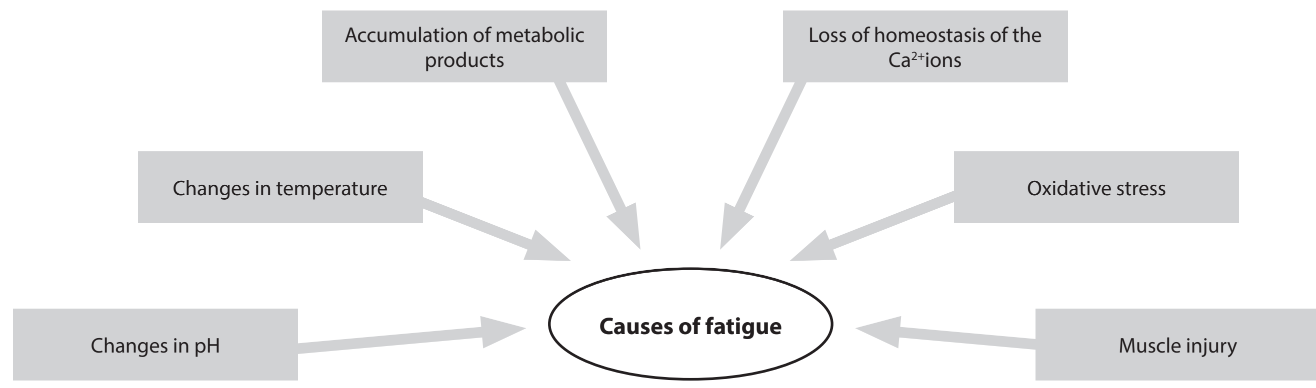
Considerations on muscle fatigue

Muscle fatigue, a phenomenon that generally limits sporting activity and the performance of prolonged, strenuous exercise, is defined as a reduction in the maximal strength or power in response to contractile

Table 1. Inclusion / exclusion criteria, key words, databases consulted.

Inclusion criteria	**Exclusion criteria**
- Relevant information on the ergogenic effect of caffeine and muscle fatigue. - Consensus documents based on scientific evidence - Languages: Spanish, English and French. - Articles with access to the full text - Publication period: January 2008 - May 2018 - Study design: original articles, literature reviews, systematic reviews and meta-analyses.	- Articles not related to the purpose of the study. - Studies not conducted on humans - Articles with no scientific relevance
Keywords	
- caffeine - ergogenic effect - muscle fatigue - muscle strength - performance-enhancing effect	
Electronic databases	**National and international scientific organisations and societies:**
- PubMed - Scielo - Dialnet	- EFSA: European Food Safety Authority - AECOSAN: Spanish Agency for Nutrition and Food Safety - SEMED/FEMEDE: Spanish Society of Sports Medicine - AIS: Australian Institute of Sport - EUFIC: European Food Information Council - WADA: World Anti-Doping Agency

Figure 1. Suggested causes of fatigue



Source: Gómez-Campos, *et al.* 2010[10].

activity. Despite the fact that the causes of exercise-related fatigue are complex, it is generally accepted that fatigue depends on a person's level of training and nutritional condition, on the type of muscle fibres, as well as the intensity, duration and type of exercise performed. It should be underscored that muscle fatigue is different from muscle injury, since the former is reversible after a few hours' rest, while complete recovery following an injury may take days or weeks[7].

Alterations at different motor levels may contribute to the appearance of muscle fatigue, allowing us to classify fatigue into *central* when it results from alterations in the central nervous system (CNS), at the brain stem or spinal cord, decreasing the output of nervous impulses to the muscles, and *peripheral*, when it is caused by the dysfunction of the peripheral nervous system (PNS) or by a musculoskeletal pathology, due to changes at the neuromuscular junction or else at the nerve endings[7-9].

The hypothesis on the origin of *central fatigue* is based on the exercise-induced changes in the concentration of neurotransmitters within the CNS (serotonin, dopamine, noradrenaline) which produce stimuli at the spinal cord motor neuron level, finally activating the motor units to generate power. The slowing down or termination of this activation, contributes to the loss of strength inherent in fatigue[7,9]. Other factors that may influence the genesis of central fatigue are the brain levels of glycogen and ammonium. Hyperthermia, which is frequently associated with exercise, may also reduce the activity of the CNS[9].

On the other hand, *peripheral fatigue* is considered to result from homoeostasis alterations in the skeletal muscle, due to a limitation of one or more processes in the motor unit[10].

The production of skeletal muscle strength depends on contractile mechanisms and some of the changes at a neural, mechanical or energy level that could cause fatigue are as follows[7]:

The accumulation of intracellular metabolites (hydrogen ions, lactate, inorganic phosphate, reactive oxygen species) that modify the muscle contractile activity through interference in the release of calcium from the sarcoplasmic reticulum, reduction in muscle fiber calcium sensitivity and direct motor neuron inhibition. However, the appearance of muscle fatigue attributed to a decrease in pH due to the accumulation of hydrogen ions is currently being questioned, given that, at physiological temperatures, it does not appear to be a limiting mechanism[7,11].

Reduction in the blood supply and, therefore, in the oxygen supply to the active muscle groups during voluntary muscle contraction due to an increase in the mean blood pressure[7].

Imbalance between the consumption and production of adenosine triphosphate (ATP) at a muscle level due to a decrease in glycogen reserves during exercise[9]. The mechanism by which glycogen depletion in the muscle leads to muscle fatigue is still under study[7].

Effect of caffeine

Caffeine exerts its ergogenic effect through a number of mechanisms, with particular mention of the competitive inhibition of adenosine receptors in the CNS at the presynaptic terminals and which govern the release of other neurotransmitters such as acetylcholine, glutamate and dopamine, thereby enhancing the attention, concentration and alertness in mental and physical exercises, and reducing the perception of fatigue during exercise[4,12,13].

Changes in perceived pain with the intake of caffeine have also been observed. This is due to an increase in the secretion of ß-endorphins[14], which favours increased endurance.

This central model is the one that would best explain the ergogenic effect of caffeine on high-intensity exercises, in contrast to the widely accepted theory of the stimulation of fatty acids and subsequent saving in muscle glycogen[15,16].

With reference to the factors related to peripheral fatigue, there is evidence of possible mechanisms that would explain the ergogenic effect of caffeine on muscle strength sports, with particular mention of the loss of potassium during contractions and the potentiation of sarcoplasmic reticulum calcium release, all of this generating an overall improvement of the neuromuscular function[9,16].

Results and discussion

Caffeine in strength sports

With regard to the effect of caffeine on muscle power and strength, the results are misleading. Pioneering authors such as Astorino *et al*.[17] or Williams *et al*.[18], both in 2008, and other subsequent authors such as Ali *et al*.[19] in 2016 did not demonstrate significant ergogenic effects on strength sports, while Goldstein *et al*.[20] in 2010 and Grgic and Mikulic[21] in 2017 supported the effectiveness of caffeine at a dose level of 6 mg/kg of body mass to increase the strength of muscle groups in the upper and lower body, respectively.

Individual studies report inconsistent findings for different reasons: total number of participants and their specific characteristics (training level, gender, level of caffeine habituation, etc.), type of exercise studied, intake method, etc. It is therefore not possible to draw sound conclusions on the ergogenic potential of caffeine for the findings of maximal muscle strength.

For this reason, in 2018, Grgic *et al*.[22] published a systematic review and meta-analysis of the findings of individual studies on the acute effects of caffeine intake on maximal muscle strength, concluding that a dose of 3-6 mg/kg of body mass could induce significant improvements in the production of muscle strength and power expressed as vertical jump height, which would be applicable to a wide variety of sports in which jumping is a predominant activity that affects the sports performance. Despite reporting small and medium ergogenic effects, it should be pointed out that, in some sports, small improvements in performance represent significant differences in the results.

Caffeine in endurance sports

There is extensive scientific literature on the utility of caffeine to improve performance in aerobic exercise, observed through diverse parameters such as an increase in work time and time-to-exhaustion, improved peak oxygen consumption in submaximal exercise and improved perceived effort, among others[23,24].

Already in 2009, a systematic review by Ganio *et al*.[25] on 33 clinical trials evidenced a mean improvement in performance of 3.2-4.3% with caffeine ingestion in quantities of 3-6 mg/kg of body mass before and/or during time-trial endurance activities of varied duration (5-150 min) and in different modes of exercise (cycling, running, rowing, cross-country skiing and swimming). These authors concluded, moreover, that abstaining from caffeine intake for at least 7 days before competition improved its ergogenic effect. However, although Irwin *et al.*[26] show an ergogenic improvement in high-intensity endurance exercises with a dose of 3mg/kg regardless of the prior period of abstention, the review in 2016 by Naderi *et al*.[27] supports the conclusions obtained by Ganio *et al*.[25], attributing the said effect to the enzymatic regulation secondary to chronic caffeine intake.

There are fewer studies on the effects of caffeine on *anaerobic exertion*, such as intense, short duration activities, supramaximal activities and repeat sprints[28]. Systematic reviews have been made, such as that by Astorino and Roberson[29] in 2010 on short-term high-intensity exercise performance (≤5 min), where approximately 65% of the studies showed an average benefit of 6.5% in performance, with variations according to the training level and caffeine intake of participants, total ingested dose and type of tests, in addition to the genetic differences among athletes.

A double blind test with placebo in 2013[30] showed how a caffeine dose of 5 mg/kg of body mass, not only improved performance but also the perception of fatigue and muscle pain in endurance exercises undertaken by trained athletes. In 2017, Wellington *et al*.[31] showed a 1% improvement in a repeated sprint test on rugby players with a does of 300 mg of caffeine 60 minutes before exercise while, in a meta-analysis, Christensen *et al.*[12] demonstrated a 1% improvement in the average velocity, also in resistance tests. Likewise, the results of the meta-analysis by Grgic *et al*.[22] in 2018 are in addition to the investigations suggesting improved anaerobic performance of caffeine, demonstrating a significant difference compared to placebo in the production of mean and maximal power on a cycle ergometer.

Pharmacokinetics and timing

Due to its pharmacokinetic characteristics, orally administered caffeine is quickly absorbed from the gastrointestinal system into the blood flow, observing high plasma concentrations 15 minutes after intake, reaching a maximum after 30-60 minutes, with a mean life of 3 to 10 hours. Absorption through the oral mucosa reaches maximum levels far more quickly. Caffeine offers complete bioavailability and high solubility, so that it is rapidly distributed throughout the body, easily passing through cell membranes as well as the placental and blood-brain barriers, reaching high concentrations throughout the body, even in the brain[32].

The metabolism primarily takes place at a hepatic level (in a much lower proportion at brain and kidney level) through the P450 cytochrome enzymes, giving rise to metabolites that are excreted through the kidney and that could mediate some of caffeine's performance enhancing effects[13].

The different genetic polymorphisms of cytochrome P450 are among the intrinsic factors that could explain the modifications in the caffeine pharmacokinetics. Moreover, the chronic intake of caffeine accelerates its metabolic clearance, giving rise to habituation in most consumers. Therefore, abstaining from food and drink containing caffeine in the days prior to a competition could promote an ergogenic effect. Studies have also demonstrated a greater neuromuscular response to morning consumption of caffeine compared to evening consumption, due to greater enzyme activity during the first hours of the day[27]. Notable exogenous factors that affect caffeine clearance include co-medication or smoking, which could even duplicate the caffeine elimination rate[4,23].

Despite the fact that high concentrations of caffeine can be found in a number of foods, this intake may not be sufficient to achieve the desired ergogenic effect due to the variable amounts of caffeine that they contain (depending on processing or preparation) or to the presence of antagonistic substances or absorption modifiers. Therefore the consumption of specific preparations is supported[23,33] (Table 2).

In athletic environments, caffeine is generally administered in an anhydrous form (dried), either in tablets or powder solutions. Other forms of presentation may have a different degree of absorption, as in the case of administration through the oral or nasal mucosa which constitutes a direct route to the CNS, making it possible to detect high plasma levels in just 5-15 minutes[34].

In different studies reporting the ergogenic benefits of caffeine, it was observed that the normal dose in adults (see Figure 2 for children-teenagers) ranges between 3-6 mg/kg of body mass, administered 30-60 minutes before exercise, obtaining improvements in time-to-exhaustion, work capacity and perceived effort in resistance sports[13,16].

Investigating the use of caffeine delivered in low doses (<3 mg/kg of body mass, ~200 mg) before or during exercise, improved performance is also observed, particularly at a cognitive level, with the subsequent improvement in wakefulness, alertness and mood during and after strenuous exercise due to the effect of caffeine on the CNS[27,35].

On the other hand, high doses of caffeine (≥9 mg/kg of body mass) do not appear to provide greater benefits, and may instead increase the risk of adverse effects (sickness, diarrhoea, dehydration, anxiety, insomnia, anxiety)[16,27] which will condition sports performance[28].

Thus, taking into account the wide range of doses with an ergogenic effect due to the considerable inter-individual variation[13], it is advisable to try out different strategies during training sessions in order to obtain individualised protocols that provide the maximum benefits with the least possible risk[28].

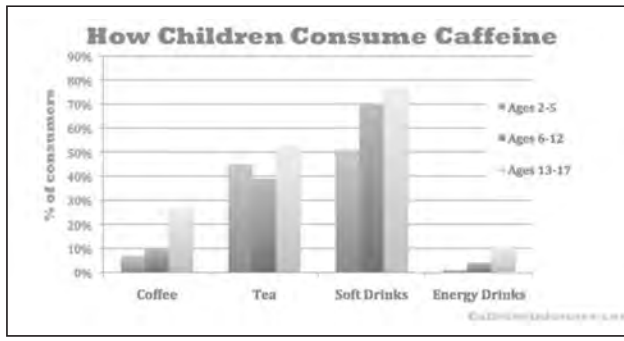
Table 2. Caffeine in foods and drinks.

Food or drink	Caffeine content (mg)
Espresso coffee (60 ml)	80
Filtered coffee (250 ml)	95-165
Decaffeinated coffee	1-2
"Starbucks" coffee (short/Venti)	160 / 400
Black tea (220 ml)	50
Green tea (220 ml)	25-30
Cola drink (330 ml)	40
Energising drink (250 ml)	80
Dark chocolate (50 g)	25
Milk chocolate (50 g)	10
Caffeinated energy bar (65 g)	50
Sports gel with caffeine (40-60 ml)	25-150
"Shot" energy gel (33 ml)	200-300
Caffeine in capsules (1 g)	100
Guarana drink (330 ml)	30

Source: Prepared by the author, based on:
- EUFIC (2016): Caffeine (Q&A): How much caffeine is found in different foods and drinks? (https://www.eufic.org/en/whats-in-food/article/caffeine-qas)
- Mayo Clinic (2018): Contenido de cafeína del café, el té, las gaseosas y más (Caffeine content of coffee, tea, carbonated & others) (https://www.mayoclinic.org/es-es/healthy-lifestyle/nutrition-and-healthy-eating/in-depth/caffeine/art-20049372)
- Botanical on-line (2019): Cantidad de cafeína de los alimentos, plantas y bebidas. (Amount of caffeine in foods, plants and drinks) (https://www.botanical-online.com/alimentos/cafeina-alimentos-ricos)
- Verster & Koenig (2018): Caffeine intake and its sources: A review of national representative studies. Crit Rev Food Sci Nutr. 2018;58(8):1250-59 (https://doi.org/10.1080/10408398.2016.1247252)

Figure 2. Caffeine consumption in children and adolescents.

- Stable daily consumption over the last decade, despite the introduction of new drinks with caffeine[1]
- Prevalence: ~ 75 % children and adolescents aged 6-17 years[2]
- Mean total daily intake below the caffeine consumption recommendations (EFSA: 3 mg/kg/day for children and adolescents)[1,2,3]:
  - 6-11 years: 25 mg/day
  - 12-17 years: 50 mg/day
- Principal sources (variable according to country)[4]:
  - Coffee and tea (consumption rising)
  - Cola drinks (consumption falling) and
  - Energy drinks (consumption increasing with age, particularly in males)
- Metabolism slower than for adults due to the lower efficiency of enzyme CYP1A2[3]
- Doses of 1.5 mg/kg/day can already produce sleep disturbances[3]
- Energy drinks[1,5]:
  - Account for a low percentage of total caffeine consumption (5-12 %)
  - Can involve a greater risk of adverse effects due to their high caffeine content (80-250 mg)
  - Consumption among adolescents is associated with a greater prevalence of risk conducts (smoking, alcoholism, drug addiction, etc.)



Source:
1. Verster & Koenig, 2018 (https://doi.org/10.1080/10408398.2016.1247252)
2. Ahluwalia, *et al*., 2015 (https://doi.org/10.3945/an.114.007401)
3. EFSA, 2015 (https://www.efsa.europa.eu/en/efsajournal/pub/4102)
4. Tran, *et al*., 2016 (https://doi.org/10.1016/j.fct.2016.06.007)
5. Temple *et al*., 2017 (https://doi.org/10.3389/fpsyt.2017.00080)

Toxicity of caffeine

The progressive increase in the consumption of energy drinks containing high concentrations of caffeine and other substances such as taurine, guarana, L-carnitine, ginseng, has led to an increased number of cases of toxicity[36] , occurring at both a cardiac level (atrial fibrillation) and at the CNS level (convulsions). However, recent investigations report that the said components consumed separately could have a neutral or even positive effect on health, provided that they do not exceed the toxic doses37.

Acute consumption of caffeine could produce a slight increase in blood pressure and the heart rate, associated with decreased myocardial blood flow, as well as an increase in plasma catecholamine, rennin and free fatty acid levels38 and although a prospective study published by Klatsky et al.39 in 2011 shows an independent inverse relationship of gender, race and age between coffee consumption and the risk of hospital admittance due to cardiac arrhythmias, there is evidence of possible adverse effects of caffeine when consumed at high doses (>500-600 mg/day), producing nervousness, anxiety, irritability, insomnia, headaches and gastrointestinal problems, in addition to increased sympathetic nerve activity at a cardiac level, estimating an average lethal dose of 10 g of caffeine for adults[40].

In 2015, Yamamoto *et al*.[41] reviewed different cases of caffeine intoxication, especially those resulting in death. The majority of the cases were associated with the consumption of other types of drugs, alcohol in particular, reporting that the caffeine concentration in individuals who had not consumed alcohol was higher than for those who had combined both substances. Hypotheses have been established with regard to the lethal mechanism of caffeine, associating it with ventricular arrhythmias, however other studies suggest other mechanisms such as convulsions, rhabdomyolysis and acute kidney failure[42] or respiratory arrest due to functional brain damage[41]. Studies on animals[43] and humans[41] show that, in lethal cases of intoxication, caffeine is distributed in different organs, primarily in the kidney, brain and liver. Therefore, the cause of death may not solely be associated with the ventricular arrhythmia mechanism but also with general organ damage.

Doping

Caffeine was included in the list of substances banned by the *World Anti-Doping Agency* (WADA) from 1984 until 2004, when it was removed. The permitted concentration in urine was <12 µgr/ml, (~6-8 cups of coffee). Due to the fact that the ergogenic doses of caffeine were found to be almost indistinguishable from normal consumption, the WADA removed its restriction in order to prevent penalizing athletes unfairly. However, considering the growing use of caffeine since the restrictions were lifted, and in order to clarify whether the said consumption was for performance-enhancing purposes, in 2017 experts considered that it ought to be included on the WADA watch list, where it is still today. Therefore, its levels are currently still being monitored[44,45].

Labelling / Regulations

The European Union strengthens the obligations to inform consumers about those drinks and foods (including food supplements) that have a high caffeine content through (EU) Regulation No. 1169/2011 on the provision of food information to consumers[46]. Although the European legislation on food supplements does not specify the maximum permitted level, it does regulate the information that must appear on the label with regard to caffeine[46]:

- Beverages in which the name of the food includes the term 'coffee' or 'tea' (except those based on coffee, tea or coffee or tea extract) and are either intended for consumption without modification or are in concentrated or dried form, and contain caffeine in a proportion in excess of 150 mg/l must indicate:
  - *"High caffeine content. Not recommended for children or pregnant or breast-feeding women"* in the same field of vision as the name of the beverage, followed by a reference to the caffeine content expressed in mg per 100 ml.
- Foods other than beverages, to which caffeine is added with a physiological purpose, must indicate:
  - *"Contains caffeine. Not recommended for children or pregnant women"* in the same field of vision as the name of the food, followed by a reference to the caffeine content expressed in mg per 100 g/ml. In the case of food supplements, the caffeine content shall be expressed per portion as recommended for daily consumption on the labelling.

With regard to the caffeine used as a flavouring in the production or preparation of a food, such as cola beverages, it shall be mentioned by its specific name in the list of ingredients immediately after the term "flavouring". In this case, however, there is no obligation to specify on the label the dose content or the aforementioned restriction on special populations, although the maximum permitted quantities of flavouring are set out in Regulation 1334/2008 on flavourings[47].

On the other hand, with regard to medicinal products containing caffeine, these are not governed by these regulations but by Directive 2001/83/EC, given that they are not classified as "foods" but as medicinal products[48].

Despite the fact that EFSA issued a favourable ruling in 2011[49] for six health claims of article 13.1 of Regulation 1924/2006 (four with specific conditions/restrictions on use and two related to sport/physical activity), there are no health claims relating to caffeine, given that the European Commission overruled the approval of the said claims, in order to protect consumers.

Conclusions

- Caffeine improves physical performance in resistance sports (aerobic exercise) and also in high-intensity activities and team sports (anaerobic exercise).
- At a central level, the effect of caffeine on fatigue is due to neurochemical changes that modify the rating of perceived exertion during exercise and reduce the sensation of pain while, at a peripheral level, it is due to the stimulation of Na^+-K^+-AT Pase that promotes the release of calcium from the sarcoplasmic reticulum, improving the neuromuscular function.
- Low-moderate doses of 3-6 mg/kg of body mass in the form of anhydrous caffeine administered 30-60 minutes before exercise appear to have the most consistent positive results on sport performance, although doses of less than 3 mg/kg of body mass (~200 mg) administered before or during prolonged activities appear to be equally beneficial, particularly at a cognitive level. On the other hand, doses of more than 9 mg/kg of body mass do not appear to increase the ergogenic benefit, and can increase the risk of adverse effects which will condition sport performance.
- Due to the variability in response based on the time of administration, interacting with other ergogenic ingredients, sporting discipline, genotype and gender, it is advisable to personalise the usage protocols in order to maximise the benefit and minimise the side effects.
- The lethal mechanism in the case of caffeine intoxication is associated with alterations not only at a cardiac level but also with the overall systemic affectation (kidney, brain, liver).

– Aspects to explore in future studies on the ergogenic response of caffeine:
  - Influence of habitual consumption of coffee/caffeine.
  - Optimal administration time / influence on circadian rhythm.
  - Variation of the ergogenic effect according to the caffeine source.
  - Influence of the athlete's prior training level.
  - Influence of the chronic administration of caffeine in the adaptation to training.
  - Influence of gender difference.

Conflict of interest

The authors have no conflict of interest at all.

Bibliography

1. NIH: National Institutes of Health. Dietary Supplements for Exercise and Athletic Performance (Actualizado 06/2017; Consultado 05/2019). Disponible en: https://ods.od.nih.gov/factsheets/ExerciseAndAthleticPerformance-HealthProfessional/
2. CRN: Council for Responsible Nutrition. 2018 CRN Consumer Survey on Dietary Supplements. Disponible en: https://www.crnusa.org/CRNConsumerSurvey
3. Muñoz Soler, A. Guía de Nutrición para el Entrenamiento de la Fuerza. Madrid. Ediciones Tutor; 2014. p.75-6.
4. Ramírez-Montes CA, Osorio JH. Uso de la cafeína en el ejercicio físico: ventajas y riesgos. *Rev. Fac. Med.* 2013;61(4):459-68.
5. AIS: Australian Institute of Sports. The AIS Sports Supplement Framework. (Actualizado 03/2019; Consultado 03/2019). Disponible en: https://www.sportaus.gov.au/__data/assets/pdf_file/0004/698557/AIS_Sports_Supplement_Framework_2019.pdf
6. ICO: International Coffee Organization. The Current State of the Global Coffee Trade Stats 2016. (Actualizado 10/2016; Consultado 05/2019). Disponible en: http://www.ico.org/monthly_coffee_trade_stats.asp
7. Wan J, Qin Z, Wang P, Sun Y, Liu X. Muscle fatigue: general understanding and treatment. *Exp Mol Med.* 2017;49(10):e384.
8. Finsterer J. Biomarkers Of Peripheral Muscle Fatigue During Exercise. *BMC Musculoskelet Disord.* 2012;13(1):218-30.
9. Boyas S, Guével A. Neuromuscular Fatigue in healthy muscle: Underlying factors and adaptation mechanisms. *Ann Phys Rehabil Med.* 2011;54(2):88-108.
10. Gómez-Campos R, Cossio-Bolaños MA, Brousett M, Hochmuller-Fogaca RT. Mecanismos implicados en la fatiga aguda. *Rev Int Med Cienc Act Fís Deporte.* 2010;10(40):537-55.
11. Arce Rodríguez E. Mecanismos fisiológicos de la fatiga neuromuscular. *Rev Med Cos Cen*. 2015;72(615):461-4.
12. Christensen PM, Shirai Y, Ritz C, Nordsborg NB. Caffeine and Bicarbonate for Speed. A Meta-Analysis of Legal Supplements Potential for Improving Intense Endurance Exercise Performance. *Front Physiol.* 2017;8:240.
13. Pickering C, Kiely J. Are the Current Guidelines on Caffeine Use in Sport Optimal for Everyone? Inter-individual Variation in Caffeine Ergogenicity, and a Move Towards Personalised Sports Nutrition. *Sports Med.* 2018;48(1):7-16.
14. Gonglach AR, Ade CJ, Bemben MG, Larson RD, Black CD. Muscle Pain as a Regulator of Cycling Intensity: Effect of Caffeine Ingestion. *Med Sci Sports Exerc.* 2016;48(2):287-96.
15. Hodgson AB, Randell RK, Jeukendrup AE. The metabolic and performance effects of caffeine compared to coffee during endurance exercise. *PloS One*. 2013;8(4):e59561.
16. Brooks JH, Wyld K, Chrismas BCR. Caffeine Supplementation as an Ergogenic Aid for Muscular Strength and Endurance: A Recommendation for Coaches and Athletes. *J Athl Enhanc*. 2016,5:4.
17. Astorino TA, Rohmann RL, Firth K. Effect of caffeine ingestion on one-repetition maximum muscular strength. *Eur J Appl Physiol.* 2008;102(2):127–32.
18. Williams A, Cribb P, Cooke M, Hayes A. The effect of ephedra and caffeine on maximal strength and power in resistance-trained athletes. *J Strength Cond Res.* 2008;22(2):464–70.
19. Ali A, O'Donnell J, Foskett A, Rutherfurd-Markwick K. The influence of caffeine ingestion on strength and power performance in female team-sport players. *J Int Soc Sports Nutr.* 2016;13:46.
20. Goldstein E, Jacobs PL, Whitehurst, Penhollow T, Antonio J. Caffeine enhances upper body strength in resistance-trained women. *J Int Soc Sports Nutr.* 2010;7:18.
21. Grgic J, Mikulic P. Caffeine ingestion acutely enhances muscular strength and power but not muscular endurance in resistance trained men. *Eur J Sport Sci.* 2017;17(8):1029–36.
22. Grgic J, Trexler ET, Lazinica B, Pedisic Z. Effects of caffeine intake on muscle strength and power: a systematic review and meta-analysis. *J Int Soc Sports Nutr.* 2018;15:11.
23. Santesteban Moriones V, Ibáñez Santos J. Ayudas ergogénicas en el deporte. *Nutr Hosp.* 2017;34(1):204-15.
24. Palacios N, Manonelles P, Blasco R, Franco L, Gaztañaga T, Manuz B, *et al.* Ayudas ergogénicas nutricionales para las personas que realizan ejercicio físico. Documento de Consenso de la Federación Española de Medicina del Deporte. *Arch Med Deporte.* 2012;29(Supl.1):5-80.
25. Ganio MS, Klau JF, Casa DJ, Armstrong LE, Maresh CM. Effect of caffeine on sport-specific endurance performance: A systematic review. *J Strength Cond Res*. 2009;23(1):315-24.
26. Irwin C, Desbrow B, Ellis A, O'Keeffe B, Grant G, Leveritt M. Caffeine withdrawal and high-intensity endurance cycling performance. *J Sports Sci*. 2011;29(5):509-15.
27. Naderi A, de Oliveira EP, Ziegenfuss TN, Willems MT. Timing, optimal dose and intake duration of dietary supplements with evidence-based use in sports nutrition. *J Exerc Nutr Biochem.* 2016;20(4):1-12.
28. Peeling P, Binnie MJ, Goods PSR, Sim M, Burke LM. Evidence-Based Supplements for the Enhancement of Athletic Performance. *Int J Sport Nutr Exerc Metab*. 2018;28(2):178-87.
29. Astorino TA, Roberson DW. Efficacy of acute caffeine ingestion for short-term high-intensity exercise performance: A systematic review. *J Strength Cond Res.* 2010;24(1):257–65.
30. Duncan MJ, Stanley M, Parkhouse N, Cook K, Smith M. Acute caffeine ingestion enhances strength performance and reduces perceived exertion and muscle pain perception during resistance exercise. *Eur J Sport Sci*. 2013;13(4):392-9.
31. Wellington BM, Leveritt MD, Kelly VG. The effect of caffeine on repeat high intensity effort performance in rugby league players. *Int J Sports Physiol Perform.* 2017;12(2):206–10.
32. Cappelletti S, Piacentino D, Sani G, Aromatario M. Caffeine: cognitive and physical performance enhancer or psychoactive drug? *Curr Neuropharmacol.* 2015;13(1):71-88.
33. Tarnopolsky MA. Caffeine and creatine use in sport. *Ann Nutr Metab*. 2010;57(Suppl.2):1-8.
34. Wickham KA, Spriet LL. Administration of Caffeine in Alternate Forms. *Sports Med.* 2018;48(Suppl.1):79-91.
35. Spriet LL. Exercise and sport performance with low doses of caffeine. *Sports Med.* 2014;44(Suppl. 2):175–84.
36. NIH: National Institutes of Health. Energy Drinks. (Actualizado 07/2018; Consultado 07/2018). Disponible en: https://nccih.nih.gov/health/energy-drinks
37. Wassef B, Kohansieh M, Makaryus AN. Effects of energy drinks on the cardiovascular system. *World J Cardiol.* 2017;9(11):796-806.
38. Noguchi K, Matsuzaky T, Sakanashi M, Hamadate N, Uchida T, Kina-Tanada M. *et al.* Effect of caffeine contained in a cup of coffee on microvascular function in healthy subjects. *J Pharmacol Sci*. 2015;127(2):217-22.
39. Klatsky AL, Hasan AS, Armstrong MA, Udaltsova N, Morton C. Coffee, caffeine, and risk of hospitalization for arrhythmias. *Perm J.* 2011;15(3):19-25.
40. González AB, Hardisson A, Gutiérrez AJ, Rubio C, Frias I, Revert C. Cafeína y quinina en bebidas refrescantes; contribución a la ingesta dietética. *Nutr Hosp.* 2015;32(6):2880-6.
41. Yamamoto T, Yoshizawa K, Kubo S, Emoto Y, Hara K, Waters B, *et al.* Autopsy report for a caffeine intoxication case and review of the current literature. *J Toxicol Pathol.* 2015;28(1):33-6.
42. Campana C, Griffin PL, Simon EL. Caffeine overdose resulting in severe rhabdomyolysis and acute renal failure. *Am J Emerg Med*. 2014;32(1):111.e3-4.
43. Che B, Wang L, Zhang Z, Zhang Y, Deng Y. Distribution and accumulation of caffeine in rat tissues and its inhibition on semicarbazide-sensitive amine oxidase. *Neurotoxicology.* 2012;33(5):1248-53.
44. WADA: World Anti-Doping Agency. The 2018 Monitored Program. (Consultado 12/2018). Disponible en: https://www.wada-ama.org/en/resources/science-medicine/monitoring-program

45. Nationalcoffeeblog.org: National Coffee Association USA (Internet): Can Olympic Athletes Have Caffeine? (Actualizado 12/02/2018; Consultado 02/2019). Disponible en: https://nationalcoffeeblog.org/2018/02/12/can-olympic-athletes-have-caffeine/

46. Unión Europea: Reglamento (UE) nº 1169/2011 del Parlamento Europeo y del Consejo de 25 octubre 2011 sobre la información alimentaria facilitada al consumidor. Diario Oficial de la Comunidades Europeas, 22 noviembre 2011. Disponible en: https://eur-lex.europa.eu/legal-content/ES/TXT/?uri=celex%3A32011R1169

47. Unión Europea: Reglamento (UE) nº 1334/2008 del Parlamento Europeo y del Consejo de 16 diciembre 2008 sobre los aromas y determinados ingredientes alimentarios con propiedades aromatizantes utilizados en los alimentos y por el que se modifican el Reglamento (CEE) nº 1601/91 del Consejo, los Reglamentos (CE) nº 2232/96 y (CE) nº 110/2008 y la Directiva 2000/13/CE. Diario Oficial de la Unión Europea, 31 diciembre 2008. Disponible en: https://www.boe.es/doue/2008/354/L00034-00050.pdf

48. Unión Europea: Directiva 2001/83/CE del Parlamento Europeo y del Consejo de 6 noviembre 2001 por la que se establece un código comunitario sobre medicamentos para uso humano. Diario Oficial de la Comunidades Europeas, 28 noviembre 2001. Disponible en: https://www.boe.es/doue/2001/311/L00067-00128.pdf

49. EFSA: European Food Safety Authority. Scientific Opinion on the substantiation of health claims related to caffeine. *EFSA Journal*. 2011;9(4):2054.

Training methods and nutritional aspects to increase muscle mass: a systematic review

Javier Raya-González, Manuel Antonio Martínez Sánchez

Facultad de Ciencias de la Salud. Universidad Isabel I. Burgos.

Received: 06.06.2019
Aceptado: 02.10.2019

Summary

Introduction: The increase of the muscle mass is one of the main challenges of the athletic trainers, either to optimize the performance, for esthetical reasons or for the health improvement. Therefore, the aim of this study was to analyse the training methods and nutritional aspects for the increase of muscle mass.
Material and method: A data search were conducted in PubMed and Google Scholar databases using the terms: "hypertrophy", "skeletal muscle", "strength" and "training", on the other hand, "hypertrophy", "skeletal muscle" and "nutrition".
Results: After applying the search strategies, a total of 322 articles on training methods and 269 regarding nutritional strategies were obtained. After reading the title and abstract, 238 and 212 articles were eliminated, respectively. Finally, 26 articles on training methods and 11 on nutritional strategies were selected, which met the inclusion criteria and were included in this review.
Conclusions: The results of this study suggest carrying out a training with external loads with the following characteristics: 3-5 series of 6-12 repetitions, with an intensity close to muscle failure (repetitions in reserve of 0 to 2), with a high weekly training volume, and a weekly frequency of 3 days per muscle group, at full range of several different exercises, combining concentric and eccentric contractions, using an internal attentional focus, and with a rest between sets of 2-3 minutes. The nutritional strategies play a fundamental role on the increase of the muscular mass, being essential a high energetic contribution so that hypertrophy occurs. In addition, the intake of nutrients such as whey protein, leucine and omega-3 fatty acids favour muscle protein accretion.

Key words:
Hypertrophy.
Strength training. Nutrition.

Métodos de entrenamiento y aspectos nutricionales para el aumento de la masa muscular: una revisión sistemática

Resumen

Introducción: El aumento de la masa muscular es uno de los principales retos de los entrenadores deportivos, ya sea para optimizar el rendimiento, por razones estéticas o para la mejora de la salud. Por ello, el objetivo de este trabajo fue analizar los métodos de entrenamiento y aspectos nutricionales de mayor importancia para el aumento de la masa muscular.
Material y método: Se realizó una búsqueda bibliográfica en las bases de datos PubMed y Google Scholar usando los siguientes términos: "hypertrophy", "skeletal muscle", "strength" y "training", y, por otro lado, "hypertrophy", "skeletal muscle" y "nutrition".
Resultados: Tras aplicar las estrategias de búsqueda, se obtuvieron un total de 322 artículos sobre métodos de entrenamiento y 269 respecto a estrategias nutricionales. Tras la lectura de título y resumen se eliminaron 238 y 212 artículos respectivamente. Finalmente, se seleccionaron 26 artículos sobre métodos de entrenamiento y 11 sobre estrategias nutricionales, los cuales cumplieron los criterios de inclusión, y fueron incluidos en esta revisión.
Conclusiones: Los resultados de este estudio sugieren la realización de un entrenamiento con cargas con las siguientes características: 3-5 series de 6-12 repeticiones realizadas en el rango de movimiento completo, con una intensidad cercana al fallo muscular (repeticiones en reserva de 0 a 2), con un volumen de entrenamiento semanal alto, y una frecuencia semanal de 3 días por grupo muscular, empleando varios ejercicios diferentes, combinando contracciones concéntricas y excéntricas, utilizando un foco atencional interno y con un descanso entre series de 2-3 minutos es el método más efectivo para el aumento de la masa muscular. Las estrategias nutricionales juegan un papel fundamental sobre el aumento de la masa muscular, siendo imprescindible un sobre aporte energético para que se produzca hipertrofia. Además, la ingesta de nutrientes como la proteína de suero de leche, la leucina y los ácidos grasos omega-3 favorecen la acreción proteica muscular.

Palabras clave:
Hipertrofia.
Entrenamiento con cargas.
Nutrición.

Correspondence: Javier Raya-González
E-mail: rayagonzalezjavier@gmail.com

Introduction

Millions of people worldwide are currently pursuing the goal of increasing muscle mass, from bodybuilders looking to perfect their body composition for aesthetic reasons to weightlifters and athletes aiming to improve their athletic performance[1]. Increased muscle mass is also sought for health purposes, mainly to avoid sarcopenia and related problems[2]. For these reasons, effectively increasing muscle mass has become a key challenge for sports educators.

In turn, this has generated greater interest in understanding the factors that lead to increased muscle mass[1]. Indeed, there seems to be a widespread consensus on the determinants of muscle growth. In particular, mechanical stress, metabolic stress and muscle damage have been identified as the fundamental aspects that must occur during resistance training with loads to generate increased muscle mass[3].

However, there is some controversy regarding the most appropriate training methods to effectively optimise muscle mass increases in different sports contexts and populations[4]. In this regard, the effects of modulating different training parameters have been studied, such as the intensity and volume of training, rest intervals and the type of contraction performed. Nevertheless, conclusive results have not been obtained[1]. Despite this, it has been observed that a fundamental aspect of generating muscle gains is exercising until muscular failure, regardless of the load used[5]. However, more studies are needed to confirm this theory; they must also be applied to a variety of populations.

Previous studies have shown that, along with exercise, nutritional strategies are critical to optimising increased muscle mass. In this sense, energy balance seems to play a key role. Indeed, hypocaloric diets are considered essential for athletes trying to increase their muscle mass[6]. Likewise, protein intake is of great importance, although the minimum recommended amount for such ends is not entirely clear[7,8]. Additionally, it has been established that pre- and post-exercise supplementation, mainly based on leucine or branched-chain amino acids, can help muscle hypertrophy[9]. However, the ideal nutritional principles and ergogenic aids to optimise the process of increasing muscle mass are not entirely clear.

Therefore, the objective of this review is to analyse the most significant training methods and nutritional aspects to increase muscle mass.

Materials and methods

To meet the objective of this study, a literature review was carried out in accordance with the PRISMA recommended guidelines for systematic reviews and meta-analyses[10]. Bibliographic research was carried out in the search engines and databases PubMed and Google Scholar, for which the terms "hypertrophy", "skeletal muscle", "strength" and "training" were searched on the one hand and, on the other, "hypertrophy", "skeletal muscle" and "nutrition". Once the articles had been selected, their references were analysed to identify other articles that could be included in the review. The inclusion criteria used were: (a) studies that analysed the impact of training and nutrition on muscle hypertrophy, (b) articles published in the past 15 years, and (c) articles published in peer-reviewed international journals *(Journal Citation Report)*. The exclusion criteria used were: (a) being written in a language other than English, (b) articles in which the sample is not healthy humans, (c) articles concerning a hypertrophy other than that of skeletal muscle, (d) articles combining training or nutrition with the consumption of anabolic steroids or other illegal substances, (e) articles that did not perform a pre-post assessment.

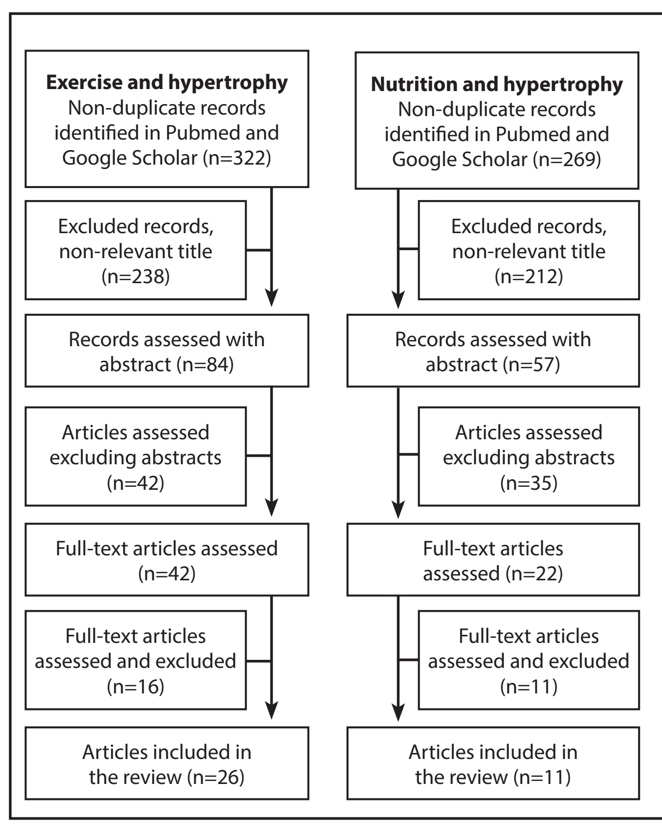
Results

Training methods

A total of 322 results were found through the initial search strategy regarding training and hypertrophy, applying the aforementioned filters. After reading the titles, 238 articles were deleted due to repetition or non-conformity with the relevant themes. Another 42 were deleted after reading their abstracts. The full text of the remaining 42 were read and 16 of these were removed, leaving 26 articles at the end of the selection process (Figure 1).

The 26 selected works were read and analysed in depth to perform the systematic review of training methods to increase muscle mass. The review consisted of a total of 772 subjects with an average of 29 participants per study. In 22 of the included studies the sample was made up of men, in one the sample was of women and the remaining 3 involved

Figure 1 Flow chart describing the systematic review procedure.



both men and women. Regarding the training-related variables, the studies covered training load (4 articles), intensity (3 articles), weekly volume (1 article), number of sets per exercise (2 articles), frequency (4 articles), rest intervals between sets (2 articles), type of training (2 articles), exercise order (2 articles), muscle action (1 article), type of exercise (3 articles), focus of attention (1 item) and range of motion (1 item). Finally, the average duration of the intervention programmes was 10 to 12 weeks, with 6 months being the longest-lasting programme and 6 weeks being the shortest (Table 1).

Nutritional strategies

A total of 269 results were found through the initial search strategy regarding nutrition and hypertrophy, applying the aforementioned filters After reading the titles, 212 articles were deleted. Another 35 were

Table 1. Training methods to increase muscle mass.

Study	Variable	Sample	Intervention	Results
Holm *et al*. (2008)	Load	n=12 untrained male youth	Intra-individual cross-selection with all subjects performing a resistance exercise protocol 3 times per week, performing one training protocol with one leg and another with the other leg: A) Light load: 36 repetitions (1 repetition every 5 seconds for 1 minute) at 15.5% of 1RM. B) Heavy load: 8 repetitions per set at 70% of 1RM. 12 weeks	Significant gains in muscle hypertrophy and strength in the leg having done the heavy-weighted exercises.
Schoenfeld *et al*. (2014)	Load	n=20 young trained males 18 -35 years	Random assignment to one of two resistance exercise protocols: A) Strength-type exercise designed to induce high levels of mechanical stress (2-3 muscle groups per session, with sets of 8-12 repetitions and a 90-second rest between sets). B) Hypertrophy-type training designed to induce high levels of metabolic stress (all muscle groups per session, with sets of 2-4 repetitions and a 3-minute rest between sets). 8 weeks	No significant differences in volume were noted between muscle groups of either group. Likewise, no differences were identified in hypertrophy between groups. However, there was a greater increase in muscle strength in strength-type training.
Tanimoto *et al*. (2008)	Load	n=36 untrained male youth 19.0 ± 1.5 years	Random assignment to one of three groups: 2 resistance exercises (full body) and 1 control: A) Low load and low motion speed exercise group (55-60% 1RM with 3 seconds for eccentric and concentric actions). B) High load training group (80-90% 1RM with 1 second for concentric and eccentric actions). C) Control group: did not perform any training. 13 weeks	Both training groups experienced an increase in strength and muscle mass, with no significant differences between the two groups.
Schoenfeld *et al*. (2015)	Load	n=24 young trained males 18 -33 years	Random assignment to one of two resistance exercise protocols: A) Low load (25-35 repetitions at 30-50% 1RM). A) High load (8-12 repetitions at 70-80% 1RM). 8 weeks	No significant differences were noted in hypertrophy between both groups. However, there was a greater increase in absolute and relative strength among those training with higher loads, as well as a greater increase in muscular resistance among those training with lower loads.
Sampson *et al*. (2016)	Intensity	n=28 inexperienced young males	Random assignment to one of three resistance exercise protocols (85% 1RM 3 days/week): A) Non-failure rapid shortening (rapid concentric) B) Non-failure stretch-shortening (rapid concentric, rapid eccentric) C) Muscle failure 12 weeks	Similar gains in muscle mass for all 3 resistance training regimen
Nóbrega *et al*. (2018)	Intensity	n=32 inexperienced young men 23 ± 3.6 years	Random assignment to one of four resistance exercise protocols (3 sets at 80% 1RM): A) Non-failure, low intensity. B) Non-failure, high intensity. C) Muscle failure, low intensity. D) Muscle failure, high intensity. 6 week	Similar gains in muscle mass when exercising until muscle failure compared to non-failure, independently of the intensity applied.

(Continúa)

Study	Variable	Sample	Intervention	Results
Martorelli *et al.* (2017)	Intensity	n=18 inexperienced young women 22 ± 3.3 years	Random assignment to one of 3 resistance exercise protocols (70% 1RM): A) Muscle failure. B) Non-failure, equalised volume. C) Not to muscle failure, low volume. 10 weeks	Similar muscular gains when muscle failure was attained or not while maintaining an equalised exercise volume.
Schoenfeld *et al.* (2019)	Volume (weekly sets)	n=34 young trained males 18 -35 years	Random assignment to one of three resistance exercise protocols: A) Low volume (6 to 9 sets per muscle group per week). B) Medium volume (18 to 27 sets per muscle group per week). C) High volume (30 to 45 sets per muscle group per week). 8 weeks	Greater increases in muscle mass as the weekly training volume increases, showing a significant dose-response ratio.
Radaelli *et al.* (2015)	Volume (sets per exercise)	n=48 young men inexperienced in weight training, but experienced in traditional military exercises 24.4 ± 0.9 years	Random assignment to one of four groups, 3 resistance exercises (3 exercises per week with at least 48-72 hours rest between sessions) and 1 control: A) Group performing 1 set per exercise. B) Group performing 3 sets per exercise. C) Group performing 5 sets per exercise. D) Control group: did not perform the weight training program but did follow a traditional military regime with their own body weight. 6 months	Significant gains in hypertrophy in the group that performed 5 sets per exercise in comparison to all other groups. A greater increase in hypertrophy was also observed in the group performing 3 sets per exercise in comparison to that which did only 1
Sooneste *et al.* (2013)	Volume (sets per exercise)	n=8 sedentary, untrained male youth 19 -29 years	Intra-individual cross-selection with all subjects performing a resistance exercise protocol 2 times per week, performing one training protocol with one arm and another with the other arm: A) 3 sets per session. B) 1 set per session. 12 weeks	Significant increases in strength and hypertrophy in the arm that did 3 sets per session.
Brigatto *et al.* (2019)	Frequency	n=20 young trained males 19 -35 years	Random assignment to one of two resistance exercise protocols: A) Frequency of 1 day per week for each muscle group. B) Frequency of 2 days per week for each muscle group. 8 weeks	No significant differences were observed in increased muscle mass when training with a weekly frequency of 1 or 2 days per muscle group.
Zaroni *et al.* (2019)	Frequency	n=18 young trained males 18 -30 years	Random assignment to one of two resistance exercise protocols: A) Frequency of 1 day per week for each muscle group. B) Frequency of 5 days per week for each muscle group. 8 weeks	Significantly higher increases in muscle mass in the group that trained with a frequency of 5 days/week compared to the group that trained 1 day/week, both in the lower and upper body muscles.
Saric *et al.* (2019)	Frequency	n=27 young trained males aged over 18	Random assignment to one of two resistance exercise protocols: A) Frequency of 3 days per week for each muscle group. B) Frequency of 6 days per week for each muscle group. 6 weeks	No significant differences were observed in increased muscle mass when training with a weekly frequency of 3 or 6 days per muscle group.
Schoenfeld *et al.* (2015)	Frequency	n=20 young trained males 19 -29 years	Random assignment to one of two resistance exercise protocols: A) Frequency of 1 day per week for each muscle group. B) Frequency of 3 days per week for each muscle group. 8 weeks	Greater significant increases in hypertrophy for the group that trained each muscle group 3 days per week.
Buresh *et al.* (2009)	Rest between sets	n=12 untrained male youth 19 -27 years	Random assignment to one of two rest protocols during resistance training: A) 1-minute rest between sets B) 2.5-minute rest between sets 10 weeks	Significant gains in increased hypertrophy for the group with longer rest intervals, without any differences in terms of strength.

(Continúa)

Study	Variable	Sample	Intervention	Results
Schoenfeld *et al.* (2016)	Rest between sets	n=23 young trained males 18-35 years	All participants performed full-body training 3 times per week composed of 3 sets of 8-12 repetitions with 7 different exercises per session. Random assignment to one of two rest protocols during resistance training: A) 1-minute rest between sets B) 3-minute rest between sets. 8 weeks	Slightly significant major increase in additional load volume in the group with longer rest intervals. Significant major gains in hypertrophy and maximum strength in the group with longer rest intervals.
Fonseca *et al.* (2014)	Type of training	n=70 untrained male youth 26.1 ± 4.3 years	Random assignment to one of five groups, 4 hypertrophy-oriented lower-limb strength training (2 sessions per week, 6-10 repetitions per set) and 1 control: A) constant intensity and constant exercise: 8 repetitions of squats. B) constant intensity and varied exercise: 8 repetitions of squats, leg-press, dead lift and lunges. C) varied intensity and constant exercise: 6-10 repetitions of squats. D) varied intensity and varied exercise: 6-10 repetitions of squats, leg-press, dead lift and lunges. E) Control group: did not perform any training. 12 weeks	Significant major increases in hypertrophy in the group that performed varied exercise, both with varied and constant intensity; the latter making greater strength gains.
Stasinaki *et al.* (2015)	Type of training	n=25 young trained males 21.9 ± 1.9 years	Random assignment to one of three resistance exercise groups: A) Compound training group: 3 weekly training sessions alternating low-speed, high load (strength) sessions with high-speed, low load (power) sessions. B) Complex training group: 3 weekly training sessions including strength and power in all sessions. C) Control group: did not perform any training. 6 weeks	Significant major increases in strength and hypertrophy in the group that did complex training. On the other hand, the compound training group showed greater increases in power levels.
Fisher *et al.* (2014)	Exercise order	n=41 trained men and women	All subjects trained two days per week with one single set and moderate intensity load until muscle failure. Random assignment to one of three resistance exercise protocols: A) Training group with isolated exercises, progressing to compound exercises, without resting between exercises. B) Training group with isolated exercises, progressing to compound exercises, including rests between exercises. C) Control group, trained with compound exercises, progressing to isolated exercises, with rests. 12 weeks	No significant differences were noted in hypertrophy between the groups.
Spineti *et al.* (2010)	Exercise order	n=30 young trained males 22 -30 years	Random assignment to one of three groups, 2 resistance exercises (2 sessions per week with at least 72 hours rest between sessions) and 1 control: A) Group trained with large muscle group exercises, progressing to small muscle group exercises. B) Group trained with small muscle group exercises, progressing to large muscle group exercises. C) Control group: they did not carry out the weight training program but did perform a traditional military program. 12 weeks	No significant differences were noted in hypertrophy between the groups.
Reeves *et al.* (2009)	Type of muscular action	n=19 untrained senior men and women 65 -77 years	All subjects performed 3 weekly training sessions with 5 repetitions at 80% of 1RM. Random assignment to one of two resistance exercise protocols: A) Conventional training: performing concentric and eccentric contractions. B) Eccentric training: performing only eccentric contractions. 14 weeks	No significant differences were noted in hypertrophy between both groups, but adaptations to the muscle architecture and strength were different.

(Continúa)

Study	Variable	Sample	Intervention	Results
Paoli *et al.* (2017)	Type of exercise	n=36 athletic men without experience in strength training 28 ± 4.5 years	Random assignment to one of two resistance exercise groups: A) Based on single-joint exercises. B) Based on multiple-joint exercises.	There were no significant differences in hypertrophy between both groups despite using different types of exercises.
De França *et al.* (2015)	Type of exercise	n=20 trained men 28 ± 4.5 years	Random assignment to one of two resistance exercise groups: A) Based on single-joint and multiple-joint exercises. B) Based on multiple-joint exercises.	No significant differences were noted in hypertrophy between both groups.
Gentil *et al.* (2015)	Type of exercise	n=29 men without experience in strength training 28 ± 4.5 years	Random assignment to one of two resistance exercise groups: A) Based on single-joint exercises. B) Based on multiple-joint exercises	There were no significant differences in hypertrophy between both groups despite using different types of exercises.
Schoenfeld *et al.* (2018)	Attentional focus	n=30 male university students 18 -35 years	Random assignment to one of two groups, (3 sessions per week with 4 sets 8-10 repetitions): A) Internal focus (concentrating on muscular contraction). B) External focus (concentrating on the outcome of the lift). 8 weeks	Significant increases in greater hypertrophy in the internal focus group both in muscle thickness of elbow flexors and quadriceps
McMahon *et al.* (2014)	Range of motion	n=26 Young physically active men and women 18 -26 years	Random assignment to one of three groups, 2 resistance exercises (3 exercises per week with 3 sets of 80% 1RM) and 1 control: A) Group training with partial range of motion (ROM). B) Group training with complete ROM. C) Control group: did not perform any training. 8 weeks	Significant increases in hypertrophy in the group that trained with a complete range of motion.

deleted after reading their abstracts. The full text of the remaining 22 were read and 11 of these were removed, leaving 11 articles at the end of the selection process (Figure 1).

The 11 selected works were read and analysed in depth to perform the systematic review of nutritional aspects to increase muscle mass. The review consisted of a total of 1,071 subjects with an average of 97 participants per study. In 9 of the included studies, the sample was made up of men, while the remaining 2 involved both men and women. Furthermore, most of the articles presented an intervention period of 12 weeks. The longest duration of an intervention was 40 months, while the shortest duration was 4 weeks (Table 2).

Discussion

This study aimed to analyse the most significant training methods and nutritional aspects to increase muscle mass.

Training methods

In relation to the training load, an increase in muscle mass was observed with very different loads, from very light[11], low[12,13] or medium loads[14] to high[11,12,14] or very high loads[13]. Differences between loads were only observed in the study conducted by Holm *et al.*[11], which found a greater increase in muscle mass in subjects who trained with heavier loads. This is indicative of the need to customise loads to meet the requirements of each athlete, as well as the importance of using a wide range of loads to favour different types of adaptation.

Various authors have postulated that muscle failure needs to take place to maximise muscle growth[15,16]. However, recent studies with both men and women have shown that this is not necessary and that training at an intensity close to muscle failure (ending the set 2-3 repetitions before reaching failure) produces similar effects on increased muscle mass to those of training to reach actual muscle failure[17–19]. In this sense, Zourdos *et al.*[20] proposed the concept of repetitions in reserve (RIR), which indicates the number of repetitions that a subject could perform at the end of each series. An RIR of 0 would represent actual muscle failure, while an RIR of 2 would mean finishing the series two repetitions before reaching muscle failure. However, subjects need to become familiar with this concept in order to apply it reliably when training[21]. Regardless, there are times when it may be advantageous to achieve real muscle failure. This would be, for example, when training with low loads, in the first set of a training program or in small training blocks (maximum of 4 weeks), as well as with low weekly training frequencies, due to the long recovery time required when applying this method[22]. Failure to follow these guidelines regarding muscle failure in

Table 2. Nutritional strategies to increase muscle mass.

Study	Theme	Sample	Intervention	Results
Boone *et al.* (2015)	Protein supplementation	n=20 untrained male youth 21.4 ± 1.9 years	All performed resistance training (3 sessions per week on non-consecutive days, 3 sets per exercise of 8-10 repetitions at 80% of 1RM). Random assignment to one of two nutritional groups: A) Protein intake. B) Placebo intake. 4 weeks	Both groups revealed an increase in strength and muscle mass, with no significant differences between the two groups.
Chappell, Simper y Barker (2018)	Nutritional habits	n=51 Male and female competitors in natural bodybuilding	The dietary practices of all bodybuilders were surveyed, requiring participants to fill out a 34-item questionnaire assessing their diet in three moments. 22 ± 9 weeks	Bodybuilders' nutritional habits proved to reflect a high carbohydrate and protein intake together with low fat intake.
Farup *et al.* (2014)	Protein supplementation	n=22 young males	Random assignment to one of two nutritional groups: A) Whey protein hydrolysate (with high leucine content) and carboyhdrate intake. B) Carbohydrates intake. In addition, within these groups an intra-individual cross selection was undertaken with subjects performing one exercise protocol with one leg and another with the other leg: A) Concentric contractions. B) Eccentric contractions. 12 weeks	Significant increases in greater hypertrophy in the group that consumed whey protein hydrolysate with high leucine content, regardless of the type of contraction.
Garthe *et al.* (2013)	Energy balance	n=47 Elite athletes 17 -31 years	All subjects continued their sports-specific training, including four additional strength training sessions per week. Random assignment to one of two nutritional groups: A) Group with nutritional guidance: following a meal plan that provided a positive energy balance (+500 kcal/day). B) "Ad libitum" group: on-demand energy intake. 8 -12 weeks	Greater fat-free mass increases in the group with a positive energy balance, in addition to greater increases in fatty deposits.
Hulmi *et al.* (2015)	Whey protein and carbohydrates	n=86 physically active men	Random assignment to one of three post-training nutritional groups: A) 30 g. whey protein. B) Isocaloric carbohydrates C) Whey protein and carbohydrates. Within those groups, subjects were randomly assigned to one of two training methods (both whole-body training, with 2-3 sessions per week): A) Maximum-strength training 4-6 repetitions at 86-95% of 1RM. B) Muscular hypertrophy training 8-12 repetitions at 75-85% of 1RM. 12 weeks	Increase in fat-free mass and strength in training with no differences between post-exercise nutritional groups. The increase in fat-free mass was slightly greater in the group that took protein after exercising, owing to a relative increase, as whey proteins increased abdominal fat loss in this group.
Kukuljan *et al.* (2009)	Supplementation: fortified milk	n=180 adult men 50 -79 years	Random assignment to one of four study groups: A) Exercise + fortified milk. B) Exercise C) Fortified milk. D) Control group. 18 months	Consuming fortified milk did not demonstrate any additional benefit in terms of strength and hypertrophy. The increase in strength and hypertrophy that took place was associated with exercise and not with supplementation.
Rahbek *et al.* (2014)	Supplementation: proteins and carbohydrates	n=24 young physically active men 23.9 ± 0.8 years	Random assignment to one of two nutritional groups: A) Whey protein hydrolysate and carbohydrate intake. B) Isocaloric carbohydrates intake. Within those groups, subjects were randomly assigned to one of two training types: A) Concentric contractions. B) Eccentric contractions. 12 weeks	Regardless of the type of contraction performed, there was a significantly greater increase in muscle hypertrophy, anabolic signalling and muscle protein synthesis in the group that consumed whey protein hydrolysate and carbohydrates.

(Continúa)

Study	Theme	Sample	Intervention	Results
Smith *et al.* (2011)	Omega-3 fatty acids	n=16 senior aged men and women 65 years or older	Random assignment to one of two post-exercise nutritional groups: A) Omega-3 fatty acid intake. B) Corn oil intake. 8 weeks	Supplementation with omega-3 fatty acids caused an increase in muscle protein synthesis while corn oil intake proved to be nonsignificant.
Snijders *et al.* (2015)	Protein before sleeping	n=44 young physically active men 22 ± 1 years	All subjects performed resistance training (3 sessions per week on non-consecutive days, gradually increasing loads from 10-15 repetitions at 70% of 1RM to 8-10 repetitions at 80% of 1RM). Random assignment to one of two pre-sleep nutritional groups: A) Protein intake. B) Placebo intake. 12 weeks	Significantly greater increases in muscle mass and strength in the group that took protein before sleeping.
Verdijk *et al.* (2009)	Protein supplemen-tation	n=28 senior aged men 72 ± 2 years	All subjects performed resistance training (3 sessions per week on non-consecutive days, gradually increasing loads from 10-15 repetitions at 60% of 1RM to 8-10 repetitions at 75% of 1RM). Random assignment to one of two nutritional groups for before and after each session: A) Protein intake. B) Placebo intake. 12 weeks	Both groups revealed an increase in strength and muscle mass, with no significant differences between the two groups.
Wardenaar *et al.* (2017)	Macronu-trients	n=553 well-trained athletes 17 -31 years	Twenty-four-hour dietary recalls and questionnaires were obtained from each athlete with the aim of comparing total energy and macronutrient intake among discipline-categories. 40 months	Strength athletes were those with the greatest quantity of protein intake.

training can negatively affect athletes' performance by increasing the chances of suffering overtraining syndrome or psychological burnout[23].

Regarding training volume, which is defined as the number of sets dedicated to each muscle group per week, a tendency of increased hypertrophy is observed when the weekly volume is increased. In this sense Schoenfeld *et al.*[24] observed a significant dose-response ratio between weekly training volume and increased muscle mass. The same trend appeared when training with untrained subjects, although without significant differences between the different training volumes. Thus, it is advisable to adapt this volume to the individual characteristics of each athlete--namely, the higher the level of the athlete, the higher the volume. On the other hand, regarding the number of sets per exercise, it was observed that levels of hypertrophy were higher in training protocols that performed more sets (3-5 sets) per exercise[25,26]. In both studies, it is recommended to increase training volumes in accordance with athletes' experience in resistance training with loads, following the principle of load progression[27].

Weekly training frequency seems to be an important aspect to increasing muscle mass. Brigatto *et al.*[28] observed that there were no significant differences in increased muscle mass after training each muscle group with a weekly frequency of 1 or 2 days. However, by substantially increasing the weekly training frequency for each muscle group (1 day *vs.* 5 days, with the same total volume), Zaroni *et al.*[29] observed a larger increase in the group that trained each muscle group 5 days per week. Likewise, the study conducted by Schoenfeld *et al.*[30] found increased muscle mass to be evident in individuals subject to a higher training frequency (1 day *vs.* 3 days, with the same total volume). Finally, Saric *et al.*[31] observed a similar increase in muscle mass when training each muscle group 3 or 6 days per week. In the light of the above, training each muscle group 3 times per week seems to be an adequate and sufficient frequency to optimise increases in muscle mass. Therefore, full body routines might be a good option to increase the weekly frequency of training for each muscle group.

In reference to rest, no significant differences were observed when applying different rest intervals between sets[32,33]. However, Schoenfeld *et al.*[33] claims that applying longer rest intervals between sets (2-3 minutes) facilitates higher training volumes and, consequently, greater increases in muscle mass.

Several studies have shown greater increases in muscle mass in subjects who performed more varied sessions in terms of the number and type of exercises[34,35]. Yet, no differences in increased muscle mass have been observed by varying the order of exercises within the same training session[36,37]. On the other hand, Reeves *et al.* [38] showed that while both concentric and eccentric contractions produce similar muscle growth, each type of contraction results in different muscle responses and adaptations. Therefore, it is recommended to incorporate both types of contractions into training sessions.

Previous studies have shown that there are no differences in increased muscle mass when using single-joint or multiple-joint exercises[39,40]. It has even been studied whether including additional single-joint exercises into training programs with mainly multiple-joint exercises would produce greater increases in hypertrophy levels, but significant results were not obtained[41]. This evidence suggests that single-joint or multiple-joint exercises are equally effective for increasing muscle mass. Accordingly, selection criteria for the type of exercise to be performed should be based on each athlete's individual needs, such as the time and equipment available, the specificity of the movements or the athlete's particular preferences.

Another aspect to consider is the focus of attention while performing strength training programs aimed at increasing muscle mass. Although there is little evidence to this effect, Schoenfeld *et al.*[42] observed a higher level of hypertrophy when the focus of attention was internal (i.e., the individual thinks of his/her body's movements while performing the exercises). This seems to be due to the existence of a "mind-muscle" connection, owing to which it is recommended to visualise the target muscle and consciously direct one's neural impulse to it for increased activation.

Finally, it has been shown that performing strength exercises with a full range of motion produces a greater increase in muscle growth, mainly because the muscles are exposed to different stimuli and adaptations at each angle of the range of motion[43].

Nutritional strategies

In reference to energy balance, Garthe *et al.*[44] demonstrated that combining a strength training program together with a positive energy intake enhances the anabolic effect, leading to fat-free mass gains. In this respect, Chappell *et al.*[45] observed that bodybuilders had nutritional habits with markedly high carbohydrate and protein intake, together with low fat intake. Despite this, excessive energy intake should be deliberated with caution due to the possible adverse effects of increasing body fat levels[46].

Upon analysing the effect of combining protein supplementation with training with loads on untrained subjects, several studies showed that no further increase in muscle mass was achieved when compared to simply training[47–50]. By contrast, Farup *et al.*[9] and Rahbek *et al.*[51] observed greater increases in muscle mass following supplementation with whey protein hydrolysate--with high leucine content--combined with carbohydrates. In this way, they demonstrated that this amino acid is a potent driver of muscle protein synthesis. In addition, it has been observed that protein-based supplementation prior to sleeping represents an effective dietary strategy to increase muscle mass when performing resistance-type exercise training[52].

As for fatty acids, Smith *et al.*[53] demonstrated that omega-3 fatty acid supplementation increases the rate of muscle protein synthesis.

Conclusion

The results obtained suggest that performing resistance-type training with the following characteristics is the most effective method to increase muscle mass: 3-5 sets of 6-12 repetitions performed with a full range of motion, with an intensity close to muscle failure (RIR 0 to 2), with a high weekly training volume, and a weekly frequency of 3 days per muscle group, using several different exercises, combining concentric and eccentric contractions, using an internal attentional focus and a rest interval of 2-3 minutes between sets. Moreover, an energy intake based on leucine and omega-3 fatty acids is suggested, as well as including an intake of whey protein before sleeping.

Conflicts of interest

The authors declare no conflict of interests.

Bibliography

1. Schoenfeld BJ. The mechanisms of muscle hypertrophy and their application to resistance training. *J Strength Cond Res.* 2010;24(10):2857-72.
2. Tesch PA, Fernandez-Gonzalo R, Lundberg TR. Clinical applications of iso-inertial, eccentric-overload (YoYoTM) resistance exercise. *Front Physiol.* 2017;8:241.
3. Ahtiainen JP, Pakarinen A, Alen M, Kraemer WJ, Häkkinen K. Muscle hypertrophy, hormonal adaptations and strength development during strength training in strength-trained and untrained men. *Eur J Appl Physiol.* 2003;89(6):555-63.
4. Csapo R, Alegre LM. Effects of resistance training with moderate vs heavy loads on muscle mass and strength in the elderly: A meta-analysis. *Scand J Med Sci Sports.* 2016;26(9):995-1006.
5. Dinyer TK, Byrd MT, Garver MJ, Rickard AJ, Miller WM, Burns E, *et al*. Low-load vs. high-load resistance training to failure on one repetition maximum strength and body composition in untrained women. *J Strength Cond Res*. (Ahead of print).
6. Lambert CP, Frank LL, Evans WJ. Macronutrient considerations for the sport of bodybuilding. *Sports Med.* 2004;34(5):317-27.
7. Schoenfeld B. *Science and Development of Muscle Hypertrophy*. Champaign: Human Kinetics; 2016. p.29.
8. Cholewa J, Trexler E, Lima-Soares F, de Araujo-Pessoa K, Sousa-Silva S, Santos AM, *et al.* Effects of dietary sports supplements on metabolite accumulation, vasodilation and cellular swelling in relation to muscle hypertrophy: A focus on "secondary" physiological determinants. *Nutrition.* 2019;60:241-51.
9. Farup J, Rahbek SK, Vendelbo MH, Matzon A, Hindhede J, Bejder A, *et al*. Whey protein hydrolysate augments tendon and muscle hypertrophy independent of resistance exercise contraction mode. *Scand J Med Sci Sports.* 2014;24(5):788-98.
10. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* 2009;6(7):e1000097.
11. Holm L, Reitelseder S, Pedersen TG, Doessing S, Petersen SG, Flyvbjerg A, *et al*. Changes in muscle size and MHC composition in response to resistance exercise with heavy and light loading intensity. *J Appl Physiol.* 2008;105(5):1454-61.
12. Schoenfeld BJ, Peterson MD, Ogborn D, Contreras B, Sonmez GT. Effects of low- vs. high-load resistance training on muscle strength and hypertrophy in well-trained men. *J strength Cond Res*. 2015;29(10):2954-63.
13. Tanimoto M, Sanada K, Yamamoto K, Kawano H, Gando Y, Tabata I, *et al.* Effects of whole-body low-intensity resistance training with slow movement and tonic force generation on muscular size and strength in young men. *J Strength Cond Res*. 2008; 22(6):1926-38.
14. Schoenfeld BJ, Ratamess NA, Peterson MD, Contreras B, Sonmez GT, Alvar BA. Effects of different volume-equated resistance training loading strategies on muscular adaptations in well-trained men. *J Strength Cond Res.* 2014;28(10):2909-18.
15. Fisher J, Steele J. Evidence-based resistance training recommendations for muscular hypertrophy. *Med Sport*. 2013;17(4):217-35.
16. Willardson JM, Norton L, Wilson G. Training to failure and beyond in mainstream resistance exercise programs. *Strength Cond J.* 2010;32(3):21-9.
17. Sampson JA, Groeller H. Is repetition failure critical for the development of muscle hypertrophy and strength? *Scand J Med Sci Sports.* 2016;26(4):375-83.
18. Nóbrega SR, Ugrinowitsch C, Pintanel L, Barcelos C, Libardi CA. Effect of resistance training to muscle failure vs. volitional interruption at high- and low-intensities on muscle mass and strength. *J Strength Cond Res.* 2018;32(1):162-9.

19. Martorelli S, Cadore EL, Izquierdo M, Celes R, Martorelli A, Cleto VA, *et al.* Strength training with repetitions to failure does not provide additional strength and muscle hypertrophy gains in young women. *Eur J Transl Myol.* 2017;27(2):6339.

20. Zourdos MC, Klemp A, Dolan C, Quiles J, Schau K, Jo E, *et al*. Novel resistance training–specific rating of perceived exertion scale measuring repetitions in reserve. *J Strength Cond Res.* 2016;30(1):267-75.

21. Hackett DA, Johnson NA, Halaki M, Chow C-M. A novel scale to assess resistance-exercise effort. *J Sports Sci.* 2012;30(13):1405-13.

22. Schoenfeld B, Grgic J. Does training to failure maximize muscle hypertrophy? Strength Cond J. (Ahead of print).

23. Fry AC, Kraemer WJ. Resistance exercise overtraining and overreaching. Sport Med. 1997;23(2):106-29.

24. Schoenfeld BJ, Contreras B, Krieger J, Grgic J, Delcastillo K, Belliard R, *et al.* Resistance training volume enhances muscle hypertrophy but not strength in trained men. *Med Sci Sports Exerc.* 2019;51(1):94-103.

25. Radaelli R, Fleck SJ, Leite T, Leite R, Pinto R, Fernades L, *et al.* Dose-response of 1, 3, and 5 sets of resistance exercise on strength, local muscular endurance, and hypertrophy. *J Strength Cond Res.* 2015;29(5):1349-58.

26. Sooneste H, Tanimoto M, Kakigi R, Saga N, Katamoto S. Effects of training volume on strength and hypertrophy in young men. *J Strength Cond Res*. 2013;27(1):8-13.

27. Grosser M, Luldjuraj P, Starischka S, Zimmermann E. *Principios del entrenamiento deportivo.* Martínez Roca; 1988.

28. Brigatto FA, Braz T V., Zanini TC da C, Germano M, Aoki M, Schoenfeld B, *et al.* Effect of resistance training frequency on neuromuscular performance and muscle morphology after 8 weeks in trained men. *J Strength Cond Res.* 2019;33(8):2104-16.

29. Zaroni RS, Brigatto FA, Schoenfeld BJ, Braz T, Benvenutti J, Germano M, *et al*. High resistance-training frequency enhances muscle thickness in resistance-trained men. *J Strength Cond Res.* 2019;33:S140-S151.

30. Schoenfeld BJ, Ratamess NA, Peterson MD, Contreras B, Tiryaki-Sonmez G. Influence of resistance training frequency on muscular adaptations in well-trained men. *J Strength Cond Res.* 2015;29(7):1821-9.

31. Saric J, Lisica D, Orlic I, Grgic J, Krieger J, Vuk S, *et al.* resistance training frequencies of 3 and 6 times per week produce similar muscular adaptations in resistance-trained men. *J Strength Cond Res*. 2019;33:S122-S129.

32. Buresh R, Berg K, French J. The effect of resistive exercise rest interval on hormonal response, strength, and hypertrophy with training. *J Strength Cond Res.* 2009;23(1):62-71.

33. Schoenfeld BJ, Pope ZK, Benik FM, Hester GM, Sellers J, Nooner J, *et al.* Longer interset rest periods enhance muscle strength and hypertrophy in resistance-trained men. *J Strength Cond Res.* 2016;30(7):1805-12.

34. Fonseca RM, Roschel H, Tricoli V, de Souza EO, Wilson JM, Laurentino GC, *et al.* Changes in exercises are more effective than in loading schemes to improve muscle strength. *J Strength Cond Res.* 2014;28(11):3085-92.

35. Stasinaki A-N, Gloumis G, Spengos K, Blazevich AJ, Zaras N, Georgiadis G, *et al.* Muscle strength, power, and morphologic adaptations after 6 weeks of compound vs. complex training in healthy men. *J Strength Cond Res.* 2015;29(9):2559-69.

36. Fisher JP, Carlson L, Steele J, Smith D. The effects of pre-exhaustion, exercise order, and rest intervals in a full-body resistance training intervention. *Appl Physiol Nutr Metab.* 2014;39(11):1265-70.

37. Spineti J, de Salles BF, Rhea MR, Lavigne D, Matta T, Miranda F, *et al*. Influence of exercise order on maximum strength and muscle volume in nonlinear periodized resistance training. *J Strength Cond Res.* 2010;24(11):2962-9.

38. Reeves ND, Maganaris CN, Longo S, Narici M V. Differential adaptations to eccentric versus conventional resistance training in older humans. *Exp Physiol.* 2009;94(7):825-33.

39. Gentil P, Soares S, Bottaro M. Single vs. Multi-joint resistance exercises: effects on muscle strength and hypertrophy. *Asian J Sports Med*. 2015;6(1):e24057.

40. de França HS, Branco PAN, Guedes Junior DP, Gentil P, Steele J, Teixeira CVLS. The effects of adding single-joint exercises to a multi-joint exercise resistance training program on upper body muscle strength and size in trained men. *Appl Physiol Nutr Metab.* 2015;40(8):822-6.

41. Paoli A, Gentil P, Moro T, Marcolin G, Bianco A. Resistance training with single vs. multi-joint exercises at equal total load volume: effects on body composition, cardiorespiratory fitness, and muscle strength. *Front Physiol.* 2017;8:1105.

42. Schoenfeld BJ, Vigotsky A, Contreras B, Golden S, Alto A, Larson R, *et al*. Differential effects of attentional focus strategies during long-term resistance training. *Eur J Sport Sci*. 2018;18(5):705-712.doi:10.1080/17461391.2018.1447020

43. McMahon GE, Morse CI, Burden A, Winwood K, Onambélé GL. Impact of range of motion during ecologically valid resistance training protocols on muscle size, subcutaneous fat, and strength. *J Strength Cond Res.* 2014;28(1):245-55.

44. Garthe I, Raastad T, Refsnes PE, Sundgot-Borgen J. Effect of nutritional intervention on body composition and performance in elite athletes. *Eur J Sport Sci.* 2013;13(3):295-303.

45. Chappell AJ, Simper T, Barker ME. Nutritional strategies of high level natural bodybuilders during competition preparation. *J Int Soc Sports Nutr.* 2018;15(1):4.

46. Baechle T, Earle R. *Principios del entrenamiento de la fuerza y del acondicionamiento físico.* 2a. Madrid: Editorial Médica Panamericana; 2007. p.73.

47. Boone CH, Stout JR, Beyer KS, Fukuda DH, Hoffman JR. Muscle strength and hypertrophy occur independently of protein supplementation during short-term resistance training in untrained men. *Appl Physiol Nutr Metab.* 2015;40(8):797-802.

48. Hulmi JJ, Laakso M, Mero AA, Häkkinen K, Ahtiainen JP, Peltonen H. The effects of whey protein with or without carbohydrates on resistance training adaptations. *J Int Soc Sports Nutr.* 2015;12(1):48.

49. Kukuljan S, Nowson CA, Sanders K, Daly RM. Effects of resistance exercise and fortified milk on skeletal muscle mass, muscle size, and functional performance in middle-aged and older men: an 18-mo randomized controlled trial. *J Appl Physiol.* 2009;107(6):1864-73.

50. Verdijk LB, Jonkers RA, Gleeson BG, Beelen M, Meijer K, Savelberg H, *et al.* Protein supplementation before and after exercise does not further augment skeletal muscle hypertrophy after resistance training in elderly men. *Am J Clin Nutr.* 2009;89(2):608-16.

51. Rahbek SK, Farup J, Møller AB, Vendelbo MH, Holm L, Jessen N, *et al*. Effects of divergent resistance exercise contraction mode and dietary supplementation type on anabolic signalling, muscle protein synthesis and muscle hypertrophy. *Amino Acids.* 2014;46(10):2377-92.

52. Snijders T, Res PT, Smeets JSJ, van Vliet S, van Kranenburg J, Maase K, *et al.* Protein ingestion before sleep increases muscle mass and strength gains during prolonged resistance-type exercise training in healthy young men. *J Nutr.* 2015;145(6):1178-84.

53. Smith GI, Atherton P, Reeds DN, Mohammed BS, Rankin D, Rennie M, *et al.* Dietary omega-3 fatty acid supplementation increases the rate of muscle protein synthesis in older adults: a randomized controlled trial. *Am J Clin Nutr*. 2011;93(2):402-12.

ENTRENAMIENTO FUNCIONAL PARA TRANSFORMAR TODO EL CUERPO

Por: Juan Carlos Santana
Edita: Tutor S.A.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf: 915 599 832 – Fax: 915 410 235. E-mail: edicionestutor.com – Web: www.editorestutor.com
ISBN: 978-84-16676-84-2. Referencia: 502138.
Nº páginas: 272. Encuadernación: Rústica. Formato: 21,5 x 28 cm.
Precio sin IVA: 28,80 euros – Precio con IVA: 29,95 euros

Este libro proporciona más de 100 *workouts*, diseñados de manera profesional y con probada eficacia. También proporciona consejos nutricionales que te ayudarán a alcanzar tus objetivos más rápido de lo que jamás creíste posible. Famoso por su enfoque funcional del entrenamiento, el autor, "JC" Santana ha creado innumerables *workouts* y sabe cómo obtener resultados para transformar todo el cuerpo con el incremento del rendimiento atlético, la fuerza y la funcionalidad.

Incluye consejos para el uso de múltiples implementos, incluidas barras, mancuernas y balones medicinales, para trabajar distintos músculos y añadir variedad. También aporta consejos nutricionales para ayudar a quemar grasa y aumentar la masa muscular; y recomendaciones sobre el descanso y la nutrición. Los *workouts* tienen en cuenta las necesidades singulares de hombres y mujeres, y proporcionan modificaciones para distintos tipos de implementos y máquinas, y directrices sobre cómo secuenciar el trabajo para crear programas diarios, mensuales y anuales.

ENTRENAMIENTO CON MANCUERNAS

Por: Allen Hedrick
Edita: Tutor S.A.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf: 915 599 832 – Fax: 915 410 235
E-mail: edicionestutor.com – Web: www.editorestutor.com
ISBN: 978-84-16676-83-5. Referencia: 502137
Nº páginas: 304. Encuadernación: Rústica. Formato: 17 x 24 cm
Precio sin IVA: 24,04 euros – Precio con IVA: 25,00 €

Las mancuernas son uno de los implementos más versátiles y eficaces; hace mucho tiempo que forman parte de la fórmula perfecta de entrenamiento para aumentar la fuerza y la potencia, y para tonificar todo el cuerpo. Este libro describe la forma de utilizar las mancuernas como elemento de trabajo físico principal para alcanzar los resultados deseados. Ya seas un deportista que desea mejorar el rendimiento, o un entusiasta del ejercicio físico que quiere mejorar su régimen habitual de trabajo, puedes usar mancuernas para lograr tus objetivos de forma física, pérdida de peso o aumento de masa muscular.

Se presentan más de 110 ejercicios para trabajar el core, el tren superior, el tren inferior y todo el cuerpo. Encontrarás fotografías y descripciones concisas de los ejercicios, así como variantes de los mismos, lo que hace que sea muy fácil comprenderlos y ponerlos en práctica por tu cuenta. También descubrirás 66 programas destinados a tus objetivos específicos. Entre ellos, los orientados a la preparación física ayudan a perder grasa, lograr un buen acondicionamiento físico general, aumentar la hipertrofia y mejorar la fuerza; mientras que los planes basados en el rendimiento ofrecen métodos para aumentar la potencia, la velocidad, la agilidad y el equilibrio en ocho deportes diferentes.

GUÍA PRÁCTICA DE ECOGRAFÍA MÚSCULO-ESQUELÉTICA

Por: José Fernando Jiménez Díaz, José Antonio Bouffard y Pedro Manonelles Marqueta (Editores)
Edita: Esmon Publicidad. S.A.
Balmes 206, 3º 2ª. 08006 Barcelona
Telf: 932 159 034 – Fax: 934 874 064
E-mail: redaccion@esmon.es
ISBN: 978-84-17394-44-8.
Nº páginas: 131. Encuadernación: Rústica. Formato: 14,85 x 21 cm
Barcelona, 2019. Precio con IVA: 30,00 €

Guía elaborada por el Grupo de Ecografía del Aparato Locomotor de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE) que describe aspectos técnicos y de procedimiento ente los que destacan las condiciones de realización de la ecografía músculo-esquelética, sus indicaciones y limitaciones, el informe ecográfico, la ecoprevención, la formación del ecografista, la ecografía musculo-esquelética en otras especialidades médicas y las consideraciones legales.

2020		
V Congreso Internacional de Readaptación y Prevención de Lesiones en la Actividad Física y el Deporte	Enero Valencia	web: https://congresojam.com/
XXII curso teórico práctico de ecografía músculo-esquelética en el deporte	19-22 Febrero Barcelona	web: http://www.geyseco.es/car2020
Jornada de Actualización en Fibrilación auricular 2º Edición	21 Febrero Barcelona	web: http://www.aulavhebron.net/aula/documentos/fibrilacion20.pdf
XXIX Congreso de la Sociedad Valenciana de Medicina Física y Rehabilitación	28-29 Febrero Valencia	web: https://www.congresosvmefr.com
I Congreso actividad física, deporte y nutrición	28 Febrero-1 Marzo Valencia	Web: http://congresodeporte.es/
14th ISPRM World Congress – ISPRM 2020	4-9 Marzo Orlando (EE.UU.)	web: http://www.isprm.org/congress/14th-isprm-world-congress
Congreso FESNAD	11-13 Marzo Zaragoza	web: http://www.fesnad.org/
IOC World Conference Prevention of Injury & Illness in Sport	12-14 Marzo Mónaco (Principado de Mónaco)	web: http://ioc-preventionconference.org/
I Congreso actividad física, deporte y nutrición	27-29 Marzo Sevilla	web: http://congresodeporte.es/
37º Congress International Society for Snowsports Medicine-SITEMSH	1-3 Abril Andorra la Vella (Principat d'Andorra)	E-mail: andorra2020@sitemsh.org
9º Congrés Societat Catalana de Medicina de l'Esport-SCME	3-4 Abril Andorra la Vella (Principat d'Andorra)	E-mail: andorra2020@sitemsh.org
2nd China International Sports Health Exhibition 2020	28-30 Abril Beijín (China)	web: www.sportandhealth.com.cn
II Congreso Internacional de la Sociedad Latinoamericana y del Caribe de Psicología de la Actividad Física y del Deporte (SOLCPAD)	7-9 Mayo Córdoba (Argentina)	web: www.solcpad.com
25th Annual Congress of the European College of Sport Science	1-4 Julio Sevilla	E-mail: office@sport-science.org
32nd FIEP World Congress / 12th International Seminar for Physical Education Teachers /15th FIEP European Congress	2-8 Agosto Jyväskylä (Finlandia)	Información: Branislav Antala E-mail: antala@fsport.uniba.sk
2020 Yokohama Sport Conference	8-12 Septiembre Yokohama (Japón)	web http://yokohama2020.jp/overview.html
International Congress of Dietetics	15-18 Septiembre Cape Town (Sudáfrica)	web: http://www.icda2020.com/
XXXVI Congreso Mundial de Medicina del Deporte	24-27 Septiembre Atenas (Grecia)	www.globalevents.gr

VIII Congreso HISPAMEF	15-17 Octubre Cartagena de Indias (Colombia)	web: http://hispamef.com/viii-congreso-hispamef-15-17-de-2020/
XXIX Isokinetic Medical Group Conference: Football Medicine	24-26 Octubre Lyon (Francia)	web: www.footballmedicinestrategies.com
26th TAFISA World Congress	13-17 Noviembre Tokyo (Japón)	web: www.icsspe.org/sites/default/files/e9_TAFISA%20World%20Congress%202019_Flyer.pdf
XVIII Congreso Internacional SEMED-FEMEDE	Murcia	web: www.femede.es
2021		
Congreso Mundial de Psicología del Deporte	1-5 Julio Taipei (Taiwan)	web: https://www.issponline.org/index.php/events/next-world-congress
26th Annual Congress of the European College of Sport Science	7-10 Julio Glasgow (Reino Unido)	E-mail: office@sport-science.org
22nd International Congress of Nutrition (ICN)	14-19 Septiembre Tokyo (Japón)	web: http://icn2021.org/
European Federation of Sports Medicine Associations (EFSMA) Conference 2021	28-30 Octubre Budapest (Hungría)	web: http://efsma.eu/
Congreso Mundial de Podología	Barcelona	web: www.fip-ifp.org
2022		
8th IWG World Conference on Women and Sport	5-8 Mayo Auckland (N. Zelanda)	web: http://iwgwomenandsport.org/world-conference/
XXXVII Congreso Mundial de Medicina del Deporte FIMS	Septiembre Guadalajara (México)	web: www.femmede.com.mx

Cursos *on-line* SEMED-FEMEDE

Curso "ENTRENAMIENTO, RENDIMIENTO, PREVENCIÓN Y PATOLOGÍA DEL CICLISMO"

Curso dirigido a los titulados de las diferentes profesiones sanitarias y a los titulados en ciencias de la actividad física y el deporte, destinado al conocimiento de las prestaciones y rendimiento del deportista, para que cumpla con sus expectativas competitivas y de prolongación de su práctica deportiva, y para que la práctica deportiva minimice las consecuencias que puede tener para su salud, tanto desde el punto de vista médico como lesional.

Curso "ELECTROCARDIOGRAFÍA PARA MEDICINA DEL DEPORTE"

ACREDITADO POR LA COMISIÓN DE FORMACIÓN CONTINUADA (ON-LINE 1/5/2018 A 1/5/2019) CON 2,93 CRÉDITOS

Curso dirigido a médicos destinado a proporcionar los conocimientos específicos para el estudio del sistema cardiocirculatorio desde el punto de vista del electrocardiograma (ECG).

Curso "FISIOLOGÍA Y VALORACIÓN FUNCIONAL EN EL CICLISMO"

Curso dirigido a los titulados de las diferentes profesiones sanitarias y a los titulados en ciencias de la actividad física y el deporte, destinado al conocimiento profundo de los aspectos fisiológicos y de valoración funcional del ciclismo.

Curso "AYUDAS ERGOGÉNICAS"

Curso abierto a todos los interesados en el tema que quieren conocer las ayudas ergogénicas y su utilización en el deporte.

Curso "CARDIOLOGÍA DEL DEPORTE"

ACREDITADO POR LA COMISIÓN DE FORMACIÓN CONTINUADA (ON-LINE 1/5/2018 A 1/5/2019) CON 6,60 CRÉDITOS

Curso dirigido a médicos destinado a proporcionar los conocimientos específicos para el estudio del sistema cardiocirculatorio desde el punto de vista de la actividad física y deportiva, para diagnosticar los problemas cardiovasculares que pueden afectar al deportista, conocer la aptitud cardiológica para la práctica deportiva, realizar la prescripción de ejercicio y conocer y diagnosticar las enfermedades cardiovasculares susceptibles de provocar la muerte súbita del deportista y prevenir su aparición.

Curso "ALIMENTACIÓN, NUTRICIÓN E HIDRATACIÓN EN EL DEPORTE"

Curso dirigido a médicos destinado a facilitar al médico relacionado con la actividad física y el deporte la formación precisa para conocer los elementos necesarios para la obtención de los elementos energéticos necesarios para el esfuerzo físico y para prescribir una adecuada alimentación del deportista.

Curso "ALIMENTACIÓN Y NUTRICIÓN EN EL DEPORTE"

Curso dirigido a los titulados de las diferentes profesiones sanitarias (existe un curso específico para médicos) y para los titulados en ciencias de la actividad física y el deporte, dirigido a facilitar a los profesionales relacionados con la actividad física y el deporte la formación precisa para conocer los elementos necesarios para la obtención de los elementos energéticos necesarios para el esfuerzo físico y para conocer la adecuada alimentación del deportista.

Curso "ALIMENTACIÓN Y NUTRICIÓN EN EL DEPORTE" Para Diplomados y Graduados en Enfermería

ACREDITADO POR LA COMISIÓN DE FORMACIÓN CONTINUADA (NO PRESENCIAL 15/12/2015 A 15/12/2016) CON 10,18 CRÉDITOS

Curso dirigido a facilitar a los Diplomados y Graduados en Enfermería la formación precisa para conocer los elementos necesarios para la obtención de los elementos energéticos necesarios para el esfuerzo físico y para conocer la adecuada alimentación del deportista.

Curso "CINEANTROPOMETRÍA PARA SANITARIOS"

Curso dirigido a sanitarios destinado a adquirir los conocimientos necesarios para conocer los fundamentos de la cineantropometría (puntos anatómicos de referencia, material antropométrico, protocolo de medición, error de medición, composición corporal, somatotipo, proporcionalidad) y la relación entre la antropometría y el rendimiento deportivo.

Curso "CINEANTROPOMETRÍA"

Curso dirigido a todas aquellas personas interesadas en este campo en las Ciencias del Deporte y alumnos de último año de grado, destinado a adquirir los conocimientos necesarios para conocer los fundamentos de la cineantropometría (puntos anatómicos de referencia, material antropométrico, protocolo de medición, error de medición, composición corporal, somatotipo, proporcionalidad) y la relación entre la antropometría y el rendimiento deportivo.

Más información:
www.femede.es

CONCLUSIONES DEL GRUPO AVILÉS DE MEDICINA DEL DEPORTE

VIII Jornadas de trabajo en Logroño (La Rioja)

El Grupo Avilés de Medicina del Deporte considera imprescindible la implantación en España de la regulación y obligatoriedad del reconocimiento médico previo a la práctica deportiva.
La Legislación existente en otros países europeos, como el caso de Italia, está teniendo buenos resultados en el ámbito de la protección de la salud en el deporte. Algunas Comunidades Autónomas ya han iniciado acciones dirigidas a la regulación en el ámbito de su competencia territorial. El borrador de reglamentación presentado por la AEPSAD que recoge, entre otros aspectos, el contenido del RMD básico, las modalidades y especialidades deportivas para las que sea obligatorio, las posibles contraindicaciones para la práctica deportiva, así como los profesionales de medicina del deporte que los llevarán a cabo; debe culminar con la publicación de una norma lo más consensuada posible.

El Grupo Avilés expresa su preocupación ante el claro aumento de los indicadores de sedentarismo en la población infantil y juvenil.
Los niños no hacen niveles suficientes de actividad física. Investigaciones, como el "Estudio PASOS", muestran claramente que los niños y adolescentes españoles no cumplen los requisitos mínimos de actividad física diaria, lo que puede tener implicaciones negativas para su salud actual y futura. Este tipo de investigaciones tienen gran relevancia por la coordinación entre entidades públicas y privadas: el Ministerio de Sanidad, Consumo y Bienestar Social, el Ministerio de Educación y Formación Profesional, el CSD, la AEPSAD y, como en este caso, la Fundación Gasol.

El Grupo Avilés destaca que el ejercicio físico es esencial en los programas de Rehabilitación Oncológica.
La realización de ejercicio físico produce una mejora de la calidad de vida en los supervivientes de cáncer de todas las edades, aplicado de forma individualizada durante todas las fases de la enfermedad, siendo aconsejable su práctica desde el momento del diagnóstico. Dentro de las modalidades de ejercicio físico el entrenamiento de fuerza debe tener un papel prioritario.

El Grupo Avilés constata la importancia de la formación en Medicina del Deporte en diferentes niveles.
Se evidencia la necesidad de que en la formación, tanto de grado como de postgrado, de los profesionales sanitarios, se incluyan los conocimientos suficientes sobre los efectos preventivos y terapéuticos de la Actividad Física.

Ante los retos propuestos es necesario volver a incidir en la importancia de la especialidad de Medicina de la Educación Física y el Deporte.
Actualmente no existe formación en esta especialidad en nuestro país, existiendo un número limitado de estos especialistas.
La competencia profesional de esta especialidad es necesaria, no solamente para realizar el reconocimiento médico deportivo, sino también para todos los aspectos concernientes a la protección de la salud en el deporte y en la utilización del ejercicio físico como herramienta preventiva y terapéutica de salud.

Firmantes:

Melchor Andrés. *Centro Regional de Medicina Deportiva de Castilla y León. Valladolid.*
Alicia Arias. *Centro de Medicina Deportiva de la Comunidad de Madrid.*
Carmen Arnaudas. *Departamento de Deporte y Salud de la AEPSAD. Madrid.*
Montse Bellver. *Centro Alto Rendimiento. Sant Cugat del Vallés. Barcelona.*
Daniel Brotons. *Consell Catalá de l'Esport. Barcelona.*
Carmen Calderón. *Centro Alto Rendimiento. Sierra Nevada. Granada.*
Vicente Elías. *Centro Tecnificación Deportiva ADÁRRAGA Logroño.*
Pablo Gasque. *Servicio de Medicina Deportiva del Ayuntamiento de Alcobendas.*
Fernando Gutiérrez. *Centro de Medicina del Deporte de la AEPSAD. Madrid.*
Fernando Herrero. *Gabinete de Medicina Deportiva del Ayuntamiento de Miranda de Ebro.*
Leocricia Jiménez. *Centro Andaluz de Medicina del Deporte. Sevilla.*
José Fernando Jiménez. *Unidad de Valoración del Rendimiento Deportivo. Toledo.*
Juan José Lacleta. *Centro de Medicina Deportiva del Gobierno de Aragón. Zaragoza.*
Xabier Leibar. *Getxo. Centro de Perfeccionamiento Técnico. Departamento de Cultura. Gobierno Vasco.*
Enrique Lizalde. *Departamento de Deporte y Salud de la AEPSAD. Madrid.*
Javier López. *Centro Tecnificación Deportiva Infanta Cristina. Murcia.*
Fernando Novella. *Servicio Médico. Patronato Municipal de Deportes. Ayuntamiento de Fuenlabrada.*
Eduardo Ribot. *Centro Tecnificación Deportiva del Gobierno Balear. Palma de Mallorca.*
Fernando Salom. *Gabinete de Medicina Deportiva del Consell Insular de Menorca.*
Luis Segura. *Servicio de Medicina Deportiva. Ayuntamiento de Tudela.*
Juan Carlos Tebar. *Centro de Medicina Deportiva del Ayuntamiento de Rivas. Madrid.*
José Luis Terreros. *Director de la AEPSAD. Madrid.*
Nicolás Terrados. *Unidad Regional de Medicina Deportiva del Principado de Asturias. Avilés.*
Gerardo Villa. *Centro Alto Rendimiento. León.*

Archivos
de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

Índice completo

189-194

Volumen XXXVI. 2019

Sumarios 2019

Volumen 36(1) - Núm 189. Enero - Febrero 2019 / January - February 2019

Editorial

Originales / Original articles

Revisiones / Reviews

Volumen 36(2) - Núm 190. Marzo - Abril 2019 / March - April 2019

Editorial

Originales / Original articles

Revisiones / Reviews

Volumen 36(3) - Núm 191. Mayo - Junio 2019 / May - June 2019

Volumen 36(4) - Núm 192. Julio - Agosto 2019 / July - August 2019

Volumen 36(5) - Núm 193. Septiembre - Octubre 2019 / September - October 2019

Editorial

Originales / Original articles

Revisiones / Reviews

Volumen 36(6) - Núm 194. Noviembre - Diciembre 2019 / November - December 2019

Editorial

Originales / Original articles

Revisiones / Reviews

Volumen 36 (Suplemento 1)

Índice analítico 2019

Índice de autores 2019

Lista de revisores evaluadores externos de los artículos recibidos en 2019 en Archivos de Medicina del Deporte

Alacid Cárceles, Fernando *(Universidad de Almería. España)*

Álvarez Herms, Jesús *(Universidad del País Vasco. España)*

Álvarez Medina, Javier *(Universidad de Zaragoza. España)*

Alvero Cruz, Jose Ramón *(Universidad de Málaga. España)*

Aramendi Aramendi, José *(Osasunkirol. Hondarribia. Guipúzcoa. España)*

Arboleda Serna, Víctor Hugo *(Universidad de Antioquia-Medellín. Colombia)*

Archanco Olcese, Miguel *(Hospital Clínico San Carlos. Madrid)*

Avella Chaparro, Rafael Ernesto *(Universidad Libre de Colombia. Bogotá. Colombia)*

Ayala Rodriguez, Francisco *(Universidad Miguel Hernandez. Elche. España)*

Barriales Villa, Roberto *(Universidad de la Coruña. España)*

Bernales Hermosilla, Marlis Andrea *(Universidad de Santo Tomás. Chile)*

Brizuela Costa, Gabriel *(Universidad de Valencia. España)*

Caamaño Navarrete, Felipe *(Universidad Católica de Temuco. Chile)*

Caballero Dorta, Eduardo *(Jefe de Servicio de Cardiología de Hospital Universitario de Gran Canaria Dr Negrín. España)*

Cabot Duran, Xabier *(Universidad internacional de Cataluña. España)*

Cagigal, Jorge *(Facultad de Humanidades Universidad Mayor. Providencia. Chile)*

Calderón Montero, Javier *(Facultad de Ciencias de la Actividad Física y del Deporte. INEF. Madrid)*

Canda Moreno, Alicia *(Agencia Española de protección de la Salud en el Deporte. Madrid)*

Cappa, Dario Fernando *(Universidad Nacional de Catamarca. Facultad de Ciencias de la Salud. Argentina)*

Castillo Sayán, Óscar *(Universidad Nacional Mayor de San Marcos. Perú)*

Chamorro Lange, Claudio *(Pontificia Universidad Católica de Chile)*

Contreras Díaz, Guido Edgardo *(Universidad Los Lagos. Chile)*

Contreras Montilla, Osmary *(Universidad Mayor. Chile)*

Correa Gonzalez, Gonzalo *(FREMAP. TraumadeportGH. Mutualidad Futbolistas Extremadura. Badajoz. España)*

Costa Teixeira, Bruno *(Universidad Regional Integrada. Campus Santo Augusto. RS. Brasil)*

de Benito Trigueros, Ana María *(Universidad Católica de Valencia San Vicente Mártir. Valencia. España)*

de la Cruz Sánchez, Ernesto *(Universidad de Murcia. España)*

de Teresa Galván, Carlos *(Universidad de Granada. España)*

Del Valle Soto, Miguel *(Universidad de Oviedo. España)*

Domínguez Díez, Marta *(Universidad Isabel I. Burgos. España)*

Dominguez Herrera, Raúl *(Universidad Isabel I. Burgos. España)*

Dopico Calvo, Xurxo *(Universidad de la Coruña. España)*

Esquius de la Zarza, Laura *(Universidad Abierta de Cataluña. España)*

Fernandes Da Silva, Sandro *(Unversitdad de Lavras. Brasil)*

Fernández Río, Francisco Javier *(Universidad de Oviedo. España)*

Ferreira Oliveira, Samuel Ângelo *(Federal University of Vicosa. Brasil)*

Ferreyro Bravo, Fernando *(Instituto de ciencias aplicadas la nutrición y salud. Anthropometrica. body measurement research lab.)*

Franco Bonafonte, Luis *(Universidad Rovira i Virgili. Reus. España)*

Garcia, Jorge Enrique *(Instituto de Educación Física San Martín. Catamarca. Argentina)*

García Cota, Juan José *(Hospital Quirón Pontevedra. España)*

García Manso, Juan Manuel *(Laboratorio de Análisis y Control del Entrenamiento Deportivo. Departamento de Educación Física de la U.L.P.G.C. Universidad de Las Palmas de Gran Canaria. España)*

Gil Agudo, Ángel Manuel *(Hospital Nacional de Parapléjicos. Toledo. España)*

González Palacio, Enoc Valentín *(Universidad de San Buenaventura. Colombia)*

Granero Gallegos, Antonio *(Universidad de Almería. España)*

Guisado Barrilao, Rafael *(Universidad de Granada. España)*

Gutiérrez Sanmartín, Melchor *(Universidad de Valencia. España)*

Guzmán Muñoz, Eduardo *(Escuela de Kinesiología. Facultad de Salud. Universidad Santo Tomás, Talca, Chile)*

Haydon, David S. *(School of Mechanical Engineering. University of Adelaide. Australia)*

Heredia Elvar, Juan Ramón *(Instituto Internacional Ciencias Ejercicio Físico y Salud. Murcia. España)*

Hernando Domingo, Carlos *(Universidad de Castellón. España)*

Hidalgo Rasmussen, Carlos Alejandro *(Universidad de Guadalajara. México)*

Iturricastillo Urteaga, Aitor *(Universidad del País Vasco. Leioa. Vizcaya. España)*

Jiménez Díaz, Fernando *(Universidad de Castilla la Mancha (UCLM). Toledo. Universidad Católica San Antonio (UCAM) Murcia. España)*

La dirección de Archivos de Medicina el Deporte desea agradecer a todos su desinteresada colaboración.

Guidelines of publication Archives of Sports Medicine

The ARCHIVES OF SPORTS MEDICINE Journal (Arch Med Deporte) with ISSN 0212-8799 is the official publication of the Spanish Federation of Sports Medicine. This journal publishes original works about all the features related to Medicine and Sports Sciences from 1984. This title has been working uninterruptedly with a frequency of three months until 1995 and two months after this date. Arch Med Deporte works fundamentally with the system of external review carried out by two experts (peer review). It includes regularly articles about clinical or basic research, reviews, articles or publishing commentaries, brief communications and letters to the publisher. The articles may be published in both SPANISH and ENGLISH. The submission of papers in English writing will be particularly valued.

Occasionally oral communications accepted for presentation in the Federation's Congresses will be published.

The Editorial papers will only be published after an Editor requirement.

The manuscripts accepted for publication will become FEMEDE property and their reproduction, total or partial, must be properly authorized. All the authors will have to send a written letter conceding these rights as soon as the article is accepted for publication.

Submit of manuscripts

1. The papers must be submitted at the Editor in Chief's attention, written in double space in a DIN A4 sheet and numbered in the top right corner. It is recommended to use Word format, Times New Roman and font size 12. They must be sent by e-mail to FEMEDE's e-mail address: femede@femede.es.
2. On the first page exclusively it should include: title (Spanish and English), authors' first name, initial of the second name (if applicable), surname and optionally the second one; Main official and academic qualifications, workplace, full address and corresponding author e-mail. Supports received in order to accomplish the study – such as grants, equipments, medicaments, etc- have to be included.
   A letter in which the first author on behalf of all signatories of the study, the assignment of the rights for total or partial reproduction of the article, once accepted for publication shall be attached.
   Furthermore, the main author will propose up to four reviewers to the editor. According to the reviewers, at least one must be from a different nationality than the main author. Reviewers from the same institutions as the authors, will not be accepted.
3. On the second page the abstract of the work will appear both in Spanish and English, and will have an extension of 250-300 words. It will include the intention of the work (aims of the research), methodology, the most out-standing results and the main conclusions. It must be written in such a way to allow the understanding of the essence of the article without reading it completely or partially. After the abstract, from three to ten key words will be specified in Spanish and English, derived from the Medical Subject Headings (MeSH) of the National Library of Medicine (available in: http://www.nlm.nih. gov/mesh/MBrowser.html).
4. The extension of the text will change according to the section applicable:
   a. Original research: maximum 5.000 words, 6 figures and 6 tables.
   b. Review articles: maximum 5.000 words, 5 figures and 4 tables. In case of needing a wider extension it is recommended to contact the journal Editor.
   c. Editorials: they will be written by Editorial Board request.
   d. Letters to the Editor: maximum 1.000 words.
5. Structure of the text: it will change according to the section applicable:
   a. **ORIGINALS RESEARCH**: It will contain an introduction, which must be brief and will contain the aim of the work, written in such a way that the reader can understand the following text.
   Material and method: the material used in the work will be exposed, as well as its characte¬ristics, selection criteria and used techniques, facilitating the necessary data in order to allow the reader to repeat the experience shown. The statistical methods will be detailed described.
   Results: Results must report and not describe the observations made with the material and method used. This information can be published in detail in the text or using tables and figures. Information given in the tables or figures must not be repeated in the text.
   Discussion: The authors will expose their opinions about the results, their possible interpretation, relating the observations to the results obtained by other authors in similar publications, suggestions for future works on the topic, etc. Connect the conclusions with the aims of the study, avoiding free affirmations and conclusions not supported by the information of the work.
   The acknowledgments will appear at the end of the text.

b. **REVIEWS ARTICLES:** The text will be divided in as much paragraphs as the author considers necessary for a perfect compre-hension of the topic treated.

c. **LETTERS TO THE EDITOR:** Discussion about published papers in the last two issues, with the contribution of opinions and experiences briefed in 3 pages, will have preference in this Section.

d. **OTHERS:** Specific sections commissioned by the Journal's Editorial Board.

6. **Bibliography:** it will be presented on pages apart and will be ordered following their appearance in the text, with a correlative numeration. In the text the quote's number will be presented between parentheses, followed or not by the authors' name; if they are mentioned, in case the work was made by two authors both of them will figure, and if there are more than two authors only the first will figure, followed by "et al".

   There will not be personal communication, manuscripts or any unpublished information included in the bibliographical ap-pointments.

   The official citation for the journal Archives of Sports Medicine is Arch Med Sport.

   References will be exposed in the following way:

   - **Journal: order number;** surnames and name's initial of the article authors with no punctuation and separated with a comma (if the number of authors is higher than six, only the six first will figure, followed by "et al"); work's title in its original language; abbreviated journal name, according to the World Medical Periodical; year of publication; volume number; first and last page of the quoted extract. Example: Calbet JA, Radegran G, Boushel R and Saltin B. On the mechanisms that limit oxygen uptake during exercise in acute and chronic hypoxia: role of muscle mass. *J Physiol.* 2009;587:477-90.
   - **Book chapter**: Authors, chapter title, editors, book title, city, publishing house, year and number of pages. Example: Iselin E. Maladie de Kienbock et Syndrome du canal carpien. En : Simon L, Alieu Y. Poignet et Medecine de Reeducation. Londres : Collection de Pathologie Locomotrice Masson; 1981. p162-6.
   - **Book**. Authors, title, city, publishing house, year of publication, page of the quote. Example: Balius R. Ecografía muscular de la extremidad inferior. Sistemática de exploración y lesiones en el deporte. Barcelona. Editorial Masson; 2005. p 34.
   - **World Wide Web**, online journal. Example: Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis (revista electrónica) 1995 JanMar (consultado 0501/2004). Available in: http://www.cdc.gov/ncidod/EID/ eid.htm

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

   Tables shall be numbered according to the order of appearance in the text, with the title on the top and the abbreviations described on the bottom. All nonstandard abbreviations which may be used in the tables shall be explained in footnotes.

   Any kind of graphics, pictures and photographies will be denomi-nated figures. They must be numbered correlatively by order of appearance in the text and will be sent in black and white (except in those works in which colour is justified). Color printing is an economic cost that has to be consulted with the editor.

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

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

8. The Journal's Editorial Staff will communicate the reception of sub-mitted articles and will inform about its acceptance and possible date of publication.
9. After hearing the reviewers' suggestions (journal uses peer correc-tion system), may reject the works which are not suitable, or indicate the author the modifications which are thought to be necessary for its acceptance.
10. The Editorial Board is not responsible for the concepts, opinions or affirmations supported by the authors.
11. Submissions of the papers: Archives of Sports Medicine. By e-mail to FEMEDE'S e-mail address: femede@femede.es. The submission will come with a cover letter on which the work's examination for its publication in the Journal will be requested, article type will be specified, and it will be certified by all authors that the work is original and has not been partially or totally published before.

Conflicts of interests

If there should be any relation between the work's authors and any public or private entity, from which a conflict of interests could appear, it must be communicated to the Editor. Authors must fulfil a specific document.

Ethics

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

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

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

Campaña de aptitud física, deporte y salud

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

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

UCAM Universidad Católica San Antonio de Murcia

Campus de los Jerónimos,
Nº 135 Guadalupe 30107

(Murcia) - España

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

UCAM
UNIVERSIDAD
CATÓLICA DE MURCIA