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"José Mataix"

Centro de Investigación
Biomédica

Facultad de Ciencias del Deporte

Universidad de Granada

Cristina Casals – Inflamación, Estrés Oxidativo y Rendimiento de Judokas Españoles de Élite

Inflamación, Estrés Oxidativo y Rendimiento de Judokas Españoles de Élite

Inflammation, Oxidative Stress and Performance of Elite Spanish Judokas

Universidad de Granada

Cristina Casals Vázquez

Tesis doctoral 2016

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INFLAMMATION, OXIDATIVE STRESS AND PERFORMANCE OF ELITE SPANISH JUDOKAS

Departamento de Fisiología

Programa de doctorado de Nutrición Humana

Instituto de Nutrición y Tecnología de los Alimentos "José Mataix"

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2016

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CERTIFICAN:

Que la Tesis Doctoral titulada: "Inflamación, estrés oxidativo y rendimiento de judokas españoles de élite" que presenta Dña. Cristina Casals Vázquez ha sido realizada bajo nuestra dirección, habiendo concluido y reunido a nuestro juicio las condiciones de originalidad y rigor científicas requeridas, por lo que autorizamos su presentación y defensa ante el Tribunal que designe la Universidad de Granada.

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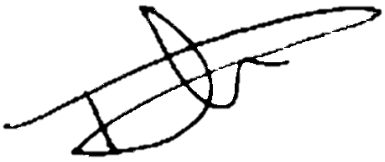

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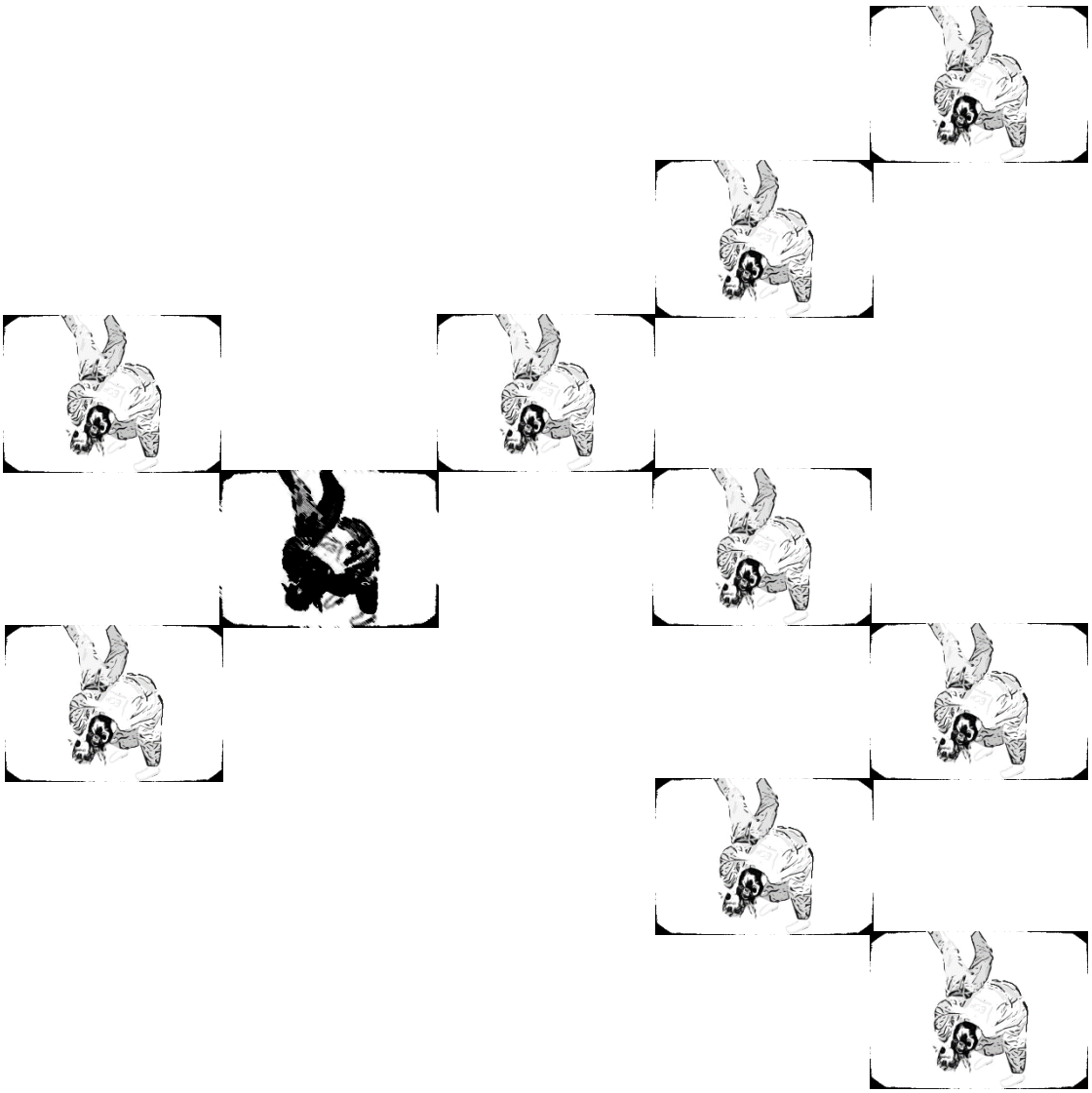
A mi madre

que me enseñó a leer

CONTENIDOS / CONTENTS



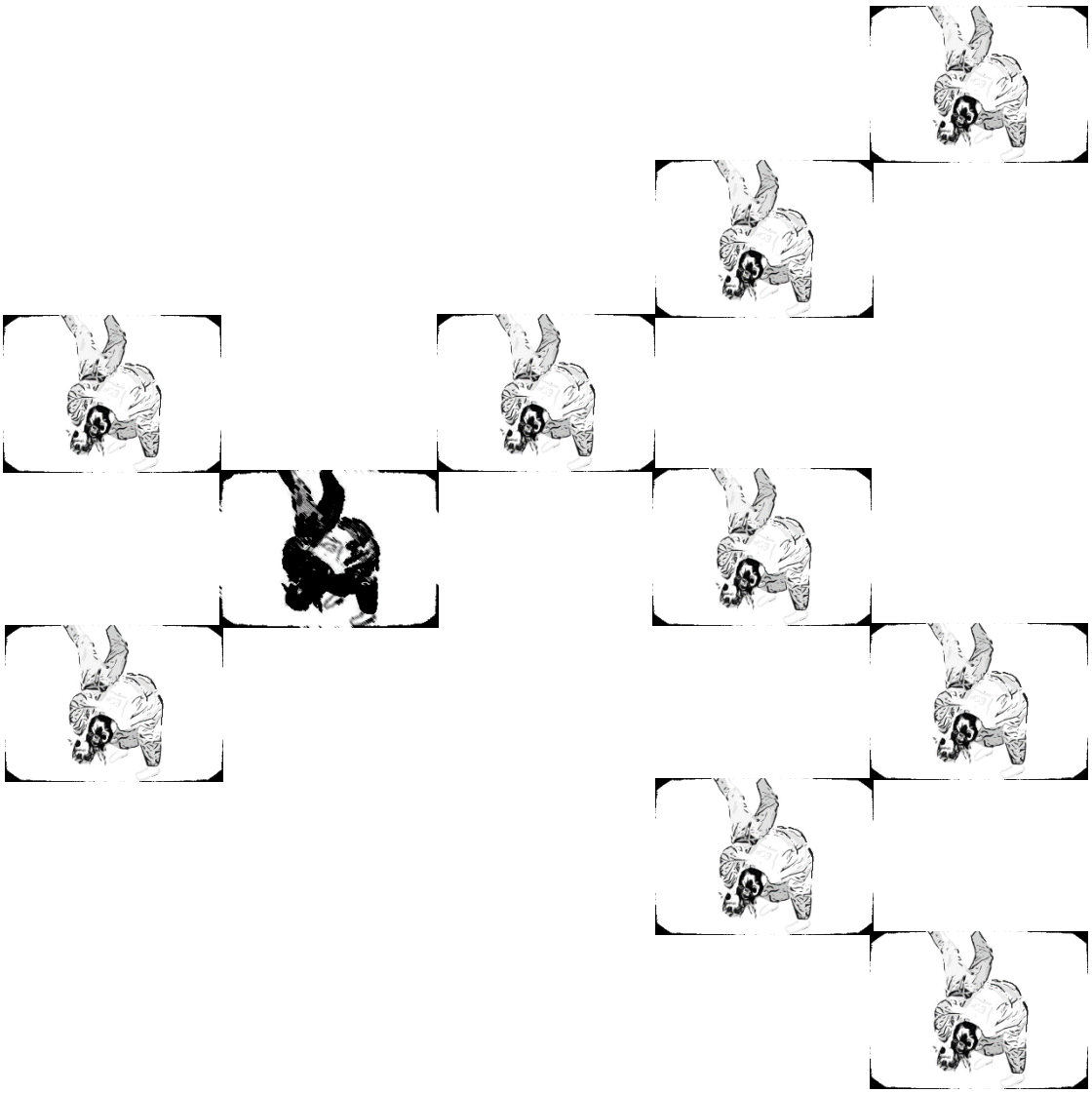
Resumen

La presente tesis doctoral titulada “Inflamación, estrés oxidativo y rendimiento de judokas españoles de élite”, consta de dos secciones principales.

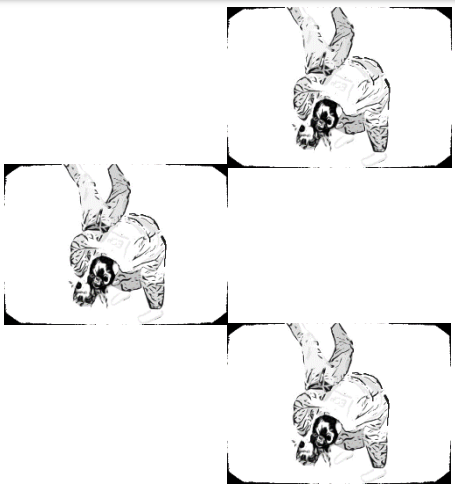
En la primera sección se realiza una evaluación antropométrica, del rendimiento y de la presencia de factores de riesgo de enfermedades cardiovasculares atendiendo a las diferentes categorías de peso en judo. En el **Artículo 1** se seleccionan las variables antropométricas que mejor predicen el rendimiento en el *Special Judo Fitness Test*, mostrando que los judokas de élite del equipo nacional deberían aumentar su porcentaje corporal de masa muscular y reducir la masa grasa, donde concretamente el pliegue subcutáneo del bíceps destacó como indicador de rendimiento. Además, los judokas de mayor masa corporal obtuvieron peores resultados en el test; por lo que, para poder interpretar adecuadamente el nivel de rendimiento específico de cada judoka, el baremo de clasificación del *Special Judo Fitness Test* debería adaptarse a las diferentes categorías de peso. El **Artículo 2** destaca la presencia de factores de riesgo cardiovascular en los judokas pese a su temprana edad y nivel de condición física. Entre los factores de riesgo analizados, predominaron la presencia de hipertensión arterial, los niveles bajos de colesterol HDL, el exceso de grasa corporal en las categorías de mayor peso y el hecho de que más de la mitad de los judokas superaban el peso permitido en su categoría de competición.

La segunda sección corresponde al **Artículo 3** y **Artículo 4**, en la cual se analizan marcadores sanguíneos de estrés oxidativo, inflamación y daño muscular en judokas españoles de élite en reposo y tras una prueba de esfuerzo específica de judo (el *Special Judo Fitness Test*). Los deportistas, que fueron evaluados durante el periodo competitivo, presentaban niveles óptimos en las variables seleccionadas; por consiguiente, no mostraron síntomas de sobre-entrenamiento y el ejercicio intermitente de alta intensidad y corta duración no supuso un aumento significativo del daño muscular. Concretamente, en el **Artículo 3** se analizan las diferencias por sexo en los valores plasmáticos de estrés oxidativo, inflamación y daño

muscular. Los resultados mostraron un aumento de las citoquinas pro-inflamatorias (IL-6 y TNF-α) en hombres como respuesta a la prueba de esfuerzo, mientras que las mujeres no presentaron diferencias en las variables inflamatorias según el momento y tenían menores valores plasmáticos de peroxidación lipídica que los varones. En el **Artículo 4** se analizaron diferencias debidas a la edad comparando dos categorías de competición (cadetes vs. seniors), así pues, se detectaron diferencias significativas en los valores inflamatorios y de estrés oxidativo. En la categoría senior, los niveles de peroxidación lipídica aumentaron en respuesta a la prueba de esfuerzo, mientras que esto no ocurrió en la categoría de cadetes debido, posiblemente, a una rápida movilización de antioxidantes no enzimáticos (α-tocoferol y retinol) del pool plasmático a los tejidos activos durante el ejercicio físico.



Abstract

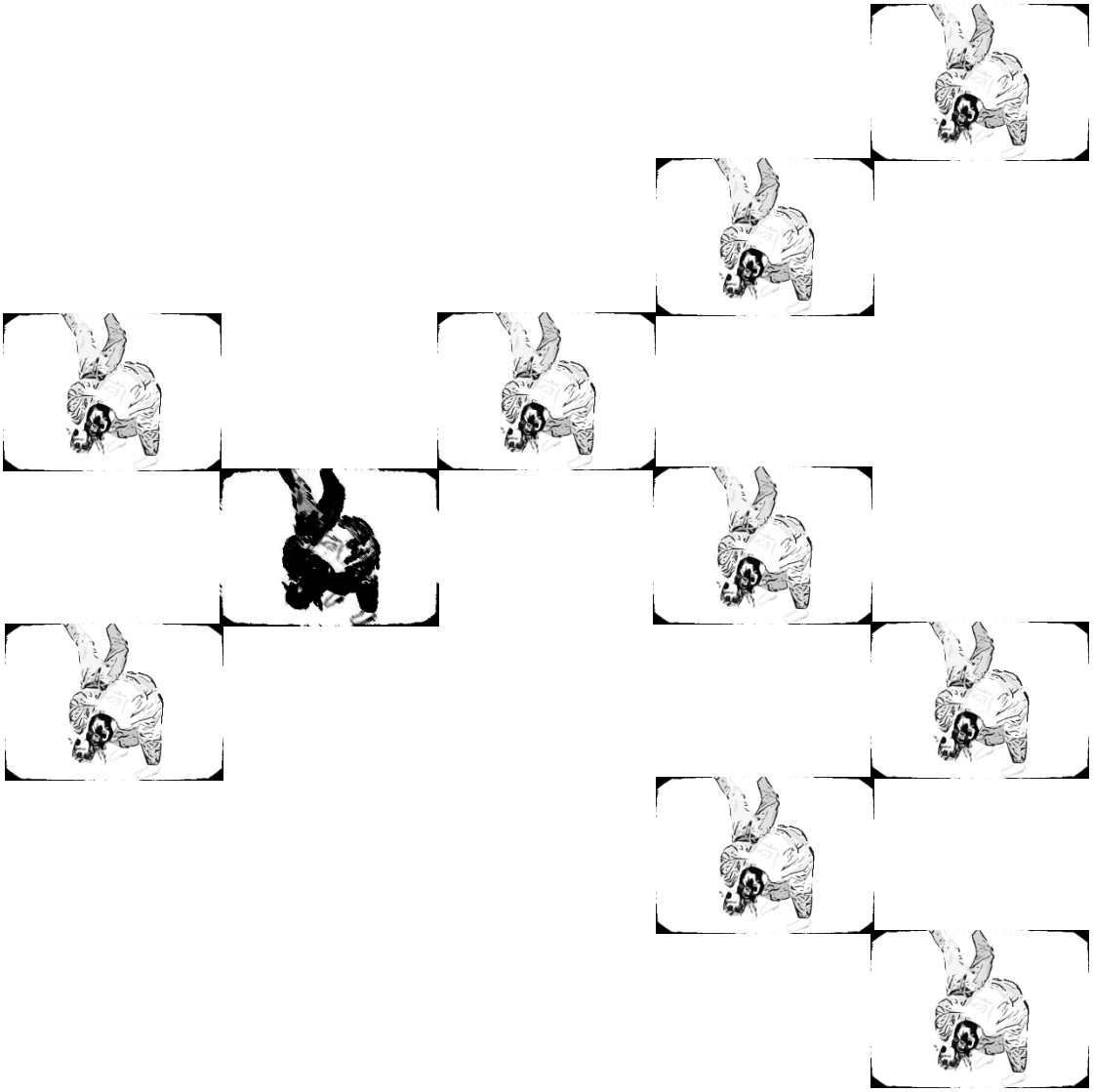


This doctoral thesis, entitled “Inflammation, oxidative stress and performance of elite Spanish judokas”, consists of two main sections.

The first section provides information about the anthropometric profile, performance, and presence of risk factors of cardiovascular diseases, analysing the differences among judo weight categories. Thus, in the **Article 1**, the anthropometric variables that best predict the Special Judo Fitness Test performance are selected, suggesting that elite judokas from the Spanish National Team should increase their body percentage of muscle mass and reduce fat mass where, specifically, the biceps skinfold highlighted as performance indicator. Additionally, heavier judokas achieved worse Special Judo Fitness Test results than lighter ones; consequently, the test classificatory norms should be adapted to weight categories in order to properly interpret the specific judo performance of each athlete. The **Article 2** indicates that the presence of cardiovascular risk factors was quite high despite the judokas’ young age and fitness level. Among the analysed risk factors highlighted the presence of hypertension, low levels of HDL-cholesterol, body fat excess in the heavier categories, and the fact that more than half of the judokas exceed the allowed weight in their respective categories.

The second section corresponds to the **Article 3** and **Article 4**, in which blood biomarkers of oxidative stress, inflammation, and muscle damage were analysed in elite Spanish judokas at rest and after a specific-judo test (the Special Judo Fitness Test). All athletes, who were assessed during a competitive period, showed optimal values in the selected variables; therefore, they did not present symptoms of overtraining syndrome and the short-duration, high-intensity intermittent effort did not promote a significant increase of muscle damage. In the **Article 3**, sex-specific differences in plasma values of oxidative stress, inflammation, and muscle damage were reported. The main findings indicated an increase of pro-inflammatory cytokine (IL-6 y TNF-α) responses to exercise in males, whereas in females the inflammatory variables were similar between moments and their plasma levels of lipid peroxidation were

lower than those of males. In the **Article 4**, age-related differences were analysed by comparing two competitive categories (cadets vs. seniors); thus, some inflammatory and oxidative stress differences were reported. In the senior category, the lipid peroxidation values increased in response to the exercise test, whereas this fact did not occur in the cadet category probably due to a quickly mobilization of non-enzymatic antioxidants (α-tocopherol and retinol) from the plasma pool to the active tissues during exercise.



Justificación

La evaluación fisiológica del deportista de élite es de vital importancia tanto para su salud como para el éxito competitivo. En judo, las demandas físicas sobre los deportistas son muy elevadas, donde el judoka necesita una excelente capacidad anaeróbica para conseguir derribar a su oponente durante la competición a través de movimientos explosivos de alta intensidad [1]. Los combates de judo suelen durar una media de 3 minutos formados por 20-30 segundos de actividad y 5-10 segundos de pausa mostrando un carácter intermitente [2,3], además en un mismo campeonato el judoka debe realizar varios combates, por lo que su capacidad aeróbica es también esencial para el éxito competitivo y para conseguir recuperaciones óptimas y eficientes [2,4].

De tal forma, el programa de entrenamiento de los judokas de élite supone una gran demanda física y un elevado estrés fisiológico [5], que puede repercutir en el status oxidativo e inflamatorio de los deportistas [6]. Asimismo, los judokas están sometidos a un doble estrés fisiológico ya que, además del entrenamiento físico, deben mantener un peso acorde al de competición. El hecho de que el judo sea un deporte con clasificaciones por peso propicia la práctica de métodos poco saludables para la reducción drástica de peso antes de la competición [7,8]. Los deportistas suelen reducir entre un 2 a un 10% del peso corporal en los 2-3 días previos a la competición para clasificarse en una categoría de peso más ligera [9], lo cual ha sido propuesto como una práctica antideportiva.

Los métodos más comunes de reducción drástica de peso comprenden tanto dietas calórico-restrictivas como métodos de deshidratación (restricción de líquidos y sudoración intencionada) [9]. Ambos métodos inciden sobre el balance de estrés oxidativo, ya que los deportistas que consumen dietas bajas en calorías para reducir el peso rápidamente parecen tener un déficit en la ingesta de vitaminas como la A, E y B9 [10] y, además, la deshidratación puede aumentar la aparición de estrés oxidativo, inflamación y daño muscular en respuesta al ejercicio físico [11-13]. Por consiguiente, el estado de salud de los judokas de élite podría estar

más comprometido que en otras disciplinas deportivas, especialmente durante el periodo competitivo. La evaluación de estos deportistas se hace, por lo tanto, esencial para controlar su estado de salud y potenciar al máximo su rendimiento deportivo. Entre los diferentes marcadores comúnmente empleados para valorar la fatiga muscular del deportista se encuentran los marcadores sanguíneos de estrés oxidativo, inflamación y daño muscular, así como las pruebas específicas de esfuerzo [14].

El estrés oxidativo puede definirse como un desequilibrio entre las sustancias pro y anti oxidantes en favor de las primeras [15]. Así pues, cuando hay un exceso de pro-oxidantes o sustancias reactivas del oxígeno (EROS) que sobrepasa la capacidad antioxidante, se produce la oxidación de lípidos y proteínas, apoptosis y reducción de la fuerza muscular [15-17]. Sin embargo, una producción moderada de EROS tiene un papel clave en la señalización de numerosas funciones vitales y de varias adaptaciones al ejercicio, como la mejora de la capacidad antioxidante y la hipertrofia [15-18].

La evidencia científica indica que en respuesta al ejercicio físico se produce un aumento de la producción de EROS, que tienen como principal fuente de origen la cadena de respiración mitocondrial [15,16]. No obstante, durante un combate de judo otros mecanismos de producción de EROS cobran importancia, como el mecanismo de isquemia-reperfusión o la inflamación local por contusiones [19,20]. Por lo tanto, se justifica la evaluación del judoka que está sometido a un gran estrés fisiológico y podría presentar estrés oxidativo con una excesiva liberación de citoquinas pro-inflamatorias y un consiguiente aumento del daño muscular llevando al deportista, en última instancia, a una reducción crónica de su rendimiento o síndrome de sobre-entrenamiento [21,22].

Igualmente cabe destacar que el establecimiento de categorías por peso de cara a la competición permite la presencia de judokas de élite con sobrepeso en las categorías más pesadas, ya que

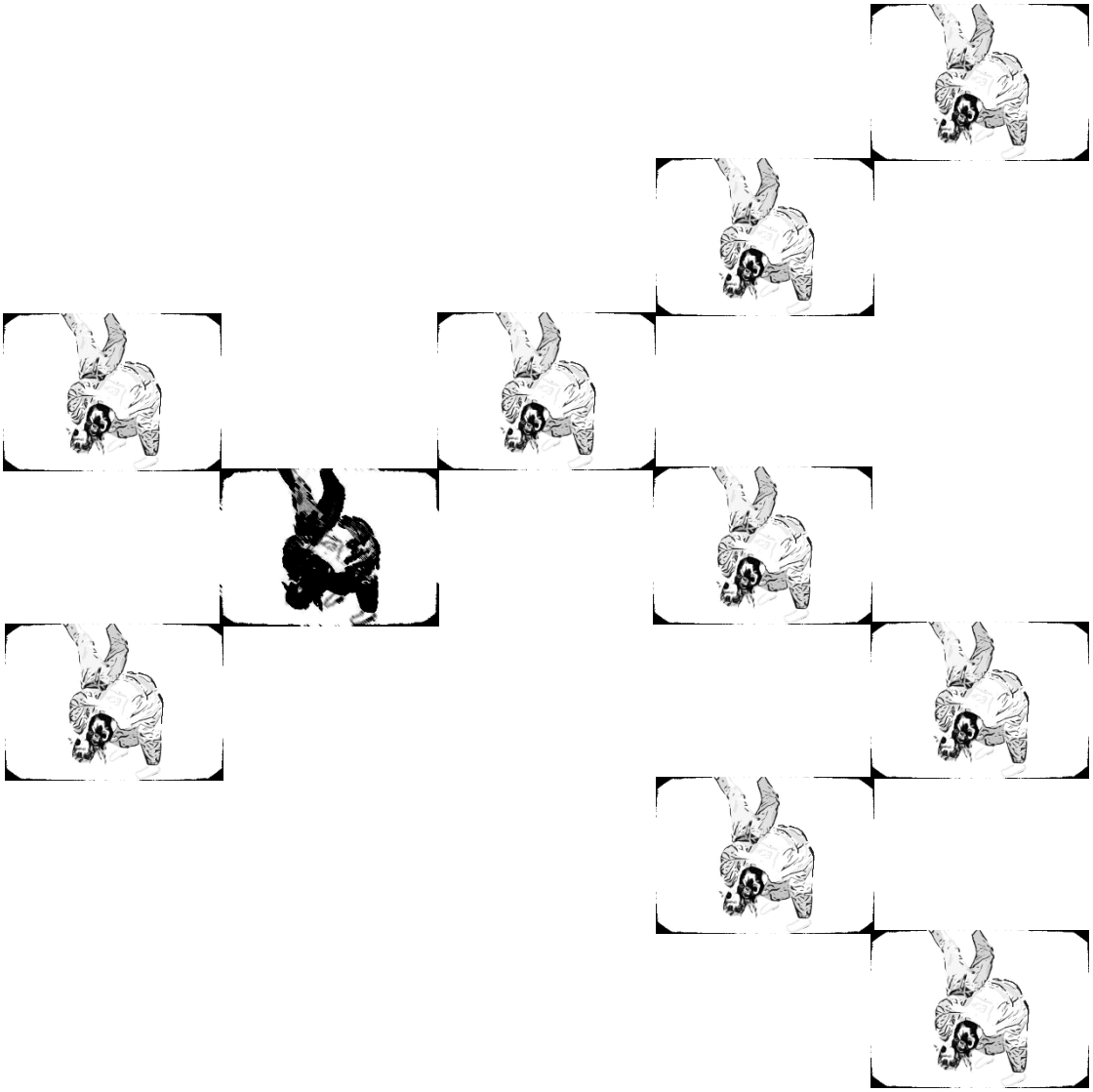
no hay ningún control del contenido graso. Así, el estado de salud de estos deportistas puede verse comprometido, en tanto en cuanto el exceso de masa grasa es un factor de riesgo del desarrollo de enfermedades cardiovasculares que suponen la primera causa de muerte mundial [23]. A esto debemos unirle lo previamente mencionado sobre el hecho de que los judokas suelen reducir drásticamente su peso en los días previos a la competición [7-9]. En concreto, se estima que más de la mitad de los atletas de deportes de combate realizan cambios cíclicos de peso [24], lo que también aumenta el riesgo cardiovascular [25,26]. De tal forma, parece conveniente la identificación de los factores de riesgo cardiovascular en judokas de élite para prevenir el desarrollo de estas enfermedades; especialmente en las categorías de peso más elevadas, donde los deportistas suelen tener un mayor porcentaje de grasa corporal pese a ser de élite [27].

Precisamente, la existencia de estas diferencias entre categorías de peso hace más difícil establecer el perfil antropométrico óptimo de los judokas de élite, que pueda ayudar en la selección de talentos deportivos y en la evaluación durante el programa de entrenamiento. Así pues, del mismo modo que parece haber un impacto de la categoría de peso sobre el perfil fisiológico y la condición física de los judokas [28], estas diferencias han sido levemente descritas en las pruebas de esfuerzo que se utilizan para evaluar el rendimiento específico, por ejemplo en los resultados del *Special Judo Fitness Test*. La importancia de este análisis radica en que el *Special Judo Fitness Test* es una de las pruebas de esfuerzo más utilizadas en judo [29-32], tanto en el ámbito científico como deportivo, debido a su fácil aplicación y a su especificidad que le hace más útil en estos deportistas que la realización de un Wingate [33]. Sin embargo, la interpretación de los resultados puede que no sea del todo adecuada ya que las normas de clasificación son comunes para todas las categorías de peso.

Por todo ello, creemos de interés la evaluación de los judokas españoles de élite a través de una valoración de la composición corporal, el rendimiento específico y analítica de sangre

estableciendo la presencia de factores de riesgo de enfermedades cardiovasculares, así como un análisis de marcadores sanguíneos de estrés oxidativo, inflamación y daño muscular en respuesta a una prueba de esfuerzo intermitente de alta intensidad específica de judo. Siendo de utilidad el realizar comparaciones según las variables de clasificación en judo, que son el sexo, la edad y el peso corporal, para establecer si deben ser consideradas tanto por los investigadores en futuras investigaciones como por los entrenadores en sus recomendaciones basadas en las variables previamente mencionadas.

Dicha información tiene un especial interés para los profesionales deportivos, ya que permite informar a los deportistas de posibles alteraciones en las variables de interés, tanto en reposo como en respuesta a una prueba de esfuerzo específica de judo; incidiendo en la importancia que tiene mantener hábitos de vida saludables y controles periódicos para llegar a competición en las mejores condiciones posibles y, además, tener un mejor estado de salud a largo plazo tras retirarse de la competición.



Justification

The physiological assessment of the elite athlete is of critical importance for his/her health and competitive success. In judo, the athletes' physical demands are very high, where the judoka requires excellent anaerobic capacity to throw the opponent during competition by executing high-intensity explosive movements [1]. Judo combats usually last about 3 minutes consisted of 20-30 seconds of activity and 5-10 seconds of pause, showing an intermittent characteristic [2,3]; additionally, judokas must perform several combats in each tournament, thus the aerobic capacity is also essential for competitive success and the achievement of optimal and efficient recoveries [2,4].

Accordingly, the judo training program is very demanding and supposes a relevant physiological stress [5], which may impact on the inflammatory status and oxidative stress of elite athletes [6]. Moreover, judokas are subjected to a double physiological stress since, besides the physical training, they should maintain their competitive weight. The fact that judo is a weight-categorized sport promotes the practice of dangerous methods for rapid weight loss before competition [7,8]. In this regard, the athletes frequently reduce a 2-10% of their body mass in the 2-3 days prior competition to classify in a lighter category [9], what has been proposed as an unfair method in sport.

Commonly methods of rapid weight loss comprise calorie-restricted diets and dehydration methods (liquid restriction and intentional sweating) [9]. Both practices impact on the oxidative stress balance since, the athletes who intake low-calorie diets to drastically reduce their weight seem to present deficits of vitamins A, E, and B9 [10], and dehydration also may increase oxidative stress, inflammatory and muscle damage responses to exercise [11-13]. Therefore, the health status of elite judokas could be more compromised than in other sport disciplines, especially during the competitive period. For that, the assessment of these athletes is essential for evaluating their health, promoting the maximum sport performance. Among the most frequently used markers for assessing muscle fatigue in athletes, it can be highlighted the blood

biomarkers of oxidative stress, inflammation and muscle damage, as well as specific exercise tests [14].

Oxidative stress can be defined as an imbalance between pro- and anti-oxidant substances in favour of the first ones [15]. Thus, when the pro-oxidants or reactive oxygen species (ROS) exceed the antioxidant capacity, then oxidative stress occurs leading to lipid and protein oxidation, apoptosis, and impaired muscle force [15-17]. However, a moderate ROS production plays a key role in signalling numerous vital functions and several adaptations to exercise including the increase of antioxidant capacity and hypertrophy [15-18].

The weight of scientific evidence indicates that ROS increase in response to exercise with a main origin source from the mitochondrial chain respiration [15,16]. Notwithstanding, during a judo match there are other relevant mechanisms of ROS production, such as the ischemia-reperfusion phenomenon or local inflammation for trauma and injuries [19,20]. Hence, it is justified the assessment of elite judokas, since they are subjected to a high physiological stress and could present oxidative stress with an up-regulation of pro-inflammatory cytokines and a consequently muscle damage increase, finally leading to a chronic performance reduction or overtraining syndrome [21,22].

Furthermore, the weight-category classification in judo competitions allows the presence of elite athletes with overweight in the heavier categories because there is not a limit of body fat mass. Thus, the judokas' health could be compromised due to the fact that a fat mass excess is a risk factor of the development of cardiovascular diseases, which are the first cause of death globally [23]. Additionally, as has been previously mentioned, judokas usually reduce their body weight in the days before competition [7-9]. Specifically, it has been estimated that more than half of the combat sport athletes practice weight cycling [24], which also increases the cardiovascular risk [25,26]. Therefore, assessing the presence of cardiovascular risk factors in

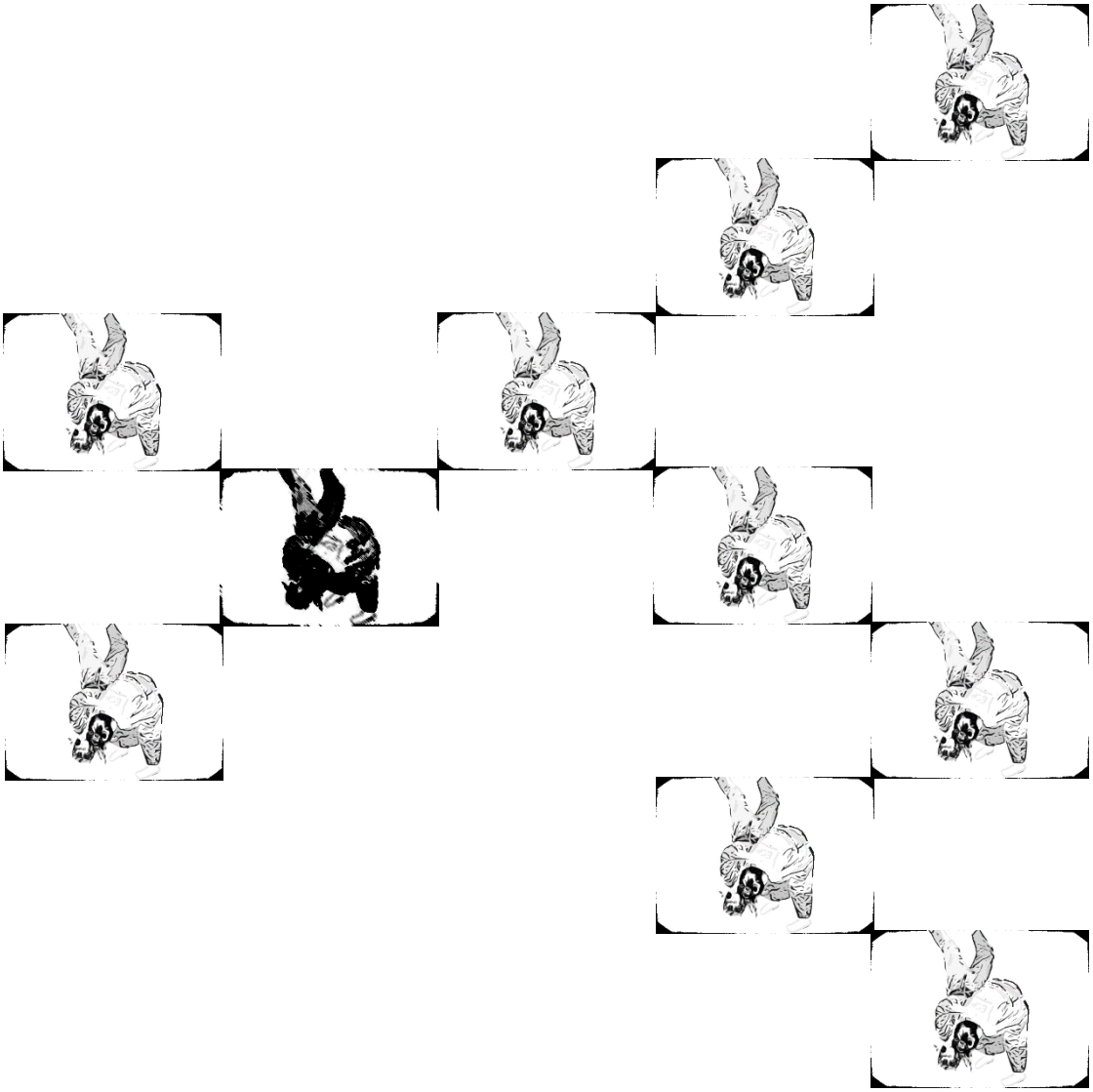
elite judokas is important to prevent the development of these diseases; especially in the heavier categories where athletes commonly have higher body fat percentages than those from lighter categories [27].

In this regard, the existence of differences between weight categories complicates the knowledge about the optimal anthropometric profile of elite judokas, which could be useful in the selection of talented athletes, as well as, in periodic assessments during the training program. Hence, despite it is known that weight category seems to impact on the physiological profile and physical fitness of judokas [28], these weight-differences have been slightly analysed in performance-specific tests, such as the Special Judo Fitness Test. The relevance of this analysis lies in the fact that the Special Judo Fitness Test is one of the most used exercise tests in judo [29-32], both in the scientific and sport context, probably explained by its easy applicability and its specificity what makes the test more appropriate for the judoka evaluation than a Wingate test [33]. Nevertheless, the results interpretation might be inadequate since the classificatory norms are similar in all weight categories.

For all these reasons, we believe that it is appropriate to evaluate the elite Spanish judokas through the assessment of body composition, specific performance, and blood analysis establishing the presence of cardiovascular-diseases risk factors, as well as the assessment of blood biomarkers of oxidative stress, inflammation and muscle damage in response to high-intensity intermittent specific-judo test. Being a key issue the comparisons by judo classificatory variables such as sex, age, and body weight, in order to elucidate whether these factors should be considered in further research and in coaches' recommendations.

This information is useful for sport professionals by providing individual results for each athlete at rest and in response to a judo-specific test; highlighting the importance of adopt

healthy life habits and periodically undergo health assessments for both competitive performance and life after sport retirement.



Referencias / References

1. Marcon G, Franchini E, Jardim JR, Neto TLB. Structural analysis of action and time in sports: judo. *Journal of Quantitative Analysis in Sports* 2010, 6:1-15.
2. Franchini E, Artioli GG, Brito CJ. Judo combat: time-motion analysis and physiology. *International Journal of Performance Analysis in Sport* 2013, 13:624-41.
3. Miarka B, Panissa VLG, Julio UF, Del Vecchio FB, Calmet M, Franchini E. A comparison of time-motion performance between age groups in judo matches. *Journal of Sports Sciences* 2012, 30:899-905.
4. Glaister M. Multiple sprint work: physiological responses, mechanisms of fatigue and the influence of aerobic fitness. *Sports Medicine* 2005, 35:757-77.
5. Franchini E, Brito CJ, Fukuda DH, Artioli GG. The Physiology of Judo-Specific Training Modalities. *Journal of Strength and Conditioning Research* 2014, 28:1474-81.
6. Tanskanen M, Uusitalo A, Kinnunen H, Häkkinen H, Kyröläinen H, Atalay M. Association of military training with oxidative stress and overreaching. *Medicine and Science in Sports and Exercise* 2011, 43:1552-60.
7. Escobar-Molina R, Rodríguez-Ruiz S, Gutiérrez-García C, Franchini E. Weight loss and psychological-related states in high-level judo athletes. *International Journal of Sport Nutrition and Exercise Metabolism* 2015, 25:110-8.
8. 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. *Medicine & Science in Sports & Exercise* 2010, 42:436-42.
9. Artioli GG, Saunders B, Iglesias RT, Franchini E. It is Time to Ban Rapid Weight Loss from Combat Sports. *Sports Medicine* 2016 [Ahead of print].

10. Reljic D, Jost J, Dickau K, Kinscherf R, Bonaterra G, Friedmann-Bette B. Effects of pre-competitional rapid weight loss on nutrition, vitamin status and oxidative stress in elite boxers. *Journal of Sports Sciences* 2015, 33:437-48.
11. King MA, Clnaton TL, Laitano O. Hyperhermia, dehydration, and osmotic stress: unconventional sources of exercise-induced reactive oxygen species. *American Journal of Physiology-Regulatory Integrative and Comparative Physiology* 2016, 310:R105-14.
12. Hillman AR, Vince RV, Taylor L, McNaughton L, Mitchell N, Siegler J. Exercise-induced dehydration with and without environmental heat stress results in increased oxidative stress. *Applied Physiology Nutrition and Metabolism* 2011, 36:698-706.
13. Ozkan I, Cicioglu IH, Dehydration, skeletal muscle damage and inflammation before the competitions among the elite wrestlers. *Journal of Physical Therapy Science* 2016, 28:162-8.
14. Finsterer J, Drory VE. Wet, volatile, and dry biomarkers of exercise-induced muscle fatigue. *BMC Musculoskeletal Disorders* 2016, 17:40.
15. Bloomer RJ, Fisher-Wellman KH. Blood oxidative stress biomarkers: influence of sex, exercise training status, and dietary intake. *Gender Medicine* 2008, 5:218-28.
16. Finaud J, Lac G, Filaire E. Oxidative stress: Relationship with exercise and training. *Sports Medicine* 2006, 36:327-58.
17. Scheele C, Nielsen S, Pedersen BK. ROS and myokines promote muscle adaptations to exercise. *Trends in Endocrinology & Metabolism* 2009, 20:95-9.
18. Radak Z, Zhao Z, Koltai E, Ohno H, Atalay M. Oxygen consumption and usage during physical exercise: the balance between oxidative stress and ROS-dependent adaptive signaling. *Antioxidants & Redox Signaling* 2013, 18:1208-46.

19. Degoutte F, Jouanel P, Filaire E. Energy demands during a judo match and recovery. *British Journal of Sports Medicine* 2003, 37:245-9.

20. Elabed K, Trabelsi K. Kinetics of Oxidative Stress Markers at Rest and in Response to Aerobic and Acute Exercise in Judokas Men. *International Journal of Science and Research* 2014, 3:756-61.

21. Tanskanen M, Atalay M, Uusitalo A. Altered oxidative stress in overtrained athletes. *Journal of Sport Sciences* 2010, 28:309-17.

22. Margonis K, Fatouros IG, Jamurtas AZ, Nikolaidis MG, Douroudos I, Chatzinikolaou A, et al. Oxidative stress biomarkers responses to physical overtraining: implications for diagnosis. *Free Radical Biology and Medicine* 2007, 43:901–10.

23. World Health Organization. January 2015. Cardiovascular diseases (CVDs) Fact Sheet no. 317. Available: http://www.who.int/mediacentre/factsheets/fs317/en/ [Accessed 14.02.2016].

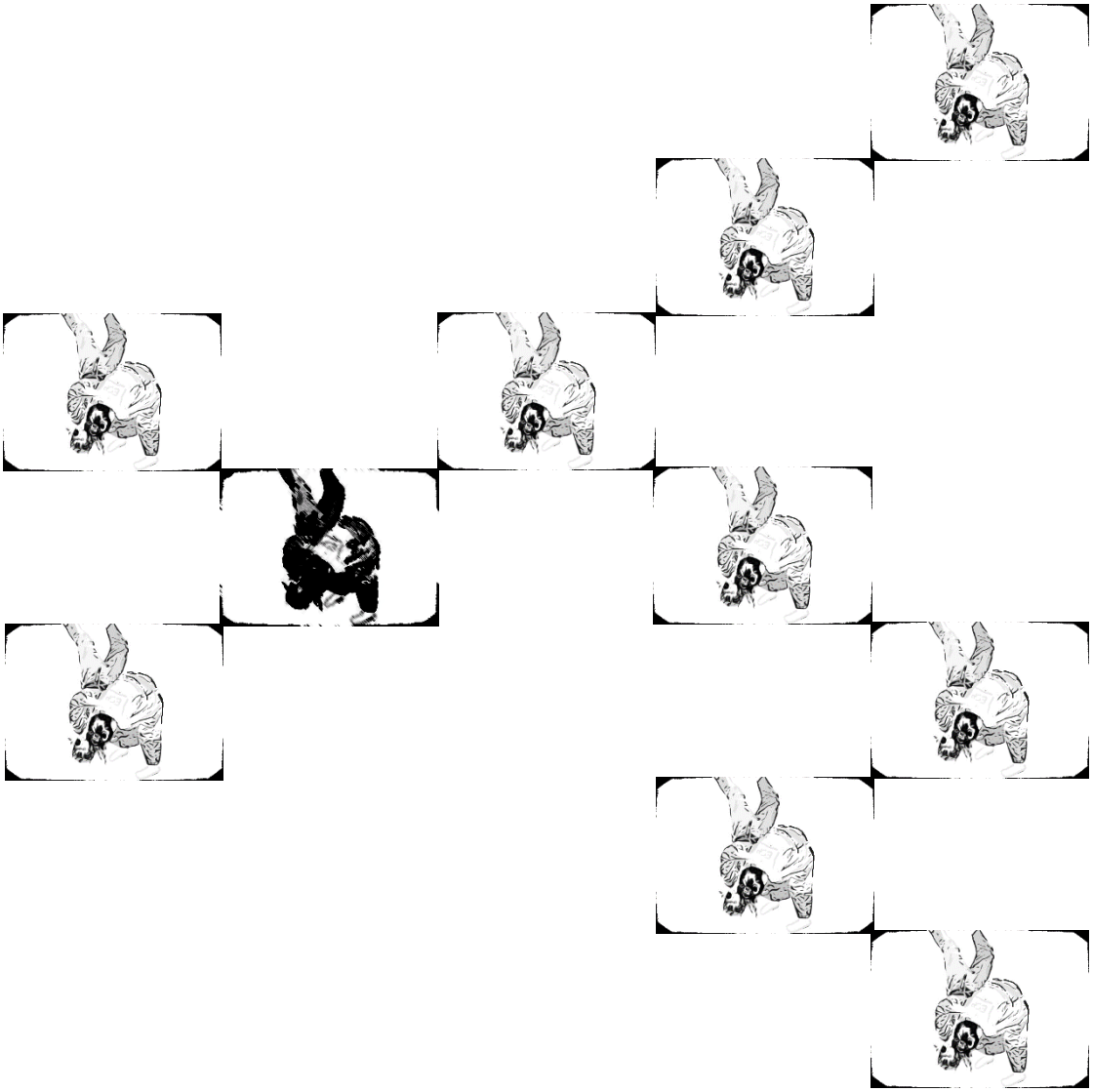
24. Khodaee M, Olewinski L, Shadgan B, Kininham RR. Rapid weight loss in sports with weight classes. *Current Sports Medicine Reports* 2015, 14:435-41.

25. Montani JP, Viecelli AK, Prévot A, Dulloo AG. Weight cycling during growth and beyond as a risk factor for later cardiovascular diseases: the 'repeated overshoot' theory. *International Journal of Obesity* 2006, 30:S58-66.

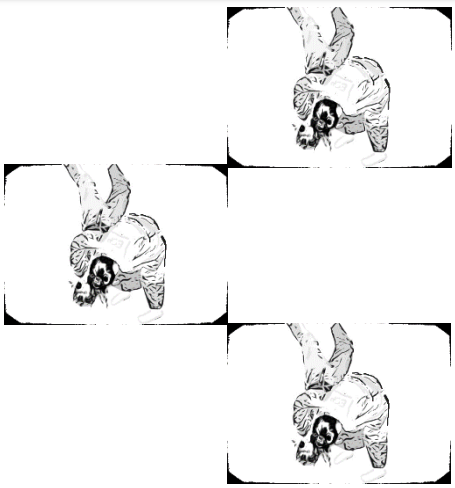
26. Phil E, Jurimae T. Relationships between body weight change and cardiovascular disease risk factors in male former athletes. *International Journal of Obesity and Related Metabolic Disorders* 2001, 25:1057-62.

27. Franchini E, Sterkowicz-Przybycien K, Takito MY. Anthropometrical Profile of Judo Athletes: Comparative Analysis Between Weight Categories. *International Journal of Morphology* 2014, 32:36-42.

28. Franchini E, Del Vecchio FB, Matsushigue KA, Artioli GG. Physiological Profiles of Elite Judo Athletes. *Sports Medicine* 2011, 41:147-66.
29. Sterkowicz S. Test specjalnej sprawnosci tuchowej w judo. *Antropomotoyka* 1995, 12-13:29-44.
30. Drid P, Trivic T, Tabakov S. Special judo fitness test – a review. *Serbian Journal of Sports Sciences* 2012, 6:119-27.
31. Franchini E, Sterkowicz S, Szmatlan-Gabrys U, Gabrys T, Garnys M. Energy System Contributions to the Special Judo Fitness Test. *International Journal of Sports Physiology and Performance* 2011, 6:334-43.
32. Tavra M, Franchini E, Krstulovic S. Discriminant and factorial validity of judo-specific tests in female athletes. *Archives of Budo* 2016, 12:93-9.
33. Szmuchrowski LA, Rodrigues SA, Corgosinho RF, Pinheiro GS, Pedrosa GF, Motta Drummond MD, et al. Correlation between the performance in the Special Judo Fitness Test and the Wingate Anaerobic Test. *Archives of Budo* 2013, 9:175-9.



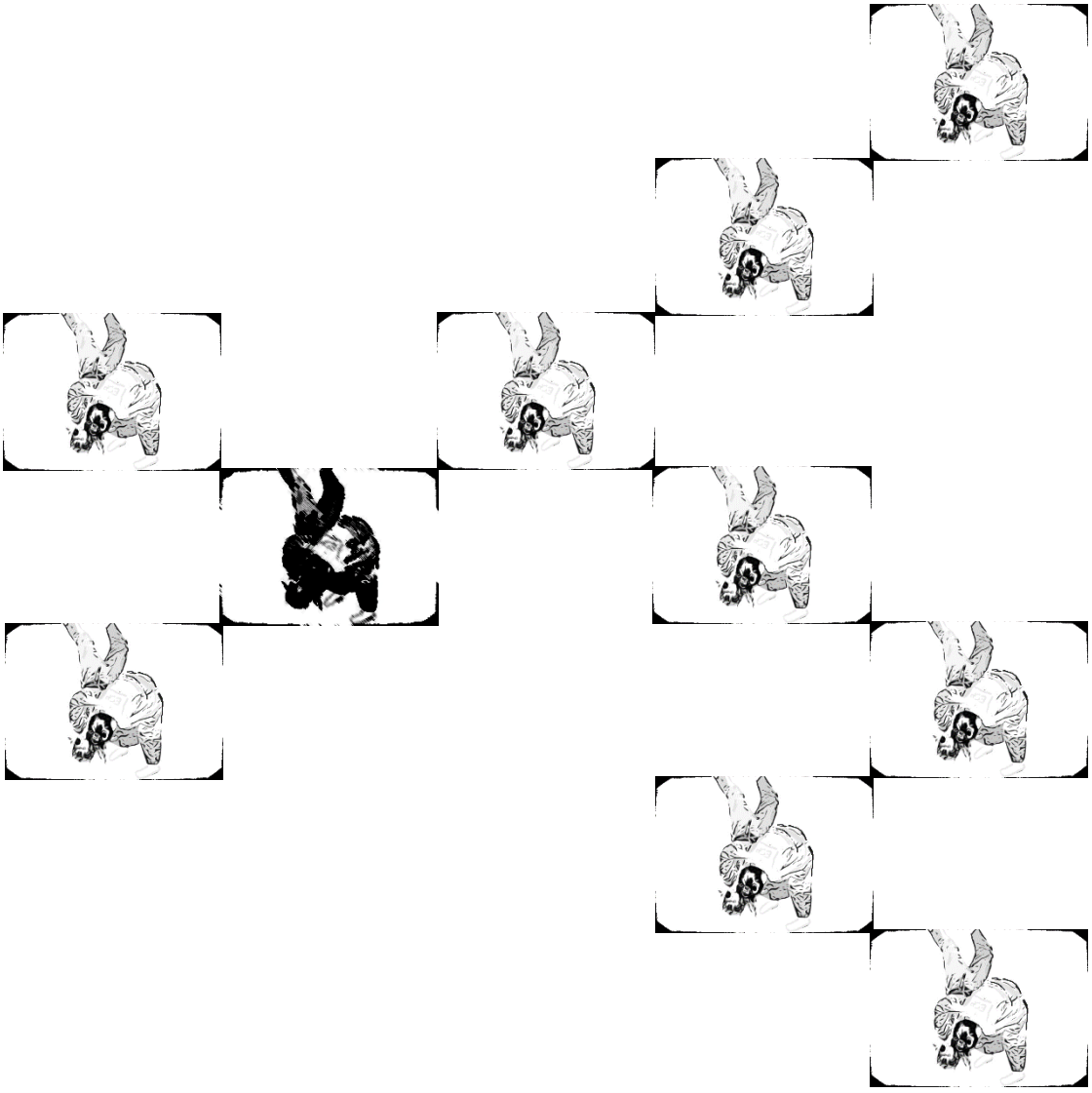
Objetivos



El objetivo general de la presente tesis doctoral fue evaluar el estado de salud y rendimiento de judokas españoles de élite durante el periodo competitivo a través de una valoración antropométrica, una prueba de esfuerzo específica de judo y la determinación de la presencia de factores de riesgo cardiovascular, así como el análisis de marcadores de estrés oxidativo, inflamación y daño muscular en reposo y tras una prueba de esfuerzo.

Los objetivos específicos pueden desglosarse en los siguientes:

- Determinar el perfil antropométrico de los judokas españoles de élite, así como su rendimiento específico, analizando las diferencias entre sexos y las categorías junior y senior (**Artículo 1**).
- Seleccionar las variables antropométricas que mejor predicen el rendimiento específico en judo estimado a través del *Special Judo Fitness Test* (**Artículo 1**).
- Analizar la presencia de factores de riesgo cardiovascular en los judokas de élite a través del índice de masa corporal, la masa grasa, presión arterial, perfil lipídico, glucemia, función renal y hepática; comparando, además, a los judokas agrupados en tres categorías de acuerdo al peso (**Artículo 2**).
- Analizar marcadores sanguíneos de estrés oxidativo, inflamación y daño muscular de judokas de élite en reposo y tras una prueba de esfuerzo consistente en un ejercicio intermitente de alta intensidad y corta duración (**Artículo 3** y **Artículo 4**).
- Comparar las diferencias entre hombres y mujeres en los mencionados marcadores tanto en reposo como en respuesta al ejercicio (**Artículo 3**).
- Determinar las diferencias entre las categorías de edad de cadetes (15-17 años) y seniors (>21 años) en el perfil inflamatorio y el estrés oxidativo en reposo y tras el esfuerzo intermitente de alta intensidad (**Artículo 4**).

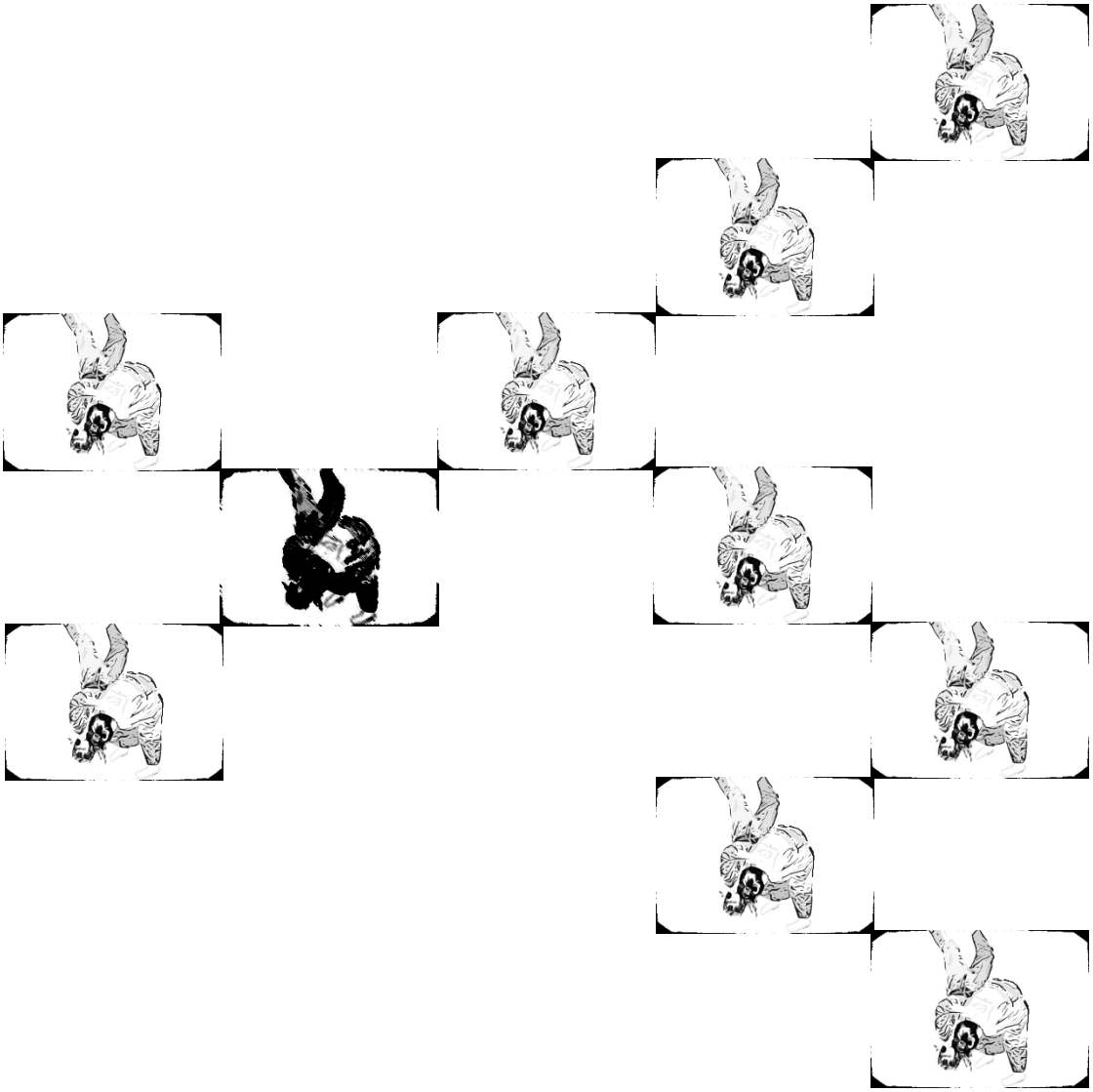


Objectives

The main aim of the present doctoral thesis was to evaluate the health and performance of elite Spanish judokas during a competitive period through an anthropometric assessment, a judo specific test and the analysis of cardiovascular risk factors, as well as the assessment of inflammatory, oxidative stress and muscle damage biomarkers at rest and after the exercise test.

The specific aims of the study can be detailed as follows:

- To assess the anthropometric profile and specific performance of elite Spanish judo athletes comparing the results by sex and the junior and senior categories (**Article 1**).
- To select the anthropometric variables that best predict the judo specific performance estimated through the Special Judo Fitness Test (**Article 1**).
- To determine the presence of cardiovascular risk factors in the elite judokas by using the body mass index, fat mass, blood pressure, lipid profile, glycaemia, renal and hepatic functions; comparing the judokas among three weight-category groups (**Article 2**).
- To analyse blood biomarkers of oxidative stress, inflammation and muscle damage of elite Spanish judokas at rest and after a short-duration, high-intensity intermittent effort (**Article 3** and **Article 4**).
- To compare the differences between male and female athletes in the mentioned biomarkers both at rest and in response to the effort (**Article 3**).
- To establish the differences between cadets (15-17 years) and seniors (>21 years) in their inflammatory profile and oxidative stress levels at rest and after the high-intensity intermittent exercise (**Article 4**).



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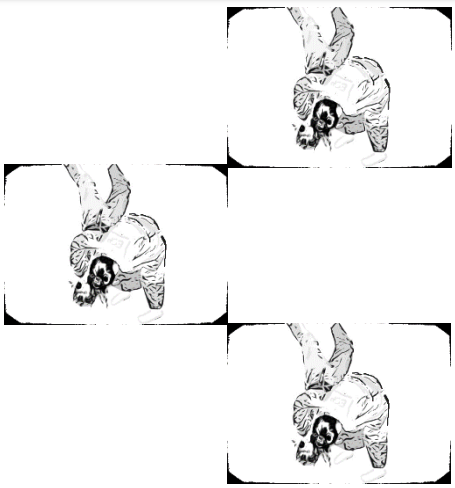

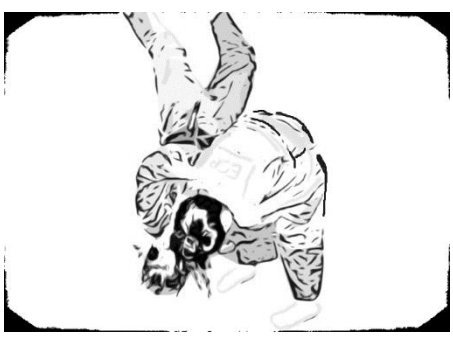

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SPECIAL JUDO FITNESS TEST LEVEL AND ANTHROPOMETRIC PROFILE OF ELITE SPANISH JUDO ATHLETES

SJFT and anthropometric profile of judokas

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ABSTRACT

The aim of the present study was to determine the anthropometric variables that best predict Special Judo Fitness Test (SJFT) performance. In addition, anthropometric profiles of elite Spanish judo athletes were compared by sex and age category (seniors and juniors). In this cross-sectional study, a total of 51 (29 females) athletes from the Spanish National Judo Team were evaluated during a competitive period. All athletes performed the SJFT and underwent an anthropometric assessment through skinfold thickness measurements. Mann-Whitney comparisons by sex and age category showed that males had significantly higher muscle mass and lower fat mass than females ($p<0.001$), whereas juniors and seniors exhibited few differences in body composition. Linear regression analyses (stepwise method) were performed to explore the relationships between anthropometric characteristics and SJFT variables. Model 1 included sex, age category, and body mass as predictors. Body mass and sex significantly predicted the SJFT index ($R2=0.27$, $p<0.001$); thus, both criteria should be considered before interpreting the test. The predictors of model 2 were quick-assessment variables, including skinfolds, breadths, girths, and height. This regression model showed that the biceps skinfold significantly predicted the SJFT index in elite athletes ($R2=0.31$, $p<0.001$). Model 3 included body compositions and somatotypes as predictors. Higher muscle and bone masses and lower ectomorphy were associated with better SJFT performance ($R2=0.44$, $p<0.001$). Hence, training programs should attempt to increase the muscle mass percentage and reduce the upper arm fat, while the bone percentage could be considered in the selection of talented athletes in conjunction with other factors.

Keywords: Anthropometry, somatotypes, body composition, skinfold thickness, martial arts, sports performance.

INTRODUCTION

As judo is a weight-categorized sport, one of the most difficult challenges for elite judo athletes is to achieve excellent physical fitness while maintaining an optimal body mass. Low body fat and a high arm muscle mass have been related to better judo competition performance (8,9,18,22). Moreover, the body composition and somatotypes of judo athletes seem to influence other performance indicators, such as anaerobic power, muscle torque, power output and maximal oxygen uptake (14,21,23). Therefore, the anthropometric profile of an elite athlete could be a relevant factor for success in competition and for performance in specific judo tests.

The assessment of physical fitness in elite judo athletes requires specific tests because the anaerobic system is responsible for the scoring actions in combat, while the aerobic component is required for recovery during and between matches in tournaments (10). On this basis, Sterkowicz (35) developed the Special Judo Fitness Test (SJFT), a specific judo test aimed at evaluating anaerobic and aerobic fitness (34), and it is currently one of the most used tests in judo research (15). Compared to the Wingate Anaerobic Test, the SJFT has proven to be more appropriate for evaluating the anaerobic capacity of judo athletes due to its specificity (38). However, although some studies have considered the correlations between some body composition parameters and SJFT performance (17,20,32), the best anthropometric predictors in elite judo athletes have not been established.

Additionally, the physical fitness of judo athletes differs by judo classification criteria (12,24), including sex (29), age (28,30), and weight category (4,33). Hence, the SJFT results could differ according to these criteria, resulting in the possibility of erroneous interpretations of the test. In light of these considerations, the present study aimed to determine the anthropometric

variables that best predict SJFT performance and to determine whether body mass, sex and age category affect the test's results. Furthermore, in our study, we aimed to compare the body composition and somatotypes of elite Spanish judo athletes by age (junior vs. senior categories) and sex (males vs. females). This information can play a role in the identification of talented athletes, in establishing desirable anthropometric characteristics in elite judo athletes, and in making training plan adjustments.

METHODS

Experimental Approach to the Problem

In this descriptive cross-sectional study, the anthropometric profiles and specific physical fitness of elite Spanish judo athletes were compared regarding sex and age (seniors and juniors). The most significant associations between anthropometric variables and the SJFT index were also established. The study was carried out in the sport facilities of the High Performance Centre "Joaquín Blume" (Madrid, Spain) during the competitive period of one training meeting prior to an international tournament of each of the Spanish national judo teams (juniors and seniors). Anthropometric assessments were performed in the morning (on an empty stomach) and before the daily training sessions. Two hours after the anthropometric evaluation, judo athletes performed the SJFT in an athletic training room after receiving thorough information about the test protocol.

Subjects

The sample consisted of 51 elite athletes from the Spanish National Judo Team (22 males and 29 females) from all weight categories; 9 males and 17 females competed in senior division

(above 20 years of age), while 13 males and 12 females competed in junior division (from 17 to 19 years of age). None of the subjects were under medical and/or psychiatric treatment when participating in the study. This study obtained ethical approval from the Research Ethics Committee of the University of Granada and was in accordance with the Helsinki declaration. After the participants were informed about the procedure and possible risks involved, written informed consent was obtained from all participants or from both parents in cases where the athlete was under 18 years of age.

Procedures

Anthropometric variables and body composition

Anthropometric measurements were performed following the protocol developed by the International Society for Advanced of Kinanthropometry (ISAK) (25). Anthropometric variables included body mass, height, 7 skinfolds (biceps, triceps, subscapular, supraspinal, abdominal, front thigh, and medial calf), 3 girths (upper arm flexed, thigh, and medial calf) and 3 breadths (humeral and femoral epicondyles and wrist). Height was measured to the nearest 0.1 cm using a stadiometer (GPM, Seritex, Inc., Carlstadt, New Jersey). Body mass was measured to the nearest 0.1 kg using a portable scale (model 707, Seca Corporation, Columbia, Maryland). Skinfold thickness was recorded to the nearest 0.2 mm at a constant pressure of 10 g/mm by using a Holtain skinfold caliper (Holtain Ltd., Crymych, UK). Girths were determined to the nearest 0.1 cm using a flexible anthropometric steel tape measure (Holtain Ltd., Crymych, UK). Skinfolds were measured three times at each site in a rotation system, as described by Heyward (19), and the mean of the 3 measurements was used in the analyses. The procedure was performed by a researcher with more than 15 years of experience with this technique. The researcher presented a variation of less than 2.29% between measurements,

with reproducibility determined by an intra-class correlation coefficient of 0.987 within the assessment performance period. Breadths and girths were measured only once at each site by the same experienced evaluator who previously presented less than 0.89% of variation between measurements. Somatotypes were determined according to the Carter and Heath method (6). Body composition was estimated following the four-component model and in accordance with the ISAK recommendations (25). Body fat was assessed by applying the following formula for males (5): Fat%= (∑6skinfolds*0.1051)+2.58; and for females, the following formula was used (5): Fat%= (∑6skinfolds*0.1548)+3.58, where the 6 skinfolds were triceps, subscapular, supraspinal, abdomen, thigh, and medial calf expressed in millimeters. Body muscle mass corresponded to the following equation (40): Muscle(kg)= Total Body Mass – (Fat+Bone+(Total Body Mass*C/100)), where C was 24.1 in males and was 20.9 in females. All variables are expressed in kilograms. Finally, body bone mass was calculated with the following formula for both males and females (31): Bone(kg)= $3.02(Height^2*WristB*FemurB*400)^{0.712}$, where B means breadth and the 3 variables were expressed in meters.

Special Judo Fitness Test

This specific judo test was developed by Sterkowicz (35). Three athletes of similar body mass are needed to perform the SJFT: one participant (tori) is evaluated, and the other two (ukes) receive throws. The tori begins the test between the two ukes (3 m away from each uke). On a signal, the tori runs to one of the ukes and applies a throwing technique called *ippon-seoi-nage* (one shoulder throw). The tori then immediately runs to the other uke and completes another throw. The athlete must complete as many throws as possible within the test time. The SJFT is composed of three parts (15, 30, and 30 seconds) separated by 10-seconds recovery periods.

The total number of throws completed by the tori during each of the three periods was recorded; the tori's heart rate (HR) was measured immediately after and 1 min after the test (Polar Team2, Polar, Finland). The SJFT index was calculated according to the following equation: Index= (HR after + HR 1 minute after) / total number of throws. The index value decreases with better test performance. Reliability values for this test were reported as 0.97 (35).

Statistical analysis

Data are presented as the median and the interquartile range. The Kolmogorov-Smirnov statistic was used to test the normality of distributions. Differences by age category and sex were compared using a Mann-Whitney U test. To explore the relationships between anthropometric characteristics and the SJFT index, linear regression analyses (stepwise method) were performed. A total of 3 models were fitted with the SJFT index as the outcome variable; b-values (B) and standardized b-values (β) were estimated, and R2 and adjusted R2 (ΔR2) were used to provide a goodness-of-fit of the models. Model 1 included sex, age category, and body mass as predictors. This model aimed to establish whether these judo-classification variables affect the SJFT index. Model 2 included the anthropometric variables that can be quickly measured and easily used by coaches and researchers as predictors. The predictors of model 2 were skinfolds, girths, breadths and height. Finally, model 3 included body composition (fat, muscle and bone masses) and somatotypes as predictors to establish possible desirable characteristics in elite judo athletes. Partial correlations were performed for each regression model to better isolate variable relationships without the effect of the other variables included in the predictor model. All analyses were conducted using the SPSS statistical package for Windows (version 17.0; SPSS, Inc., Chicago, Illinois, USA); the level of significance was set at $p<0.05$.

RESULTS

Some classification parameters in judo, such as body mass and sex, significantly affected the SJFT performance of elite Spanish athletes. Moreover, the biceps skinfold had a significant association with the SJFT index, with a prediction of up to 31%, while the ectomorphy component, bone and muscle masses were able to jointly predict 44% of the test results (see Table 1).

Descriptive statistics of the athletes' anthropometric profiles are presented in Table 2, comparing data by sex and age category. Sexual dimorphism in judo athletes was apparent for body fat and muscle percentages, whereas juniors and seniors exhibited few differences in body composition.

Performance indicators achieved in the SJFT are shown in Table 3; their corresponding classifications were estimated according to previous classification norms (11,37). Few significant differences of the specific fitness were found between the four groups of elite athletes, although their SJFT classifications showed relevant differences with better performance grades in juniors than in seniors.

Table 1. Regression analyses and partial correlations of physical fitness and body composition in elite Spanish judo athletes (n=51).

	Regression analyses				Partial correlation	
	B	**SE *B***	***β***	***P***	***r***	***P***
Model 1						
Body mass (kg)	.03	.01	.54	<.001	.489	<.001
Sex (0=female, 1=male)	-.93	.35	-.35	.010	-.225	.116
Model 2						
Biceps skinfold (mm)	.17	.04	.56	<.001	-	-
Model 3						
Bone mass (%)	-.53	.13	-.82	<.001	-.519	<.001
Ectomorphy	.78	.24	.67	.002	.435	.002
Muscle mass (%)	-.06	.02	-.36	.010	-.363	.010

Model 1 Dependent variable: SJFT index, R^2= .27, ΔR^2= .24, p< .001.
Excluded variables: Age category.

Model 2 Dependent variable: SJFT index, R^2= .31, ΔR^2= .30, p< .001.
Excluded variables: Triceps, subscapular, supraspinal, abdominal, thigh and calf skinfolds, arm, thigh and leg girths, femur, humerus and wrist breadths, and height.

Model 3 Dependent variable: SJFT index, R^2= .44, ΔR^2= .40, p< .001.
Excluded variables: Body fat mass, arm and leg muscle areas, endomorphy and mesomorphy.

SJFT: Special Judo Fitness Test.

Table 2. Anthropometric characteristics of elite Spanish judo athletes.

	Median (Interquartile Range)				P values			
	Males		Females		Males vs Females		Seniors vs Juniors	
	Senior (n=9)	Junior (n=13)	Senior (n=17)	Junior (n=12)	Seniors	Juniors	Males	Females
Body mass (kg)	85.9 (24.50)	73.5 (35.35)	62.4 (16.90)	69.8 (23.10)	0.005 *	0.270	0.471	0.152
Height (cm)	180 (15.50)	173 (15.50)	164 (10.80)	167 (10.50)	<0.001 *	0.002 *	0.393	0.370
Body fat (%)	7.81 (3.53)	7.19 (7.29)	16.98 (6.39)	24.97 (13.69)	<0.001 *	<0.001 *	0.896	0.097
Body muscle (%)	52.59 (3.64)	52.11 (4.19)	47.71 (6.88)	40.31 (13.73)	<0.001 *	<0.001 *	0.235	0.140
Body bone (%)	15.09 (2.04)	15.62 (3.46)	14.69 (2.69)	13.63 (2.88)	0.916	0.060	0.324	0.166
Endomorphy	1.91 (1.47)	1.77 (3.25)	2.81 (1.56)	4.63 (2.70)	0.016 *	0.014 *	0.896	0.021 #
Mesomorphy	5.56 (1.36)	4.86 (1.63)	4.39 (2.00)	4.59 (1.15)	0.200	0.225	0.556	0.679
Ectomorphy	1.60 (1.99)	2.31 (2.02)	1.74 (1.28)	0.93 (2.16)	0.597	0.270	0.512	0.152
Arm muscle area (cm^2)	95.7 (24.37)	77.2 (27.36)	70.4 (16.17)	61.3 (9.31)	<0.001 *	<0.001 *	0.021 #	0.080
Leg muscle area (cm^2)	202.5 (35.48)	197.6 (49.94)	143.0 (29.69)	135.4 (20.13)	0.001 *	<0.001 *	0.209	0.263
Biceps skinfold (mm)	3.5 (1.25)	4.0 (3.75)	4.5 (2.00)	6.7 (6.88)	0.021 *	0.019 *	0.357	0.012 #
Triceps skinfold (mm)	6.0 (4.25)	7.5 (7.00)	11.0 (8.50)	16.5 (9.63)	0.002 *	<0.001 *	0.556	0.152
Subscapular skinfold (mm)	10.0 (3.25)	8.5 (15.50)	10.0 (4.25)	17.7 (13.38)	0.396	0.110	0.471	0.117
Supraspinal skinfold (mm)	5.0 (6.25)	5.5 (15.50)	5.0 (4.00)	12.2 (11.13)	0.958	0.030 *	0.948	0.002 #
Abdominal skinfold (mm)	7.5 (7.00)	6.0 (12.25)	13.0 (6.25)	18.5 (14.63)	0.045 *	0.026 *	0.556	0.195
Thigh skinfold (mm)	9.5 (5.75)	10.0 (17.25)	23.0 (13.00)	37.5 (30.25)	<0.001 *	0.004 *	0.556	0.227
Calf skinfold (mm)	12.0 (6.75)	11.0 (10.75)	14.5 (8.00)	27.5 (22.13)	0.013 *	0.007 *	0.896	0.195
Arm girth (cm)	36.2 (5.35)	33.0 (6.45)	32.0 (5.05)	32.0 (4.20)	0.006 *	0.205	0.082	0.811
Thigh girth (cm)	52.8 (7.40)	52.6 (14.50)	51.4 (8.35)	53.5 (8.85)	0.200	0.769	0.512	0.879
Leg girth (cm)	37.6 (5.50)	37.3 (6.70)	35.5 (5.05)	37.2 (5.00)	0.066	0.852	0.647	0.303
Femur breadth (cm)	10.1 (1.25)	9.8 (0.80)	8.8 (0.90)	9.1 (1.00)	0.004 *	0.005 *	0.794	0.370
Humerus breadth (cm)	6.8 (0.45)	7.0 (0.70)	5.8 (0.70)	6.1 (0.60)	<0.001 *	<0.001 *	0.896	0.394
Wrist breadth (cm)	5.9 (0.60)	5.6 (0.50)	5.1 (0.50)	5.0 (0.30)	<0.001 *	<0.001 *	0.082	0.811

* significant differences by sex, # significant differences by age category, both established through the Mann Whitney U test.

Table 3. Special Judo Fitness Test (SJFT) performance of elite Spanish judo athletes.

	Median (Interquartile Range)				SJFT classifications according to:			
	SJFT index	**Number of throws**	**HR after (ppm)**	**HR 1min after (ppm)**	**SJFT index**	**Number of throws**	**HR after (ppm)**	**HR 1min after (ppm)**
Male seniors (n=9)	13.22 (1.94)	27 (2)	185 (14.0)	160 (24.5)	*Regular*	*Good*	*Regular*	*Good*
Male juniors (n=13)	12.44 (1.43)	27(3)	183 (8.5)	153 (11.0) *	*Good*	*Good*	*Good*	*Good*
Total males (n=22)	**12.80 (1.55)**	**27 (3)**	**184 (9.5)**	**155 (18.3)**	-	-	-	-
Female seniors (n=17)	12.56 (1.98)	25 (3)	178 (10.0) #	154 (15.0)	*Regular*	*Poor*	*Regular*	*Regular*
Female juniors (n=12)	12.89 (0.96)	27 (2)	187 (11.5)	162 (17.8)	*Good*	*Excellent*	*Regular*	*Poor*
Total females (n=29)	**12.70 (1.29)**	**26 (2)**	**181 (14.0)**	**157 (19.0)**	-	-	-	-

***** significant differences by sex, p= 0.035; # significant differences by age category, p= 0.014; both using a Mann Whitney U test.

Classificatory norms were obtained from Franchini et al. (12) and Sterkowicz-Przybycien et al. (37) for males and females respectively.

DISCUSSION

As has been previously mentioned, the SJFT is widely used by researchers and coaches to test the physical fitness of judo athletes (15). For this reason, the SJFT classification norms have been published for males (11) and females (37), but only the SJFT norms for females differ between senior and junior categories. The present study highlights that body mass and sex are significantly associated with the SJFT index. This information should be taken into consideration when evaluating athletes of different weight categories because heavier judo athletes achieve worse SJFT results than lighter athletes, although there is not a classificatory adjustment by weight (14,32). Additionally, it has been reported that lighter judo athletes have higher throwing speed (seoi-nage technique), more power and better oxygen uptake than heavyweight athletes (1,4,12). Hence, the judo athlete's body mass should be considered before applying the SJFT results at an elite level.

In our study, the body composition of elite judo athletes was significantly related to the SJFT index. Thus, higher relative bone and muscle masses were associated with better SJFT performance (lower index). Accordingly, previous studies showed that high fat-free mass might be an advantage for judo performance (21,22). In addition, the ectomorphic component showed to be an undesirable body composition in our athletes; this result is expected because the mean somatotype of international judo athletes is endomorphic mesomorph (36). Therefore, the training program should attempt to increase muscle mass and slightly reduce or maintain body fat, thus increasing the percentage of muscle mass. Moreover, the present study provides information about the quickly assessable anthropometric variables that best predict judo-specific performance. This analysis revealed that the biceps skinfold has a strong association with SJFT performance and is able to explain 31% of the index, which is a high prediction

value for a single anthropometric measure. Thus, although the fat mass percentage does not seem to be relevant for judo performance (8,14,20), decreased upper arm fat at the biceps may be a discriminating variable in the elite context (3). As the relative body bone mass cannot be modified by training or diet, this information has an application only in the selection of talented athletes; however, other factors must also be taken into consideration in this process.

The anthropometric characteristics of the elite Spanish judo athletes differed by sex but demonstrated few differences by age. Thus, male judo athletes had higher muscle mass, lower body fat and a lower endomorphic component than female judo athletes for both age categories (junior and senior). Age differences in somatotype components were found only for females with a lower endomorphy component in seniors than in juniors, while male seniors showed a higher arm muscle area than male juniors, without other relevant differences. The few studies that examined anthropometric differences by sex or age category in judo athletes (2,13,36) reported similar results. A common limitation when analyzing judo athletes is the fact that they are classified according to their body mass, which results in differences concerning anthropometric variables between weight categories (16). For this reason, body mass can be a confusing variable in judo research and training, as we have previously mentioned regarding the SJFT index.

Previous research showed correlations between the SJFT and aerobic capacity and power in both males (7,34) and females (32,39). Our SJFT results indicated that female seniors should improve their anaerobic capacity inferred from the total number of throws, whereas female juniors must increase their aerobic component because their recovery capacities were classified as poor. Male seniors also should improve their aerobic capacity, while male juniors had similar

classifications (good) for all the SJFT variables. Both classificatory norms have five levels (very poor, poor, regular, good, excellent), but only the female classification (37) differed between seniors and juniors; thus, the male classification (11) can overestimate our senior values. To the best of our knowledge, this is the first study to compare SJFT results between males and females. Sex-related differences were found when analyzing groups by their SJFT classifications; however, these differences were not statistically significant, except for the HR 1 min after the test in the junior category. Despite the fact that sex and age should be considered in testing the athlete and planning the training program (26,27,30), our sample was not of sufficient magnitude for detecting relevant SJFT differences unless classificatory norms are used.

PRACTICAL APPLICATIONS

The present study analyzed the anthropometric profiles of elite judo athletes and their judo-specific physical fitness assessed through the Special Judo Fitness Test (SJFT). This study has three main applications: 1) body mass should be considered in the SJFT interpretation because heavier athletes achieve worse results than lighter athletes, but they can have similar competitive success in their respective weight divisions; 2) the biceps skinfold is able to predict up to 31% of the SJFT index and can be quickly assessed, making it a useful tool in testing elite judo athletes; and 3) higher muscle and bone mass percentages and lower ectomorphy are associated with better judo-specific fitness and can jointly predict 44% of the SJFT index. These predictions are high for a model exclusively based on anthropometric characteristics at an elite level. The anthropometric profile of elite judo athletes seems relevant for their physical fitness and can be partially modified by training. Thus, the training program of these elite athletes should aim to increase their muscle mass. Further research is needed to confirm

whether changes in these anthropometric variables translate into SJFT performance and to judo competition performance. The body fat percentage was not relevant for the judo-specific physical fitness of elite athletes, although it must be at least maintained because an increase supposes a decrease of the body muscle and bone percentages. However, upper arm fat at the biceps may discriminate judo performance at an elite level. Other parameters, such as bone mass, can be used only in the selection process of talented judo athletes in conjunction with other sport-specific abilities.

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CONFLICT OF INTEREST

None declared.

REFERENCES

1. Almansba, R, Franchini, E, Sterkowicz, S, Imamura, RT, Calmet, M, and Ahmaidi, S. A comparative study of speed expressed by the number of throws between heavier and lighter categories in judo. Science & Sports 23: 186-188, 2008.
2. Almansba, R, Sterkowicz, S, Belkacem, R, Sterkowicz-Przybycien, K, and Mahdad, D. Anthropometrical and physiological profiles of the Algerian Olympic judoists. Arch Budo 6: 185-193, 2010.
3. Bala, G, and Drid, P. Anthropometric and motor features of young judoists in Vojvodina. Coll Anthrop 34: 1347-1353, 2010.
4. Callister, R, Callister, RJ, Staron, RS, Fleck, SJ, Tesch, P, and Dudley, GA. Physiological characteristics of elite judo athletes. Int J Sports Med 12: 196-203, 1991.
5. Carter, J. Body composition of Montreal Olympic athletes. In: Carter, J. Physical structure of Olympic athletes Part 1. The Montreal Olympic Games Anthropological Project. Basel, Switzerland: Karger, 1982. pp. 107-116.
6. Carter, JEL, and Health, BH. Somatotyping: development and applications. Cambridge, UK: Cambridge University Press, 1990.
7. Detanico, D, Dal Pupo, J, Franchini, E, and Giovana dos Santos, S. Relationship of aerobic and neuromuscular indexes with specific actions in judo. Science & Sports 27: 16-22, 2012.
8. Drid, P, Casals, C, Mekic, A, Radjo, I, Stojanovic, M, and Ostojic, SM. Fitness and anthropometric profiles of international vs. national judo medallists in half-heavyweight category. J Strength Cond Res 29: 2115-2121, 2015.

9. Drid, P, Maksimovic, N, Matic, R, Obradovic, B, Milosevic, Z, and Ostojic, SM. Fitness profiles of female judokas of the Serbian national team. Medicina dello Sport 62: 251-263, 2009.
10. Franchini, E, Artioli, GG, and Brito, CJ. Judo combat: time-motion analysis and physiology. Int J Perform Anal Sport 13: 624-641, 2013.
11. Franchini, E, Del Vecchio, FB, and Sterkowicz, S. A special judo fitness test classificatory table. Arch Budo 5: 127-129, 2009.
12. Franchini, E, Del Vecchio, FB, Matsushique, KA, and Artioli, GG. Physiological profiles of elite judo athletes. Sports Med 41: 147-166, 2011.
13. Franchini, E, Huertas, JR, Sterkowicz, S, Carratalá, V, Gutiérrez-García, C, and Escobar-Molina, R. Anthropometrical profile of elite Spanish Judoka: Comparative analysis among ages. Arch Budo 7: 239-245, 2011.
14. Franchini, E, Nunes, AV, Moraes, JM, and Del Vecchio, FB. Physical fitness and anthropometrical profile of the Brazilian male judo team. J Physiol Anthropol 26: 59-67, 2007.
15. Franchini, E, Sterkowicz, S, Szmatlan-Gabrys, U, Gabrys, T, and Garnys, M. Energy system contributions to the Special Judo Fitness Test. Int J Sports Physiol Perform 6: 334-43, 2011.
16. Franchini, E, Sterkowicz-Przybycien, K, and Takito, MY. Anthropometrical profile of judo athletes: Comparative analysis between weight categories. Int J Morphol 32: 36-42, 2014.
17. Franchini, E, Takito, MY, and Bertuzzi, RCM. Morphological, physiological and technical variables in high-level college judoists. Arch Budo 1: 1-7, 2005.

18. Franchini, E, Takito, MY, Kiss, MAPDM, and Sterkowicz, S. Physical fitness and anthropometrical differences between elite and non-elite judo players. Biol Sport 22: 315-328, 2005.
19. Heyward, VH. Advanced fitness assessment and exercise prescription. Champaign, IL: Human Kinetics, 1977.
20. Katralli, J, and Goudar, SS. Anthropometric profile and Special Judo Fitness levels of Indian judo players. Asian J Sports Med 3: 113-118, 2012.
21. Kim, J, Cho, HC, Jung, HS, and Yoon, JD. Influence of performance level on anaerobic power and body composition in elite male judoists. J Strength Cond Res 25: 1346-1354, 2011.
22. Kubo, J, Chishaki, T, Nakamura, N, Maramatsu, T, Yamamoto, Y, Ito, M, et al. Differences in fat-free mass and muscle thicknesses at various sites according to performance level among judo athletes. J Strenght Cond Res 20: 654-657, 2006.
23. Lewandowska, J, Busko, K, Pastuszak, A, and Boguszewska, K. Somatotype variables related to muscle torque and power in judoists. J Hum Kinet 30: 21-28, 2011.
24. Little, NG. Physical performance atributes of junior and senior women, juvenile, junior, and senior men judokas. J Sports Med Phys Fitness 31: 510-520, 1991.
25. Marfell-Jones, M, Olds, T, Stewart, A, and Carter, JEL. International Standards for Anthropometric Assessment. Potchefstroom, SAF: North-West University, 2006.
26. Miarka, B, Panissa, VLG, Julio, UF, Del Vecchio, FB, Calmet, M, and Franchini, E. A comparison of time-motion performance between age groups in judo matches. J Sports Sci 30: 899-905, 2012.
27. Palka, T, Lech, G, Tyka, A, Tyka, A, Sterkowicz-Przybycien, K, Sterkowicz, S, et al. Differences in the level of anaerobic and aerobic components of physical capacity in judoists at different age. Arch Budo 9: 195-203, 2013.

28. Pocceco, E, Gatterer, H, Ruedl, G, and Burtscher, M. Specific exercise testing in judo athletes. Arch Budo 8: 133-9, 2012.
29. Pocecco, E, and Burtscher, M. Sex-differences in response to arm and leg ergometry in juvenile judo athletes. Arch Budo 9: 181-187, 2013.
30. Pocecco, E, Faulhaber, M, Franchini, E, and Burtscher, M. Aerobic power in child, cadet and senior judo athletes. Biol Sport 29: 217-222, 2012.
31. Rocha, MSL. Peso ósseo do brasileiro de ambos os sexos de 17 a 25 años. Arquivos de anatomía e antropología 1: 445-451, 1975.
32. Smulski, W, Wolska, B, Jagiello, W, and Sawczyn, S. The correlation of general and sport-specific preparation indices of elite female judo competitors with their age-somatic characteristics. Arch Budo 7: 233-238, 2011.
33. Sterkowicz, S, Lech, G, Palka, T, Tyka, A, Sterkowicz-Przybycien, KL, Szygula, Z, and Klys, A. Body build and body composition vs. physical capacity in young judo contestants compared to untrained subjects. Biology of Sport 28: 271-277, 2011.
34. Sterkowicz, S, Zuchowicz, A, and Kubica, R. Levels of anaerobic and aerobic capacity indices and results for Special Fitness Test in judo competitors. J Hum Kinet 2: 115-35, 1999.
35. Sterkowicz, S. Test specjalnej sprawnosci ruchowej w judo. Antropomotoryka 12: 29-44, 1995.
36. Sterkowicz-Prybycień, K, and Almansba, R. Sexual dimorphism of anthropometrical measurements in judoists vs untrained subject. Science & Sports 26: 316-323, 2011.
37. Sterkowicz-Przybycien, K, and Fukuda, DH. Establishing normative data for the Special Judo Fitness Test in female athletes using systematic review and meta-analysis. J Strength Cond Res 28: 3585-3593, 2014.

38. Szmuchrowski, LA, Rodrigues, SA, Corgosinho, RF, Pinheiro, GS, Pedrosa, GF, Motta Drummond, MD, et al. Correlation between the performance in the Special Judo Fitness Test and the Wingate Anaerobic Test. Arch Budo 9: 175-179, 2013.
39. Wolska, B, Smulskij, P, and Jagiello, W. The level of aerobic and anaerobic capacity and the results of a special mobility fitness test of female judo contestants. Baltic J Health Phys Act 1: 105-110, 2009.
40. Würch A. La femme et le sport. Med Sport Française 4: 441-5, 1974.

ASSESSING CARDIOVASCULAR RISK IN ELITE SPANISH JUDO ATHLETES

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Abstract

Background and Study Aim: Cardiovascular diseases are the first cause of death globally and, although athletes have a longer life expectancy, they are not exempt from these diseases. Thus, the aim of this study was to assess the presence of cardiovascular-risk factors in elite judo athletes amongst weight categories.

Material and Methods: Cross-sectional descriptive study in 49 (29 females) elite Spanish judo athletes. Cardiovascular risk was assessed through body mass index, body fat percentage, blood pressure, lipid profile, glycaemia, renal and hepatic functions. The athletes were grouped into 3 weight categories and compared using a one-way analysis of variance and Tukey test as post hoc.

Results: 50% of male athletes presented high blood pressure, and stage I hypertension was diagnosed in 30% of cases, while only 17% of females had high blood pressure. Moreover, 45% and 34% of males and females, respectively, showed low HDL-cholesterol levels. Most of the athletes had low body fat percentages; however, 10% of males and 20% of females presented fat excess, and 59% of athletes showed higher body mass than the allowed for their weight category. Fat percentages were higher in heavier categories than in lighter ones ($p<0.001$), and HDL-cholesterol was also significantly impaired in heavier categories for males ($p=0.015$), but not for females. Nevertheless, uric acid levels of female athletes was higher in heavier categories compared with lighter ones ($p=0.026$).

Conclusions: The relatively high presence of cardiovascular risk factors suggest the need for monitoring the health status of judo athletes to prevent cardiovascular diseases.

Keywords: Cardiovascular diseases, lipids, blood pressure, hypertension, blood glucose, liver function, creatinine, body weight, elite athletes.

Glossary:

Cardiovascular diseases (CVDs) – Is a broad term for a range of diseases affecting the heart and blood vessels, e.g. a heart attack or stroke.

Hypertension – Elevated blood pressure that is diagnosed as a systolic blood pressure at or above 140 mmHg and/or a diastolic blood pressure at or above 90 mmHG. It is a risk factor for CVDs, including ischaemic and haemorrhagic strokes.

Systolic blood pressure – Is the maximum pressure in the arteries when the heart contracts.

Diastolic blood pressure – Is the minimum pressure in the arteries between the heart's contractions.

Lipid profile – Is the levels of lipids (fats) in the blood, abnormal levels are risk factors for CVDs. The most commonly used blood markers are total cholesterol, LDL-cholesterol, HDL-cholesterol and triglycerides.

LDL-cholesterol – Is the low-density cholesterol, elevated values lead to atherosclerosis increasing the risk of heart attack and ischemic stroke.

HDL-cholesterol – Is the high-density cholesterol, it is a preventive factor for CVD since it carries cholesterol away from the blood stream.

Triglyceride – Is the most common type of fat, elevated levels increases the risk for heart attack and stroke by developing atherosclerosis.

AST – Is the aspartate transaminase or aspartate aminotransferase, also known as glutamic oxaloacetic transaminase (GOT). It is commonly measured clinically as a biomarker for liver function.

ALT – Is the alanine transaminase or alanine aminotransferase; a commonly used marker of liver function.

GGT – Is the gamma glutamyltransferase; a biomarker of liver function.

Glycaemia – Is the level of glucose in blood, high level is a risk for future development of CVDs and diabetes.

INTRODUCTION

The World Health Organization established that cardiovascular diseases (CVDs) are the first cause of death globally, and they can be prevented by changing risk habits, such as tobacco use, unhealthy diet, physical inactivity and harmful use of alcohol [1]. Current best practice to prevent CVDs involves an early detection of their risk factors, including hypertension, hyperlipidaemias, diabetes, obesity, or impaired renal and hepatic functions [1]. An estimated 17.5 million people died from CVDs in 2012 [1], whereas athletes develop training benefits presenting lower rates of CVDs and living longer than untrained individuals [2]. Therefore, it has been established that regular intense exercise training has protective effects on CVDs and premature death [3,4]. However, elite athletes are not exempt from CVDs that have been related to sudden cardiac death in the young population (<35 years of age) [5]. In this sense, the prevalence of hypertension in athletes varied from 0% to 83% among different studies, where strength-trained athletes had higher blood pressure than endurance-trained athletes [6]. Furthermore, the lipid profile of some senior and even junior athletes showed altered levels [7,8]; consequently, assessing cardiovascular risks in athletes from an early age might be necessary to prevent CVDs.

A study with 935 martial arts practitioners [9], indicated that most of them had a body mass index between overweight (karate, Brazilian jiu-jitsu and judo) and normal (kung-fu and taekwondo). When the body mass index of judo practitioners were considered [9], 43.3% were classified as overweight and 12.2% as obese, who also presented a high body fat percentage classified as above average (27.8%) and well above average (16.7%). Although the body composition of elite athletes is frequently characterized by a low body fat mass, weight-categorized sports enable different body compositions at elite level, with higher fat contents in heavier athletes [10]. Hence, combat-sport athletes could show risk-factors differences amongst weight categories [11], with an increased CVDs risk compared with other disciplines.

Furthermore, combat-sport athletes usually undergo rapid weight loss before competitions by dehydration or caloric restriction [12]; thus, periodic anthropometric and haematological assessments are recommended since these athletes can have an impaired health status.

For all these reasons, the aim of the present study was to describe the presence of CVDs risk factors in elite judo athletes from the Spanish National Team according to their body mass index (BMI), body fat percentage, blood pressure, lipid profile, glycaemia, hepatic and renal functions, in order to prevent health problems.

MATERIAL AND METHODS

Design

In this descriptive cross-sectional study, the presence of CVDs risk factors in Spanish elite judo athletes was analysed. The CVDs risk factors were compared among three weight groups in males (group 1: -60, and -66 kg categories; group 2: -73, -81, and -90 kg categories; group 3: -100, and +100 kg categories) and females (group 1: -48, and -52 kg categories; group 2: -57, -

63, and -70 kg categories; group 3: -78, +78 kg categories) according to their weight category in competition. The CVDs risk was assessed through the following variables: BMI, body fat percentage, blood pressure, lipid profile, glycaemia, renal and hepatic functions. Blood sampling, blood pressure, and anthropometric assessments were all performed in fasting. The study was carried out in the sport facilities of the High Performance Centre "Joaquín Blume" (Madrid, Spain) during the competitive period.

Participants

The sample consisted of 49 elite athletes from the Spanish National Judo Team (20 males and 29 females) and all weight categories. The participants had an age average of 20.9±3.4 years, with a minimum of 17 years and a maximum of 31 years of age. None of the subjects had a history of renal, cardiovascular or hepatic diseases, and none were under medical or psychiatric treatments when participating in the study. This study obtained ethical approval from the Research Ethics Committee of the University of Granada and was in accordance with the Helsinki declaration. After the participants were informed about the procedure and possible risks involved, written informed consent was obtained from all participants or from both parents in cases where the athlete was under 18 years of age.

Procedures

Body composition. BMI was calculated as weight (kg) divided by the square of height (m), its classificatory norms were in accordance with the Spanish Society for Obesity Research (*Sociedad Española para el Estudio de la Obesidad*) [13]. Height was measured to the nearest 0.1 cm using a stadiometer (GPM, Seritex, Inc., Carlstadt, New Jersey). Body mass was measured to the nearest 0.1 kg using a portable scale (model 707, Seca Corporation, Columbia,

Maryland. Body fat percentage was estimated through the Carter equation [14]: males' fat%= (Σ6skinfolds*0.1051)+2.58, females' fat%= (Σ6skinfolds*0.1548)+3.58, where the 6 skinfolds were triceps, subscapular, supraspinal, abdomen, thigh, and medial calf expressed in millimetres). Skinfold thickness was recorded to the nearest 0.2 mm at a constant pressure of 10 g/mm by using a Holtain skinfold caliper (Holtain Ltd., Crymych, UK). Normal ranges of body fat percentages were values between 18-22% in females <21 years old and 21-23% in females ≥21 years old, and values between 15-18% in males <21 years old and 16-20% in males ≥21 years old [15].

Blood pressure. Systolic (SBP) and diastolic (DBP) blood pressures were recorded three times with the athlete seated after they rested 5 minutes, by auscultatory technique using a hybrid sphygmomanometer (Nissei DM-3000). The guidelines of the Hypertension and Cardiology European Societies were used to classify blood pressure stages [16].

Haematological parameters. Lipid profile, blood glucose, creatinine and hepatic function markers were analysed as CVDs risk factors; thus, haematological parameters were classified following current medical consensus, according to age or sex if appropriate. In adults (≥19 years), total cholesterol was considered desirable for <190 mg/dl, borderline high from 190 to 239 mg/dl, or high for values ≥240 mg/dl [17]. In young athletes (<19 years), total cholesterol was desirable for <170 mg/dl, borderline high from 170 to 199 mg/dl, or high for values ≥200 mg/dl [17]. Triglycerides values were classified as desirable, borderline high, and high in adults (≥19 years) for values <150, 150-199, ≥200 mg/dl, respectively; and in young athletes (<19 years) for values <90, 90-129, ≥130 mg/dl, respectively [17]. Low-density lipoprotein cholesterol (LDL-c) was classified as optimal (<70 mg/dl), good (70-99 mg/dl), borderline high

(100-114 mg/dl), or high (>114 mg/dl) [18]. High-density lipoprotein cholesterol (HDL-c) was considered desirable if it was >40 mg/dl in males and >45 mg/dl in females [19].

Blood glucose was altered for levels ≥100 mg/dl according to the last consensus [20]. The hepatic function was estimated considering aspartate (AST) and alanine (ALT) aminotransferases (high for values >40 U/l) and gamma-glutamyltransferase (GGT) (high for values >50 U/l) [21]. Uric acid values were classified as desirable (<6.00 mg/dl), borderline high (6.00-8.49 mg/dl), or high (≥8.5 mg/dl) [22]. Creatinine values, as a renal function marker, was high for 1.3 mg/dl in males and 1.1 mg/dl in females [23].

Statistical analysis

Data are presented as mean and standard deviation. The Shapiro-Wilk statistic was used to test the normality of distributions. Differences between the 3 weight-category groups were compared for the same sex only by using a one-way analysis of variance followed by Tukey test for post hoc comparisons. All analyses were conducted using the SPSS statistical package for Windows (version 17.0; SPSS, Inc, Chicago, Illinois, USA), and the level of significance was set at $p<0.05$.

RESULTS

A considerable number of athletes had a higher body mass than the established by their weight categories: 65% of the male athletes (13 of 20 males) and 55% of the female athletes (16 of 29 females) were heavier than the allowed in their respective weight category for competition. The number of athletes with overweight or obesity according to their BMI and body fat

percentage is presented in table 1. The prevalence of high blood pressure levels or hypertension in elite Spanish judo athletes is described in table 2. The hepatic function markers (AST, ALT, and GGT) showed normal values in all participants, the rest of haematological variables (lipid profile, blood glucose and creatinine) are presented in table 3 showing the number of athletes with CVDs risk factors. Only 30% of males (6 of 20) and 24% of females (7 of 29) did not presented any risk factor; 45% of males (9 of 20) and 59% of females (17 of 29) presented 1 or 2 risk factors; and 25 of males (5 of 20) and 17% of females (5 of 29) presented 3 or 4 CVDs risk factors. Weight-category comparisons are shown in table 4 reporting few significant differences in both females and males. These comparisons indicate that heavier athletes had higher body fat percentages than lighter judo athletes. Additionally, male athletes from the heaviest weight category had lower HDL-c levels than those from the lightest weight category.

Table 1. Prevalence of overweight in elite Spanish judo athletes according to the body mass index and body fat percentage.

		Females n=29	Males n=20	Total n=49
Body Mass Index	Insufficient weight (<18.5 kg/m^2)	0	0	0
	Normal weight (18.5-24.9 kg/m^2)	22	11	33
	Overweight degree I (25.0-26.9 kg/m^2)	3	3	6
	Overweight degree II (27.0-29.9 kg/m^2)	3	2	5
	Obesity class I (30.0-34.9 kg/m^2)	1	2	3
	Obesity class II (35.0-39.9 kg/m^2)	0	2	2
Body fat	Insufficient fat	17	18	35
	Normal fat	6	0	6
	Excess of fat	6	2	8

Table 2. Blood pressure of elite Spanish judo athletes.

		Females n=29	Males n=20	Total n=49
Systolic blood pressure	Optimal (<120 mmHg)	13	6	19
	Normal (120-129 mmHg)	11	4	15
	High-normal (130-139 mmHg)	5	4	9
	Stage 1 hypertension (140-159 mmHg)	0	6	6
Diastolic blood pressure	Optimal (<80 mmHg)	25	13	38
	Normal (80-84 mmHg)	3	4	7
	High-normal (85-89 mmHg)	1	0	1
	Stage 1 hypertension (90-99 mmHg)	0	3	3

Table 3. Prevalence of cardiovascular risk according to haematological parameters of elite Spanish judo athletes.

		Females n=29	Males n=20	Total n=49
Cholesterol	Desirable	24	13	37
	Borderline high	2	6	8
	High	3	1	4
LDL-c	Optimal	25	12	37
	Good	4	6	10
	Borderline high	0	2	2
HDL-c	Desirable	19	11	30
	Low	10	9	19
Triglycerides	Desirable	27	15	42
	Borderline high	1	2	3
	High	1	3	4
Glycaemia	Good	28	19	47
	Altered	1	1	2
Uric acid	Good	12	4	16
	Borderline high	15	15	30
	High	2	1	3
Creatinine	Good	26	20	46
	High	3	0	3

Table 4. Comparisons of cardiovascular risk factors amongst weight categories in elite Spanish judo athletes.

		Females		**1w anova**		**Males**		**1w anova**
Weight categories *(n)*	-48/-52 *(8)*	-57/-63/-70 *(16)*	-78/+78 *(5)*	**P values**	-60/-66 *(6)*	-73/-81/-90 *(9)*	-100/+100 *(5)*	**P values**
BMI (kg/m^2)	21.2±1.86$^{\#}$	23.2±1.61$^{\#}$	28.7±2.76	<0.001	22.3±1.13*$^{\#}$	25.2±1.86$^{\#}$	33.0±3.33	<0.001
Body fat (%)	15.1±2.75*$^{\#}$	18.9±3.25$^{\#}$	28.3±5.07	<0.001	7.1±1.13$^{\#}$	7.9±1.73$^{\#}$	18.0±6.38	<0.001
Cholesterol (mg/dl)	161±43.33	162±24.55	165±31.34	0.974	179±44.09	170±26.50	163±47.11	0.171
HDL-c (mg/dl)	54.8±15.8	53.0±12.11	59.1±15.30	0.692	55.9±13.74$^{\#}$	46.7±7.98	35.5±8.68	0.015
LDL-c (mg/dl)	60.1±11.86	55.9±13.94	55.3±18.79	0.769	64.2±19.83	70.4±17.34	73.3±28.53	0.762
Triglycerides (mg/dl)	59.8±25.35	71.2±25.84	68.1±9.45	0.555	83.3±47.63	104.9±37.07	94.3±45.75	0.634
Glycaemia (mg/dl)	74.4±12.57	71.1±8.75	84.3±15.16	0.085	83.0±14.75	71.5±8.91	84.6±7.69	0.065
Uric acid (mg/dl)	7.36±1.30	6.81±1.26	7.07±1.61	0.260	6.97±1.31	6.77±0.83	6.93±1.42	0.937
Creatinine (mg/dl)	0.95±0.15	0.93±0.14	0.93±0.11	0.256	0.90±0.21	0.82±0.20	0.88±0.22	0.738
AST (IU/l)	15.6±5.50	17.0±7.23	14.7±6.13	0.760	19.5±3.70	18.0±6.50	22.6±2.27	0.281
ALT (IU/l)	12.8±3.84	11.3±3.55	12.1±1.10	0.601	17.6±4.87	14.1±3.17	18.3±4.57	0.144
GGT (IU/l)	6.7±8.46	3.2±0.52	3.2±0.41	0.172	3.8±1.95	8.4±15.92	10.2±16.04	0.713
Systolic BP (mmHg)	118±6.41	112±13.41	119±8.94	0.372	120±8.94	126±18.50	133±14.83	0.397
Diastolic BP (mmHg)	40±1.60	40±3.61	40±2.19	0.901	45±1.67	45±2.24	43±2.07	0.416

AST: Aspartate aminotransferase, ALT: alanine aminotransferase, GGT: gamma-glutamyltransferase, BP: Blood pressure, *: p<0.005 respect to the middle-weight group (Tukey's post-hoc), $^{\#}$: p<0.005 respect to the heavy-weight group.

DISCUSSION

This study highlights that the presence of cardiovascular risk factor in elite Spanish athletes is substantial; thus, their top-level training status seems not enough to achieve good health. Up to 70% of male and 76% of female elite Spanish judo athletes presented at least one CVDs risk factor. Our data showed a high percentage of elite athletes with altered lipid profile; 45% and 34% of male and female athletes, respectively, showed low HDL-cholesterol levels. Moreover, 15% of males presented high triglycerides values, while the number of cases in the rest of lipid profile variables represented less than 10%. A previous study showed an HDL-c decrease in elite athletes after four weeks of judo training [24]; hence, it is possible that this group of athletes should specifically consider this point in order to improve their health, for example, through a fat intake modification [25]. Notwithstanding, Yamaner et al. [26] compared wrestlers and sedentary males, reporting that athletes had higher HDL-c levels, but also higher triglycerides levels; whereas in our study, most of the elite athletes had desirable triglycerides values. Thus, assessing the lipid profile is essential since some athletes can have abnormal values. To sum up, the most impaired lipid profile parameter in elite judo athletes was the HDL-c, while all athletes had desirable or borderline LDL-c values. Triglycerides and total cholesterol values were under health recommendations in most of the cases, although some athletes showed high values. Food habits of elite Spanish judo athletes have been previously analysed [27], showing a high intake of fat and protein; hence, a fat-modified diet could be convenient to improve their lipid profiles [25].

Moreover, a main point of this study is that a considerable number of elite judo athletes showed high blood pressure levels, even presenting hypertension of stage I (30% of male athletes). Accordingly, a previous study established the hypertension as the most prevalent diagnosed disease in athletes [28]; however, it was performed in athletes older than 35 years of age. Thus,

the presence of hypertension in our athletes has a special significance due to the fact that our sample is young so they have an increased risk of presenting worse blood pressure levels with aging [29], especially if no preventive actions were taken. The prevalence of hypertension in young adults and adolescents is increasing and, it has been suggested that current hypertension and pre-hypertension diagnosis in the young population could underestimate the longitudinal risk [30]. Therefore, assessing blood pressure is justified in elite athletes even if they are young and, as it is a non-invasive tool, it can be used frequently without affecting performance.

As expected, the BMI overestimated the fat content of judo athletes since they have a high muscle mass [9,10]. In accordance with this result, the body fat percentage should be a tool for preventing obesity in athletes instead of BMI. Our results showed that most of the athletes had low fat mass; however, 16% of the elite athletes presented an excess of body fat, which is lower than previously reported in judo practitioners [9]. In our study, the athletes competing in heavier weight categories had higher body fat percentages and, as has previously been mentioned, it is important to note the young age of these athletes with overweight (from 17 to 30 years), who could develop CVDs in the future. On the one hand, overweight and obese people that practice sport can present a good health status, where fitness is a preventing factor for CVDs [31]. On the other hand, the association between overweight and CVDs risk is well documented, and it has been also established in adolescents (17 years old) [32]. Additionally, 59% of the athletes of the present study had a higher body mass than the maximum allowed in their weight categories what suggests weight cycling, an habitual practice in elite judo athletes [12,33], that induces alterations in haematological parameters of judo athletes [34] and has been related to CVDs even in normal-weight people [35]. Specifically, post-competitive weight gain has been associated with a higher prevalence of CVDs in former athletes [36].

Consequently, some changes in the weight management control of judo athletes should be considered for their current and future health status.

Moreover, CVDs are responsible of the high premature mortality of professional combat sport athletes, such as wrestlers [37]. For all that, assessing CVDs risks in elite judo athletes is necessary for the prevention of health problems. On this basis, research has demonstrated that a complex evaluation of the athlete is the best clinical practice to estimate the long-term risk. Hence, haematological markers of hepatic and renal functions have been also included as CVDs risk factors and they are also used in athletes [38]. The results of the present study showed normal hepatic function in elite judo athletes, as occurred with the glycaemia levels. In addition, AST, ALT and GGT levels showed desirable values without evidence of impaired renal function in these athletes.

CONCLUSIONS

Elite Spanish judo athletes showed an altered lipid profile and a considerable prevalence of high blood pressure, generally presenting normal glycaemia, renal and hepatic functions. This significant prevalence of CVDs risk factors, and the presence of heavy athletes with an excess of fat mass, suggest the need for monitoring health status of judo athletes in order to prevent CVDs. In addition, our results suggested weight cycling and rapid weight loss practices, which can be related to the altered lipid profile presented in these athletes.

REFERENCES

1. World Health Organization. January 2015. Cardiovascular diseases (CVDs) Fact Sheet no. 317. Available: http://www.who.int/mediacentre/factsheets/fs317/en/ [Accessed 14.02.2016]
2. Garatachea N, Santos-Lozano A, Sanchis-Gomar F et al. Elite athletes live longer than the general population: a meta-analysis. Mayo Clin Proc 2014; 89(9):1195-200
3. Ruiz JR, Fiuza-Luces C, Garatachea N et al. Reduced mortality in former elite endurance athletes. Int J Sports Physiol Perform 2014; 9(6): 1046-9
4. Sheikholeslami Vatani D, Ahmadi S, Ahmadi Dehrashid K et al. Changes in cardiovascular risk factors and inflammatory markers of young, healthy, men after six weeks of moderate high intensity resistance training. J Sports Med Phys Fitness 2011; 51(4): 695-700
5. Ranthe MF, Winkel BG, Andersen EW et al. Risk of cardiovascular disease in family members of young sudden cardiac death victims. Eur Heart J 2013; 34(7): 503-11
6. Berge HM, Isern CB, Berge E. Blood pressure and hypertension in athletes: a systematic review. Br J Sports Med 2015; 49(11): 716-23
7. Gonçalves MC, Passos MC, Beltrame JD et al. Is it possible to identify underlying cardiovascular risk in young trained military? J Sports Med Phys 2016; 56(1-2): 125-32
8. Faustino Arias DM, Tapia Escarcena N, Benito Aragón G. Lipids profile in children and adolescent sportsmen in Peru. Rev Med Hered 2007; 18(1): 22-7
9. Schwartz J, Takito MY, Del Vecchio FB et al. Health-related physical fitness in martial arts and combat sports practitioners. Sport Sci Health 2015; 11: 171-180

10. Franchini E, Del Vecchio FB, Matsushigue KA et al. Physiological profiles of elite judo athletes. Sports Med 2011; 41(2): 147-66

11. Guo JJ, Zhang X, Wang L et al. Prevalence of metabolic syndrome and its components among Chinese professional athletes of strength sports with different body weight categories. Plos One 2013; 8: e79758

12. Escobar-Molina R, Rodríguez-Ruiz S, Gutiérrez-García C et al. Weight loss and psychological-related states in high-level judo athletes. Int J Sport Nutr Exerc Metab 2015; 25(2): 110-8

13. Salas-Salvadó J, Rubio MA, Barbany M et al. SEEDO 2007 Consensus for the evaluation of overweight and obesity and the establishment of therapeutic intervention criteria. Med Clin (Barc) 2007; 128(5): 184-96.

14. Carter JL, Ross WD, Aubry SP et al. Anthropometry of Montreal Olympic athletes. Physical structure of Olympic athletes: Part I. 1982, 25-52

15. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. Lippincott Williams & Wilkins, 2013

16. Mancia G, Fagard R, Narkiewicz K et al. 2013 ESH/ESC guidelines for the management of arterial hypertension: the Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). Blood pressure 2013; 22(4): 193-278

17. Perk J, De Backer G, Gohlke H et al. European Guidelines on cardiovascular disease prevention in clinical practice (version 2012). Eur Heart J 2012; 33(13): 1635-701

18. Bejarano JML, Galve E, Royo-Bordonada MA et al. Spanish Interdisciplinary Committee for Cardiovascular Disease Prevention and the Spanish Society of

Cardiology Position Statement on Dyslipidemia Management: differences between the European and American Guidelines. Rev Esp Salud Publica 2015; 89(1): 15-26

19. Stone NJ, Robinson JG, Lichtenstein AH et al. 2013 ACC/AHA guideline on the treatment of blood cholesterol to reduce atherosclerotic cardiovascular risk in adults. J Am Coll Cardiol 2014; 63: 2889-934

20. Simmons RK, Alberti KG, Gale AM et al. The metabolic syndrome: useful concept or clinical tool? Diabetologia 2010; 53: 600-5

21. Stranges S, Dorn JM, Muti P et al. Body fat distribution, relative weight, and liver enzyme levels: a population-based study. Hepatology 2004; 39(3): 754-63

22. Cebollada J, Gimeno JA. Uric acid as cardiovascular risk factor. Hipertens Riesgo Vasc 2012; 29(2): 36-43

23. Banfi G, Del Fabbro. Relation between serum creatinine and body mass index in elite athletes of different sport disciplines. Br J Sports Med 2006: 40: 675-8

24. Trivic T, Radjo I, Tabakov S et al. Influence of exercise on blood lipids and immune system in female Serbian judokas. Healthmed 2011; 5(5): 1287-92

25. Berg A, Konig D, Deibert P et al. Effect of an oat bran enriched diet on the atherogenic lipid profile in patients with an increased coronary heart disease risk. A controlled randomized lifestyle intervention study. Ann Nutr Metab 2003; 47(6): 306-11

26. Yamaner F, BayraktarogluT, Atmaca H et al. Serum leptin, lipoprotein levels, and glucose homeostasis between national wrestlers and sedentary males. Turk J Med Sci 2010; 40(3): 471-7

27. Úbeda N, Gil-Antuñano P, Zenarruzabeitia M et al. Food habits and body composition of Spanish elite athletes in combat sports. Nutr Hosp 2010; 25(3): 414-21

28. De Matos LD, Caldeira NA, Perlingeiro PS et al. Cardiovascular risk and clinical factors in athletes: 10 years of evaluation. Med Sci Sports Exerc 2011; 43(6): 943-50

29. Kotchen JM, McKean HE, Kotchen TA. Blood pressure trends with aging. Hypertension 1982; 4(5): III128-34

30. Falkner B. Hypertension in children and adolescents: epidemiology and natural history. Pediatr Nephrol 2010; 25(7): 1219-24

31. Ortega FB, Lee DC, Katzmarzyk PT et al. The intriguing metabolically healthy but obese phenotype: cardiovascular prognosis and role of fitness. Eur Heart J 2013; 34(5): 389-97

32. Lusky A, Barell V, Lubin F et al. Relationship between morbidity and extreme values of body mass index in adolescents. Int J Epidemiology 1996; 25(4): 829-34

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

34. Drid P, Trivic T, Tabakov S et al. Influences of weight loss on hematological parameters in male judokas. HealthMED 2012; 6(4): 1285-1290

35. Montani JP, Viecelli AK, Prevot A et al. Weight cycling during growth and beyond as a risk factor for later cardiovascular diseases: the ‘repeated overshoot’ theory. Int J Obesity 2006; 30(S4): S58-66

36. Phil E, Jurimae T. Relationships between body weight change and cardiovascular disease risk factors in male former athletes. Int J Obes Relat Metab Disord 2001; 25(7): 1057-62

37. Herman CW, Conlon ASC, Rubenfire M et al. The very high premature mortality rate among active professional wrestlers is primarily due to cardiovascular disease. Plos One 2014; 9(11): e109945

38. Chamera T, Spieszny M, Klocek T et al. Could biochemical liver profile help to assess metabolic response to aerobic effort in athletes? J Strength Cond Res 2014; 28(8): 2180-6

SEX DIFFERENCES IN INFLAMMATORY AND LIPID PEROXIDATION RESPONSES TO HIGH-INTENSITY INTERMITTENT EXERCISE IN ELITE JUDO ATHLETES

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Abstract

Purpose: To determine sex-related differences in inflammation and lipid peroxidation of elite judo athletes at rest and 15-min after short-duration, high-intensity intermittent exercise (SD-HIIE).

Methods: Twenty-eight elite judo athletes (14 females, and 14 males) participated, during a competitive period, in this descriptive cross-sectional study. Blood sampling was performed before and after a 15-min passive recovery from SD-HIIE consisted in a specific-judo test (the Special Judo Fitness Test), to measure lipid peroxidation (hydroperoxides and thiobarbituric acid reactive substances (TBARS)), pro-oxidant cytokines (interleukin-6 (IL-6), and tumour necrosis factor (TNF-α)), soluble forms of their main receptors (sIL-6R and sTNF-R1), and skeletal muscle damage of sarcomeric origin (α-actin). Statistical differences were determined using a two-way mixed analysis of variance, followed by Bonferroni post-hoc test.

Results: There was a significant interaction between sex and time for IL-6 and TNF-α levels. Females presented significantly lower plasma levels of hydroperoxides (1.40±0.58 nmol/mL), TBARS (3.55±1.38 nmol/mL), and sIL-6R (6375±1478 pg/mL) than males. In males, there were significant increases 15-min after SD-HIIE for TNF-α (0.42±0.11 pg/mL), sTNF-R1 (277±67 pg/mL), and IL-6 (0.07±0.26 pg/mL); whereas in females there were increases only for sTNF-R1 (151±67 pg/mL). There were no differences between experimental groups and conditions in α-actin levels.

Conclusions: Elite athletes presented sex-related differences in inflammatory responses to SD-HIIE but similar muscle damage levels. Female athletes showed lower lipid peroxidation and anti-inflammatory cytokines levels than males. Moreover, the sTNF-R1 cytokine might be a useful marker for monitoring recoveries from judo-specific performance tests, as the Special Judo Fitness Test, in elite athletes.

Keywords: oxidative stress; cytokine; inflammation; elite athletes; gender differences; martial arts.

Abbreviations

EIMUF: exercise-induced muscle fatigue

SD-HIIE: short-duration, high-intensity intermittent exercise

IL-6: interleukin-6

sIL-6R: soluble interleukin-6 receptor

ROS: reactive oxygen species

TBARS: thiobarbituric acid reactive substances

TNF-α: tumour necrosis factor

sTNF-R1: soluble tumour necrosis factor receptor 1

Introduction

The assessment of a combination of biomarkers, including lipid peroxidation and inflammatory markers, has been proposed as a useful tool in monitoring exercise-induced muscle fatigue (EIMUF) (Finsterer et al. 2016). The accurate monitoring of EIMUF in elite athletes plays an important role by indicating whether the athlete might need higher recovery periods, avoiding impaired muscle strength and, ultimately, overtraining syndrome (Finaud et al. 2006; Finsterer et al. 2016; Reid 2008). Furthermore, the assessment of EIMUF might have a special relevance in high-intensity intermittent sports with explosive actions, such as judo (Franchini et al. 2014). In this regard, during the judo practice, there is an increase of the reactive oxygen species (ROS) production, mainly from mitochondria but also from local inflammation and ischemia-reperfusion processes with a transitory hypoxic condition followed by re-oxygenation (Bloomer et al. 2004; Elabed et al. 2014). This possible overproduction of ROS leads to protein and lipid oxidation, systemic inflammation, and cell death (Tanskanen et al. 2010). However, moderate production of ROS and myokines promotes several muscle adaptations to exercise related to improved sport performance and health (Lira et al. 2014; Radak et al. 2013; Scheele et al. 2009).

Moreover, elite judo athletes require quickly and efficient recoveries that partly determines success in competition, since it consists in several matches, typically separated by 15-min time intervals in the last eliminatory phases (Detanico et al. 2015; Franchini et al. 2013). Consequently, judo-specific performance is usually evaluated through the Special Judo Fitness Test (Sterkowicz 1995) aimed at evaluating anaerobic and aerobic fitness, which consisted in a short-duration, high-intensity intermittent exercise (SD-HIIE). Thus, assessing EIMUF biomarkers in elite judo athletes after short recovery from SD-HIIE can be useful in planning

their training programs by providing a more accurate diagnosis of the recovery processes and status (Bessa et al. 2016).

However, oxidative stress and inflammatory responses to high-intensity intermittent exercise have been analysed in a few studies involving athletes (Deminice 2010; Lira et al. 2015; Ugras 2013) and, although scientific evidence suggests that there are sex-related differences in oxidative stress and inflammatory responses to exercise (Kabasakalis et al. 2014, Finsterer et al. 2016; Borras et al. 2007), these differences in response to SD-HIIE have not been established. For all these reasons, the present study analysed some EIMUF biomarkers in elite athletes who compete in a high-intensity intermittent sport; specifically, the aim of the study was to compare inflammatory, lipid peroxidation and muscle damage blood biomarkers between elite male and female judo athletes during a competitive period, at rest and after 15-min passive recovery from SD-HIIE widely used to evaluate judo-performance.

Methods

Design

In this descriptive cross-sectional study, sex-related differences in lipid peroxidation, inflammatory status and muscle damage of elite judo athletes were evaluated and compared at rest and 15 minutes after SD-HIIE. The study was carried out in the sport facilities of the High Performance Centre “Joaquín Blume” (Madrid, Spain) during the competitive period of one training meeting prior to an international tournament of the Spanish national judo team. All judo athletes performed the SD-HIIE (the Special Judo Fitness Test) in the morning in an athletic training room after receiving thorough information about the test protocol. Blood sampling was drawn from the antecubital vein by qualified nursing staff, before and 15 minutes

after the SD-HIIE. The samples were centrifuged (obtaining plasma and erythrocytes) and frozen at -80ºC awaiting analysis.

Subjects

The sample consisted of 28 elite athletes (14 females, 14 males) from the Spanish National Judo Team and all weight categories (Table 1). None of the subjects were under medical and/or psychiatric treatment when participating in the study. This study obtained ethical approval from the Research Ethics Committee of the University of Granada and was in accordance with the Helsinki declaration. After the participants were informed about the procedure and possible risks involved, written informed consent was obtained from all participants.

Short-Duration, High-Intensity Intermittent Exercise

The SD-HIIE consisted in the Special Judo Fitness Test (Sterkowicz 1995), previously described by Casals et al. (2015). The athlete must complete as many throwing techniques (*ippon-seoi-nage*) as possible within the test time, running from one adversary to the other one (both are separated by 6 m). The test is composed of three parts (15, 30, and 30 seconds) separated by 10-seconds recovery periods. This test has been validated in judo athletes showing a reliability of 0.97 (Sterkowicz et al. 1999) and is currently one of the most used in judo research (Drid et al. 2012). Heart rates (Polar Team2, Polar, Finland) were measured immediately and 1-min after the test in order to calculate the index of the Special Judo Fitness Test by using the following equation:

Index= (heart rate after + heart rate 1 min after) / total number of throws.

Inflammatory markers

Plasma interleukin-6 (IL-6) and tumour necrosis factor (TNF-α) levels, as pro-oxidant cytokines, and their respective soluble receptors (sIL-6R and sTNF-R1), as anti-inflammatory markers, were determined by Immunology Multiplex Assay (HSTCMAG-28SK and HSCRMAG-32K, Merck Millipore, Darmstadt, Germany) and the Luminex® 200^{TM} System (Luminex Corp., Austin, TX, USA) according to the manufacturer's instructions.

Lipid peroxidation markers

Lipid hydroperoxides in plasma were assessed by PeroxideDetect^{TM} Kit (code no. PD1; Sigma-Aldrich Co., St Louis, MO, USA) based on the fact that peroxides convert Fe^{2+} to Fe^{3+} ions under acidic conditions. Fe^{3+} ions form a coloured adduct with xylenol orange that were measured spectrophotometrically (Synergy HT, Bioteck, USA) at 560 nm. Plasma concentrations of thiobarbituric acid reactive substances (TBARS) was measured spectrophotometrically (Synergy HT, Bioteck, USA), determined by the reaction of malondialdehyde with thiobarbituric acid to form a colorimetric product that was read at 532 nm, following the method described by Orrenius et al. (1997).

Muscle damage marker

Sarcomeric α-actin was determined by Western blot dissolving 5 µl of plasma in Laemmli's sample buffer using the procedures and reagents described by Martinez-Amat et al. (2005). All conditions (sex and time) were included in each gel. A standard curve was obtained by immunoblotting with an amount of known proteins (nanograms of pure α-actin) and

densometrically quantifying the bands obtained. Circulating α-actin was detected by immunoblotting as a band located at 43 kDa.

Statistical analysis

Data are presented as the mean and the standard deviation. The Shapiro-Wilk statistic was used to test the normality of distributions. Statistical differences were determined using a two-way mixed analysis of variance with sex (females vs. males) as the between-subjects variable and time (at rest vs. 15-min post-exercise) as the within-subjects variable, followed by Bonferroni post-hoc test. Effect sizes were calculated using partial eta squared (η^2_p). All analyses were conducted using the SPSS statistical package for Windows (version 17.0; SPSS, Inc., Chicago, Illinois, USA); the level of significance was set at $p<0.05$.

Results

Our data showed a statistically significant interaction between sex and time in pro-oxidant cytokines (IL-6: $F(1,26)=4.17$, $p=0.050$, $\eta^2_p=0.14$; TNF-α: $F(1,26)=4.49$, $p=0.044$, $\eta^2_p=0.15$). These results indicated that the pro-inflammatory responses to the SD-HIIE differed by sex. Specifically, both pro-oxidant cytokines of males increased in response to SD-HIIE, whereas there were no differences by time in females for these variables.

In addition, a statistically significant main effect of the sex factor was reported for anti-inflammatory cytokines (sIL-6R: $F(1,26)=18.59$, $p<0.001$, $\eta^2_p=0.42$, sTNF-R1: $F(1,26)=4.35$, $p=0.047$, $\eta^2_p=0.12$) and lipid peroxidation markers (Hydroperoxides: $F(1,26)=5.80$, $p=0.023$, $\eta^2_p=0.18$; TBARS: $F(1,26)=6.66$, $p=0.016$, $\eta^2_p=0.20$). Therefore, the above pro-oxidant

variables were significantly lower in females compared with males considering both time-conditions values.

The time factor presented a significant main effect for pro-inflammatory (IL-6: $F(1,26)=4.17$, $p=0.050$, $\eta^2_p=0.11$; TNF-α: $F(1,26)=9.41$, $p=0.005$, $\eta^2_p=0.27$) and sTNF-R1 ($F(1,26)=20.46$, $p<0.001$, $\eta^2_p=0.44$) markers. Thus, inflammatory (pro- and anti-inflammatory) cytokines significantly increased from baseline to 15-min recovery time considering all athletes in the analysis (males and females).

The results of the specific-judo test were similar between sexes, and are shown in Table 1. All pairwise comparisons of the oxidative stress, inflammatory and muscle damage markers are shown in table 2.

Table 1. Participants' characteristics and results in the SD-HIIE test

	Females (n=14)	**Males (n=14)**
	Mean (SD)	*Mean (SD)*
Age (years)	24.3 (3.5)	23.3 (2.7)
Body mass (kg)	66.6 (19.1)	87.3 (20.4)
Special Judo Fitness Test		
Index	12.92 (1.12)	13.05 (1.70)
Total number of throws	27 (3)	27 (2)
Heart rate after (ppm)	179 (10.4)	184 (13.2)
Heart rate 1-min after (ppm)	155 (13.7)	157 (14.6)

SD-HIIE: Short-Duration, High-intensity intermittent exercise (the Special Judo Fitness Test)

Table 2. Oxidative stress and inflammatory responses to SD-HIIE of elite Spanish judo athletes

	Females (n=14)		*Males (n=14)*	
	Rest	**15-min recovery**	**Rest**	**15-min recovery**
	Mean (SD)	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
IL-6 (pg/mL)	0.51 (0.53)	0.51 (0.53)	0.27 (0.08)[#]	0.34 (0.12)
sIL-6R (pg/mL)	7,710 (2,493)*	7,822 (2,040)*	13,888 (6,375)	14,395 (5,828)
TNF-α (pg/mL)	0.86 (0.28)	0.88 (0.31)*	0.81 (0.39)[#]	1.23 (0.61)
sTNF-R1 (pg/mL)	497 (178)[#]	648 (259)	585 (229)[#]	862 (291)
Hydroperoxides (nmol/mL)	1.88 (0.80)*	2.12 (0.89)*	3.23 (1.77)	3.55 (2.43)
TBARS (nmol/mL)	4.29 (1.79)*	6.05 (2.68)	9.22 (5.95)	8.21 (5.29)
Alpha-actin (µg/mL)	77.39 (13.07)	83.26 (11.26)	78.34 (12.30)	84.84 (17.09)

*: differences between females and males, [#]: differences between rest and 15-min recovery conditions. SD-HIIE: short-duration, high-intensity intermittent exercise, IL-6: interleukin 6, sIL-6R: soluble IL-6 receptor, TNF-α: tumour necrosis factor, sTNF-R1: soluble TNF receptor-1, TBARS: thiobarbituric acid reactive substances.

Discussion

The present study analysed sex-related differences in inflammation, lipid peroxidation and muscle damage of elite judo athletes at rest and after 15-min passive recovery from SD-HIIE. The main findings of this study indicated different pro-oxidant cytokine responses to SD-HIIE between males and females. The SD-HIIE triggered an IL-6 and TNF-α up-regulation in males, detected in plasma levels after 15-min recovery, but not in females. Several studies have reported increases of inflammatory markers after intense exercise in male athletes (Scott et al. 2013), and specifically in combat sports (Laskowski et al. 2011), showing sex differences in the temporal pattern of cytokines responses (Benini et al. 2015) what might explain the sex-related different responses to HIIE showed in this study.

However, although IL-6 and TNF-α levels increased in males 15 min after SD-HIIE, Abedelmalek et al. (2015) reported no significant changes of both markers in male judo athletes after the same exercise protocol, showing significant increases in those athletes who were under caloric restriction condition even when they achieved worse results in the Special Judo Fitness Test. Moreover, Lira et al. (2015) analysed male judo athletes before and immediately after high-intensity intermittent exercise, finding significant increases for IL-4 and IL-10, but not for IL-6 and TNF-α. In our study, the elite female athletes showed significantly lower levels of sIL-6R and, consequently, higher plasma IL-6 levels than males similarly to previous studies (Finsterer 2012). Notwithstanding, the inflammatory status of female athletes was also under normal range, and the response to SD-HIIE was adequate probably due to the training adaptations.

Moreover, female elite athletes showed lower lipid peroxidation compared with male judokas. Accordingly, similar results have been reported (Kabasakalis et al. 2014), mainly caused by sex-related differences in mitochondria where females' mitochondria generate half the amount of hydroperoxides than those of males (Borras et al. 2003; Borras et al. 2007). Thus, although lipid peroxidation must be specially considered in male athletes, both groups showed normal increases after executing the performance test (without significant differences) during the competitive period. Accordingly, Trivic et al. (2011) reported that combat-sport athletes subjected to demanding training present normal oxidative stress levels, indicating beneficial adaptations to training in antioxidant mechanisms and oxidant-repairing systems (Dopsaj et al. 2013; Douris et al. 2009). This is due to the fact that ROS production is essential for performance due to its signalling function in muscle adaptations and enhanced antioxidant capacity (Abruzzo et al. 2013; Scheele et al. 2009), and only an overproduction leads to oxidative damage (Finaud et al. 2006; Reid 2008). For that, the assessment of EIMUF biomarkers in elite athletes might improves performance and health, by offering a method for evaluating the relative state of recovery (Bessa et al. 2016).

In light of this, a proper selection of EIMUF markers can impact in the accuracy of the gathered information. In our study, we included the assessment of sTNF-R1, one of the main soluble receptors of the TNF-α, which is an anti-inflammatory marker since competes with the membrane receptors inhibiting TNF bioactivity. The sTNF-R1 marker has been previously associated with exercise intensity in athletes, preventing an overproduction of pro-inflammatory response to exercise (Pussieldi et al. 2014). However, sTNF-R1 is not a commonly assessed marker of EIMUF (Finsterer et al. 2016) and, according to our results, it might play a relevant role in monitoring the responses to SD-HIIE in elite athletes; specifically in judo-specific test, since sTNF-R1 significantly changed from baseline to 15-min recovery

time. Moreover, including a muscle damage marker is convenient for preventing overtraining in athletes subjected to elite-level training, especially during the competitive period, as in this study. In this respect, the α-actin marker is able to detect injured athletes (Martinez-Amat et al. 2005). Above non-injured levels, α-actin also differs between sedentary and trained people with higher levels in the last ones as consequence of hypertrophy mechanisms (Barranco-Ruiz et al. 2016). Our elite athletes had normal muscle damage values and, although α-actin levels increase in response to intense exercise in athletes (Martinez-Amat et al. 2010), this maker did not change after the 15-min passive recovery from SD-HIIE compared with baseline, maybe due to the short-duration of the test used in this study. Thus, this skeletal muscle damage marker of sarcomeric origin indicated that both females and males have similar muscle damage results, although this response to exercise might be regulated through sex-specific inflammatory and oxidative mechanisms (Benini et al. 2015).

Summarizing, several sex-related differences in inflammatory and lipid peroxidation markers have been found in this study involving elite judo athletes. The SD-HIIE triggered a cytokine up-regulation in the male judo athletes but not in females, assessed after 15-min passive recovery, what efficiently stimulated the anti-inflammatory response though liberation of the soluble IL-6 and TNF-α receptors. The SD-HIIE did not significantly increase lipid peroxidation or skeletal muscle damage markers, whereas it can be especially interesting to include sTNF-R1 and sIL-6Rα when evaluating their pro-oxidant cytokines in order to improve the physiological understanding of EIMUF. Female athletes showed lower lipid peroxidation and anti-inflammatory cytokines, with higher levels of pro-inflammatory cytokines than males. Finally, in our study there were no evidence for overtraining syndrome or abnormal EIMUF, as there were no muscle damage evidences. Therefore, the training program during the competitive period of the elite Spanish judo athletes was probably appropriate and well-

adjusted, since the athletes had a good preparation to perform SD-HIIE. Notwithstanding, although blood biomarkers offer an accurately evaluation of the recovery status and EIMUF, they should be used in conjunction with performance specific tests for an appropriate and global assessment of the elite athlete status.

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Conflict of interest

None declared.

References

Abedelmalek S, Chtourou H, Souissi N, Tabka Z (2015). Caloric restriction effect on proinflammatory cytokines, growth hormone, and steroid hormone concentrations during exercise in judokas. Oxid Med Cell Longev 2015: 1-8. doi: 10.1155/2015/809492

Abruzzo PM, Esposito F, Marchionni C, di Tullio S, Belia S, Fulle S, et al. (2013). Moderate exercise training induces ROS-related adaptations to skeletal muscles. Int J Sports Med 34: 676-687. doi: 10.1055/s-0032-1323782

Barranco-Ruiz Y, Aragon-Vela J, Casals C, Martinez-Martinez-Amat A, Villa-González E, Huertas JR (2016). Lifelong Martinez-Amateur endurance practice attenuates oxidative stress and prevents muscle wasting in senior adults. J Sport Med Phys Fit [Ahead of Print]

Benini R, Nunes PRP, Orsatti CL, Portari GV, Orsatti FL (2016). Influence of sex on cytokines, heat shock protein and oxidative stress markers in response to an acute total body resistance exercise protocol. J Exerc Sci Fit 13: 1-7. doi: 10.1016/j.jesf.2014.10.002

Bessa AL, Oliveira VN, Agostini GG, Oliveira RJS, Oliveira ACS, White GE, et al (2016). Exercise Intensity and Recovery: Biomarkers of Injury, Inflammation, and Oxidative Stress. J Strength Cond Res 30: 311-319. doi: 10.1519/JSC.0b013e31828f1ee9

Bloomer RJ, Goldfarb AH (2004). Anaerobic exercise and oxidative stress: a review. Can J Appl Physiol 29: 245-263. doi: 10.1139/h04-017

Borras C, Gambini J, Vina J (2007). Mitochondrial oxidant generation is involved in determining why females live longer than males. Front Biosci 1: 1008-1013. doi: 10.2741/2120

Borras C, Sastre J, García-Sala D, Lloret A, Pallardó FV, Viña J (2003). Mitochondria from females exhibit higher antioxidant gene expression and lower oxidative damage than males. Free Radic Biol Med 34: 546-552. doi: 10.1016/S0891-5849(02)01356-4

Casals C, Huertas JR, Franchini E, Sterkowicz-Przybycien K, Sterkowicz S, Gutiérrez-García C, Escobar-Molina R (2015). Special Judo Fitness Test level and anthropometric profile of elite Spanish judo athletes. J Strength Cond Res [Ahead of print].

Detanico D, Dal Pupo J, Franchini E, Dos Santos SG (2015). Effects of successive judo matches on fatigue and muscle damage markers. J Strength Cond Res 29: 1010-1016. doi: 10.1519/JSC.0000000000000746

Deminice R, Trindade CS, Degiovanni GC, Garlip MR, Portari GV, Teixeira M, Jordao AA (2010). Oxidative stress biomarkers response to high intensity interval training and relation to performance in competitive swimmers. J Sports Med Phys Fitness 50: 356-362. doi: R40102854

Dopsaj V, Martinovic J, Dopsaj M, Kasum G, Kotur-Stevuljevic J, Koropanovski N (2013). Hematological, oxidative stress, and immune status profiling in elite combat sport athletes. J Strength Cond Res 27: 3506-3514. doi: 10.1519/JSC.0b013e31828ddeea

Dopsaj V, Martinovic J, Dopsaj M, Stevuljevic JK, Bogavac-Stanojevic N (2011). Gender-Specific Oxidative Stress Parameters. Int J Sports Med 32: 14-19. doi: 10.1055/s-0030-1267930

Drid P, Trivic T, Tabakov S (2012). Special Judo Fitness Test – a Review. Serbian J Sports Sci 6: 117-125.

Douris PC, Elokda AS, Handrakis JP, Principal S, Rondo E, Bovell J, et al. (2009). Martial arts training enhances the glutathione antioxidant system in middle-aged adults. J Strength Cond Res 23: 1518-1523. doi: 10.1519/JSC.0b013e3181b339ac

Elabed K, Trabelsi K (2014). Kinetics of oxidative stress markers at rest and in response to aerobic and acute exercise in judokas men. Int J Sci Res 3: 756-761.

Finaud J, Lac G, Filaire E (2006). Oxidative stress: Relationship with exercise and training. Sports Med 36: 327-358. doi: 3644

Finsterer J (2012). Biomarkers of peripheral muscle fatigue during exercise. MBC Musculoskelet Disord 13: 218. doi: 10.1186/1471-2474-13-218

Finsterer J, Drory VE (2016). Wet, volatile, and dry biomarkers of exercise-induced muscle fatigue. BMC Musculoskelet Disord 17: 40. doi: 10.1186/s12891-016-0869-2

Franchini E, Artioli GG, Brito CJ (2013). Judo combat: time-motion analysis and physiology. Int J Perform Anal Sport 13: 624-641.

Franchini E, Brito CJ, Fukuda DH, Artioli GG (2014). The physiology of judo-specific training modalities. J Strength Cond Res 28: 1474-1481. doi: 10.1519/JSC.0000000000000281

Kabasakalis A, Tsalis G, Zafrana E, Loupos D, Mougios V (2014). Effects of endurance and high-intensity swimming exercise on the redox status of adolescent male and female swimmers. J Sports Sci 32: 747-756. doi: 10.1080/02640414.2013.850595

Laskowski R, Ziemann E, Olek RA, Zembron-Lancy A (2011). The effect of three days of judo training sessions on the inflammatory response and oxidative stress markers. J Hum Kinetics 30: 65-73. doi: 10.2478/v10078-011-0074-1

Lira FS, Neto JC, Seelaender M (2014). Exercise training as treatment in cancer cachexia. Appl Physiol Nutr Metab 39: 679-686. doi: 10.1139/apnm-2013-0554

Orrenius S, Moldeus P, Theor H, Hogberg J (1977). Microsomes and Drugs Oxidations. New York: Pergamon.

Martínez-Amat A, Boulaiz H, Marchal JA, Padial Puche P, Caba O, et al. (2005). Release of α-actin into serum after skeletal muscle damage. Br J Sports Med 39: 830-834. doi: 10.1136/bjsm.2004.017566

Martínez-Amat A, Marchal JA, Prados J, Hita F, Rodríguez-Serrano F, Boulaiz H, et al. (2010). Release of muscle α-actin into serum after intensive exercise. Biol Sport 27: 263-268.

Pepe H, Balci SS, Revan S, Akalin PP, Kurtoglu F (2009). Comparison of oxidative stress and antioxidant capacity before and after running exercises in both sexes. Gend Med 6: 587-595. doi: 10.1016/j.genm.2009.10.001

Pussieldi GA, Gomes EC, Veneroso CE, De Paz JA, Fonseca TR, Mendes TT, et al (2014). Soluble tumour necrosis factor receptor-1 (sTNFR1) levels are positively associated with exercise intensity in athletes after strenuous off-road cycling. J Sports Med Phys Fitness 54: 225-231. doi: R40Y2014N02A0225

Radak Z, Zhao Z, Koltai E, Ohno H, Atalay M (2013). Oxygen consumption and usage during physical exercise: the balance between oxidative stress and ROS-dependent adaptative signaling. Antioxid Redox Signal 18: 1208-1246. doi: 10.1089/ars.2011.4498

Reid MB (2008). Free radical and muscle fatigue: Of ROS, canaries, and the IOC. Free Radic Biol Med 44: 169-179. doi: 10.1016/j.freeradbiomed.2007.03.002

Scheele C, Nielsen S, Pedersen BK (2009). ROS and myokines promote muscle adaptation to exercise. Trends Endocrinol Metab 20: 95-99. doi: 10.1016/j.tem.2008.12.002

Scott JPR, Sale C, Greeves JP, Casey A, Dutton J, Fraser WD (2013). Cytokine response to acute running in recreationally-active and endurance-trained men. Eur J Appl Phys 113: 1871-1882. doi: 10.1007/s00421-013-2615-x

Sterkowicz S (1995). Test specjalnej sprawnosci ruchowej w judo. Antropomotoryka 12: 29-44.

Sterkowicz S, Zuchowicz A, Kubica R (1999). Levels of anaerobic and aerobic capacity indices and results for Special Fitness Test in judo competitors. J Hum Kinet 2: 115-135. doi: 10.1136/bjsm.35.4.231

Tanskanen M, Atalay M, Uusitalo A (2010). Altered oxidative stress in overtrained athletes. J Sports Sci 28: 309-317. doi: 10.1080/02640410903473844

Trivic T, Drid P, Drapsin M, Ostojic S, Obadov S, Radjo I (2011). Strength and endurance training does not lead to changes in major markers of oxidative stress. HealthMED 5: 616-620.

Ugras AF (2013). Effect of high intensity interval training on elite athletes' antioxidant status. Sci Sports 28: 253-259. doi: 10.1016/j.scispo.2012.04.009

OXIDATIVE STRESS AND INFLAMMATORY RESPONSES TO HIGH-INTENSITY INTERMITTENT EXERCISE IN ELITE CADET AND SENIOR FEMALE JUDOKAS

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ABSTRACT

The aim of this study was to evaluate the oxidative stress and inflammatory responses to high-intensity intermittent exercise in elite judo athletes comparing cadets and seniors. The sample consisted of 29 (14 seniors, 15 cadets) female athletes from the Spanish National Judo Team. During a competitive period, all athletes performed the Special Judo Fitness Test, consisted in a short-duration, high-intensity intermittent effort. Blood sampling was performed before and 15-min the test to measure lipid peroxidation (hydroperoxides and thiobarbituric acid reactive substances), antioxidants (retinol, α-tocopherol and catalase), pro-inflammatory cytokines (IL-6 and TNF-α) and their soluble receptors (sIL-6 and sTNF-R1). The inflammatory status of elite female judo athletes was similar at rest and after the test, however, TNF-α (0.41±0.12 pg/mL, $p<0.01$) and sIL-6R (3070±737 pg/mL, $p<0.001$) values were higher in seniors than in cadets. Moreover, seniors showed increased lipid peroxidation 15-min after the exercise (hydroperoxides: 0.76±0.21 nmol/mL, $p=0.001$; TBARS: 3.32±0.77 nmol/mL, $p<0.01$); while cadets showed similar levels before and after exercise. This fact indicates age differences in lipid peroxidation responses to short duration, high-intensity intermittent exercise ($p<0.01$), what might be explained by a quickly mobilization of non-enzymatic antioxidants (retinol: 1.76±0.39 nmol/mL, $p<0.001$, α-tocopherol: 6.83±02.72 nmol/mL, $p<0.03$) during recovery in the cadets group.

Keywords: lipid peroxidation; antioxidants; cytokines; elite athletes; judo; age differences.

INTRODUCTION

It is well established that the exercise-induced stress promotes the generation of reactive oxygen species (ROS) and triggers an inflammatory reaction [13]. Although ROS have a dominant role in cell damage, their signalling function is needed in several physiological responses and adaptations to exercise, such as mitochondrial biogenesis, enhanced antioxidant and oxidative stress-repairing system, and muscle adaptations [28,31]. Nevertheless, when the ROS exceed available antioxidant capacity, oxidative stress appears resulting in lipid and protein oxidation, DNA damage, and apoptosis [13,28,31]. Increasing evidence has shown that acute strenuous exercise may induce oxidative stress and tissue inflammation in trained athletes [3,23]. Hence, with inadequate recovery, these unfavourable responses to high-intensity exercise lead to impaired muscle strength and overtraining syndrome [13,30].

For this reason, the oxidative stress assessment might be a useful tool for improving performance and health of elite athletes [1]; especially in adolescent athletes that are more susceptible than adults to oxidative stress because their endogenous antioxidant system seems to be less efficient [12]. Moreover, elite judo athletes, including cadets, are subjected to high-intensity training regimen and demanding competitions with explosive actions and intermittent efforts [15]. Thus, oxidative stress and inflammation in judo athletes is notable since its origin is not only from mitochondria, but probably also from ischemia-reperfusion phenomenon and local inflammation [2,11]. During competition, the elite judo athlete achieves high-intensity intermittent efforts [14]; for that, specific judo tests have been developed considering this characteristic, such as the Special Judo Fitness Test [32]. Specific-judo tests are useful tools during competitive periods in testing the athlete's performance and are applied in all age-

categories. However, it is still unknown whether adolescent elite judo athletes may present redox balance differences compare with adult ones.

Therefore, the aim of the present study was to compare modifications of the redox status under exercising condition in elite female judo athletes comparing by age (cadets vs. seniors), throughout selected oxidative stress and inflammatory blood markers before and 15-min after a specific judo test (the Special Judo Fitness Test) consisted in a short-duration, high-intensity intermittent exercise (SD-HIIE). This information could be useful for judo coaches and athletes by elucidating whether elite female judokas present age-related demands and different recovery needs according to their antioxidant and anti-inflammatory capacities.

METHODS

Experimental Approach to the Problem

In this descriptive cross-sectional study, the oxidative stress and inflammatory status of elite cadet and senior female judo athletes were evaluated and compared at rest and 15 minutes after SD-HIIE. The study was carried out in the sport facilities of the High Performance Centre "Joaquín Blume" (Madrid, Spain) during the competitive period of one training meeting prior to an international tournament of each of the Spanish national judo teams (cadets and seniors). All judo athletes performed a judo-specific test (the Special Judo Fitness Test), consisted in a SD-HIIE, in an athletic training room after receiving thorough information about the test protocol. Blood sampling was drawn from the antecubital vein by qualified nursing staff, before and 15 minutes after the test. The samples were centrifuged and plasma samples were frozen at -80ºC awaiting analysis.

Subjects

The sample consisted of 29 elite female athletes from the Spanish National Judo Team and all weight categories; 14 athletes competed in senior division (above 20 years of age, mean of 23.5±3.1 years), while the other 15 athletes competed in cadet division (from 15 to 17 years of age, mean of 15.9±0.7 years). None of the subjects were under medical and/or psychiatric treatment when participating in the study. This study obtained ethical approval from the Research Ethics Committee of the University of Granada and was in accordance with the Helsinki declaration. After the participants were informed about the procedure and possible risks involved, written informed consent was obtained from all participants or from both parents in cases where the athlete was under 18 years of age.

Procedures

Short-Duration, High-Intensity Intermittent Exercise

The SD-HIIE consisted in the Special Judo Fitness Test [5] previously described [32]. Briefly, the athlete must complete as many throwing techniques (*ippon-seoi-nage*) as possible within the test time, running from one adversary to the other one (both are separated by 6 m). The test is composed of three parts (15, 30, and 30 seconds) separated by 10-seconds recovery periods. This test has been validated in judo athletes [33] and is currently one of the most used in judo research [9]. Heart rates (Polar Team2, Polar, Finland) and capillary finger blood lactates (Lactate PRO^{TM}, KDK Corp., Kyoto, Japan) were measured immediately after the test.

Lipid peroxidation markers

Lipid hydroperoxides in plasma were assessed by PeroxideDetect^{TM} Kit (code no. PD1; Sigma-Aldrich Co., St Louis, MO, USA) based on the fact that peroxides convert Fe^{2+} to Fe^{3+} ions under acidic conditions. Fe^{3+} ions form a coloured adduct with xylenol orange that were measured spectrophotometrically (Synergy HT, Bioteck, USA) at 560 nm. Plasma concentrations of thiobarbituric acid reactive substances (TBARS) was measured spectrophotometrically (Synergy HT, Bioteck, USA), determined by the reaction of malondialdehyde with thiobarbituric acid to form a colorimetric product that was read at 532 nm, following the method described by Orrenius [25].

Antioxidant markers

Plasma levels of retinol and α-tocopherol were determined by reverse-phase High Performance Liquid Chromatography (HPLC) at 292 nm according to Quiles et al. [27], using a Spherisorb S5 ODS1 (Merck, Darmstadt, Germany) column and ethanol:purified water 97:3 (v/v) as the mobile phase. The HPLC system was a Beckman in-line Diode Array Detector (Fullerton, CA, USA) connected to a Water (Milford, MA, USA) 717 plus autosampler (Gen Tech Scientific, NY, USA). Catalase activity was measured in erythrocytes samples as described by Ochoa et al. [24], based on monitoring at 240 nm spectrophotometrically (Synergy HT, Bioteck, USA) the H_2O_2 decomposition, as a consequence of the catalytic activity of catalase. The activity was calculated from the first-order rate constant (sec^{-1}).

Inflammatory markers

Plasma interleukin-6 (IL-6) and tumour necrosis factor (TNF-α) levels, as pro-inflammatory cytokines, and their respective soluble receptors (sIL-6R and sTNF-R1) were determined by Immunology Multiplex Assay (HSTCMAG-28SK and HSCRMAG-32K, Merck Millipore,

Darmstadt, Germany) and the Luminex® 200^{TM} System (Luminex Corp., Austin, TX, USA) according to the manufacturer's instructions.

Statistical analysis

Data are presented as the mean and the standard deviation. The Shapiro-Wilk statistic was used to test the normality of distributions. Statistical differences were determined using a two-way mixed anova with age-category (cadets vs. seniors) as the between-subjects variable and effort-moment (at rest vs. 15-min post-exercise) as the within-subjects variable, followed by Bonferroni post-hoc test. Effect sizes were calculated using partial eta squared (η^2_p). All analyses were conducted using the SPSS statistical package for Windows (version 17.0; SPSS, Inc., Chicago, Illinois, USA); the level of significance was set at $p<0.05$.

RESULTS

Our data showed a statistically significant main effect of the age-category factor in lipid hydroperoxides ($F(1,27)= 8.09$, $p= 0.008$, $\eta^2_p= 0.23$), TBARS ($F(1,27)= 7.69$, $p= 0.010$, $\eta^2_p= 0.22$), retinol ($F(1,27)= 29.38$, $p< 0.001$, $\eta^2_p= 0.52$), catalase ($F(1,27)= 5.42$, $p= 0.028$, $\eta^2_p= 0.17$), TNF-α ($F(1,27)= 11.35$, $p= 0.002$, $\eta^2_p= 0.30$) and sIL-6R ($F(1,27)= 17.33$, $p< 0.001$, $\eta^2_p= 0.39$) markers. Therefore, the above variables differed between age categories considering both at rest and 15-min post-exercise conditions. The effort-moment factor presented a significant main effect in lipid peroxidation (hydroperoxides: $F(1,27)= 7.48$, $p= 0.011$, $\eta^2_p= 0.22$; TBARS: $F(1,27)= 5.64$, $p= 0.025$, $\eta^2_p= 0.17$) and non-enzymatic antioxidants (retinol: $F(1,27)= 14.89$, $p= 0.001$, $\eta^2_p= 0.36$; α-tocopherol: $F(1,27)= 5.78$, $p= 0.023$, $\eta^2_p= 0.18$). Thus, oxidative stress significantly differed from baseline compared with 15-min post-exercise condition considering all female judokas in the analysis.

Moreover, a statistically significant interaction between factors (age category and effort moment) was reported in hydroperoxides ($F(1,27)= 5.04$, $p= 0.033$, $\eta^2_p= 0.16$), TBARS ($F(1,27)= 12.85$, $p= 0.001$, $\eta^2_p= 0.32$), retinol ($F(1,27= 7.11$, $p= 0.013$, $\eta^2_p= 0.21$) and sTNF-R1 ($F(1,27)= 5.76$, $p= 0.024$, $\eta^2_p= 0.176$) variables. These results indicated that the lipid peroxidation, retinol and sTNF-R1 responses to the specific-judo test differed by age category, while the rest of oxidative stress and inflammatory markers had similar responses to the mentioned SD-HIIE in cadets and seniors. All pairwise comparisons are shown in table 1, showing means and standard deviations for each experimental group. The lactates and heart rates responses to the SD-HIIE were similar between cadet and senior athletes, and the results confirm the high intensity of the exercise protocol. The means of lactate concentrations were 12.3±1.3 mmol/ml in cadets and 11.6±2.0 mmol/ml in seniors, and heart rate means were 183±8 ppm in cadets and 181±8 in seniors.

Table 1. Oxidative stress and inflammatory responses to SD-HIIE of elite Spanish female judokas

	Cadets (n=15)				*Seniors (n=14)*			
	Rest		**15-min recovery**		**Rest**		**15-min recovery**	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Hydroperoxides (nmol/mL)	2.17	0.57	2.24	0.43	2.47	0.53$^{\#}$	3.24	1.16*
TBARS (nmol/mL)	4.40	1.60	3.73	1.50	3.83	1.77$^{\#}$	7.14	2.90*
Retinol (nmol/mL)	3.15	2.01	1.38	0.72$^{\#}$	0.71	0.74*	0.38	0.25*
α-tocopherol (nmol/mL)	20.63	10.51	13.80	5.17$^{\#}$	15.78	5.66	13.52	6.60
Catalase (sec^{-1}*mg^{-1})	0.23	0.06	0.23	0.07	0.18	0.07	0.17	0.07*
IL-6 (pg/mL)	0.61	0.60	0.62	0.96	0.52	0.52	0.51	0.51
sIL-6R (pg/mL)	10,693	2,991	10,879	2,495	7,686	2,404*	7,745	1,988*
TNF-α (pg/mL)	1.40	0.39	1.38	0.28	0.95	0.38*	1.01	0.37*
sTNF-R1 (pg/mL)	635	205	571	186	514	184	651	249

*: differences between seniors and cadets, $^{\#}$: differences between rest and 15-min recovery conditions. SD-HIIE: short-duration, high-intensity intermittent exercise, TBARS: thiobarbituric acid reactive substances, IL-6: interleukin 6, sIL-6R: soluble IL-6 receptor, TNF-α: tumour necrosis factor, sTNF-R1: soluble TNF receptor-1.

DISCUSSION

In the present study, age-related differences in oxidative stress and inflammation have been reported in elite female judo athletes, at rest and after 15-min passive recovery from SD-HIIE. The main findings indicated that, despite adolescent athletes can have an immature antioxidant capacity [12,36], in our study the elite cadet judokas presented lower oxidative stress levels after recovery from SD-HIIE than seniors. Accordingly, some studies have reported that adolescents undergoing professional training regime show adequate antioxidant capacity [34]. However, there is a lack of studies analysing age differences in oxidative stress and inflammation in elite athletes that are subjected to very demanding training regimes. In light of this, our results showed that senior athletes presented increased lipid peroxidation 15-min after SD-HIIE, while cadet athletes had similar values to the baseline. In judo competition the athlete must participate in various matches, and the time interval between combats is about 15 min in the last matches of the eliminatory phases in international competitions (minimum interval of 10 minutes); hence, this time interval for recovery has been widely used in judo research [8,16,17,18]. Contrary to expected findings, the elite Spanish cadets showed a better oxidative stress response to the specific-judo test than seniors, which might be explained by the significantly reduction of plasmatic retinol and α-tocopherol 15-min after the test, since this decrease did not occur in seniors.

The above decrease of non-enzymatic antioxidants has been previously described in male judo practitioners [10,11], and has been related to oxidative stress increases [11,26]. It seems to act as a defence mechanism, mobilizing non-enzymatic antioxidants from plasma to exercise-activated membrane tissues [4,21,27], specifically mobilizing retinol and α-tocopherol to mitochondrial membranes. Moreover, the cadet judo athletes had higher catalase activities than

seniors, although a previous study in judo athletes found no significant differences between seniors and cadets in this biomarker [29]. These differences can be due to the sample characteristics (elite female judo athletes) and the training-period of the assessment (competitive period). Summarizing, a main result of this study indicates that the cadets did not increase their lipid peroxidation markers after the SD-HIIE showing, consequently, a better response to exercise compared with seniors, probably due to a quickly mobilization of non-enzymatic antioxidants from plasma to tissues.

Notwithstanding, the SD-HIIE did not induce a significant inflammatory response in either seniors or cadets, with similar plasmatic levels of pro-inflammatory cytokines (Il-6, TNF-α) and their soluble receptors (sIL-6R, sTNF-R1) at rest and after 15-min passive recovery. Accordingly, although exercise increases pro-inflammatory cytokines, high-intensity interval training, as judo training, attenuates the exercise-induced increase in plasma cytokines in response to acute exercise [6]. Thus, in spite of the demanding training during competitive period, both senior and cadet female athletes showed good inflammatory baseline levels and responses to SD-HIIE, with no symptoms of overtraining syndrome. Similar results have been previously reported, establishing that mixed strength and endurance training does not lead to oxidative damage in combat-sport male athletes [35].

Though inflammatory biomarkers were not altered by the effort moment as previous studies with judo athletes (20), some age differences were reported. The TNF-α and sIL-6R values were higher in seniors than in cadets. Moreover, our results showed a significantly different sTNF-R1 response to SD-HIIE between groups, increasing in seniors and decreasing in cadets as a response to SD-HIIE. The sTNF-R1 is an inhibitor of apoptosis induced by TNF-α

production stimulated by high-intensity exercise [22]; therefore, cadet athletes also showed slightly better inflammatory responses after recovery from SD-HIIE than seniors. Blood biomarkers offers a potentially more accurate method for evaluating inflammation caused by exercise indicating the relative state of recovery [1]; however, the use of several markers, as in this study, is convenient for a proper evaluation of the athlete. Our results highlight the need of analysing inflammatory markers in conjunction with their receptors, since although some pro-inflammatory markers are more elevated in seniors than in cadets, their receptors are also higher suggesting good exercise-induced adaptations; nevertheless, most of the current studies assessing IL-6 and TNF-α do not determine their main receptors.

In conclusion, the elite Spanish female judo athletes had normal inflammatory and oxidative stress values, with no evidences of overtraining; hence, their training planning during competitive period was generally appropriated. Although the SD-HIIE did not stimulate an inflammatory response, it significantly induced lipid peroxidation increases after 15-min recovery in elite seniors, but not in cadets. This better response to exercise of female cadets respect to seniors might be explained by a quickly mobilization of non-enzymatic antioxidants. The knowledge on the oxidative and inflammatory responses to judo-specific tasks can help athletes and coaches to improve their training prescription avoiding overtraining syndrome and, maximizing the athlete's health and performance.

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CONFLICT OF INTEREST

None declared.

REFERENCES

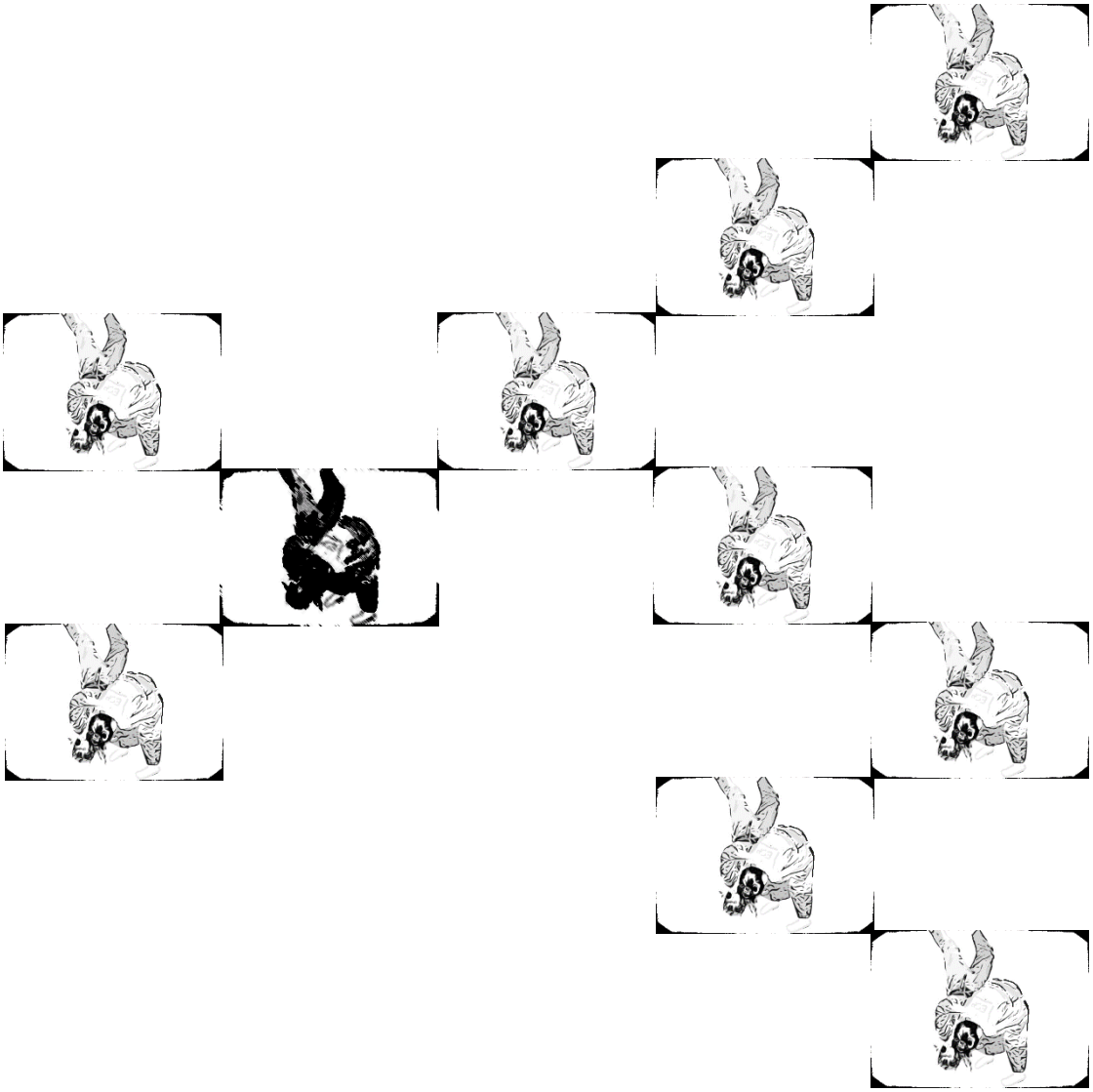
1. Bessa, AL, Oliveira, VN, Agostini, GG, Oliveira, RJS, Oliveira, ACS, White, GE, et al. Exercise Intensity and Recovery: Biomarkers of Injury, Inflammation, and Oxidative Stress. J Strength Cond Res 30: 311-319, 2016.
2. Bloomer, RJ, Goldfarb, AH. Anaerobic exercise and oxidative stress: a review. Can J Appl Physiol 29: 245-263, 2004.
3. Branth, S, Hambraeus, L, Piehl-Aulin, K, Essén-Gustavsson, B, Akerfeldt, T, Olsson, R, et al. Metabolic stress-like condition can be induced by prolonged strenuous exercise in athletes. Ups J Med Sci 114: 12-25, 2009.
4. Bregañó, JW, Dichi, JB, Barbosa, DS, El Kadri, MZ, Matsuo, T, Rodrigues, MA, et al. Decreased total antioxidant capacity in plasma, but not tissue, in experimental colitis. Dig Dis Sci 54: 751-757, 2009.
5. Casals, C, Huertas, JR, Franchini, E, Sterkowicz-Przybycien, K, Sterkowicz, S, Gutiérrez-García, C, et al. Special Judo Fitness Test level and anthropometric profile of elite Spanish judo athletes. J Strength Cond Res [Ahead of print].
6. Croft, L, Bartlett, JD, MacLaren, DPM, Reilly, T, Evans, L, Mattey, DL, et al. High-intensity interval training attenuates the exercise-induced increase in plasma IL-6 response to acute exercise. Appl Physiol Nutr Metab 34: 1098-1107, 2009.
7. Degoutte, F, Jouanel, P, Filaire, E. Energy demands during a judo match and recovery. Br J Sports Med 37: 245-249, 2003.
8. Detanico, D, Dal Pupo, J, Franchini, E, Dos Santos, SG. Effects of successive judo matches on fatigue and muscle damage markers. J Strength Cond Res 29: 1010-1016, 2015.
9. Drid, P, Trivic, T, Tabakov, S. Special Judo Fitness Test – a Review. Serbian J Sports Sci 6: 117-125, 2012.

10. El Abed, K, Rebai, H, Bloomer, RJ, Trabelsi, K, Masmoudi, L, Zbidi, A, et al. Antioxidant Status and Oxidative Stress at Rest and in Response to Acute Exercise in Judokas and Sedentary Men. J Strength Cond Res 25: 2400-2409, 2011.
11. Elabed, K, Trabelsi, K. Kinetics of Oxidative Stress Markers at Rest and in Response to Aerobic and Acute Exercise in Judokas Men. Int J Sci Res 3: 756-761, 2014.
12. Gougoura, S, Nikolaidis, MG, Kostaropoulos, IA, Jamustas, AZ, Koukoulis, G, Kouretas, D. Increased oxidative stress indices in the blood of child swimmers. Eur J Appl Physiol 100: 235-239, 2007.
13. Finaud, J, Lac, G, Filaire, E. Oxidative stress: Relationship with exercise and training. Sports Med 36: 327-358, 2006.
14. Franchini, E, Artioli, GG, Brito, CJ. Judo combat: time-motion analysis and physiology. Int J Perform Anal Sport 13: 624-641, 2013.
15. Franchini, E, Brito, CJ, Fukuda, DH, Artioli, GG. The physiology of judo-specific training modalities. J Strength Cond Res 28: 1474-1481, 2014.
16. Franchini, E, Branco, M, Agostinho, MF, Calmet, M, Candau, R. Influence of Linear and Undulating Strength Periodization on Physical Fitness, Physiological, and Performance Responses to Simulated Judo Matches. J Strength Cond Res 29: 358-367, 2015.
17. Franchini, E, de Moraes Bertuzzi, RC, Takito, MY, Kiss, MA. Effects of recovery type after a judo match on blood lactate and performance in specific and non-specific judo tasks. Eur J Appl Physiol 107: 377-383, 2009.
18. Franchini, E, Takito, MY, Nakamura, FY, Matsushigue, KA, Kiss MAPDM. Effects of recovery type after a judo combat on blood lactate removal and on performance in an intermittent anaerobic task. J Sports Med Phys Fitness 43: 424–443, 2003.

19. Kuwahara, H, Horie, T, Ishikawa, S, Tsuda, C, Kawakami, S, Noda, Y, et al. Oxidative stress in skeletal muscle causes severe disturbance of exercise activity without muscle atrophy. Free Radic Biol Med 48:1252-1262, 2010.
20. Lira, FS, Panissa, VL, Julio, UF, Franchini, E. Differences in metabolic and inflammatory responses in lower and upper body high-intensity intermittent exercise. Eur J Appl Physiol 115: 1467-1474, 2015.
21. Mataix, J, Quiles, JL, Huertas, JR, Battino, M, Mañas, M. Tissue specific interactions of exercise, dietary fatty acids, and vitamin E in lipid peroxidation. Free Radic Biol Med 24: 511-521, 1998.
22. Monkiewicz, M, Kuliczkowski, K, Zagrobelny, Z. Effect of an intensive exercise of short duration on the expression of TNF-alpha and receptor TNF-R1 (sTNF) in the blood serum. Medina dello Sport 54: 319-323, 2001.
23. Muñoz Marín, D, Olcina, G, Timón, R, Robles, MC, Caballero, MJ, Maynar, M. Effect of different exercise intensities on oxidative stress markers and antioxidant response in trained cyclists. J Sports Med Phys Fitness 50: 93–98, 2010.
24. Ochoa, JJ, Quiles, JL, Huertas, JR, Mataix, J. Coenzyme Q10 protects from aging-related oxidative stress and improves mitochondrial function in heart of rats fed a polyunsaturated fatty acid (PUFA)-rich diet. J Gerontol A Biol Sci Med Sci 60: 970-975, 2005.
25. Orrenius, S, Moldeus, P, Theor, H, Hogberg, J. Microsomes and Drugs Oxidations. New York: Pergamon, 1997.
26. Quiles, JL, Huertas, JR, Mañas, M, Battino, M, Ochoa, J, Mataix, J. Plasma antioxidants are strongly affected by iron-induced lipid peroxidation in rats subjected to physical exercise and different dietary fats. Biol Factors 8: 119-127, 1998.

27. Quiles, JL, Huertas, JR, Mañas, M, Ochoa, JJ, Battino, M, Mataix, J. Oxidative stress induced by exercise and dietary fat modulates the coenzyme Q and vitamin A balance between plasma and mitochondria. Int J Vitam Nutr Res 69: 243-249, 1999.
28. Radak, Z, Zhao, Z, Koltai, E, Ohno, H, Atalay, M. Oxygen consumption and usage during physical exercise: the balance between oxidative stress and ROS-dependent adaptative signaling. Antioxid Redox Signal 18: 1208-1246, 2013.
29. Radjo, I, Trivic, T, Bilic, A, Atanasov, D, Todorov, I, Drid, P. Alteration in biomarkers of oxidative stress in judokas with different age. HealthMED 6: 3228-3232, 2012.
30. Reid, MB. Free radical and muscle fatigue: Of ROS, canaries, and the IOC. Free Radic Biol Med 44: 169-179, 2008.
31. Scheele, C, Nielsen, S, Pedersen, BK. ROS and myokines promote muscle adaptation to exercise. Trends Endocrinol Metab 20: 95-99, 2009.
32. Sterkowicz, S. Test specjalnej sprawnosci ruchowej w judo. Antropomotoryka 12: 29-44, 1995.
33. Sterkowicz, S, Zuchowicz, A, Kubica, R. Levels of anaerobic and aerobic capacity indices and results for Special Fitness Test in judo competitors. J Hum Kinet 2: 115-135, 1999.
34. Tong, TK, Kong, Z, Lin, H, Lippi, G, Zhang, H, Nie, J. Serum Oxidant and Antioxidant Status Following an All-Out 21-km Run in Adolescent Runners Undergoing Professional Training –A One-Year Prospective Trial. Int J Mol Sci 14: 15167-15178, 2013.
35. Trivic, T, Drid, P, Drapsin, M, Ostojic, S, Obadov, S, Radjo, I. Strength and endurance training does not lead to changes in major markers of oxidative stress. HealthMED 5: 616-620, 2011.

36. Zalavras, A, Fatouros, IG, Deli, CK, Draganidis, D, Theodorou, AA, Soulas, D, et al. Age-Related Responses in Circulating Markers of Redox Status in Healthy Adolescents and Adults during the Course of a Training Macrocycle. Oxid Med Cell Longev 283921, 2015.



Conclusiones

Según lo aportado en el **Artículo 1** podemos concluir que las diferencias antropométricas entre hombres y mujeres fueron evidentes en los porcentajes de masa grasa y muscular, pero las diferencias entre las categorías senior y junior fueron escasas. El nivel de rendimiento específico de los judokas españoles de élite no fue muy elevado según los resultados del *Special Judo Fitness Test*, que además mostraron diferencias según la categoría de peso; concretamente los judokas de mayor peso obtuvieron peores resultados en el test que los de categorías de peso más ligeras. Por consiguiente, las normas clasificatorias del test deberían tener en consideración no solo el sexo y la edad sino también el peso de los deportistas haciendo las modificaciones pertinentes.

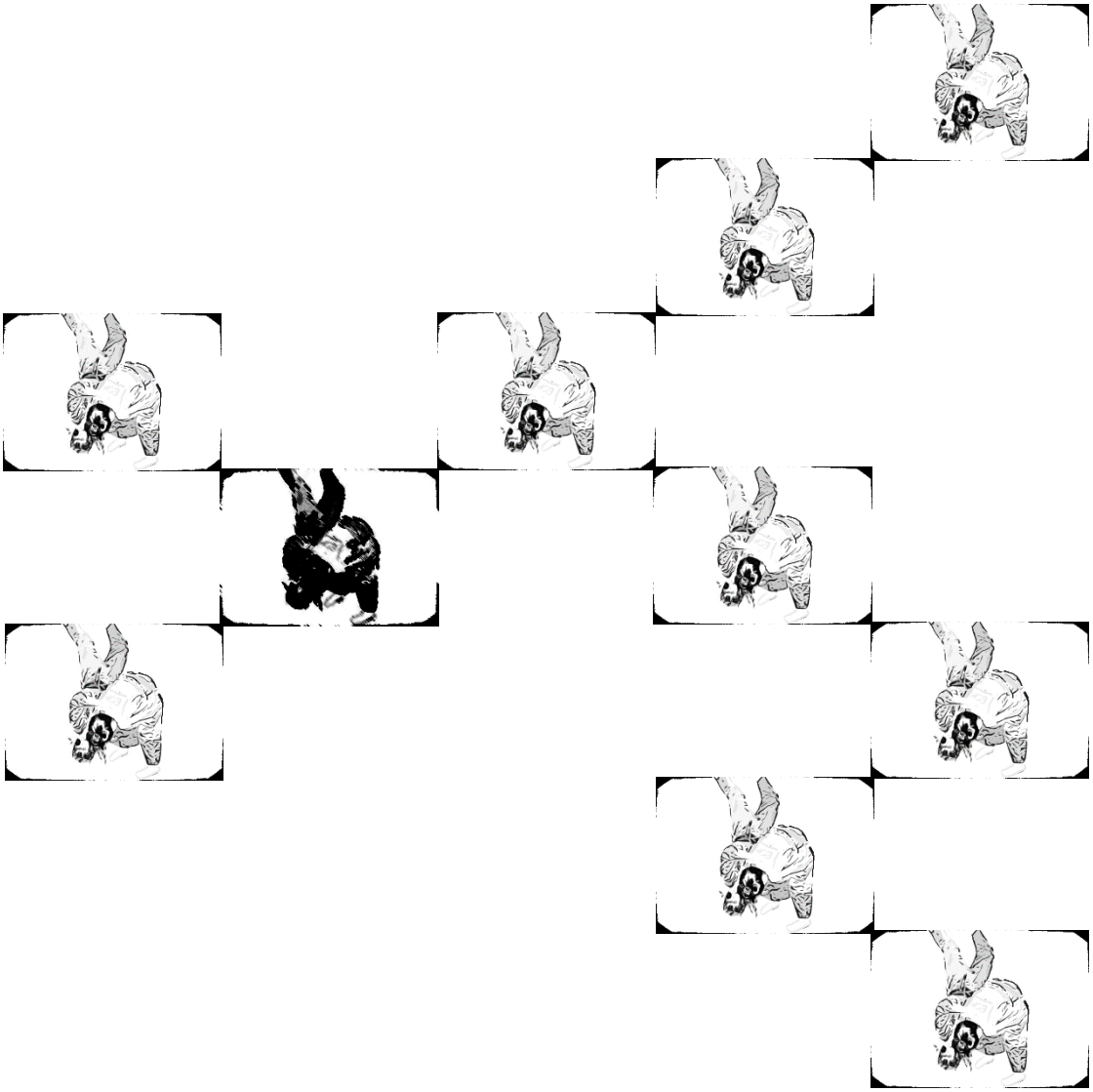
De acuerdo a los resultados del *Special Judo Fitness Test*, podemos concluir que las deportistas de la categoría senior deberían mejorar su capacidad anaeróbica, mientras que las juniors necesitaban incidir sobre el componente aeróbico mejorando su capacidad de recuperación tras el esfuerzo intermitente de alta intensidad. En cuanto a los judokas varones de la categoría senior, también debería mejorarse la capacidad aeróbica, sin embargo los juniors obtuvieron resultados valorados como *buenos* en todas las variables del test.

Además, el perfil antropométrico de los judokas de élite parece ser determinante para su rendimiento específico, ya que el pliegue subcutáneo del bíceps fue capaz de predecir el 31% del índice del *Special Judo Fitness Test* y, al ser una variable antropométrica rápida de medir, puede ser una herramienta útil para evaluar a dichos deportistas. Un mayor porcentaje de masa grasa y ósea y una menor ectomorfia parece estar relacionado con un mejor rendimiento en el test siendo capaz de predecir un 44% del índice. Tratándose de un modelo basado exclusivamente en las características antropométricas de judokas de élite, cabe destacar que estas predicciones son elevadas, por lo que se destaca la importancia de la composición corporal en el rendimiento deportivo.

Así pues, podemos concluir que el hecho de que el judo sea un deporte con categorías de peso incide sobre la composición corporal y los resultados de rendimiento específico en pruebas de esfuerzo. Además, la existencia de categorías pesadas sin un control del porcentaje de grasa corporal permite que haya deportistas de élite bajo situaciones de riesgo para la salud, tal y como se describe en el **Artículo 2**. La presencia de factores de riesgo de enfermedades cardiovasculares en los judokas españoles de élite fue considerable, destacando la presencia de hipertensión, los niveles bajos de colesterol HDL y el exceso de grasa corporal en las categorías de mayor peso. Por lo tanto, pese a la temprana edad de los judokas y su alto nivel de condición física, estos deportistas deberían ser evaluados periódicamente para prevenir el desarrollo de enfermedades cardiovasculares. A su vez, sería conveniente la inclusión de herramientas para la monitorización periódica del peso de los judokas, evitando tanto la ganancia excesiva de grasa corporal como el cambio cíclico de peso que suelen realizar estos deportistas y que también es un factor de riesgo de enfermedades cardiovasculares incluso manteniéndose en normopeso. Esto se hace especialmente notable en el hecho de que más de la mitad de los judokas españoles de élite estaban por encima del peso permitido en su categoría durante el periodo competitivo, sugiriendo la práctica de reducciones drásticas de peso previa a la competición. Destaca pues, la importancia de correctos hábitos alimenticios y la educación sanitaria, con el fin de evitar que los judokas incurran en métodos de reducción drástica del peso corporal poniendo en riesgo su salud a largo plazo.

No obstante, los valores sanguíneos de estrés oxidativo, inflamación y daño muscular mostraron valores normales tanto en reposo como en respuesta al esfuerzo intermitente en alta intensidad. Por lo tanto, los judokas españoles de élite habían desarrollado adaptaciones al ejercicio eficientes que les permitían llevar a cabo el programa de entrenamiento competitivo sin liberar un exceso de las mencionadas variables ni presentar síntomas de sobre-entrenamiento. Los principales hallazgos del **Artículo 3** muestran diferencias debidas al sexo

en la respuesta inflamatoria al ejercicio intermitente de alta intensidad pero con niveles similares de daño muscular. Además, las mujeres presentaban menor peroxidación lipídica y citoquinas anti-inflamatorias que los hombres. En base a lo aportado en el **Artículo 4**, podemos concluir que existen diferencias en los niveles de estrés oxidativo entre las categorías de edad cadete (de 15 a 17 años) y senior (>21 años). De esta forma, en la categoría senior los niveles de peroxidación lipídica aumentaron en respuesta a la prueba de esfuerzo, mientras que esto no ocurrió en la categoría de cadetes que mantuvieron valores similares pre y post ejercicio. Este hecho puede ser debido al mecanismo de defensa antioxidante consistente en la rápida movilización de antioxidantes no enzimáticos del pool plasmático a los tejidos activos durante el ejercicio que se dio en cadetes pero no en seniors.



Conclusions

According to the provided in **Article 1**, we can conclude that sexual dimorphism in judo athletes was apparent for body fat and muscle percentages, whereas juniors and seniors exhibited few differences in body composition. The Special Judo Fitness Test results suggest that the judo-specific performance of the elite Spanish judokas was not very high. Moreover, the weight category impacted on the test performance; specifically, heavier judo athletes achieved worse results than lighter athletes. Therefore, the classificatory norms of the Special Judo Fitness Test should consider not only the sex and age, but also the judokas' weight category.

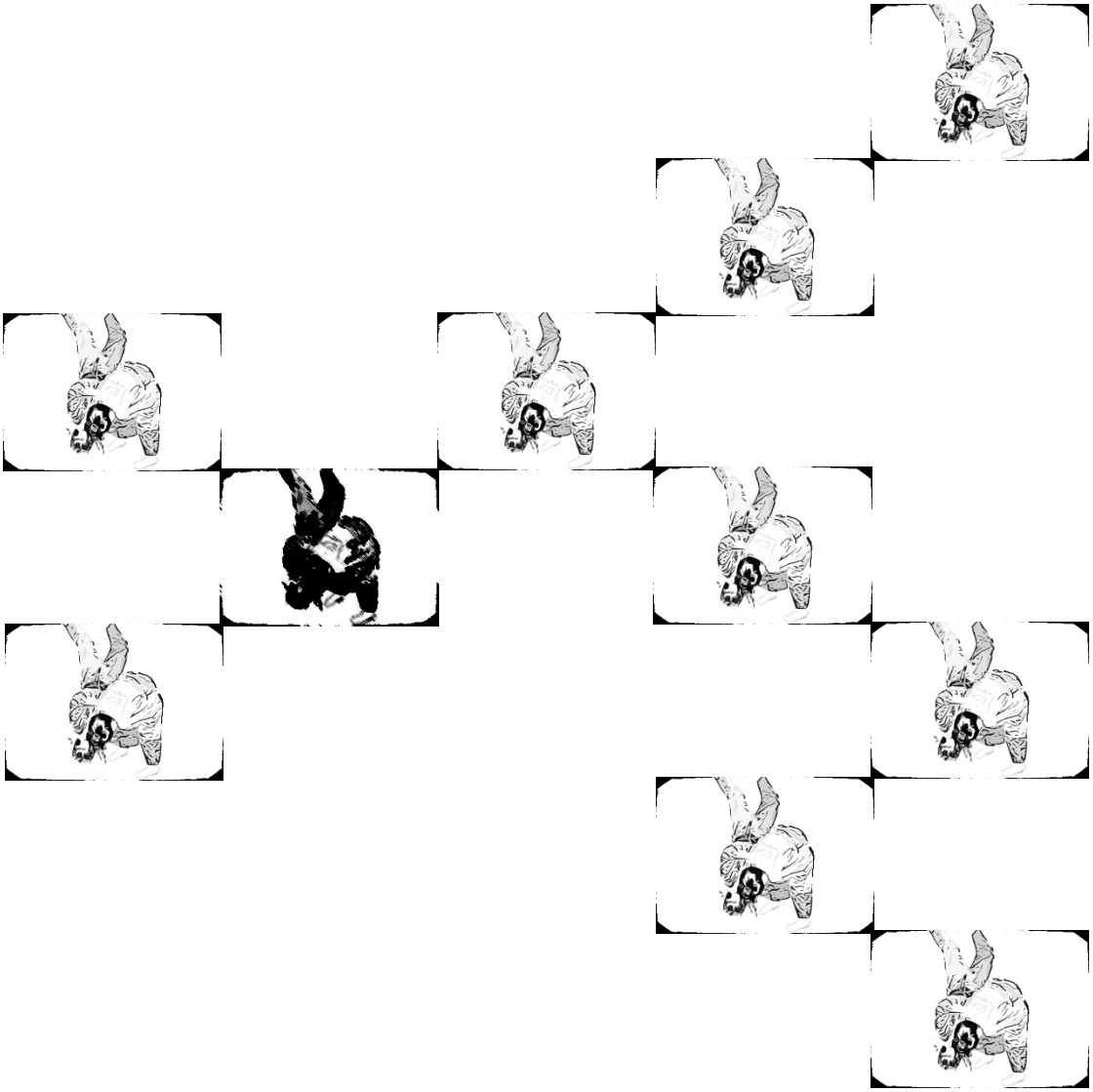
The Special Judo Fitness Test results indicated that female seniors should improve their anaerobic capacity, whereas female juniors must increase their aerobic component improving their recovery capacities from high-intensity intermittent exercise. Male seniors also should improve their aerobic capacity, while male juniors had similar classifications (*good*) for all the test variables.

Additionally, the anthropometric profile of elite judo athletes seems relevant for their specific performance since the biceps skinfold was able to predict up to 31% of the Special Judo Fitness Test index and can be quickly assessed, making it a useful tool in testing these athletes. Higher muscle and bone mass percentages and lower ectomorphy seem to be associated with better performances and can jointly predict 44% of the test index. It should be noted that these predictions are high for a model exclusively based on anthropometric characteristics of elite judokas; therefore, the body composition of these athletes is relevant for their specific performance.

Thus, we can conclude that the fact that judo is a weight-categorized sport impacts on body composition and performance achieved in judo-specific tests. Furthermore, the presence of heavy-weight categories with no body fat limits allows the existence of elite athletes with

increased health risk, as reported **Article 2**. The presence of risk factors of cardiovascular diseases in the elite Spanish judokas was notable, highlighting the cases of hypertension, low HDL-cholesterol levels, and body fat excess in heavier categories. Hence, despite the young age and high fitness level of the judokas, these athletes should be periodically evaluated in order to prevent the development of cardiovascular diseases. In addition, monitoring the judokas' weight would be necessary to avoid excessive body fat and weight cycling which are related to cardiovascular diseases even maintaining normowieght. In this regard, it must be emphasized that, during the competitive period, more than half of the elite Spanish judokas were above the limit of their respective weight categories, suggesting rapid weight loss practices before competition. Thus, appropriate dietary habits and health counselling are relevant for avoiding rapid weight loss practices and improve the long-term health of elite judokas.

Notwithstanding, plasma levels of oxidative stress, inflammation and muscle damage were normal both at rest and in response to the high-intensity exercise. Probably, the elite Spanish judokas had developed efficient adaptations to exercise, thus, they were able to undergo elite training programs with neither excessive values in the mentioned variables nor overtraining symptoms. The main findings of **Article 3** showed sex-related differences in inflammatory responses to high-intensity intermittent exercise but similar muscle damage levels. Female athletes showed lower lipid peroxidation and anti-inflammatory cytokines than males. Moreover, the results of **Article 4** indicated oxidative stress differences between cadets (from 15 to 17 years of age) and seniors (>21 years of age). Therefore, the senior category showed increased lipid peroxidation levels in response to exercise, while cadets had similar values before and after exercise. This fact can be due to the antioxidant defence mechanism consisted of a quickly mobilization of non-enzymatic antioxidants from the plasma pool to active tissues during exercise what occurred in cadets but not in seniors.



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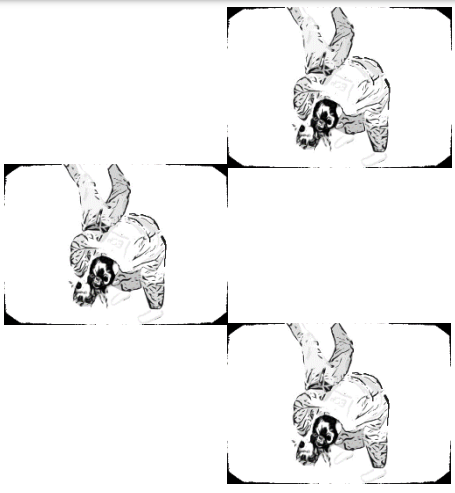

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