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Sumario / Summary

Declaraciones nutricionales y propiedades saludables en productos alimenticios para la actividad física y el deporte

Nutritional and health claims made on foodstuffs for physical activity and sport

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El interés por el beneficio de los nutrientes y otras sustancias con efecto fisiológico ha ido aumentando en los últimos años, referido a esto cada vez se han aprobado más declaraciones nutricionales y propiedades saludables por la *European Food Safety Authority* (EFSA) y autorizados a través de Reglamento 432/2012 por la Comisión Europea. Por este motivo, es imprescindible que los profesionales de la nutrición, actividad física y el deporte y la salud en general conozcan los que están legalmente aprobados y autorizados bajo a aprobación de la evidencia científica de la EFSA. Claramente una alimentación que proporcione los nutrientes y otras sustancias con efecto fisiológico, en cantidades adecuadas para la práctica de la actividad física y el deporte, basados en criterios de dieta variada y equilibrada, puede ser suficiente. No obstante, se puede aumentar la ingesta de ciertos nutrientes a través de una selección de alimentos para incorporar determinados nutrientes o también con la complementación de suplementos alimenticios, sin que estos sean sustitutos de una alimentación equilibrada. La gran diferencia en ambos casos, es primero la presentación, matriz alimento o forma farmacológica, pues según la Directiva 2002/46/CE del Parlamento Europeo, los complementos alimenticios son "productos alimenticios cuya finalidad es complementar la dieta normal y que son fuentes concentradas de nutrientes u otras sustancias con un efecto nutricional o fisiológico, solos o en combinación, comercializados en forma de dosis, a saber, formas como cápsulas, pastillas, tabletas, píldoras y otras formas similares, sobres de polvo, ampollas de líquidos, botellas dispensadoras de gotas y otras formas similares de líquidos y polvos diseñados para tomarse en pequeñas cantidades unitarias medidas".

Hay que tener en cuenta, que cuando un producto alimenticio cumple las condiciones de uso establecidas en el Reglamento (CE) Nº 1924/2006 de la Unión Europea, puede llevar, de forma voluntaria, declaraciones sobre su etiquetado, presentación o publicidad. Hay varios tipos de declaraciones: declaraciones nutricionales, como "bajo en energía" cuya lista positiva se encuentra recogida en dicho Reglamento, declaraciones de propiedades saludables según establece el artículo 13, del R 1924/2006, distinta de las de reducción de riesgo y de las de niños y que ha sido aprobadas a través del listado autorizado en el Reglamento 432/2012, como "la vitamina D contribuye al mantenimiento de la función muscular normal" y declaraciones relativas al desarrollo y la salud de los niños según el apartado b del punto 1 del artículo 4 del mencionado Reglamento y que se aprueban y autorizan caso por caso a través de Reglamento específicos.

Estas declaraciones son menciones de carácter voluntario contempladas en el etiquetado, la presentación y publicidad de los productos alimenticios, conocido legislativamente desde el año 2011 como información alimentaria facilitada al consumidor, Reglamento 1169/2011. Por eso, si se realizan estas declaraciones en cualquier soporte deben cumplir con las condiciones de uso establecidas para cada uno de ellos. Aunque se permite cierta flexibilidad en la redacción de la declaración, no puede inducir a error al consumidor y debe tener el mismo significado que el autorizado por la Unión Europea. Así pues, las declaraciones nutricionales indican la presencia, ausencia, aumento o reducción del contenido de nutrientes/sustancias con efecto fisiológico/energía, mientras que las declaraciones de propiedades saludables relacionan un nutriente, sustancia, alimento o categoría de alimentos con la salud. En el caso de las declaraciones de propiedades saludables no deben ser taxativas y siempre se anteceden por términos como ayuda, contribuye, posibilita…

Entre todas las declaraciones de propiedades saludables, hay aquellas que se relacionan con el desarrollo de los niños, las declaraciones de reducción de riesgos y las declaraciones de propiedades saludables funcionales. Algunas de estas declaraciones de propiedades saludables

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están relacionadas con la actividad deportiva con el objetivo de mejorar el rendimiento físico de la persona.

Además, para que se obtenga el efecto beneficioso mencionado en la declaración, el nutriente, sustancia, alimento o categoría de alimento debe estar en cantidades mínimas establecidas en el Reglamento (CE) Nº 1924/2006. Estas declaraciones están destinadas a ayudar a los consumidores a tomar decisiones bien informadas, siendo atributos de credibilidad ya que como se ha mencionado anteriormente, antes de ser aprobadas por la Comisión Europea, la Autoridad Europea de Seguridad Alimentaria (EFSA) evalúa la evidencia científica que respalda estas afirmaciones, siendo "veraz, clara, fiable y útil para el consumidor".

Actualmente, hay casi de 300 declaraciones aprobadas por la EFSA, de las cuales, aproximadamente, 30 son declaraciones nutricionales, y 265 son declaraciones de propiedades saludables. De estas casi 300 declaraciones de propiedades saludables, XX están relacionadas con la actividad deportiva, de las cuales un total de 48 nos han servido (0 referidas al desarrollo de los niños, 1 a la reducción del riesgo de enfermedad y 47 a las declaraciones de propiedades saludables funcionales).

Hay contempladas para 26 nutrientes diferentes, declaraciones de propiedades saludables relacionadas con la actividad física y deportiva, de los cuales 12 son relacionadas con minerales (calcio, sodio, cobre, cromo, fósforo, hierro, magnesio, manganeso, molibdeno, potasio, yodo y zinc), 10 con vitaminas (ácido pantoténico (vitamina B5), biotina, folato, niacina (vitamina B3), riboflavina (vitamina B2), tiamina (vitamina B1), vitamina B12, vitamina B6, vitamina C y vitamina D), 2 con hidratos de carbono, 2 con agua, 1 con proteína y 1 con creatina. Cada uno de estos nutrientes o sustancias con efecto fisiológico puede tener varias declaraciones de propiedades saludables con diferentes funciones, por ejemplo, "el agua contribuye al mantenimiento de las funciones físicas y cognitivas normales" y "el agua contribuye al mantenimiento de la regulación normal de la temperatura corporal".

Según se recoge en el buscador de declaraciones nutricionales y saludables de la Agencia Española de Seguridad Alimentaria y Nutrición (AESAN), podemos indicar varias declaraciones:

Tipo: absorción de agua; nutriente, sustancia, alimento o categoría de alimentos: soluciones electrolíticas a base de hidratos de carbono; declaración: soluciones electrolíticas a base de hidratos de carbono mejoran la absorción de agua durante el ejercicio físico; condiciones de uso de la declaración: para que un producto pueda llevar esta declaración, las soluciones electrolíticas a base de hidratos de carbono deben contener entre 80 kcal/l y 350 kcal/l procedentes de hidratos de carbono, y al menos el 75 % de la energía debe derivarse de hidratos de carbono que provoquen una respuesta glucémica alta, como la glucosa, los polímeros de glucosa y la sacarosa. Además, estas bebidas deben contener entre 20 mmol/l (460 mg/l) y 50 mmol/l (1,150 mg/l) de sodio, y tener una osmolalidad entre 200 mOsm/kg y 330 mOsm/kg de agua.

Tipo: cansancio y fatiga; nutriente, sustancia, alimento o categoría de alimentos: (1) ácido pantoténico, (2) folatos, (3) hierro, (4) magnesio; (5) niacina, (6) riboflavina, (7) vitamina B12, (8) vitamina B6, (9) vitamina C; declaración: (1)(2)(3)(4)(5)(6)(7)(8)(9) ayuda a disminuir el cansancio y la fatiga; condiciones de uso de la declaración: esta declaración solo puede utilizarse respecto a alimentos que son, como mínimo, fuente de folatos de acuerdo con la declaración FUENTE DE [NOMBRE DE LAS VITAMINAS] Y/O [NOMBRE DE LOS MINERALES] que figura en el anexo del Reglamento (CE) no 1924/2006.

Tipo: ejercicio de Resistencia; nutriente, sustancia, alimento o categoría de alimentos: (1) soluciones electrolíticas a base de hidratos de carbono, (2) creatina; declaración: (1) las soluciones electrolíticas a base de hidratos de carbono contribuyen a mantener el nivel de resistencia en ejercicios que requieren una resistencia prolongada (2) el consumo diario de creatina puede reforzar el efecto del entrenamiento de resistencia en la fuerza muscular en adultos mayores de 55 años; condiciones de uso de la declaración: (1) para que un producto pueda llevar esta declaración, las soluciones electrolíticas a base de hidratos de carbono deben contener entre 80 kcal/l y 350 kcal/l procedentes de hidratos de carbono, y al menos el 75 % de la energía debe derivarse de hidratos de carbono que provoquen una respuesta glucémica alta, como la glucosa, los polímeros de glucosa y la sacarosa. Además, estas bebidas deben contener entre 20 mmol/l (460 mg/l) y 50 mmol/l (1,150 mg/l) de sodio, y tener una osmolalidad entre 200 mOsm/kg y 330 mOsm/kg de agua, (2) Se informará al consumidor de que: —esta declaración está dirigida a los adultos mayores de 55 años que realicen regularmente un entrenamiento de resistencia; — el efecto beneficioso se obtiene con una ingesta diaria de 3 g de creatina en combinación con un entrenamiento de resistencia, que permite un aumento de la carga de trabajo a lo largo del tiempo y que debe realizarse al menos tres veces por semana durante varias semanas, con una intensidad de al menos un 65 %-75 % de la carga de una repetición máxima(*). (*) La carga de una repetición máxima es el peso máximo que una persona puede levantar o la fuerza máxima que puede ejercer en un solo levantamiento.

Tipo: función muscular; nutriente, sustancia, alimento o categoría de alimentos: (1) (2) proteínas, (3) hidratos de carbono declaración: (1) las proteínas contribuyen a que aumente la masa muscular, (2) las proteínas contribuyen a conservar la masa muscular, (3) Los hidratos de carbono contribuyen a la recuperación de la función muscular normal (contracción) después de un ejercicio físico de gran intensidad o de larga duración que conduce a la fatiga muscular y al agotamiento del glucógeno almacenado en los músculos esqueléticos; condiciones de uso de la declaración: (1)(2) esta declaración solo puede utilizarse respecto a alimentos que son, como mínimo, fuente de proteínas de acuerdo con la declaración FUENTE DE PROTEÍNAS que figura en el anexo del Reglamento (CE) no 1924/2006, (3) esta declaración solo puede utilizarse en alimentos que aporten hidratos de carbono que sean metabolizados por las personas (lo que excluye a los polialcoholes). Se informará al consumidor de que el efecto benéfico se obtiene al consumir hidratos de carbono de todas las fuentes en una ingesta total de 4 g por kg de peso corporal, en dosis tomadas antes de transcurridas cuatro horas (o, como máximo, seis) después de finalizar un ejercicio físico de gran intensidad o de larga duración que conduzca a la fatiga muscular y al agotamiento del glucógeno almacenado en los músculos esqueléticos.

Tipo: funciones físicas y cognitivas; nutriente, sustancia, alimento o categoría de alimentos: agua; declaración: el agua contribuye a mantener las funciones físicas y cognitivas normales; condiciones de uso de la declaración: para que un producto pueda llevar esta declaración, se informará al consumidor de que el efecto beneficioso se obtiene con una ingesta diaria de al menos 2,0 L de agua al día, procedente de cualquier fuente.

Tipo: metabolismo energético; nutriente, sustancia, alimento o categoría de alimentos: (1) ácido pantoténico, (2) biotina, (3) calcio, (4) cobre, (5) fósforo, (6) hierro, (7) magnesio, (8) manganeso, (9) niacina, (10) riboflavina, (11) tiamina, (12) vitamina B12, (13) vitamina B6, (14) vitamina C, (15) Yodo; declaración: (1)(2)(3)(4)(5)(6)(7)(8)(9) (10)(11)(12)(13)(14)(15) contribuye al metabolismo energético normal; declaración: condiciones de uso de la declaración: (1)(2)(3)(4)(5)(6)(7)(8)(9) (10)(11)(12)(13)(14)(15) esta declaración solo puede utilizarse respecto a alimentos que son, como mínimo, fuente de yodo de acuerdo con la declaración FUENTE DE [NOMBRE DE LAS VITAMINAS] Y/O [NOMBRE DE LOS MINERALES] que figura en el anexo del Reglamento (CE) no 1924/2006.

Tipo: metabolismo de macronutrientes, nutriente, sustancia, alimento o categoría de alimentos: (1) biotina, (2) cromo, (3) zinc; (4) Vitamina B6 ; declaración: (1)(2)(3) contribuye al metabolismo normal de los macronutrientes, (4) contribuye al metabolismo normal de las proteínas y del glucógeno; condiciones de uso de la declaración: (1)(2)(3) (4) esta declaración solo puede utilizarse respecto a alimentos que son, como mínimo, fuente de zinc de acuerdo con la declaración FUENTE DE [NOMBRE DE LAS VITAMINAS] Y/O [NOMBRE DE LOS MINERALES] que figura en el anexo del Reglamento (CE) no 1924/2006.

Tipo: recuperación muscular; nutriente, sustancia, alimento o categoría de alimentos: hidratos de carbono; declaración: los hidratos de carbono contribuyen a la recuperación de la función muscular normal (contracción) después de un ejercicio físico de gran intensidad o de larga duración que conduce a la fatiga muscular y al agotamiento del glucógeno almacenado en los músculos esqueléticos; condiciones de uso de la declaración: Esta declaración solo puede utilizarse en alimentos que aporten hidratos de carbono que sean metabolizados por las personas (lo que excluye a los polialcoholes). Se informará al consumidor de que el efecto benéfico se obtiene al consumir hidratos de carbono de todas las fuentes en una ingesta total de 4 g por kg de peso corporal, en dosis tomadas antes de transcurridas cuatro horas (o, como máximo, seis) después de finalizar un ejercicio físico de gran intensidad o de larga duración que conduzca a la fatiga muscular y al agotamiento del glucógeno almacenado en los músculos esqueléticos.

Tipo: rendimiento físico; nutriente, sustancia, alimento o categoría de alimentos: creatina; declaración: mejora el rendimiento físico en series sucesivas de ejercicios breves de alta intensidad; condiciones de uso de la declaración: Esta declaración solo puede utilizarse respecto a alimentos que aporten una ingesta diaria de 3 g de creatina. Para que un producto pueda llevar esta declaración, se informará al consumidor de que el efecto beneficioso se obtiene con una ingesta diaria de 3 g de creatina.

Tipo: sistema inmunológico; nutriente, sustancia, alimento o categoría de alimentos: vitamina C; declaración: contribuye al funcionamiento normal del sistema inmunitario durante el ejercicio físico intenso y después de este; condiciones de uso de la declaración: Esta declaración solo puede utilizarse respecto a alimentos que aporten 200 mg diarios de vitamina C. Para que un producto pueda llevar esta declaración, se informará al consumidor de que el efecto beneficioso se obtiene con una ingesta de 200 mg al día añadida a la ingesta diaria recomendada de vitamina C.

Tipo: temperatura corporal; nutriente, sustancia, alimento o categoría de alimentos: agua; declaración: el agua contribuye a la regulación normal de la temperatura corporal; condiciones de uso de la declaración: para que un producto pueda llevar esta declaración, se informará al consumidor de que el efecto beneficioso se obtiene con una ingesta diaria de al menos 2,0 L de agua al día, procedente de cualquier fuente.

Tipo: transporte de oxígeno; nutriente, sustancia, alimento o categoría de alimentos: hierro; declaración: el hierro contribuye al transporte normal de oxígeno en el cuerpo; condiciones de uso de la declaración: esta declaración solo puede utilizarse respecto a alimentos que son, como mínimo, fuente de hierro de acuerdo con la declaración FUENTE DE [NOMBRE DE LAS VITAMINAS] Y/O [NOMBRE DE LOS MINERALES] que figura en el anexo del Reglamento (CE) no 1924/2006.

No obstante, algunas de las declaraciones de propiedades saludables tienen algunas condiciones, restricciones o advertencias complementarias, como:

Declaración: el consumo diario de creatina puede reforzar el efecto del entrenamiento de resistencia en la fuerza muscular en adultos mayores de 55 años; condiciones, restricciones o advertencias complementarias: esta declaración solo puede utilizarse en alimentos destinados a los adultos mayores de 55 años que realicen regularmente un entrenamiento de resistencia.

Declaración: la creatina mejora el rendimiento físico en series sucesivas de ejercicios breves de alta intensidad; condiciones, restricciones o advertencias complementarias: solo puede utilizarse esta declaración respecto a alimentos para adultos que realicen ejercicio de alta intensidad.

Declaración: Los hidratos de carbono contribuyen a la recuperación de la función muscular normal (contracción) después de un ejercicio físico de gran intensidad o de larga duración que conduce a la fatiga muscular y al agotamiento del glucógeno almacenado en los músculos esqueléticos; condiciones, restricciones o advertencias complementarias: la declaración solo podrá utilizarse en alimentos destinados a personas adultas que hayan realizado un ejercicio físico de gran intensidad o de larga duración que conduzca a la fatiga muscular y al agotamiento del glucógeno almacenado en los músculos esqueléticos.

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Effect of 3-week progressive overloading and 1-week tapering on performance, internal training load, stress tolerance and heart rate variability in under-19 Brazilian badminton players

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Summary

Objective: This study aimed to determine the effect of 3-week progressive overloading and 1-week tapering during a pre-season on performance, internal training load, stress tolerance, and heart rate variability in under-19 Brazilian badminton players.
Material and method: Eight male under-19 badminton players (age 16.1 ± 0.6 years; height 1.68 ± 7.7 m; body mass 57.2 ± 5.8 kg; body mass index 20.3 ± 2.5 kg·m^{-2}; body fat 8.0 ± 2.7 %), competing at the state level had physical and physiological monitored over four weeks during pre-season. Players underwent a badminton-specific movement agility test, 5-m multiple shuttle test, Yo-Yo Intermittent Recovery test level 1, and performed vertical jumps before and after the pre-season. During the training, the heart rate variability and internal training load were monitored daily, and weekly were stress tolerance was recorded by psychometric responses.
Results: The players showed significant improvements in all performance variables assessed after the training period. The internal training load during overloading was higher (1635 ± 109.9; 2490 ± 124; 2850 ± 210 AU) compared to tapering (1335 ± 100 AU). The stress tolerance decreased during overloading (4.0 ± 0.7; 8.2 ± 1.3; 10.1 ± 1.4) and increased during tapering (5.5 ± 1.5). In addition, higher internal training load during overloading resulted in a greater reduction in root-mean-square difference of successive R-R intervals (lnRMSSDmean) (4.2 ± 0.2; 4.1 ± 0.1; 4.0 ± 0.1 ms) and a smaller coefficient of variation (lnRMSSDcv) (4.5 ± 2.6; 2.1 ± 1.2; 1.4 ± 0.9 %), and the significant reduction in the internal training load during tapering led to a decrease in lnRMSSDmean (1.3 ± 0.5 ms).
Conclusions: Our results suggest that using badminton training programs during the pre-season, including intermittent high-intensity actions with progressive overloading followed by a tapering is sufficient to result in positive adaptations in performance and led to adaptative changes in internal training load, stress tolerance, and heart rate variability.

Key words:
Performance. Autonomic nervous system. Periodization. Monitoring.

Efecto de la sobrecarga progresiva de 3 semanas y la reducción gradual de 1 semana sobre el rendimiento, la carga de entrenamiento interno, la tolerancia al estrés y la variabilidad de la frecuencia cardíaca en jugadores brasileños de Bádminton menores de 19 años

Resumen

Objetivo: Este estudio tuvo como objetivo determinar el efecto de la sobrecarga progresiva de 3 semanas y la reducción gradual de 1 semana durante una pretemporada sobre el rendimiento, la carga de entrenamiento interno, la tolerancia al estrés y la variabilidad de la frecuencia cardíaca en jugadores de bádminton brasileños menores de 19 años.
Material y método: Ocho jugadores masculinos de bádminton sub-19 (edad 16,1 ± 0,6 años; altura 1,68 ± 7,7 m; masa corporal 57,2 ± 5,8 kg; índice de masa corporal 20,3 ± 2,5 kg·m^{-2}; grasa corporal 8,0 ± 2,7 %), que competían a nivel estatal fueron monitoreados en sus aspectos físicos y fisiológicos durante cuatro semanas en la pretemporada. Los jugadores realizaron un test de agilidad específico de bádminton, el test 5-m multiple shuttle test, el test Yo-Yo y realizaron saltos verticales antes y después de la pretemporada. Durante el entrenamiento, se monitoreó diariamente la variabilidad de la frecuencia cardíaca y la carga interna de entrenamiento. Además, semanalmente se registró la tolerancia al estrés mediante respuestas psicométricas.
Resultados: Los jugadores mostraron mejoras significativas en todas las variables de rendimiento evaluadas después del período de entrenamiento. La carga de entrenamiento interna durante la sobrecarga fue más grande (1.635 ± 109,9; 2.490

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± 124; 2.850 ± 210 AU) en comparación con la última semana de cargas reducidas (1.335 ± 100 AU). La tolerancia al estrés disminuyó durante la sobrecarga (4,0 ± 0,7; 8,2 ± 1,3; 10,1 ± 1,4) y aumentó durante la última semana (5,5 ± 1,5). Además, las altas cargas del entrenamiento interno durante la sobrecarga resultaron en una gran reducción en la diferencia de la raíz cuadrada media de intervalos R-R sucesivos (lnRMSSDmean) (4,2 ± 0,2; 4,1 ± 0,1; 4,0 ± 0,1 ms) y un coeficiente de variación más pequeño (lnRMSSDcv) (4,5 ± 2,6; 2,1 ± 1,2; 1,4 ± 0,9 %), y la reducción significativa en la carga de entrenamiento interno durante la última semana condujo a una disminución en lnRMSSDmean (1,3 ± 0,5 ms).

Conclusión: Nuestros resultados sugieren que el uso de programas de entrenamiento de bádminton durante la pretemporada, que incluyen acciones intermitentes de alta intensidad con sobrecarga progresiva seguida de una semana de cargas reducidas, es suficiente para dar como resultado adaptaciones positivas en el rendimiento y condujo a cambios adaptativos en la carga de entrenamiento interno, en la tolerancia al estrés y en la variabilidad de la frecuencia cardiaca.

Palabras clave:
Rendimiento. Sistema nervioso autónomo. Periodización. Supervisión.

Introduction

Badminton has been characterized as a high-intensity sport that combines intermittent actions of very intense anaerobic exercises with changes in direction and longer lower-intensity periods of aerobic exercises[1,2]. Due to these demands, a high level of speed, coordination, agility, strength, and explosive jumps are required from badminton players[1-3].

The pre-season is considered as a period to develop positive physiological adaptations that maximize physical components (*e.g.*, maximum strength and power, speed, and agility), which are required for the competitive season[4-6]. A strategy that usually occurs during this period involves phases of deliberate overloading (OL), followed by a tapering period (TP) that consist of a gradual reduction in the training load (TL)[4,6]. However, this requires careful individual TL monitoring in an attempt to balance periods of stress and recovery, leading to an increase in performance. Thus, it is important that coaches use physiological, psychological, and performance parameters for measurement and control TL to obtain information on how athletes are responding to different training stressors[5-7].

Among the measures used to effectively estimate the internal training load (ITL), the session rating of perceived exertion (sRPE) is considered a practical and valid method that demonstrated high correlations with physiological and psychological parameters[7,8]. Furthermore, changes in ITL are associated with changes in stress levels during training programs[7,9]. In this context, previous studies have demonstrated that measures of stress tolerance (ST) evaluated using the daily analysis of life demands for athletes (DALDA) questionnaire[10] are sensitive to increases and decreases in the ITL[4,7,9], reflecting some positive adaptations[6,7]. In addition to sRPE and DALDA, another important physiological measure used to monitor ITL in different sports is heart rate variability (HRV), which is typically characterized by decreases during periods of higher TL, with increases following periods of lower TL, mirroring recovery, which leads to improvements in performance[4,11,12].

Some studies involving racquet sports sought to monitor the TL and training effects using tools, such as sRPE, DALDA, heart rate (HR), and physical tests[6,13,14]. Gomes *et al.*[6] when monitoring the ITL and ST of young tennis players during the pre-season, found an increase in stress symptoms in the weeks with higher ITL values, generating adaptive changes in the ST assessed by the DALDA questionnaire. In addition, Moreira *et al.*[14] monitored the training of 12 professional tennis players based on the sRPE and the HR methods and verified an even distribution for low and moderate intensities zones, but relatively few sessions in high intensity zone. However, specifically with badminton training, previous studies aimed to test the effectiveness of complementary training programs by assessing the performance variables of the players[15,16], or to monitor a training period using HR and blood markers (*e.g.*, lactate, creatine kinase)[16,17]. Moreover, no study involving badminton players used physical tests, sRPE, DALDA, and HRV to monitor training responses and changes in performance. Thus, we are not aware of studies that clarify adaptive physiology responses during periods of badminton training, especially during the pre-season.

Concerning badminton training, coaches should incorporate periodization models during the pre-season that effectively lead to performance improvements and keep players in an optimal condition to compete[1,15,16]. Therefore, this study aimed to determine the effect of 3-week progressive OL and 1-week TP during the pre-season on performance, ITL, ST and HRV in under-19 Brazilian badminton players. The hypothesis is that the training period improves the performance of the players and that ITL, ST and HRV are different between the training phases.

Material and method

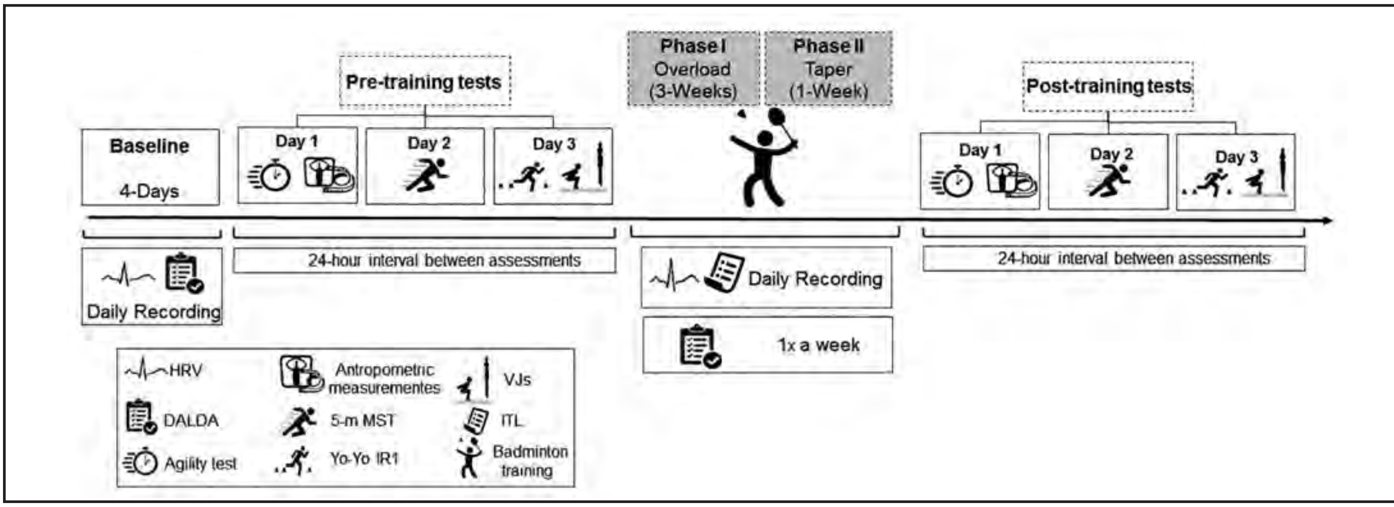
Participants

Eight male under-19 Brazilian badminton players (age 16.1 ± 0.6 years; height 168 ± 7.7 cm; body mass 57.2 ± 5.8 kg; body mass index (BMI) 20.3 ± 2.5 kg·m^{-2}; body fat 8.0 ± 2.7%), competing at state level volunteered to participate in this study. For a participant's data to be included in the final analysis, the following criteria were adopted: (a) completion of 100% of the training sessions during the pre-season; (b) completion of the sRPE to determine the ITL and DALDA questionnaire to determine the ST; (c) completion HRV daily before each training session; and (d) have no injuries during the training period. Before the study, the participants and their parents were informed about the testing and training procedures, possible risks involved, and provided written informed consent. This study was approved by the Human Research Ethics Committee. All research was conducted ethically according to Helsinki declaration.

Design

The experimental protocol consisted of a baseline (BL) period of 4 days during which DALDA and HRV were measured daily. After the

Figure 1. Schematic representation of the experimental design.



Note: HRV: heart rate variability; DALDA: daily analysis of life demands for athletes questionnaire; 5-m MST: 5-m multiple shuttle test; Yo-Yo IR1: Yo-Yo intermittent recovery test level I; VJs: vertical jumps; ITL: internal training load.

BL, participants performed the following tests with an interval of 24 h between trials: anthropometric measurements and badminton-specific movement agility test (day 1); 5-m multiple shuttle test (5-m MST) (day 2); vertical jumps tests (VJs) and Yo-Yo Intermittent Recovery test level 1 (Yo-Yo IR1) (day 3). These tests were repeated after the end of the training program following the same procedures. The pre-season training program consisted of two phases. The phase I consisted of a 3-week progressive OL, and the phase II consisted of a 1-week TP. During both phases, HRV and ITL were monitored daily, and DALDA questionnaire evaluated at the end of each training week. The experimental protocol is illustrated in Figure 1.

Procedures

Badminton-specific movement agility test

The test to determine agility was performed with specifics badminton movements using the protocol described previous by Ooi *et al.*[3]. Each participant had 10 min to complete own specific warm-up and two submaximal efforts on the badminton-specific movement agility test. The test was performed on a single badminton court with standardized measures, and required players to perform rapid sideways and diagonal movements with abrupt changes in direction to touch the shuttlecocks with their hands. The test had two phases, in which the players should position themselves in the central base of the court to start and return with at least one foot to the center of the court to validate their execution during and at the end of the test.

The first phase was performed with sideways agility movements, in which the players had to move laterally across the width of the court for a total of 10 repetitions in order to strike each up-turned shuttlecocks placed at each corner. There were five shuttlecocks on each side of the court on the lateral line at a distance of 30 cm between them. In the second phase of the test, there were four shuttlecocks positioned diagonally in the four corners of the court within the service zones with a distance of 30 cm between them. In this phase, the players moved diagonally in a sequence of four different directions for a total of 16 repetitions. Between the phases the players had five minutes for recovery. The execution time was monitored by a manual stopwatch adjusted by the evaluator; a visual analysis of the movement was performed to verify if the participant was performing displacements with specific Badminton movement. For the data analysis, the duration times of phase 1 and phase 2 were added and it was considered as the total time performance[3].

5-m multiple shuttle test (5-m MST)

The 5-m MST was performed according to the methods described by Boddington *et al.*[18] to determine sprint performance. Each participant had 10 min to complete own specific warm-up and two submaximal efforts of the 5-m MST. For this test, six cones were placed 5 m apart from each other in a straight line to cover a total distance of 25 m. The test consisted of six sprints with a change of direction, with run time of 30 s sprint and 35 s recovery time between sprints. To start the test, players positioned themselves in the first cone and upon an auditory signal they sprinted 5 m to a second cone, touched the ground with one hand and returned to the first cone. Then, they sprinted 10 m to a third cone and back to the first cone, etc., until 30 s. The players should accumulate the greatest possible distance within the 30 s execution time. The performance was determined by the total distance (m) (the total distance covered during the 6 × 30-s sprints/shuttles)[18].

Vertical jumps (VJs)

Performances in VJs were measured using an electronic platform (Jump System Pro 1.0 Cefise®, Nova Odessa-SP, Brazil), equipment designed to determine contact time and vertical jump flight time[19]. Participants performed three different vertical jump tests: Squat Jump (SJ), Countermovement Jump (CMJ), and Countermovement Jump with arms help (CMJA). Before testing, the players performed self-administered submaximal CMJs and SJ as warm-up. In the SJ test, the participants were crouched isometric with his hands on his waist, at the signal of the evaluator performed the jump. In the CMJ tests, the participants stood on the mat, fully erect with his hands positioned at the waist; at the signal of the appraiser, he squatted quickly and then made the jump. Finally, in the CMJA participants followed the same recommendations of the CMJ test but used the aid of the arms to propel themselves. All tests were performed three times, with an interval of 10 s between repetitions and the highest value obtained of height (cm) was used as the performance for analysis[19].

Yo-Yo intermittent recovery test level I (Yo-Yo IR1)

The Yo-Yo Intermittent Recovery Test Level I (Yo-Yo IR1) protocol was conducted according to procedures of the established methods[20]. This test consisted of 20-m shuttle runs performed at increasing velocities, with 10 s of active recovery between runs until voluntary exhaustion. The test was controlled by audio beeps located immediately adjacent to the 20-m long running lanes indicated by markers. The test was considered ended when the participant twice failed to reach the front line in time (objective evaluation) or the participant felt unable to complete another shuttle at the dictated speed. The total distance covered (m) during the Yo-Yo IR1 was considered as the testing score[20].

Internal training load (ITL)

The sRPE method was adopted to measure ITL[21]. Thirty minutes after the end of each training session, players were asked to report RPE for the intensity of the session using the CR-10 scale[22]. To determine ITL, expressed in arbitrary units (AU), the product of session duration (minutes) and sRPE score (CR-10) rated by the player was used. The duration of the training sessions was recorded from the start (warm-up) to the end of the session (cool-down). The weekly-accumulated ITL was calculated intra-individually for the analysis. From the ITL data, strain and monotony were calculated weekly. Monotony was calculated by dividing the average load of the week by the standard deviation, while the strain was calculated by multiplying the monotony by the weekly sum of training loads[21].

Stress tolerance (ST)

To evaluate ST, the Portuguese version[23] of the DALDA questionnaire[10] was filled out daily during BL and at the end of each training week. Although it has been suggested that DALDA be used on a daily basis, it was previously used on a weekly basis without having its sensitivity diminished. The DALDA is divided into parts A (9 questions) and B (25 questions), which represents the sources and symptoms of stress respectively. The possible answers for each item are "better than normal", "normal" and "worse than normal". For each training session, the sum of the scores marked as "worse than normal" of the questionnaire was recorded for analysis.

Heart rate variability (HRV)

All HRV measures were performed daily during BL and before each training session. The same conditions were maintained during each HRV measurement. HRV was recorded with a portable heart rate monitor (RS800cx Polar®, Kempele, Finland), previously validated for this purpose[24]. After allowing 1 min for stabilization, HRV were measured for 1 min[25] in a quiet environment, with the participants in a standing position. These data were then downloaded to Polar Pro-trainer 5 software (Polar Electro Oy®, Kempele, Finland). Occasional artefacts and non-sinus beats were replaced with the interpolated adjacent normal cycle. Subsequently, the data were analysed using specialized HRV analysis software (Kubios HRV Analysis®, version 3.0 Biomedical Signals Analysis Group, University of Kuopio, Finland). The vagally mediated HRV parameter used for analysis was the logarithm of the root-mean square difference of successive R-R interval (lnRMSSD). Since lnRMSSD is considered consistent under paced and spontaneous breathing[26], all HRV recordings were completed under spontaneous-breathing conditions. The intra-individual weekly mean (lnRMSSDmean) and its coefficient of variation (lnRMSSDcv) were calculated for the analysis. The lnRMSSDcv was calculated as follows: CV = ([SD/mean] × 100).

Training program

The training program consisted of four weeks of traditional badminton training during the pre-season (*i.e.*, general preparatory) divided into two phases (3-week OL, and 1-week TP). Each training week included three training sessions lasting 117.8 ± 7.6 min. The training focus was on developing resistance, strength, power, mobility, repeat sprints, speed, agility, coordination and pattern movements. Table 1 displays the weekly training microcycles from the training program. Badminton practice sessions (BP) involved the development of technical and tactical skills in conjunction with pattern movement's exercises and anticipation skills during all weeks. Additionally, the agility, coordination, flexibility and lower and upper limb power development, court-based drills were completed during the BP.

Specific resistance training (RT) was performed, involving the multi-shuttle feeding (*i.e.*, shuttlecock control) and continuous displacements in game situations[27]. During RT the players hit eight shuttles which were fed by the trainer. The shuttle feeding was standardized with the trainer serving the shuttles with a badminton racket a frequency of 8 shuttlecocks every 15 s was standardized as described by Wee *et al.*[27]. Sprint-agility training (SAT) was performed daily over all training weeks, requiring participants to complete sprints with specific movement on the court (four points). The number of sprints was gradually increased

Table 1. Microcycle structure during the badminton pre-season training.

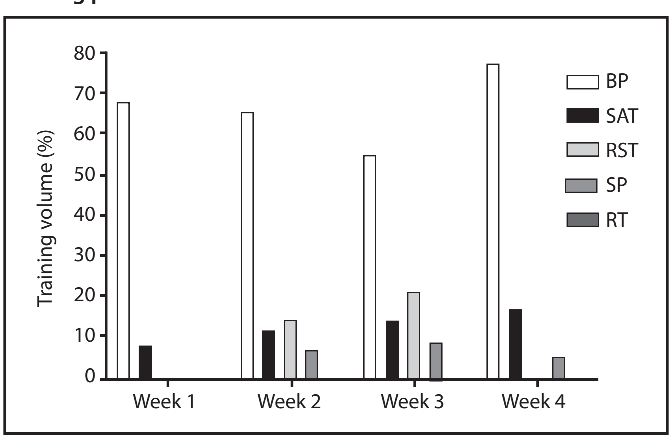
	Week 1	Week 2	Week 3	Week 4
Monday	BP, RT, SAT	BP, SAT, RST	BP, SAT, RST	BP, BP, SAT
Tuesday	—	—	—	—
Wednesday	BP, SAT	BP, SAT, SP	BP, SAT, SP	BP, SAT, SP
Thursday	—	—	—	—
Friday	BP, RT, SAT	BP, SAT, RST	BP, SAT, RST	BP, SAT

Note: RT: Specific resistance training; BP: Badminton practice session; SAT: Sprint agility training in court; RST: Repeat sprint training; SP: Speed training; —: rest.

Table 2. Description of the specific badminton training program during the 4-week pre-season.

	Week 1	Week 2	Week 3	Week 4
Sprint-Agility training (SAT)				
Repetitions	7 to 9 × 20 s	9 to 11 × 20 s	11 to 13 × 20 s	13 to 15 × 20 s
Goal intensity	All-out	All-out	All-out	All-out
Rest period between repetitions	10 s	10 s	10 s	10 s
Repeated sprint training (RST)				
Number of sets	-	2	3	-
Repetitions	-	4 × 30 s	4 × 30 s	-
Goal intensity	-	High	All-out	-
Rest period between repetitions	-	35 s	35 s	-
Rest period between sets	-	3 min	2.30 min	-
Speed training (SP)				
Number of sets	-	3	3	2
Repetitions	-			
	-	5 × 10 m	8 × 10 m	4 × 10 m
		4 × 20 m	6 × 20 m	3 × 20 m
Goal intensity	-	High	All-out	High
Rest period between repetitions	-	20 s	40 s	20 s
Rest period between sets	-	2 min	3 min	2 min
Specific Resistance training (RT)				
Number of sets	3	-	-	-
Repetitions	10 x 15 s			
Goal intensity	High	-	-	-
Rest period between repetitions	30 s	-	-	-
Rest period between sets	1 min	-	-	-

Figure 2. Description of the training volume (%) during the 4-week training period.



RT: Specific resistance training; BP: Badminton practice session; SAT: Sprint agility training in court; RST: Repeat sprint training; SP: Speed training; —: rest.

from seven to 15 during the 4-week training period as described by Waklate *et al.*[15]. A maximal power program was implemented in weeks two and three, which included a repeated sprint training (RST), and speed training (SP), prescribed based on the 5-m MST protocol[18]. During week four, the volume of SP was decreased by decreasing the number of sets while training intensity was maintained. Conditioning program details (i.e. RT, SAT, RST and SP) are displayed in Table 2, the volume of the training program is detailed in Figure 2.

Statistical analysis

Statistical procedures were performed using the software Statistical Package for the Social Sciences (SPSS® v 23.0 for Windows, Inc, Chicago, IL, USA). Data normality was verified by the Shapiro-Wilk test and the data are showed as mean ± standard deviation (SD). The sphericity was tested with Mauchly`s test and Greenhouse-Geisser corrections were made when assumptions of sphericity were violated. One-way analysis of variance for repeated measures (ANOVA) followed by the Bonferroni *post-hoc* test was used to evaluate differences in ITL, monotony, strain, ST values and HRV parameters across the training weeks. To evaluate differences in performance variables from pre to post training intervention a paired-sample t test was used. Additionally, the percentage change value (%) was calculated for each variable. The level of significance was set at $P < 0.05$ for all statistical analysis.

Results

Table 3 shows the results of SJ, CMJ, CMJA, badminton-specific movement agility test, 5-m MST and Yo-Yo IR1 pre- and post-training. There were significant improvements in all variables pre- to post-training.

Figure 3 demonstrates the ITL, monotony, and strain during the 4-weeks. The ITL increase in week two and three (2490 ± 124 and 2850 ± 210 AU, respectively) compared to week one (1635 ± 109.9 AU). These variables decreased significantly during week four (1335 ± 100 AU) when compared to all training weeks. Regarding monotony, there was no changes during week two and four (1.85 ± 0.1 and 1.63 ± 0.2

Table 3. Mean ± standard deviation (SD) and change (%) for performance variables at pre- and post-training (N = 8).

Variables	Pre-training	Post-training	% Change	*P*
SJ (cm)	33.2 ± 6.2	34.7 ± 5.4*	5.2 ± 6.3	0.048
CMJ (cm)	35.0 ± 6.5	37.1 ± 5.6*	6.6 ± 7.1	0.028
CMJA (cm)	41.1 ± 8.2	43.5 ± 7.8*	6.4 ± 5.7	0.012
Agility test (s)	57.5 ± 5.1	54.4 ± 3.9*	-5.3 ± 3.2	0.003
5-m MST (m)	556.5 ± 75.8	685.6 ± 72.8*	21.9 ± 12.1	<0.001
Yo-Yo IR1 (m)	737.5 ± 239.4	1065 ± 337.3*	49.5 ± 47.3	0.011

SJ: Squat Jump; CMJ: Counter Movement Jump; CMJA: Counter Movement Jump with arms help; 5-m MST: 5-m Multiple Shuttle Test; Yo-Yo IR1: Yo-Yo Intermittent Recovery test level 1. *: Significantly different from pre-training.

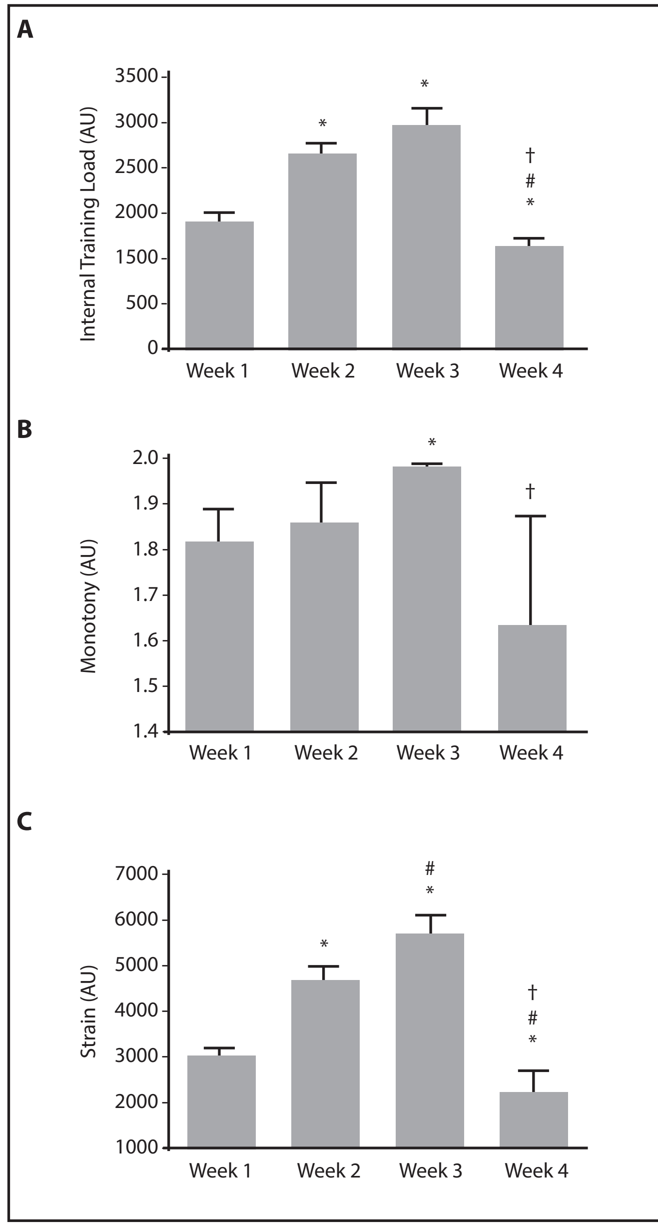
AU, respectively) compared to week one (1.81 ± 0.1 AU), with higher values during week three (2.0 ± 0.0 AU) compared to week one and two. In addition, training monotony was lower during week four (1.63 ± 0.2 AU) when compared to week three (2.0 ± 0.0 AU). Significant increases in training strain were found during week two and three (4615 ± 333 and 5621 ± 419 AU) compared to week one (2962 ± 216 AU), with a significant decrease during week four (2192 ± 447 AU) compared to all training weeks (Figure 3).

Table 4 presents the results of lnRMSSDmean, lnRMSSDcv and DALDA "worse than normal" scores during BL and throughout the training weeks. When compared to BL, reduction in lnRMSSDmean was significant only during week four. In addition, lnRMSSDmean was significantly lower during week three compared with week two. During week four, lnRMSSDmean was significantly lower compared to all weeks of training. Regarding to lnRMSSDcv, there was a significantly reduction during week three compared to week one, while reduction in week four were found when compared to BL and week one. DALDA "worse than normal" scores progressively increased until week three compared to BL, with a decreased during week four compared to week two and three.

Discussion

The aim of this study was to determine the effect of 3-week progressive overloading and 1-week tapering during a pre-season on performance, internal training load (ITL), stress tolerance (ST), and heart rate variability (HRV) among under-19 badminton players. The main findings were as follows: an improvement in all performance variables

Figure 3. Overall internal training load (A), monotony (B) and strain (C) in arbitrary units (AU) during the 4-week training period (N = 8).



* P < 0.05 compared to week 1; # P < 0.05 compared to week 2; † P < 0.05 compared to week 3.

Table 4. Mean ± standard deviation (SD) for lnRMSSDmean, lnRMSSDcv and DALDA "worse than normal" score during baseline (BL) and throughout training weeks (N = 8).

Variable	BL	Week 1	Week 2	Week 3	Week 4
lnRMSSD$_{mean}$ (ms)	4.2 ± 0.2	4.2 ± 0.2	4.1 ± 0.1	4.0 ± 0.1 †	3.9 ± 0.1*, #, †, ‡
lnRMSSDcv (%)	2.7 ± 1.2	4.5 ± 2.6	2.1 ± 1.2	1.4 ± 0.9 #	1.3 ± 0.5 *, #
DALDA "worse-than-normal"	2.5 ± 0.5	4.0 ± 0.7 *	8.2 ± 1.3 *, #	10.1 ± 1.4 *, #, †	5.5 ± 1.5 *, †, ‡

Note: lnRMSSDmean, weekly mean log-transformed root-mean square difference of successive R-R intervals; lnRMSSDcv, coefficient of variation of weekly log-transformed root-mean square difference of successive R-R intervals; DALDA, daily analysis of life demands for athlete's questionnaire.

*: P < 0.05 compared to BL; #: P < 0.05 compared to week 1; †: P < 0.05 compared to week 2; ‡: P < 0.05 compared to week 3.

after the pre-season, the ITL during OL was higher compared to that during the TP, and the ST decreased during OL and increased during TP. In addition, a higher ITL during OL resulted in a greater reduction in lnRMSSDmean and a smaller lnRMSSDcv, and the significant decrease in ITL during the tapering period led to a decrease in lnRMSSDmean. These results confirm the initial hypothesis of the study.

According to previous research, it is suggested that a badminton training program should address intensities and actions that resemble the competitive reality[2,15]. Thus, it is essential that the physical preparation of badminton players consist of repetitive high-intensity actions of short duration combined with actions of agility, speed, and VJs[2,3,28]. The training program of the present study not only addressed the development of anaerobic power and aerobic endurance, but also sought to promote improvements in the agility, speed, and VJs, which are variables associated to the technical complexity and tactic of badminton players[3,15,28].

In the present study, the pre-season training led to significant improvements in VJs, badminton-specific movement agility test, Yo-Yo IR1 and 5-m MST performances. Similar to our findings, Gomes *et al*.[6] investigated the effect of four weeks of progressive OL training and a 1-week TP during the pre-season on ITL, ST, immune-endocrine responses, and physical performance in 10 young tennis players was investigated. In addition, similarly to the present study, agility-speed exercises and high-intensity intermittent actions were prescribed. The authors identified significant improvements in the Yo-Yo IR1 and agility T-test as found in our results; however, Gomes *et al*.[6] did not identify a significant increase in VJs (*e.g*., SJ and CMJ), which was different from our findings.

Regarding the badminton investigations Waklate *et al*.[15] investigated whether supplementing regular group training with short sessions of badminton-specific agility-sprint training conferred any greater changes in performance than regular training alone during a 4-week pre-season in 12 elite badminton players. The supplementary training group reported improvements in the 300-m shuttle run (2.4 ± 2.7%) and in the badminton sprint protocol (3.6 ± 2.6%); however, the control group did not show significant improvements in any performance variable, which was different our findings. It is important to mention that Waklate *et al*.[15] did not evaluate the aerobic power and VJs of the players. Wee *et al*.[16] investigated the effects of four weeks of high-intensity intermittent badminton multi-shuttle complementary training on the performance variables of 18 university badminton players, the authors reported significant improvements in $\dot{V}O_{2max}$, mean power, leg reactive strength, and agility in the experimental group. However, the control group with regular badminton training showed no improvement in all performance variables.

The training strategy used in the present study sought to integrate specific and general physical exercises[15,16], within a strategy that is characterized by an OL in weeks one to three, followed by a TP during the week four. Concerning the analysis of the training intensity distribution based on the sRPE method, the data showed that ITL at weeks two and three and were higher compared to week one, followed by a significant reduction in week four. Similar to our findings, Gomes *et al*.[6] using a similar training intervention during the pre-season led to a progressive increase in the ITL in 4-weeks (≈ 2000 - 4500 AU), followed by a significant reduction in week five (≈ 2000 AU) that promoted improvements in performance of tennis players.

It is known that despite the risk of nonfunctional overreaching or even an overtraining syndrome, high ITL during the pre-season are necessary to generate positive adaptations and increases in performance[13], which was proven in the present study. Moreover, our results demonstrated that the ITL and strain were aligned with the planned OL and TP training weeks. This finding is in agreement with previous studies that identified a relationship between strain and changes in ITL in racket sports[6,13]. The decrease in ITL and strain identified in the week four is related to the programmed TP strategy.

It is important to mention that the balance between strain and recovery can determine the benefits of the training; thus, monitoring measures related to fatigue (*i.e*., physiological and psychometric variables) can predict symptoms of overtraining and stress during a training period[7,13]. In our study, we identified a decrease in ST during the OL period compared to the BL, indicated by the greater number of "worse than normal" responses from DALDA questionnaire; changes in the DALDA score of "worse than normal" responses are related to adaptive changes in the ST[4,6,7,13]. Similar ST responses were reported by Gomes *et al*.[6] identified decreases in ST, during OL, indicated by the greater number of "worse than normal" responses from DALDA; followed by an improvement during TP in tennis players during the pre-season. These results confirm that DALDA is a sensitive tool that detects changes in ITL as previously reported[4,7]. However, no previous study sought to monitor ST responses to ITL changes in badminton players.

Concerning the HRV results, we found no changes in lnRMSSDmean during the first 2-weeks of OL, but found increases in lnRMSSDcv during the first week OL and a decrease during the second week of OL. In addition, during the TP, lnRMSSDmean and lnRMSSDcv decreased. It is important to emphasize that no study with racquet sports investigated HRV responses during the pre-season, especially during badminton training. These findings during OL are similar to a previous study with female soccer players, which demonstrated that lnRMSSDcv increases with no changes in lnRMSSDmean during a period of increased ITL[29]. Thus, it seems that the badminton players from the present investigation were not able to cope well with the initial TL. The decrease in lnRMSSDcv during the week two of OL was similar to a previous study with rugby sevens athletes during a second exposure to higher ITL, which the authors interpreted as a reflection of an improved ability to maintain cardiac autonomic homeostasis even when ITL is intensified[30].

Furthermore, during the week three of OL and during TP a decrease in lnRMSSDcv and lnRMSSDmean was found. These results could be related to the increases in anaerobic workload imposed during weeks two and three. It has been shown that parasympathetic reactivation is highly impaired after repeated sprint training, which is associated with an increase in plasma metabolites and a higher sympathetic activity[31]. The results found during TP are in contrast with previous studies, which demonstrated increases in lnRMSSDmean coupled with decreases in lnRMSSDcv values after reductions in the ITL[29,25]. However, despite the increase in ST found during TP, we suggest that the reduction in ITL in the last week of training was not sufficient to reestablish the ST and lnRMSSD values of the players in relation to the baseline value[4,29,32], or was due to some of the persisting effects of fatigue or the inadequate recovery from the higher TLs weeks.

The small sample size in the present study could be considered as a limitation. However, it can be explained by the fact that in Brazil badminton is an incipient modality making it difficult to carry out studies with a large number of players with a higher competitive level. In addition, there are few studies in the literature related to the training and performance of badminton players; therefore, the comparisons in the present study are limited to other modalities. The lack of performance tests at the end of the OL phase could be considered another limitation, which in turn would provide more data related to the effects of increased ITL on performance, ST, and HRV responses.

Conclusions

Four-week pre-season improved performance in under-19 badminton Brazilian players and the periodized training program evoked a progressive increase in ITL during OL, followed by a significant reduction during TP. Furthermore, modifications in ITL resulted in adaptive changes in ST, indicated by the DALDA questionnaire, and in HRV, demonstrated by the fluctuations in the values of lnRMSSDmean e lnRMSSDcv. Monitoring individual ITL in conjunction with ST and lnRMSSD responses can provide valuable information that leads coaches to strategically manipulate ITLs individually. The results of the present study provide new information on the performance testing and monitoring of ITL, ST, and HRV in under-19 badminton players during a pre-season, which can help coaches to prescribe badminton training programs more successfully.

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Conflict of interest

The authors do not declare a conflict of interest.

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Estudio del comportamiento sedentario analizado mediante autocuestionario y acelerometría y su asociación con factores de riesgo cardiovascular en población adulta de un centro de salud

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Resumen

Introducción: En la actualidad, el sedentarismo ha ido ganando protagonismo en el día a día de las personas adultas aumentando el tiempo que pasan en sedestación, existiendo una relación entre tiempo sedentario y el aumento de la mortalidad por cualquier causa, mayor incidencia en enfermedades cardiovasculares, cáncer y diabetes tipo 2.
Objetivo: Los objetivos de este estudio son valorar la aplicabilidad de métodos de registro subjetivos y objetivos en el ámbito de la actividad física y la salud, y determinar las posibles relaciones entre el comportamiento sedentario y sus variables y el nivel de actividad física diaria con la prevalencia de uno o más factores de riesgo cardiovascular.
Material y método: Se estudió a un grupo de 64 adultos de un Centro de atención primaria a los que se les administró el Autocuestionario Internacional de Actividad Física (IPAQ) y se les aplicó un acelerómetro triaxial ActivPal durante 72h.
Resultados: Se obtuvieron diferencias significativas entre el tiempo sentado reportado mediante auto-cuestionario y los valores de acelerometría, IPAQ (265.45±129.67 min/día) y ActivPal (387.78±215.06 min/día). También se observaron diferencias significativas entre las variables de acelerometría relativas al comportamiento sedentario y la presencia de factores de riesgo cardiovascular (FRCV), tiempo sedentario (H=8.42; df=3; p=.03), número de transiciones (H=10.41; df=3; p=.01) y número de pasos totales (H=13.4; df=3; p=.004).
Conclusiones: Los resultados de este estudio demuestran la subestimación del tiempo sentado por parte de la población mediante el IPAQ, la relación entre las variables del comportamiento sedentario y la presencia de FRCV y la necesidad de adoptar medidas de promoción para el cambio hacia un estilo de vida activo utilizando estrategias que puedan generar consciencia de la importancia en la adquisición de hábitos que generen transiciones de sedestación a bipedestación.

Palabras clave:
Comportamiento sedentario. Tiempo sentado. Factores de riesgo cardiovasculares. Autocuestionario. Acelerometría.

Study of sedentary behavior analyzed by self-questionnaire and accelerometry, and its association with cardiovascular risk factors in the adult population of a health center

Summary

Introduction: Currently, sedentary lifestyle has been gaining prominence in the daily life of adults, increasing the time they spend seated, with a relationship between sedentary time and increased mortality from any cause, higher incidence of cardiovascular diseases, cancer and type 2 diabetes.
Purpose: The aim of this study are to assess the applicability of subjective and objective recording methods in the field of physical activity and health, and to determine the possible relationships between sedentary behavior and its variables and the level of daily physical activity with the prevalence of one or more cardiovascular risk factors.
Material and method: A group of 64 adults from a Primary Care Center were studied, who were administered the International Physical Activity Self-Questionnaire (IPAQ) and an ActivPal triaxial accelerometer was applied for 72h.
Results: Significant differences were observed between self-reported sitting time and accelerometry values, IPAQ (265.45±129.67 min/day) and ActivPal (387.78±215.06 min/day). Significant differences were also observed between the accelerometry variables related to sedentary behavior and the presence of cardiovascular risk factors (CVRF), sedentary time (H=8.42; df=3; p=.03), number of transitions (H=10.41 ; df=3; p=.01) and number of total steps (H=13.4; df=3; p=.004).
Conclusions: The results of this study demonstrate the underestimation of sitting time by the population using the IPAQ, the relationship between sedentary behavior variables and the presence of CVRF, and the need to adopt promotional measures for the change towards an active lifestyle using strategies that can generate awareness of the importance in the acquisition of habits that generate transitions from sitting to standing.

Key words:
Sedentary behavior. Sitting time. Cardiovascular risk factors. Self-questionnaire Accelerometry.

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Introducción

La mayoría de estudios epidemiológicos en poblaciones de cohortes numerosas muestran una asociación inversa entre la actividad física y el riesgo de sufrir enfermedad cardiovascular. A su vez, la actividad física regular es la única intervención conductual que ha demostrado su utilidad para aumentar la aptitud cardiorrespiratoria, un fuerte indicador de buena salud metabólica, baja morbilidad y bajo riesgo de muerte[1].

El comportamiento sedentario y su relación con la salud es un tema estudiado des de hace muchos años[2–4]. Este ha sido definido como cualquier conducta de vigilia caracterizada por un gasto de energía menor a 1,5 veces la tasa metabólica basal, es decir, 1,5 equivalentes metabólicos (MET), mientras se está sentado, acostado o reclinado[5]. Dentro del concepto de comportamiento sedentario se engloba el concepto de tiempo sentado, definido como el tiempo que pasa una persona en una posición en la que el peso se apoya en las nalgas en lugar de los pies y en la que la espalda está erguida[6]. Actualmente, se ha observado que este tiempo representa la mayor parte del tiempo despierto de una persona. En estos estudios se ha propuesto que el tiempo sedentario se asocia, independientemente del nivel de actividad física, con un mayor riesgo de mortalidad por cualquier causa, mayor incidencia en enfermedades cardiovasculares, mayor incidencia en cáncer y diabetes tipo2[6,7]. Debido a estos hallazgos, muchas autoridades científicas de la salud como la *American Heart Association* han publicado unas guías para reducir el tiempo sentado y aumentar el tiempo activo[8].

El tiempo sentado es una variable que ha sido estudiada usando, principalmente, dos instrumentos, los autocuestionarios y los acelerómetros[9–11]. El cuestionario que diversos estudios han utilizado es el *International Physical Activity Questionnaire* (IPAQ), en el cual se interroga a la persona sobre el tiempo en el que está sentado en un día[10,12–14]. Esta misma variable también ha sido analizada en diferentes estudios con dispositivos de acelerometria, que miden la aceleración del movimiento, como el acelerómetro ActivPal, donde paralelamente se han analizado otras variables como los pasos y las interrupciones del tiempo sentado[5,9,10].

En el análisis del comportamiento las transiciones deben entenderse como interrupción del tiempo sentado, con la comprensión emergente que apuntan a los mecanismos biológicos de los beneficios para la salud cardiovascular[6]. Estas, pueden ser una estrategia para contrarrestar los riesgos asociados, como las disfunciones vasculares[15]. Paing *et al*.[16], en su estudio, observaron efectos sobre el control de la glucosa. También, se ha observado que más interrupciones en el tiempo sedentario se asociaron de manera beneficiosa con variables de riesgo metabólico, en particular con las medidas de adiposidad, triglicéridos y glucosa plasmática a las 2 h[17].

Otra de las variables analizadas a lo largo de los años han sido el número de pasos diarios y su relación con los factores de riesgo cardiovascular[18–20]. Estos estudios obtuvieron resultados favorables en la disminución del riesgo de mortalidad y de desarrollar enfermedades cardiovasculares en las personas que más caminaban.

Los objetivos de este estudio son valorar la aplicabilidad de métodos de registro subjetivos y objetivos en el ámbito de la actividad física y la salud, y determinar las posibles relaciones entre el comportamiento sedentario y el nivel de actividad física diaria con la prevalencia de uno o más factores de riesgo cardiovascular (FRCV), en pacientes adultos de un Centro de atención primaria en la isla de Menorca.

Material y método

Participantes

Estudio retrospectivo con datos de carácter prospectivo de una muestra perteneciente a un colectivo de 64 participantes (36 hombres, 28 mujeres), con una edad de 50,1±5,6 (promedio ± DE) años, peso 74,4±1,6 kg., altura 167±1 cm. y IMC 26,8±4,3, procedentes del cupo de pacientes de un centro de atención primaria en una población de la isla de Menorca. La selección se llevó a cabo mediante la característica común que comparten todos los pacientes: pertenecer al cupo de dicho centro y estar diagnosticados de uno o más FRCV. Con la ayuda de la base de datos del Centro de salud, se realizó la selección de pacientes adultos de entre 40 y 80 años, de forma aleatoria, del cupo de atención primaria, que estaban diagnosticados de uno o más factores de riesgo cardiovascular. Este grupo de edad fue escogido por la mayor presencia de FRCV. La duración del estudio clínico fue del 3 de enero al 5 de marzo del 2020. La totalidad de los pacientes que ofrecían dicho criterio de inclusión era de 580, pero atendiendo al estado de emergencia sanitaria, la muestra se redujo a los pacientes que realizaron el protocolo completa antes de esta (n=64). Se diagnosticaron los siguientes FRCV: diabetes mellitus, hipertensión arterial, hipercolesterolemia, obesidad y sobrepeso (0,62±0,48), y tabaquismo.

Todos los participantes fueron informados de los riesgos y beneficios del estudio y dieron su consentimiento informado por escrito para participar en este estudio. Los participantes pudieron rechazar la inclusión de sus datos. El estudio se llevó a cabo siguiendo los principios éticos para la investigación biomédica con seres humanos, establecidos en la Declaración de Helsinki de la Asociación Médica Mundial (actualizada en 2013) y fue aprobado por el Comité de Ética de la Investigación de la Secretaría General de l'Esport de la Generalitat de Catalunya (032/CEICGC/2021).

Diseño del estudio

La actividad física y el comportamiento sedentario se valoraron mediante el cuestionario IPAQ[21] y un acelerómetro triaxial (ActivPAL)[22] instalado en el miembro inferior derecho de los pacientes seleccionados durante un período de 72 horas. El acelerómetro ActivPAL monitorizó el tiempo de sedestación, bipedestación y actividad

Tabla 1. Datos de los participantes.

Variables	Registros	Media	Desviación estándar	Mínimo	Máximo
Edad (años)	269	50,1	5,6	40	63
Peso (kg)	269	74,45	15,56	47	127
Talla (cm)	269	167	8	150	183
IMC	269	26,41	5,7	0	41,8

(tiempo en movimiento). Un acelerómetro triaxial es un dispositivo que mide el movimiento del cuerpo en el espacio en diferentes planos (vertical, media-lateral u anteroposterior), que, mediante la aceleración del cuerpo, lo convierte en una señal digital cuantificable. Se trata de una medida directa y objetiva[23].

Para llevar a cabo la selección de pacientes se contactó telefónicamente con los pacientes para citarles en consulta o se aprovechó el tiempo en una consulta habitual para explicarles los objetivos del estudio y se mantuvo una entrevista individual con cada uno. Se usaron los datos recogidos en la historia clínica en los últimos 6 meses para determinar el grado de control de la patología mediante: HbA1c en diabéticos, cifras tensionales en hipertensos, perfil lipídico analítico en dislipidémicos, IMC en obesos y número de consumo de cigarrillos/día en pacientes fumadores. Además, se tuvo en cuenta cuántos de los pacientes en estudio recibieron recomendaciones de ejercicio físico el último año (reflejadas en la historia clínica) y si existe alguna diferencia con los que no recibieron recomendaciones.

Variables estudiadas

Las variables registradas y analizadas en el presente estudio fueron las que se muestran en la Tabla 2.

Método estadístico

Los datos se presentan como media ± desviación estándar (DE). Tras realizar un estudio descriptivo de tendencia central y considerando la no normalidad de la muestra, se utilizó el test de U de Mann-Whitney para determinar posibles diferencias entre los variables obtenidas mediante IPAQ y Activpal. Posteriormente, se utilizó el test Kruskal-Wallis para determinar las posibles diferencias entre los valores de las variables por valores absolutos y por cuartiles en relación con el comportamiento sedentario del FRCV.

El análisis estadístico se realizó con el software JASP versión 0.11.1 (The Jasp Team, Amsterdam, Holanda). El nivel de significación para todo el análisis fue $p < 0,05$.

Resultados

Se diagnosticaron los siguientes FRCV por paciente: diabetes mellitus (0,1±0,31), hipertensión arterial (HTA; 0,1±0,31), hipercolesterolemia (0,22±0,41), obesidad y sobrepeso (0,62±0,48), y tabaquismo (0,44±0,49) (Tabla 3). 139 participantes tenían al menos un FRCV (50,9%); 96 tenían dos FRCV (35,1%); 33 tenían tres (12%), y cinco tenían los cuatro FRCV (2%). Atendiendo a cada uno de los FRCV analizados, a 61

Tabla 2. Variables subjetivas y objetivas analizadas en el estudio.

Variable	Acrónimo	Tipo de variable	Descripción	Unidad métrica
Hipertensión	HTA	Objetiva	Presencia de tensión arterial excesivamente alta. La tensión sistólica ha de ser superior o igual a 140 mmHg y la diastólica superior o igual a 90 mmHg.	mmHg
Dislipemia	DLP	Objetiva	Presencia de una concentración elevada de lípidos (colesterol, triglicéridos o ambos) o una concentración baja de colesterol rico en lipoproteínas (HDL).	mg/DL
Diabetes	DM	Objetiva	Enfermedad crónica que aparece cuando el páncreas no secreta suficiente insulina o cuando el organismo no utiliza eficazmente la insulina que produce. Presencias superiores a 126 mg/dl	mg/dl
Tabaquismo	TB	Subjetiva	Consumo del tabaco a diario	Si/no
Obesidad/sobrepeso	OB	Objetiva	Relación entre el peso y la talla que se utiliza para identificar el sobrepeso y la obesidad en los adultos. Se calcula dividiendo el peso de una persona en kilos por el cuadrado de su talla en metros (kg/m^2). **Sobrepeso:** IMC igual o superior a 25. **Obesidad:** IMC igual o superior a 30.	Kg/m^2
Tiempo sentado ActivPal	TSA	Objetiva	Tiempo registrado por el ActivPal en la posición en la que la persona mantiene la verticalidad a través del apoyo de su pelvis sobre la base de sustentación, total o parcial	Minutos
Tiempo sentado IPAQ	TSI	Subjetiva	Tiempo auto registrado por el IPAQ en la posición en la que la persona mantiene la verticalidad a través del apoyo de su pelvis sobre la base de sustentación, total o parcial	Minutos
Tiempo sedentario ActivPal	TSedA	Objetiva	Tiempo registrado por el ActivPal en comportamiento de vigilia caracterizado por un gasto de energía <1,5 veces la tasa metabólica basal, es decir, 1,5 equivalentes metabólicos de tarea (MET), mientras se está sentado, acostado o reclinado)	Minutos
Pasos Totales ActivPal	PTA	Objetiva	Número de pasos contabilizados a lo largo de un día por el dispositivo ActivPal	Recuento acumulativo
Transiciones Activpal	TA	Objetiva	Número de interrupciones del tiempo sentado pasando a una posición bípeda registrado por el ActivPal	Recuento acumulativo

Tabla 3. Prevalencia de factores de riesgo cardiovascular.

Variable	Registros	Sumatorio	Porcentaje
Hipertensión arterial	273	61	22,34%
Dislipemia	273	72	26,37%
Diabetes	273	29	10,62%
Tabaquismo	273	120	43,96%
Sobrepeso/obesidad	273	168	61,54%

Tabla 4. Variables de actividad física y tiempo sedentario objetivas (Activpal) y subjetivas (IPAQ).

Variables	n	Media	Desviación estándar	Mínimo	Máximo
Tiempo sentado (Activpal, TSA)	273	387,78	215,06	0,27	888,06
Tiempo sentado IPAQ (min, TSI)	273	265,2	129,6	90	600
Tiempo sedentario Activpal (min; TSedA)	273	731,17	396,56	0	2.010,63
Pasos Totales Activpal (TPA)	273	11.936,01	5.605,01	1.808	31.996
Transiciones Activpal (TA)	273	47,46	19,87	16	136

pacientes (22,34%) se les diagnosticó HTA; a 72 (26,37%) Dislipidemia; a 29 (10,62%) diabetes; a 120 (43,96%) tabaquismo y a 168 (61,54%) obesidad o sobrepeso.

En relación a la acelerometría, se obtuvieron un total de 273 registros válidos (4,2±1) por paciente (Tabla 4). En lo relativo al comportamiento sedentario, el tiempo sentado reportado fue de 265,45±129,67 min/día para TSI y 387,78±215,06 min/día para TSA por paciente. El análisis estadístico determino diferencias significativas en lo relativo al TSI y TSA (W=115,00; p<,001; SE=-0,99).

Se observaron diferencias significativas entre las variables de acelerometría relativas al comportamiento sedentario y la presencia de FRCV, tanto para el tiempo sedentario Activpal (H=8,42; df=3; p=,03), definido por los cuartiles <4h, 4-6h, 6-8h, >8h diarias[6], como para las TA (H=10,41; df=3; p=,01). También en relación a la presencia de FRCV diagnosticados, se observaron diferencias significativas con la variable pasos totales medidos con el ActivPal (H=13,4; df=3; p=,004), definido por los cuartiles <4000, 4000-7999, 8000-11999 y >12000 pasos diarios[24].

Discusión

Uno de los principales objetivos del estudio era valorar la aplicabilidad de métodos de registro subjetivos y objetivos en el ámbito de la actividad física y los comportamientos sedentarios. Con los datos obtenidos se observan diferencias significativas en la cantidad de tiempo sentado durante el día entre valores obtenidos por auto cuestionario (IPAQ) y acelerómetro (ActivPal). Estos resultados respaldan el hecho de que las personas tienden a infravalorar el tiempo que pasan sentados a lo largo del día observando que el acelerómetro registra un tiempo medio en sedestación 2 h por encima del registrado en el IPAQ. Estos resultados son similares a los obtenidos por Chastin *et al.*[10] en el que obtuvieron una infravaloración del tiempo sentado mediante el uso del IPAQ. En su caso también obtuvieron unas diferencias de 2h por día respecto al acelerómetro. Valores diarios con una diferencia superior a las 2h, también fueron obtenidas en el estudio de Fitzsimons[12].

Otro de los objetivos de este estudio era determinar las posibles relaciones entre el comportamiento sedentario y el nivel de actividad física diaria con la prevalencia de uno o más factores de riesgo cardiovascular (FRCV). En nuestro estudio hemos obtenido diferencias significativas en el número de factores de riesgo CV presentados y el tiempo sedentario, teniendo una mayor prevalencia en el número de factores de riesgo en personas con un tiempo sedentario mayor. Estos resultados siguen la línea del estudio de Leiva *et al.*[3] donde encontraron una relación entre el tiempo sedentario y el incremento de factores de riesgo cardiovascular y metabólico. En el mismo estudio se observó que el efecto del sedentarismo sobre estos factores de riesgo no estaría modulado por una mayor ingesta calórica, sino por un gasto energético reducido. Otros estudios en los que se usó el auto cuestionario y la acelerometría también obtuvieron resultados similares en el aumento de la presencia de factores de riesgo con el incremento del tiempo sedentario[25,26].

Además, uno de los hallazgos más sorprendentes del análisis de Charles E. M. *et al.*[27] fue que aquellos que reportaron realizar más de 7 h/semana de actividad física, de moderada a vigorosa durante el tiempo libre, pero que también miraban televisión ≥7 h/día tenían un riesgo 50% mayor de muerte por cualquier causa y el doble de riesgo de muerte por enfermedad cardiovascular en relación con aquellos que realizaron la misma cantidad de actividad física pero vieron la televisión <1 h.

Una de las formas de reducir el tiempo sedentario es incluir transiciones entre la posición de sentado a posición de pie[15]. En nuestro estudio se ha observado una menor presencia de factores de riesgo cardiovasculares en personas con un mayor número de transiciones. En su estudio, Paing *et al.*[16] observaron mejoras sobre el control de la glucosa en personas que realizaban interrupciones recurrentes durante el tiempo sedentario. Estos resultados fueron parecidos a los obtenidos por Bergouignan et al. en su estudio en personas con sobrepeso que realizaban interrupciones del tiempo sedentario cada 20 minutos[28]. Nakayama *et al.*[29] observaron que una disminución en el tiempo en sedestación podría inducir actividad parasimpática durante el sueño. Por lo tanto, la reducción del tiempo de sedestación continua durante el día podría contribuir, en parte, a mejorar el pronóstico de los pacientes con factores de riesgo cardiovascular, no solo al evitar la pérdida de masa muscular, sino también al proporcionar influencias positivas sobre el tono parasimpático durante el sueño.

Peterson C. *et al.*[15] observaron que la exposición a una sedestación aguda prolongada e ininterrumpida da como resultado aumentos significativos en la presión arterial sistólica y la presión arterial media. Efectos que se podrían ver reducidos con la inclusión de transiciones para interrumpir la prolongación del tiempo de sedestación. Resultados parecidos se demostraron en la publicación de Dunstan *et al.*[6]. Más estudios han observado mejoras en variables asociadas con los factores de riesgo cardiovascular[30,31].

Otra variable analizada en este estudio ha sido la relación entre el número de pasos y la prevalencia de factores de riesgo cardiovascular, donde se ha podido observar una menor prevalencia de los mismos entre las personas que caminaban más pasos a lo largo del día. Nuestros resultados están de acuerdo con estudios previos que han observado que los aumentos en el número de pasos se asocian con una menor prevalencia de los factores de riesgo y menor riesgo de mortalidad en adultos[25,32,33]. Katherine S. Hall *et al*.[20] en su estudio observaron que, por cada incremento de 1.000 pasos diarios al inicio del estudio, había una posible reducción del riesgo de mortalidad por cualquier causa (6-36%) durante 4-10 años. Pedro F. Saint – Maurice *et al*.[24] obtuvieron resultados en la misma línea que los estudios anteriores y también observaron que no existen diferencias significativas en cuanto a la intensidad de la caminata y el riesgo de mortalidad.

Históricamente, los signos vitales se han utilizado como indicadores clave del estado de salud e incluyen el pulso, la presión arterial, la temperatura, la frecuencia respiratoria y el peso corporal (índice de masa corporal). Como las causas de la enfermedad han cambiado en el último siglo, se han propuesto nuevas medidas del estado de salud para abordar las causas más contemporáneas de muerte y discapacidad. El registro de los niveles de actividad física (o ejercicio) es una manera fácil de satisfacer esta necesidad y se recomienda como una estrategia clave de atención médica en el Plan Nacional de Actividad Física de EE. UU. Los datos de los niveles de actividad física diaria deberían constar en la historia clínica de cada paciente que visite un centro de atención primaria como "un nuevo" signo vital[34].

Conclusiones

Con los datos obtenidos podemos concluir que existen diferencias entre la medición del tiempo de comportamiento sedentario según el método utilizado. El uso de métodos subjetivos (autocuestionario IPAQ) demuestran que los minutos registrados de comportamiento sedentario, en general, subestiman la duración del periodo de dicho comportamiento en comparación con la medida objetiva (acelerómetro ActivPal).

Además, como se demuestra con nuestros resultados y, en coincidencia con otros autores, este mayor comportamiento sedentario podría conllevar un aumento en la prevalencia en el número de factores de riesgo cardiovascular asociados.

En cuanto al estudio de la variable número de pasos diarios realizados, hemos obtenido una relación inversa entre el número de pasos realizados y la presencia de factores de riesgo cardiovascular, observando una mayor prevalencia de factores de riesgo en las personas que realizan menor número de pasos en sus actividades diarias.

Una de las aportaciones de nuestro trabajo ha sido el análisis de las transiciones de la posición sentado a la posición de pie y su importancia en la interrupción del comportamiento sedentario, así como la probable incidencia en los perjuicios para la salud de la sedestación prolongada. Estas transiciones de sedestación a la posición bípeda, limitan los cambios fisiológicos perjudiciales generados por el comportamiento sedentario.

Por consiguiente, estas conclusiones reafirman la necesidad de disminución del tiempo de comportamiento sedentario para reducir la prevalencia de factores de riesgo cardiovascular. Una estrategia de utilidad en salud pública, podría incluir la realización de transiciones con descanso activo en ciertas actividades laborales o académicas en las que el desarrollo de las mismas implica un elevado tiempo de prolongada sedestación.

Otra área de importante incidencia sería la población infantil y adolescente, edades en las que la tendencia a excesivo uso de dispositivos electrónicos y el uso de la televisión puede acarrear un elevado tiempo de comportamiento sedentario ininterrumpido. Por lo que las estrategias que puedan generar consciencia de la importancia en la adquisición de hábitos que generen transiciones de sedestación a bipedestación podrían ser de utilidad, como integrante de un estilo de vida activo en el futuro.

Por último, reafirmar la validez y precisión de los acelerómetros ActivPal para la medición del comportamiento sedentario y el análisis específico de sus componentes. Herramienta que, por su simplicidad y comodidad, podría incluirse en las consultas de atención primaria para obtener los datos de actividad física como un signo vital.

Conflicto de interés

Los autores no declaran conflicto de interés alguno.

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Creatine improves anaerobic performance and promotes anthropometric changes in Brazilian college soccer players

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Summary

Objective: This study aimed to evaluate the effects of creatine on the body composition and performance of college soccer players.
Materials and method: Sixteen amateur soccer players were supplemented with creatine (n=8) or maltodextrin (placebo, n=8) for four weeks, using a loading protocol (20g/day in the first week, followed by 5g/day for the rest of the study period). Anthropometric measurements and three physical tests were performed before and after the intervention.
Results: After the protocol, the Cr group showed increased body mass (pre 65.1 ± 8.2; post 66.4 ± 8.4; p=0.002), arm (pre 27.7 ± 4.3; post 28.3 ± 4.3; p=0.01), thigh (pre 49.9 ± 4.3; post 51.3 ± 4.6; p=0.012), and leg (pre 34.6 ± 2.3; post 34.8 ± 2.4; p=0.029) circumferences. For bangsbo repeat vertical jump test (BRVJ), there was an increase in maximum power (pre 2965.4 ± 691.8; post 3102.1 ± 818; p=0.034), maximum relative power (pre 44.5 ± 6.5; post 47.1 ± 6.5; p=0.045) and average power (pre 2757.6 ± 653.2; post 2937.7 ± 739.9; p=0.05) only in the Cr group. For running anaerobic sprint test (RAST), there was a significant improvement in average sprint and total times, and in the average power for both groups; however, only the Cr group showed significant improvement in maximum power (pre 517.93 ± 118.82; post 580.15 ± 119.06; p=0.01) and maximum relative power (pre 7.9 ± 1.2; post 8.5 ± 1.3; p<0.001). For wingate test (WIN), improvements were observed in maximum power (pre 456.4 ± 91.0; post 508 ± 79.7; p=0.003), maximum relative power (pre 7.0 ± 0.9; post 7.6 ± 0.6; p=0.012), average power (pre 354.8 ± 69.5; post 410 ± 71.5; p<0.001) and relative average power (pre 5.4 ± 0.6; post 6.1 ± 0.4; p=0.012) only in the Cr group.
Conclusions: This study findings demonstrated that Cr supplementation during four weeks promotes positive anthropometric and anaerobic performance changes in college soccer players, especially in lower limbs, but also in upper limbs. However, a possible body mass gain with its use should be considered, so the viability should be individually analysed.

Key words:
Creatine. Soccer. Performance. Body Composition.

La creatina mejora el rendimiento anaeróbico y promueve cambios antropométricos en futbolistas universitarios brasileños

Resumen

Objetivo: Evaluar los efectos de la creatina en la composición corporal y el rendimiento anaeróbico en jugadores de fútbol universitario.
Material y método: Dieciséis jugadores fueron suplementados con creatina (Cr) (n=8) o maltodextrina (placebo, n=8) durante cuatro semanas, utilizando un protocolo de carga (20g/día la primera semana, seguidos de 5g/día durante el resto del período de estudio), realizándose mediciones antropométricas y tres pruebas físicas anaeróbicas antes y después de la intervención.
Resultados: El grupo Cr mostró un aumento en las circunferencias del brazo (antes 27,7 ± 4,3; después 28,3 ± 4,3; p=0,01), muslo (antes 49,9 ± 4,3; después 51,3 ± 4,6; p=0,012) y pierna (antes 34,6 ± 2,3; después 34,8 ± 2,4; p=0,029) y aumento en la masa corporal (antes 65,1 ± 8,2; después 66,4 ± 8,4; p=0,002). No se registraron cambios significativos en el grupo placebo. En la prueba de saltos verticales repetidos (Test de Bangsbo) hubo un aumento en la potencia máxima (antes 2965,4 ± 691,8; después 3102,1 ± 818; p=0,034), relativa máxima (antes 44,5 ± 6,5; después 47,1 ± 6,5; p=0,045) y media (antes 2757,6 ± 653,2; después 2937,7 ± 739,9; p=0.05) solo en el grupo Cr. En la prueba de carrera (RAST), hubo una mejora significativa en los tiempos de sprint total y promedio, y en la potencia promedio para ambos grupos; sin embargo, únicamente el grupo Cr mostró una mejora significativa en la potencia máxima (antes 517,93 ± 118,82; después 580,15 ± 119,06; p=0,01) y máxima relativa (antes 7,9 ± 1,2; después 8,5 ± 1,3; p<0,001). Para la prueba de Wingate en miembros superiores, se observaron mejoras en potencia máxima (antes 456,4 ± 91,0; después 508 ± 79,7; p=0,003), relativa máxima (antes 7,0 ± 0,9; después 7,6 ± 0,6; p=0,012), media (antes 354,8 ± 69,5; después 410 ± 71,5; p<0,001) y potencia relativa media (antes 5,4 ± 0,6; después 6,1 ± 0,4; p=0,012) solo en el grupo Cr.
Conclusiones: Los hallazgos de este estudio mostraron que la suplementación con Cr durante cuatro semanas promueve cambios positivos en el rendimiento anaeróbico y mediciones antropométricas en futbolistas universitarios, especialmente en las extremidades inferiores, pero también en las superiores. Sin embargo, debe considerarse una posible ganancia de masa corporal con su uso, por lo que la viabilidad debe analizarse individualmente.

Palabras clave:
Creatina. Fútbol. Rendimiento. Composición Corporal.

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Introduction

Sports scientists, coaches, and nutritionists look for different ways to improve soccer players' performances[1]. Considering the level of competitiveness and early exposure to competitive training[2], several nutritional strategies, including supplementation, have been used[3]. Creatine (Cr), caffeine, isotonic drinks, and whey protein are examples of products offered mainly to professional athletes[4–6].

Cr is a natural amino acid mainly found in skeletal muscle[7], stored as phosphocreatine (PCr), a fast-consuming energy reserve used as a substrate for the resynthesis of adenosine triphosphate (ATP) through the phosphagen pathway. Thus, athletes and physical activity practitioners can benefit from Cr consumption due to the increase of PCr stocks, especially in modalities that use the anaerobic alactic system as a primary source of energy[7,8], which is precisely the energy profile of high demand in soccer[2,3,9].

A 70 Kg adult requires approximately 2-3 g/day of Cr, part of which is synthesized by the body through the combination of the amino acids glycine, arginine, and methionine[10]. The remaining requirement is obtained from dietary sources, especially meat and fish[8]. Cr supplementation can be beneficial in a Cr deficiency. Such supplementation is frequently performed by the "loading" protocol, which consists of two phases. The first one (loading) lasts a week using 20 g/day or 0.3 g/Kg/day of Cr. The second one (maintenance) usually lasts three weeks using a dose of 5g/day or 0.03g/kg/day[11,12]. Furthermore, it is well established that continuous Cr supplementation is safe[8].

Increased cellular hydration status is one of the ergogenic effects caused by Cr supplementation, which can be beneficial for soccer players since matches and training sessions induce dehydration[13,14]. Other known effects are enhanced muscle and energy recovery, strength and power gain, muscle hypertrophy, and reduction of muscle acidosis[2,3,15]. On the other hand, deleterious effects on the upper airways, cramps, and gastrointestinal discomforts have already been reported[2,16].

Several studies have shown the potential of Cr supplementation to increase performance in soccer players[5,17], while other studies have found no positive evidence[18,19]. A current systematic review and meta-analysis[3] showed that the changes in physical test performance in soccer players are dependent on the metabolic pathway involved. Therefore, investigating the impact of Cr supplementation on performance in different soccer-related physical tests can help us better understanding the effectiveness of Cr supplementation in this modality. Thus, the objective of this study was to evaluate the effects of Cr monohydrate supplementation on body composition and performance in a physical test battery in college soccer players, including a muscle region less frequently used in this modality. We hypothesize that the Cr supplementation will improve body composition and anaerobic performance in soccer-related physical tests in university soccer players, including the performance in an upper-limb physical test.

Material and method

Participants

The volunteers were male, between 18-33 years old, who had practiced soccer regularly in the last 6 months without having consumed Cr in the last 3 months. The recruitment was carried out through academic community social media and direct contact with the coaches of the athletic associations of the local University. This study was approved by the Local Human Research Ethics Committee, under protocol number 2.706.172. The volunteers were properly informed about the study procedures and provided written informed consent to participate in the study, according to the recommendations of the Brazilian Human Research Legislation – Ordinance 466/12.

Initially, 27 players were enrolled in the study. During the experiment, a volunteer manifested an adverse reaction to supplementation, claiming facial and foot swelling; a second volunteer injured a knee ligament during training, and nine participants did not proceed for personal reasons. Thus, complete data were collected from a sample of sixteen players (19.7 ± 2.3 years).

Experimental design

The experiment consisted of two moments, M1 and M2, defined as an initial assessment before the supplementation (baseline), and the final assessment 28 days after the start of supplementation (post), respectively. Each moment consisted of one meeting to perform physical tests and analyzes of body composition and hydration status. At M1, the volunteers performed anamnesis and answered the PAR-Q questionnaire (Physical Activity Readiness Questionnaire) proposed by Chisholm *et al.*[17], when only those who had no positive answer were selected. Next, the volunteers were randomly assigned to the Creatine (Cr) (n=8, experimental treatment) or Placebo (Pl) (n=8, control treatment with maltodextrin) groups.

Anthropometric and hydration assessment

At M1 and M2, body mass (kg) (BM), height (cm), and right-side body circumferences (cm) were measured (arm, forearm, abdomen, thigh, and calf). Circumferences were measured on the right side since all volunteers were right-handed. The BM, height, and circumference measures were obtained through a digital electronic scale (Toledo®, Model 2090), a stadiometer with a 0.5 cm scale (SECA®), and an inelastic measuring tape was used (Cescorf®), respectively. To estimate the fat percentage (%G) and total body hydration (%H_2O), a digital bioimpedance scale (Tanita®, IRONMAN BC-558) was used. Urinary density was obtained by collecting urine in a suitable container before the start of physical tests, using an analog refractometer (ATC®, RTP-20ATC).

Nutritional assessment

To analyze the participants' nutritional profile, and to verify whether protein consumption could influence the response to supplementation, the volunteers were instructed to maintain their regular eating habits and complete a 3-day food record, two non-consecutive weekdays and one day on the weekend, according to each volunteer's preference[18,19]. To provide more accurate assistance for completing the records, illustrative pictures with standardized homemade measurements of some foods were delivered along with the record sheet. The data obtained were entered individually in the AVAnutri® software (Rio de Janeiro, Brazil; Version 4.5.1), and analyzed for energy intake, carbohydrates, proteins, and fats. After that, the groups' average intake was calculated. To assess whether the protein consumption would impact the results of Cr supplementation, physical performance was compared between the two individuals from each group who ingested the highest (+PTN) and the lowest (-PTN) quantity of protein.

Physical tests

At M1 and M2, after BM measurement, the participants underwent three physical tests:

A) Bosco repeat vertical jump (BRVJ)

To measure the explosive strength of the lower limbs, the BRVJ test was applied on a Jump System NewFit jumping platform (Cefise®). The test consisted of 2 sets of 15 seconds, in which the participants performed the highest possible number of countermovement jumps, with their hands fixed on the waist. A 3-minute passive interval was respected between sets. The volunteers were positioned between the platform sensors in an upright position. After a regressive 10-second count, a beep was emitted, authorizing the start of jumps. During the 15 seconds, the volunteers started from the upright position, flexing their knees up to 90° and making as many jumps as they could, as high as possible without flexing their knees during the jump, then returning to the upright position with both feet at the same time[20]. The Jump System® 1.0.4.2 software was used to obtain the results of Maximum Power (MaxP), Maximum Height, Maximum Relative Power (MaxRP), and Fatigue Index (FI).

B) Running-based anaerobic sprint test (RAST)

To assess the power of lower limbs, the RAST protocol was used[21]. This test consisted of a traditional soccer warm-up of 5 to 10 minutes, then proceeding to the performance of 6 maximum sprints of 35 meters in a straight line, in a flat area of lawn. Considering that RAST was developed for professional soccer players, and our participants were college players, the physical load of the test was adapted by increasing the original interval between sprints from 10 to 30 seconds. To perform the test, a photocell system (Hidrofit®, MultiSprint Full) and its specific software were used. Data was obtained for MaxP, MaxRP, Average Power (AP), Relative Average Power (RAP), and the FI.

C) Wingate of upper limbs (WIN).

To evaluate the influence of Cr consumption over secondary muscles, the Wingate test was performed using an arm crank ergometer (Technogym® Excite TOP 700), focusing on the anaerobic power of the upper limbs. The players were positioned in front of the equipment, with their feet shoulder-width apart and making a pronounced grip on the ergometer crank. The height of the ergometer crank module was positioned at the height of the xiphoid process. The test started with a 30-second warm-up at 50 rpm. At the end of the warm-up, the players applied as much force as possible to maintain the maximum speed on the ergometer for 30 seconds, ending with a 30-second active recovery. At the end of the test, MaxP, AP, RAP, and tiredness level values were obtained.

Supplementation protocol

The loading protocol was used to deliver the desired dosages of Cr. It consisted of a loading phase (1 week) and a maintenance phase (3 weeks)[16,18,22]. During the loading phase, all volunteers consumed 20 g of their respective supplementation, distributed in the main meals of the day[7]. The doses were weighed on an electronic scale with an accuracy of 0.01 g (Shimadzu®, Series BL-3200H) and separated into individual doses of 5 g, packed in sterile plastic packages. During the maintenance period, the volunteers were instructed to consume just one dose after lunch.

All the Cr needed for the experiment was provided by a local food supplement company. For Pl, 1 Kg sealed packages with unflavored maltodextrin were purchased, aiming to approximate as much as possible the texture and flavor of the experimental treatment.

Statistical analysis

The Shapiro-Wilk test was used to analyze the data distribution. There was a non-normal distribution ($p < 0.05$) in the following variables: pre-intervention body fat (group Pl), post-intervention MaxP (group Pl), and basal FI (group Pl) in the RAST protocol, and pre-intervention MaxP and RAP (both groups), and post-intervention RAP (group Cr) in the WIN test. In these cases, the Wilcoxon and Mann-Whitney tests were used to perform intragroup (pre vs. post-intervention) and intergroup comparisons, respectively.

In the other cases of normal distribution, the paired T-test was used in intragroup comparisons, and the independent T-test was used to make comparisons between groups. Cohen effect sizes (ES) were calculated for pair comparisons and classified as small (0.2–0.5), moderate (0.5–0.8), or large (>0.8)[23]. The statistical software SPSS 20.0 was used to perform the statistical analysis. Data were presented as mean ± standard deviation (SD), minimum and maximum values. A level of significance was set at $p \leq 0.05$.

Results

Energy and macronutrient intake

There was no significant difference in the amount of ingested kilocalories (Kcal) ($p=0.067$), protein (PTN) ($p=0.059$), and lipids (LIP) ($p=0.594$) between groups. However, the Pl group consumed a greater amount of carbohydrates (CHO) compared to the Cr group ($p=0.049$) (Table 1).

The average percentage distribution of macronutrients consumed by the Cr group was 56.2% CHO, 17.1% PTN, and 26.7% LIP, whereas for the Pl group the values corresponded to 57.3% CHO, 18.7% PTN, and 24% LIP. No significant difference was observed in the relative distribution of energy and macronutrients between groups (Table 1).

Anthropometry and body composition

There was no significant difference between groups for anthropometric and body composition variables, as well as for hydration status (urine density) before and after the intervention ($p>0.05$). In addition, the average age was similar between groups (Cr: 20.5±3.0 years; Pl: 18.9±1.0 years; $p=0.505$).

Table 1. Average of absolute and relative energy and macronutrient intake before intervention.

Variable	Cr	Pl	p	ES
Energy (kcal)	2136.8 ± 491.4 (1589.4 – 3159)	2585.7 ± 411.1 (1873.1 – 3191.2)	0.067	0.99
CHO (g)	300.4 ± 74 (222 – 436.5)	370.2 ± 54.1 * (281.8 – 449.9)	0.049	0.94
PTN (g)	91.4 ± 24.5 (66 – 138.3)	120.6 ± 31.8 (85.4 – 167)	0.059	1.03
LIP (g)	63.3 ± 18.9 (37.1 – 95.5)	69.2 ± 23.9 (42.3 – 114.8)	0.594	0.27
Energy (kcal/Kg)	32.8 ± 5.8 (25.0 – 42.3)	37.1 ± 7.6 (29.0 – 50.4)	0.226	0.64
CHO (g/Kg)	4.6 ± 0.8 (3.1 – 5.8)	5.3 ± 0.9 (4.1 – 6.8)	0.116	0.82
PTN (g/Kg)	1.4 ± 0.3 (1.0 – 1.9)	1.7 ± 0.5 (1.2 – 2.6)	0.145	0.73
LIP (g/Kg)	1.0 ± 0.3 (0.5 – 1.4)	1.0 ± 0.4 (0.6 – 1.8)	0.943	0.0

Kcal: kilocalories; CHO: carbohydrate; PTN: protein; LIP: lipids; ES: effect size; * represents significant difference between groups (p<0.05).

The intragroup comparisons showed significant increased BM (p=0.002), BMI (p=0.001), biceps (p=0.010), thigh (p=0.012) and calf (p=0.029) circumferences in the Cr group. Moreover, the Pl group had a significant reduction in the calf circumference (p=0.009) (Table 2).

BRVJ

There was no significant difference between groups for the maximum height achieved in the jump test, as well as for the power and FI values before and after the intervention (p>0.05) (Table 3). However, Cr supplementation significantly increased MaxP (p=0.034), MaxRP (p=0.045), and AP (p=0.050) post-intervention.

RAST

There was no significant difference between groups for the performance, power, and FI variables obtained in the RAST before and after the intervention (p>0.05) (Table 4).

The intragroup paired comparisons (Table 4) showed significant improvement after the intervention, for both groups, in the total time of the 6 sprints (Cr, p=0.049; Pl, p=0.038), in the average of the sprints (Cr, p=0.050; Pl, p=0.039), and AP (w) (Cr, p=0.014; Pl, p=0.042). The Cr group significantly improved the time obtained in the best sprint (p<0.001), MaxP (p=0.001), and MaxRP (p<0.001). On the other hand, a significant improvement in RAP (p=0.036) was observed exclusively in the Pl group.

WIN

After the intervention, significant improvements were observed, only in the Cr group, in MaxP (p=0.003), MaxRP (p=0.012), AP (p<0.001), and RAP (p=0.012) (Table 5).

Table 6 describes the percentage difference in MaxP of the three post-intervention tests of the volunteers who consumed more and less protein in each group.

Table 2. Anthropometric and body composition variables of the groups before and after intervention.

Variable	Group	Pre -intervention	Post -intervention	p	ES
BM (Kg)	Cr	65.1 ± 8.2 (54.8 – 74.9)	66.4 ± 8.4 * (56.2 – 76.3)	0.002	0.16
	Pl	70.3 ± 6.4 (63.3 – 83)	70.3 ± 6.7 (61 – 81.9)	0.953	0.0
BMI (Kg/m²)	Cr	20.7 ± 2.9 (17.1 – 25.2)	21.1 ± 2.9 * (17.7 – 25.8)	0.001	0.14
	Pl	22.2 ± 1.4 (20.2 – 24.6)	22.1 ± 1.5 (19.5 – 24.5)	0.879	0.07
Body fat (%)	Cr	7.6 ± 4.0 (5.0 – 16.4)	7.8 ± 3.3 (5.0 – 14.8)	0.739	0.05
	Pl	9.3 ± 2.8 (6.3 – 15.5)	8.7 ± 3.0 (5.0 – 14.8)	0.489	0.21
H_20 (%)	Cr	69.2 ± 6.1 (59.3 – 80.3)	69.3 ± 6.1 (61 – 82)	0.930	0.02
	Pl	67.7 ± 6.2 (59.4 – 77.9)	66.3 ± 3.5 (60.2 – 71.1)	0.467	0.28
Urine density (g/ml)	Cr	1.022 ± 0.009 (1.004 – 1.032)	1.021 ± 0.011 (1.006 – 1.036)	0.814	0.1
	Pl	1.024 ± 0.005 (1.020 – 1.033)	1.026 ± 0.005 (1.020 – 1.034)	0.377	0.4
Right biceps circ. (cm)	Cr	27.7 ± 4.3 (22.9 – 34.6)	28.3 ± 4.3 * (23.3 – 35.1)	0.010	0.14
	Pl	29.1 ± 2.2 (26.5 – 32.2)	28.8 ± 1.8 (26 – 31.6)	0.208	0.15
Right forearm circ. (cm)	Cr	25.4 ± 2.4 (21.8 – 28.4)	25.8 ± 2.9 (22 – 30.5)	0.154	0.15
	Pl	27.2 ± 1.3 (24.7 – 28.9)	27.4 ± 1.5 (24.9 – 28.9)	0.212	0.14
Abdominal circ. (cm)	Cr	72.8 ± 4.7 (66.7 – 80.1)	73.4 ± 4.5 (67.4 – 78.9)	0.159	0.13
	Pl	75.1 ± 2.8 (71.7 – 80.8)	74.8 ± 3.3 (68.6 – 79.9)	0.449	0.1
Right thigh circ. (cm)	Cr	49.9 ± 4.3 (44.7 – 56.4)	51.3 ± 4.6 * (45.9 – 58.6)	0.012	0.31
	Pl	52.1 ± 4.1 (47.2 – 59.9)	52.5 ± 3.9 (47.4 – 59.8)	0.557	0.1
Right calf circ. (cm)	Cr	34.6 ± 2.3 (31.6 – 38.5)	34.8 ± 2.4 * (31.8 – 38.7)	0.029	0.09
	Pl	36.9 ± 2.3 (34.3 – 40.3)	36.4 ± 2.4 * (33.7 – 39.8)	0.009	0.21

Cr: creatine group; Pl: placebo group; BM: body mass; Circ: circumference; BMI: body mass index; ES: effect size; * represents significant intra-group difference (p<0.05).

Table 3. Bangsbo Repeat Vertical Jump.

Variable	Group	Pre-intervention	Post-intervention	p	ES
Maximum height (cm)	Cr	33.4 ± 6.9 (20.8 – 40.7)	36.4 ± 7.5 (25.5 – 50.5)	0.056	0.42
	Pl	34.5 ± 7.0 (24.1 – 45.5)	37.2 ± 6.8 (27.9 – 46.1)	0.126	0.39
MaxP (w)	Cr	2965.4 ± 691.8 (1980.8 – 3798.4)	3102.1 ± 818 * (2242.5 – 4469.3)	0.034	0.28
	Pl	3227.7 ± 609.3 (2332.1 – 4420.2)	3464 ± 712.6 (2510.6 – 4452.1)	0.202	0.36
MaxRP (w/kg)	Cr	44.5 ± 6.5 (32.4 – 50.9)	47.1 ± 6.5 * (36.9 – 58.6)	0.045	0.4
	Pl	45.7 ± 5.9 (36.1 – 53.9)	47.8 ± 5.4 (39.6 – 54.4)	0.120	0.37
AP (w)	Cr	2757.6 ± 653.2 (1804.1 – 3475.1)	2937.7 ± 739.9 * (2064.2 – 3904.6)	0.050	0.26
	Pl	3039.6 ± 617.9 (2196.5 – 4213.3)	3130.8 ± 613.5 (2305.5 – 4354.8)	0.182	0.15
FI (%)	Cr	1.0 ± 0.1 (0.9 – 1.1)	1.0 ± 0.1 (0.9 – 1.1)	0.421	0.0
	Pl	0.9 ± 0.1 (0.8 – 1)	0.9 ± 0.1 (0.9 – 1)	0.309	0.0

Cr: creatine group; Pl: placebo group; w: watts; MaxP: maximum power; MaxRP: maximum relative power; AP: average power; FI: fatigue index; ES: effect size; * represents significant intra-group difference ($p < 0.05$).

Table 4. RAST results.

Variable	Group	Pre-intervention	Post-intervention	p	ES
Total time (s)	Cr	33.18 ± 1.68 (31.5 – 36.6)	32.56 ± 1.7 * (31.5 – 36.6)	0.049	0.52
	Pl	33.82 ± 1.15 (31.80 – 35.11)	32.54 ± 1.37 * (30.09 – 34.16)	0.038	1.01
Best sprint (s)	Cr	5.40 ± 0.29 (5.09 – 5.96)	5.26 ± 0.28 * (4.92 – 5.79)	< 0.001	0.49
	Pl	5.41 ± 0.18 (5.05 – 5.60)	5.26 ± 0.21 (4.89 – 5.50)	0.089	0.77
Worst sprint (s)	Cr	5.68 ± 0.29 (5.35 – 6.20)	5.64 ± 0.40 (5.12 – 6.35)	0.642	0.11
	Pl	5.89 ± 0.26 (5.52 – 6.21)	5.60 ± 0.29 (5.12 – 6.05)	0.058	1.05
Sprint average (s)	Cr	5.53 ± 0.28 (5.25 – 6.10)	5.43 ± 0.28 * (5.08 – 5.98)	0.050	0.36
	Pl	5.64 ± 0.19 (5.30 – 5.85)	5.42 ± 0.23 * (5.02 – 5.69)	0.039	1.04
AP (w)	Cr	480.77 ± 99.95 (321.49 – 579.36)	530.21 ± 110.33 * (349.04 – 677.57)	0.014	0.47
	Pl	490.82 ± 96.16 (391.35 – 679.03)	550.73 ± 120.33 * (441.46 – 796.75)	0.042	0.09

(continuated)

Table 4. RAST results (*continuation*).

Variable	Group	Pre-intervention	Post-intervention	p	ES
RAP (w/kg)	Cr	7.36 ± 1.03 (5.40 – 8.47)	7.80 ± 1.14 (5.75 – 9.36)	0.055	0.41
	Pl	6.93 ± 0.72 (6.18 – 8.28)	7.78 ± 1.03 * (6.69 – 9.73)	0.036	0.96
MaxP (w)	Cr	517.93 ± 118.82 (344.46 – 697.82)	580.15 ± 119.06 * (383.87 – 775.16)	0.001	0.52
	Pl	551.60 ± 107.99 (449.89 – 781.36)	599.26 ± 125.92 (497.13 – 858.01)	0.093	0.41
MaxRP (w/kg)	Cr	7.9 ± 1.2 (5.8 – 9.3)	8.5 ± 1.3 * (6.3 – 10.3)	< 0.001	0.48
	Pl	7.8 ± 0.8 (7.0 – 9.5)	8.5 ± 1.1 (7.4 – 10.5)	0.077	0.73
FI (w/s)	Cr	2.3 ± 1.8 (0.9 – 6.6)	3.2 ± 1.7 (1.2 – 5.8)	0.161	0.51
	Pl	3.6 ± 1.1 (1.9 – 5.7)	3.0 ± 0.8 (2.1 – 4.3)	0.232	0.62

Cr: creatine group; Pl: placebo group; w: watts; AP: average power; RAP: relative average power; MaxP: maximum power; MaxRP: maximum relative power; FI: fatigue index; ES: effect size; * represents significant intra-group difference (p<0.05).

Table 5. WIN results.

Variable	Group	Pre-intervention	Post-intervention	p	ES
MaxP (w)	Cr	456.4 ± 91.0 (263 – 553)	508 ± 79.7 * (373 – 601)	0.003	0.6
	Pl	473.1 ± 111.9 (358 – 650)	517.6 ± 82.1 (430 – 654)	0.088	0.45
MaxRP (w/kg)	Pl	7.0 ± 0.9 (4.9 – 8.2)	7.6 ± 0.6 * (6.5 – 8.4)	0.012	0.78
	Cr	6.7 ± 1.0 (5.7 – 7.9)	7.4 ± 0.8 (6.4 – 8.5)	0.141	0.77
AP (w)	Cr	354.8 ± 69.5 (225 – 438)	410 ± 71.5 * (306 – 488)	< 0.001	0.78
	Pl	385.5 ± 86.7 (303 – 522)	413.1 ± 71.9 (335 – 527)	0.096	0.35
RAP (w/kg)	Cr	5.4 ± 0.6 (4.2 – 5.9)	6.1 ± 0.4 * (5.4 – 6.4)	0.012	1.37
	Pl	5.5 ± 0.8 (4.8 – 6.5)	5.9 ± 0.7 (4.9 – 6.7)	0.233	0.53
Tiredness level (%)	Cr	63.0 ± 8.1 (53 – 79)	62.1 ± 4.2 (55 – 68)	0.780	0.14
	Pl	60.8 ± 5.3 (50 – 68)	65 ± 6.0 (59 – 75)	0.174	0.74

Cr: creatine group; Pl: placebo group; w: watts; MaxP: maximum power; MaxRP: maximum relative power; AP: average power; RAP: relative average power; ES: effect size; * represents significant intra-group difference (p<0.05).

Table 6. Percentage difference in MaxP according to protein consumption.

Test	Group	Subject	MaxP Pre	MaxP Post	%
BRVJ	Cr	+ PTN	3798.4	4469.3	17.7
		- PTN	2424.7	2572.9	6.1
	Pl	+ PTN	3646.3	3598.2	-1.3
		- PTN	2332.1	2510.6	7.7
RAST	Cr	+ PTN	539.0	597.2	10.8
		- PTN	397.4	525.6	32.3
	Pl	+ PTN	576.6	531.6	-7.8
		- PTN	449.9	511.5	13.7
WIN	Cr	+ PTN	553.0	590.0	6.7
		- PTN	263.0	373.0	41.8
	Pl	+ PTN	545.0	519.0	-4.8
		- PTN	370.0	430.0	16.2

Cr: creatine group; Pl: placebo group; MaxP: maximum power in watts; + PTN: subject of the group with the highest protein consumption; - PTN: subject of the group with the lowest protein consumption.

Discussion

The percentage distribution of macronutrients in the diet is in accordance with the nutritional recommendations proposed by Ranchordas *et al.*[5] (Table 1). Except for CHO consumption, there was no significant difference in energy, protein, and lipid consumption between groups, which is an important aspect to consider before the experimental intervention. Since Cr is endogenously produced, individuals with higher dietary protein intake may experience less benefit from its supplementation. Kreider *et al.*[8] consider that subjects with reduced protein consumption (lower biological value sources) in the diet would obtain more benefits from Cr supplementation, due to the possible amino acid deficiency for the endogenous synthesis of Cr. Since the protein intake was statistically similar in both absolute and proportional values (g/Kg BM), and the percentage distribution was appropriate, we consider that the dietary factor did not influence the results.

Cr consumption has been appointed as an ergogenic agent that may increase BM[8,24] through an increase in body water[25] or muscle hypertrophy[26]. The results obtained in the present study (Table 2) indicate an increase of approximately 1.3 Kg of BM in the Cr group. This reinforces the rapid effect of consuming this ergogenic resource. However, for athletes in events categorized by BM, such as fighters, weight gain may not be beneficial, reinforcing the need for more rigorous control of the applicability of Cr supplementation.

Body fat was not altered by Cr consumption, which is in line with the findings of previous studies[19,24]. This result can be somewhat expected because Cr supplementation does not interfere with the fat metabolism, but it does interfere in the phosphagens pathway for rapid energy production. To lose body fat, the volunteers must be in an energy deficit, which did not happen. In addition, fatty acid metabolism for energy production starts in activities of submaximal intensity with prolonged duration[27].

One of the reasons for BM gain may be accumulation of body water following Cr supplementation. However, the results show that water percentage and urine density indicators were not altered by the Cr consumption, refuting this theory. This result contradicts a study published by Deminice *et al.*[25], where a significant increase in total body water (≈ 5%) after Cr supplementation was found. Therefore, a possible explanation for BM gains would be muscle hypertrophy since circumference increases in the brachial biceps, thigh, and calf for the Cr group was detected, contrarily to the Pl group, in which the calf circumference significantly reduced after the intervention. The increased circumferences may be related to an increased muscle mass[16]. However, in this study, it is not possible categorically to state whether there was myofibrillar hypertrophy, which could only have been confirmed by biopsy or imaging techniques such as magnetic resonance.

An important aspect to be considered is the participants' initial hydration level. According to the urinary density, both groups showed signs of dehydration, with density values above 1.020[28]. However, after the intervention, individuals of the Cr group improved their hydration status, while the Pl distanced itself from it, which may be due to ad libitum water consumption. The practice of physical exercise in a state of dehydration is extremely harmful to athletes' health[29,30], and soccer competitions have a high risk of dehydrating players[31]. In agreement with our findings, Castro-Sepúlveda *et al.*[14], and Arnaoutis *et al.*[13] showed how dehydrated soccer players are before and after training sessions and matches, and that hydration ad libitum is not enough to replace the water lost[13]. This reinforces the need of raising awareness and educating the athlete about the importance of performing constant hydration to avoid severe dehydration, which, in addition to impairing the quality of training, will also be harmful to health.

To our knowledge, no study has analyzed the impacts of Cr supplementation on the BRVJ test. The performance data obtained in this test (Table 3) are very interesting since none of the five variables considered significantly improved in the Pl group. On the other hand, the Cr group showed noteworthy improvement in MaxP, MaxRP, and AP, as well as an increment in the strength and explosive power of the lower limbs without interfering with the IF. This indicates an important ergogenic effect since the test protocol is primarily dependent on the ATP-PC system, in which PCr stocks have a decisive influence. These results are contrary to previous studies that evaluated the impacts of Cr supplementation in jump protocols and found no significant improvement in power and maximum jump height[18,32,33]. Thus, Cr supplementation can be recommended especially for soccer players who have more active jumping actions, such as attackers, defenders, and goalkeepers. Likewise, athletes from other sports in which the jumping component is also present, like volleyball and basketball, could also benefit.

In amateur female soccer players, Ramírez-Campillo *et al.*[32] observed a significant improvement in performance in the RAST in the Cr group. At the end of our research, the Cr and Pl groups showed a significant difference in the temporal effect in three analyzed parameters (total time, average of sprints, and AP) (Table 4). Thus, the influencing factor of this behavior cannot be justified by Cr consumption. A possible explanation is that the learning effect can have influenced these parameters since the protocol was applied to the players for the first time. However, the Cr group achieved improvements in the performance of the best sprint and MaxRP. This result, which is directly influenced by PCr stocks, is especially important in the dynamics of a soccer match. Thus, it can be inferred that the proposed supplementation protocol contributed to this result. On the other hand, the Pl group increased the RAP, which represents an unusual result with no reasonable justification, considering that the dietary pattern was similar and that the training activities were maintained.

The groups had no statistically significant changes in the FI results. These results are contrary to Ateş *et al.*[34], who observed improvements in the FI, an important indicator for the athletic performance of a soccer player, who can be submitted to up to 250 short distance and high-intensity stimuli during the match[35]. Ideally, soccer players should have good repeated sprint ability maintained throughout the match. Considering that the players evaluated were recreational, this may have been a determining factor. Perhaps recreational players could benefit from a longer period of supplementation, which should be investigated in further studies.

In this study, we applied the WIN test to verify how Cr supplementation could impact the performance of a muscle that was not directly trained. Cr supplementation promoted a positive adaptation in four (MaxP, MaxRP, AP, and RAP) of the five monitored parameters (Table 5), while in the level of tiredness there was a similarity between groups, contrarily to the work of Yáñez-Silva *et al.*[2]. These preliminary results of improved performance observed in an untrained musculature are somewhat surprising since the physical stimulus of the exercise has an anabolic local adaptation action over the worked musculature.

To analyze whether protein consumption could interfere with supplementation results, a more detailed analysis was performed in the groups, selecting the individuals who consumed more and less PTN (Table 6). Specifically, in the MaxP variable (common in the 3 tests), it was possible to notice that, in the BRVJ, the individual who had consumed more protein in the Cr group showed better performance than the individual with the lowest consumption (17.7% *vs.* 6.1%). However, these data are inverted in RAST and WIN, showing an improvement of 10.8% against 32.3% of the individual with lower protein consumption in RAST, and 6.7% against 41.8% in WIN. Despite what was expected, the results in Pl group indicated an improvement of greater magnitude for the individual who consumed less PTN, probably due to the learning effect. These results, analyzed in a particular way, somehow reinforce the theory that the magnitude of the ergogenic effect of Cr consumption may be influenced by the daily protein consumption pattern. An individual who consumes less PTN may benefit more from Cr supplementation, supplying the deficiency of endogenous synthesis resulting from the consequent amino acid deficit.

The side effects reported for Cr consumption include cramps, weight gain, and gastric discomfort[2,16]. During the experimental period, one of the volunteers manifested an adverse reaction to Cr supplementation, showing facial and foot swelling after the loading phase (first week), who was forwarded to the doctor and excluded from the study. Reports of allergic reactions of this nature associated with the consumption of Cr are not common. Cr has been used as an aid in several medical treatments and is considered safe for consumption, even in higher doses[8].

The final sample size of sixteen individuals can be considered one of the limitations of this study. However, several similar works also had a similar sample size, like Gann *et al.*[24], with 14 individuals, and Ramírez-Campillo *et al.*[32], with 20 participants. Other limitations of this study are the training and the food records accuracies. The training record was not performed; however, 13 volunteers from the final sample trained together, and separate training could generate different results. Although there was prior guidance on how to fill out the food record, errors can still occur when registering information, even though this is a usual methodology in studies like this[18,19].

For future studies, we suggest applying this model to investigate the effects of Cr supplementation on women, athletes from other modalities such as futsal, or even with different age groups. If available, using DXA for body composition analysis can improve the quality of information.

Conclusion

From this study, it was found that Cr supplementation for four weeks was able to promote positive anthropometric and anaerobic performance changes in college soccer players, especially in lower limbs, but also in upper limbs. Because it is a low-cost nutritional ergogenic resource, with a low rate of reported side effects, and which has presented positive results on performance, Cr can be recommended for recreational soccer players seeking performance improvements. However, a possible body mass gain due to Cr supplementation should be considered, and its viability should be individually analyzed for each athlete.

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Conflict of interest

The authors do not declare a conflict of interest.

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Artículo original

Ten years of football (soccer) injuries in the literature. A bibliometric approach

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Summary

The aim of this research is to analyse the scientific production of publications produced during a decade (2010-2019) about injuries in football (soccer). A bibliographic search was done for publications featuring key terms such as football, soccer, and injuries. We searched for studies in journals that had a five-year impact factor in the Journal Citation Report in the "Sport Sciences" category. The PRISMA methodology was used. The following bibliometric indicators were analysed: number of publications by journal; country of origin; country of publication; publications per year; number of authors; authors' native language; evidence level; type of study; sex; anatomical location and topographic location of injuries. To assess the level of evidence, the Oxford Centre for Evidence-Based Medicine (CEBM) level of evidence classification was used, dichotomised as follows: articles with level 1 and level 2 evidence were 'high evidence', and articles with levels 3, 4, and 5 were 'low evidence'. The statistical tests were performed using SPSS V. 28. A total of 222 articles published in four journals met the inclusion criteria. Production rose as the decade progressed. The highest frequency was in 2013. *The British Journal of Sports Medicine* (BJSM) had the highest number of publications. *Sports Medicine* (SM) had the most authors per article and the highest level of evidence. The United States was the main producer. There were more publications regarding injuries in males, and in males and females, compared to publications that only took females into account. More muscle, thigh, and hip injuries were described. The level of evidence was generally low. The increase in scientific production related to football (soccer) injuries during the decade reflect an elevated interest for the subject matter. Publications that prevail around this theme consider injuries in the thigh and lower extremities and in men.

Key words:
Football. Soccer. Injuries. Bibliometrics. Evidence-based medicine.

Diez años de lesiones de fútbol en la literatura. Una aproximación bibliométrica

Resumen

Con el objetivo de analizar la producción científica de publicaciones realizadas durante una década (2010-2019) sobre lesiones en el fútbol, se realizó una búsqueda bibliográfica de publicaciones con términos clave como fútbol, soccer y lesiones, en revistas con mayor Factor de Impacto acumulado en 5 años en el Journal Citation Report, en la categoría "Sport Sciences". Se utilizó la metodología PRISMA. Se analizaron los indicadores bibliométricos: número de publicaciones por revista; país de origen; país de publicación; publicaciones por año; número de autores; lengua materna de los autores; nivel de evidencia; tipo de estudio; sexo; localización anatómica, y localización topográfica de las lesiones. Para evaluar el nivel de evidencia se utilizó la clasificación del Oxford Centre for Evidence-Based Medicine (CEBM) y se dicotomizó en alto (artículos con niveles de evidencia 1 y 2) y bajo (artículos con nivel de evidencia 3, 4 y 5). El análisis estadístico se realizó con SPSS V.28. Un total de 222 artículos publicados en cuatro revistas cumplieron con los criterios de inclusión. La producción aumentó a medida que avanzaba la década, siendo mayor en 2013. El *British Journal of Sports Medicine* (BJSM) realizó el mayor número de publicaciones. La revista *Sports Medicine* (SM) tuvo la mayor cantidad de autores por artículo y el mayor nivel de evidencia. Estados Unidos fue el principal productor. Hubo más publicaciones que investigaron las lesiones en hombres, y en hombres y mujeres, en comparación con las publicaciones que solo tomaron en cuenta a las mujeres. Se describieron más lesiones musculares, en muslo y en cadera. El nivel de evidencia en general fue bajo. El incremento de la producción científica durante la década refleja un elevado interés en el tema. Predominaron las publicaciones acerca de lesiones en la cadera y extremidades inferiores y en hombres.

Palabras clave:
Fútbol. Soccer. Lesiones. Bibliometría. Medicina basada en la evidencia.

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Introduction

Bibliometrics can be understood as a research technique that analyses the size, growth, and distribution of publications in a scientific field[1]. This type of studies helps researchers to analyse existing knowledge, through the study of publication patterns using quantitative analysis and statistics[2]. To fulfil their mission, researchers need to identify relevant studies on a topic of interest and to critically assess the level of the evidence presented[3].

Evidence-Based Medicine (EBM) is defined as the judicious utilisation of the best scientific evidence available to make decisions about the care and treatment of patients[4]. "Evidence-based medicine is defined as a conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients"[5]. The practice of EBM integrates the individual clinical expertise with the best available external clinical evidence[6]. The need for EBM in the treatment of football (soccer) injuries is justified given the ever-increasing demands of this sport, with more games per calendar year with insufficient recovery time between games, all of this to win games, titles and trophies[7,8]. When injured, athletes need to obtain the best treatment available to return to the field as soon as possible. While physicians need to keep abreast of current knowledge to inform their medical practice[4,9], the increasing number of academic publications on the subject of football makes it difficult for them to assimilate the never-ending stream of new information. In addition, scientific inquiry into football is saturated with empirical contributions from different sources and networks that have produced misleading knowledge and evidence[10].

Treating sports injuries is often challenging, costly, and time consuming[11]. Given the increasing participation in football recently, topics related to football injuries are of great interest[10,12,13]. Furthermore, the economic, social, and health burdens resulting from the high incidence of football-related injuries are also the main factors behind the recent interest in football injuries[14]. Given this context, the necessity of a review to quantify the quality of football-related studies and to identify the areas that have attracted the most research interest becomes evident.

The aim of this study is to outline the evolution of publications regarding football-soccer related injuries over a time span of ten years, to show what areas were most studied in order to know which ones carry greater interest and potential for further exploration, to identify which journals have published the most regarding football injuries, and to explore the levels of evidence. Thus, the main objective of this investigation is to analyse the scientific production of football injuries by using the following bibliometric indicators: country of affiliation, country of publication, publications per year, journal production, number of authors per publication, authors' native language, evidence level, type of study, sex, anatomical location of the injuries, and topographic location of the injuries.

Material and method

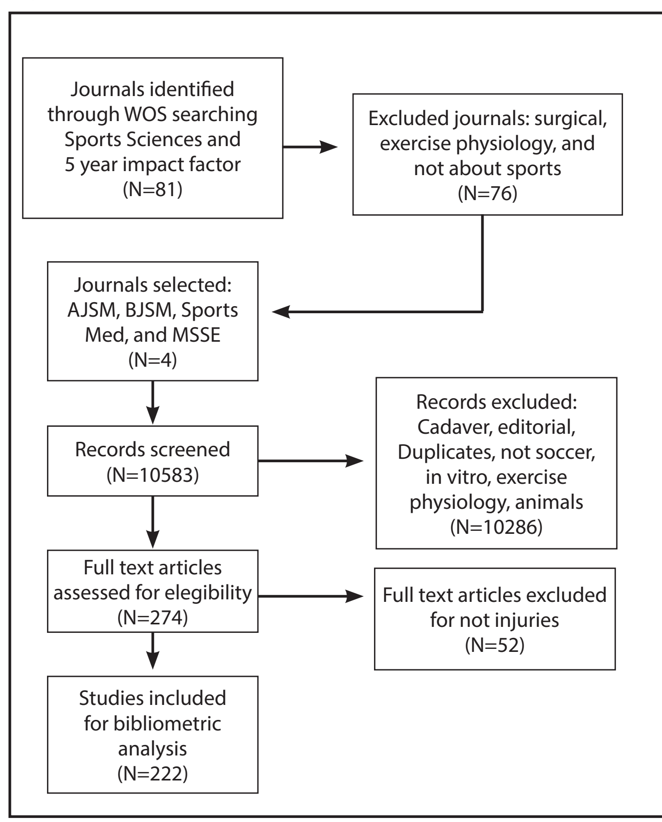
This bibliometric analysis was conducted in accordance with the PRISMA-DTA Statement[15].

A wide variety of journals with 5- year JIF were selected through searching the Journal Citation Reports™ database (JCR) in the category 'Sport Sciences'. After excluding journals that worked with subjects such as surgery and exercise physiology and those that were not about sports per se, four journals remained: British Journal of Sports Medicine (BJSM), American Journal of Sports Medicine (AJSM), Sports Medicine (SM), and Medicine and Science in Sports and Exercise (MSSE). The journal impact factor (JIF) was obtained from the JCR 2020 edition. In 2019, BJSM had a JIF of 12.68, with a 5-year JIF of 10.67; AJSM had a JIF with a 5-year JIF of 6.8; SM had a JIF of 8.5, with a 5-year JIF of 9.7; and MSSE had a JIF of 4.02, with a 5-Year JIF of 5.09.

Of those four source journals selected, a bibliographic search was developed in the Web of Science database (WoS) collecting records from 2010 to 2019. The following were excluded: articles that studied sports through cadavers; editorials; articles relating to sports other than soccer (such as American football, Australian football, and Gaelic football); studies involving in vitro research; exercise physiology studies; studies with animals; studies that were not related to injuries, and of course duplicates. This search strategy returned 222 articles which were the ones that were bibliometrically analysed. See Figure 1 for a flow diagram.

Data extracted from the articles were as follows: number of publications by journal; country of origin; country of publication; publications per year; number of authors; authors' native language (refers to the language of the institution where the main author is affiliated),

Figure 1. PRISMA flow of studies for the review.



evidence level; type of study (therapeutic, prognostic, diagnostic, and economic); sex (male and female); anatomical location (ligament, joint, tendon, bone, and muscle) and topographic location (head, back, pelvis, hip, thigh, knee, leg, ankle, and foot) of injuries. To assess the level of evidence, the Oxford Centre for Evidence-Based Medicine (CEBM) level of evidence classification was used, dichotomised as follows: articles with level 1 and level 2 evidence were 'high evidence', and articles with levels 3, 4, and 5 were 'low evidence'.

A chi-square test for association was used to analyse most of the categorical and nominal variables; for continuous variables, a Kruskal-Wallis H test was performed. These tests were chosen because none of the variables had a normal distribution. The statistical tests were performed using SPSS V. 28. All statistical comparisons were bilateral; $p < .05$ was considered statistically significant.

Results

Country of affiliation

Country of affiliation corresponding to the country of filiation of the first author. Most studies regarding injuries in football were undertaken in the United States (23.9%), followed by the United Kingdom (13.1%) and Sweden (11.7%). These countries produced almost half (48.7%) of the total number of articles. See Table 1.

Table 1. Frequency of publications by country of affiliation.

Country	Country of affiliation		
	Frequency (N=222)	Percentage	Cumulative percentage
United States	53	23.9	23.9
United Kingdom	29	13.1	36.9
Sweden	26	11.7	48.6
Denmark	16	7.2	55.9
Switzerland	14	6.3	62.2
Norway	12	5.4	67.6
New Zealand	8	3.6	71.2
Qatar	8	3.6	74.8
Australia	7	3.2	77.9
Italy	6	2.7	80.6
Germany	5	2.3	82.9
Canada	5	2.3	85.1
Ireland	4	1.8	86.9
Japan	4	1.8	88.7
Belgium	3	1.4	90.1
Spain	3	1.4	91.4
Finland	3	1.4	92.8
France	3	1.4	94.1
Greece	3	1.4	95.5
Netherlands	3	1.4	96.8
Other*	7	3.5	100.0

*Saudi Arabia. Austria, Brazil, China, Iran, Mexico and Portugal (1 publication; 0.5% each).

Country of publication

In the ten-year period under review, British journals (BJSM and SM) published 145 articles (65.3%) and American journals (MSSE and AJSM) published 77 articles (34.7%).

Publications per year

The ten-year span was divided quinquennially. British journals published 49 articles in the first quinquennium (33.8%) and 96 articles in the second quinquennium (66.2%). American journals published 57 articles in the first quinquennium (74%) and 20 articles in the second quinquennium (26%). In the first quinquennium, most articles regarding injuries in football were written by American journals (53.7%) whereas in the second quinquennium British journals published more football injury-related articles (82.8%) than American journals. According to this analysis, the differences in publications highlighted above between British and American journals was statistically significant ($p < .001$), with a moderate association between the variables ($p < .001$).

Journal production

The data shows that half of the articles considered for this analysis come from the BJSM (51,28%), followed by the AJSM (26,6%), the SM journal (13,5%), and the MSSE journal (8,1%). This means that almost 65% of the articles published regarding injuries in football come from British journals. This also shows a trend to rise in article production in all journals, except in AJSM, see Figure 2. Regarding years of publication, the production of journals reached a peak in 2013, with 33 articles published in total (14.9%). Additionally, in this same year, British journals published 21 articles (63.3% of the annual total; 9.5% of the overall total), while American journals published only 12 articles (36.4% of the annual total; 5.4% of the overall total). The graph shows that in the first 5-year period the BJSM and the AJSM published the most articles, compared to the number of articles published by the SM Journal and the MSSE journal. Nonetheless, in the second 5-year period there is a change in the number of publications, with the BJSM and Sports Medicine starting to publish the most, and the AJSM decreasing its rate of publications significantly.

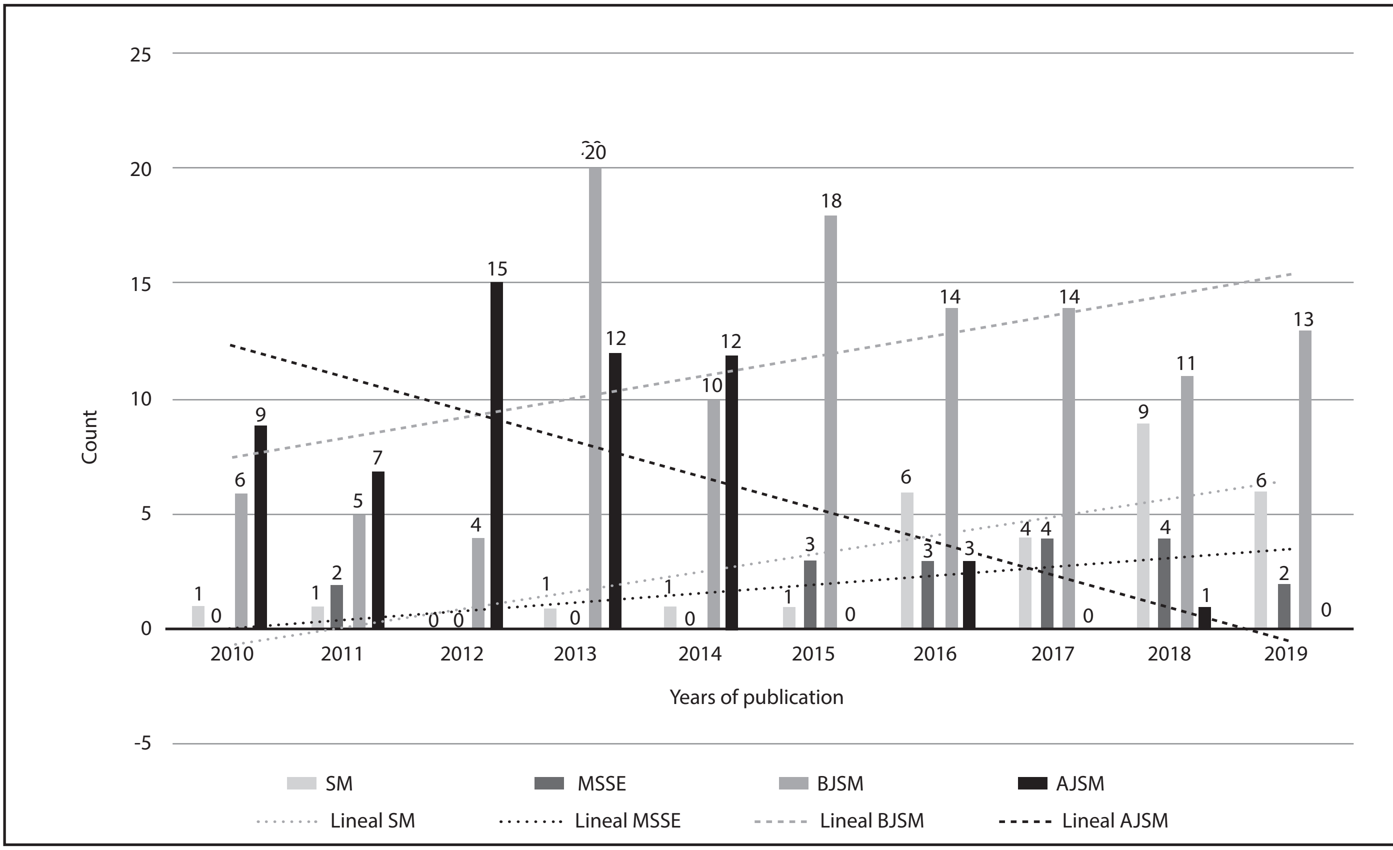
Number of authors

The journal with the highest mean number of authors was SM ($M = 8.73$), followed by MSSE ($M = 6.33$), BJSM ($M = 5.3$), and AJSM ($M = 5.00$). The number of authors was statistically and significantly different between the different journals ($p = .025$). Post-hoc analyses indicated that the differences were more marked between AJSM and SM ($p = .013$).

Authors' native language

To determine whether the native language of the majority of authors was English, the sample was divided between those with anglophone and non-anglophone authors. It was found that 105 authors (47.3%) did not have English as their native language and 117 (52.7%) had English as their native language.

Figure 2. Journal production and years of publication.



The number of non-anglophone authors in BJSM was significantly higher than in the other journals. A greater number of anglophone authors was found in SM, AJSM, and MSSE (p = .003).

Evidence level

An analysis of the publications' evidence levels found that 36.4% of the publications presented a level of evidence 2. The level of evidence 1 was least represented with 6.7%. There were 24.3% articles with level of evidence 3 and 22.9% with level of evidence 4. There were 9,4% articles with level of evidence 5. See Table 2.

Dichotomizing the evidence levels in terms of the total number of articles published, 96 (43.2%) presented a high level of evidence and 126 (56.7%) presented a low level of evidence.

SM was the only journal in which most articles presented a high level of evidence (60%). Fifty percent of the articles published in SM were systematic reviews (SRs), cohort studies or ecological studies. Three articles (10%) in SM presented level of evidence 1 and 3 presented level of evidence 3 (p = .013). The BJSM has the most articles in all the levels of evidence. Nonetheless, many of its articles (59,11%) have low levels of evidence. Despite this, the BJSM has 38 articles that are systematic reviews, cohort studies, or ecological studies, which represent a high level of evidence. The AJSM doesn't have articles classified in the first level of evidence, and most of its articles (59,18%) have low levels of evidence. The MSSE overall has very few articles published regarding injuries in football (soccer). Most of its articles have low levels of evidence (60,9%). see Figure 3.

In order to find out the trend of the evidence levels of the different publications, we have analysed this variable as a continuous variable, this shows us where the evidence levels tend to cluster. Regarding the mean level of evidence per journal, SM presented the highest level of evidence (M = 2.8), followed by AJSM and MSSE, both with a mean of 2.9. BJSM's mean was lowest, M = 3.0, see Figure 4.

Comparing the levels of evidence with the years of publication, no significant associations between the levels of evidence published in the articles were found across the 10-year span (p = .75).

Table 2. Overall evidence level.

Evidence Level	Frequency
1	15
2	81
3	54
4	51
5	21

Figure 3. Evidence level per journal.

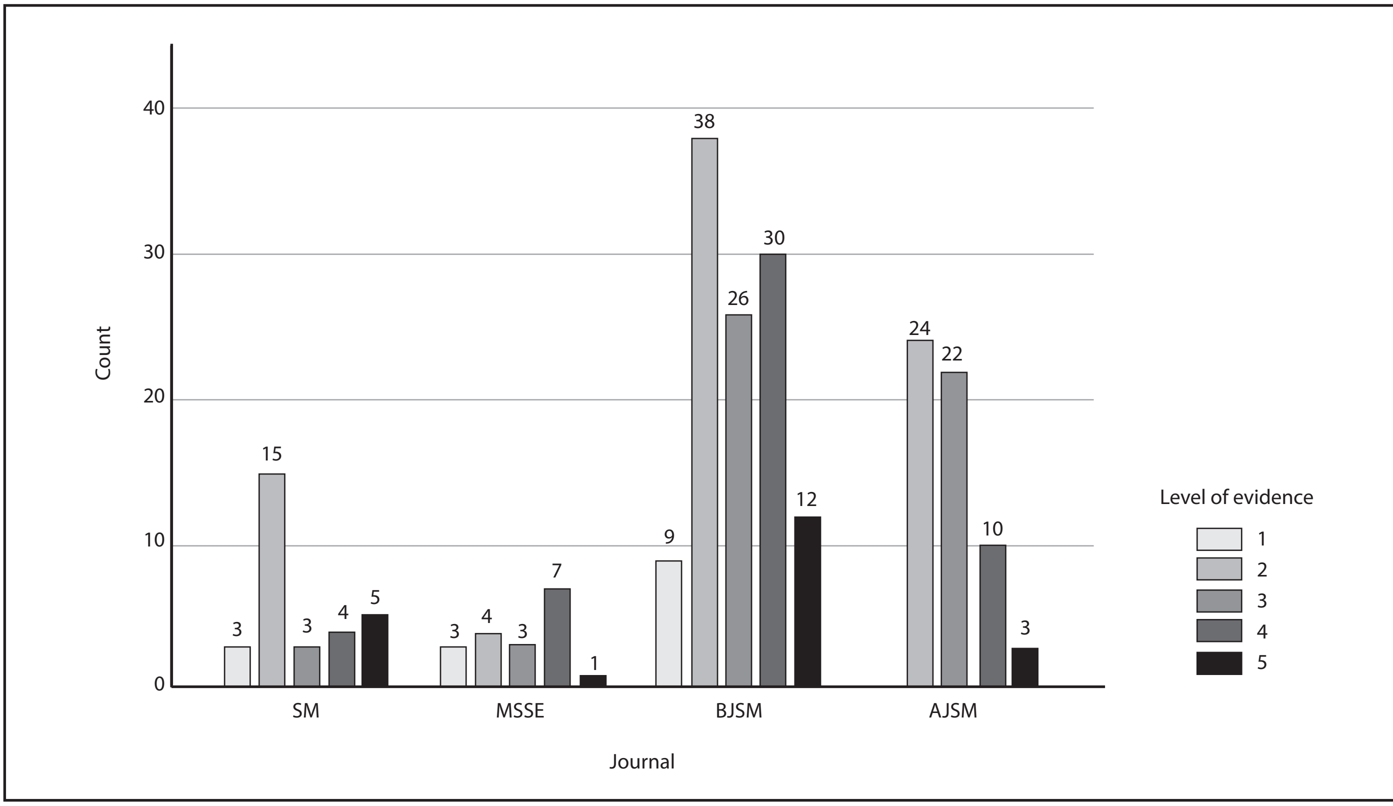


Figure 4. Mean evidence level per journal.

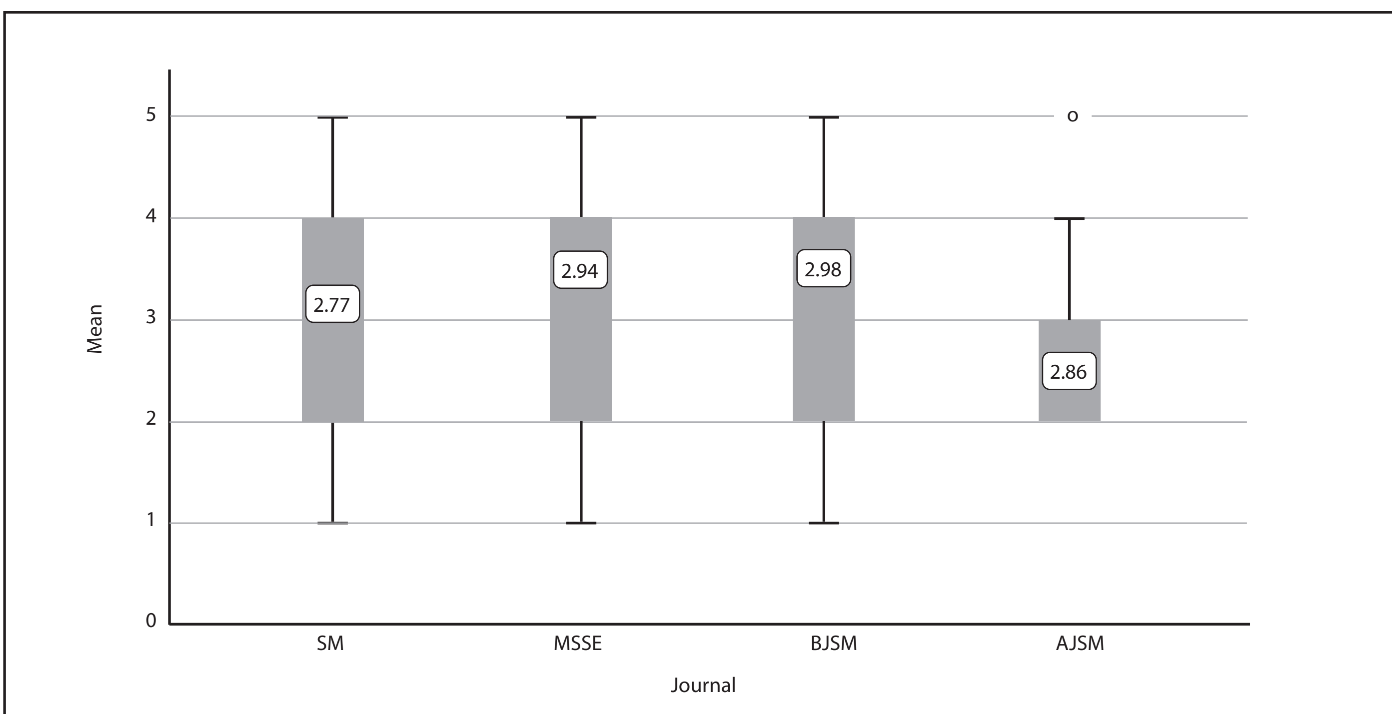


Table 3. Type of study per journal.

Type of study	SM	MSSE	BJSM	AJSM	Total
			Journal		
Therapeutic	11	1	15	2	29
Prognosis	10	14	72	44	140
Diagnosis	2	1	12	6	21
Economic	7	2	16	7	32
Total	30	18	115	59	222

SM: Sport Medicine; MSSE: Medicine and Science in Sport and Exercise; BJSM: British Journal of Sport Medicine; AJSM: American Journal of Sport Medicine.

With respect to native language, anglophone authors published more articles with high levels of evidence, and non-anglophone authors published more articles with low levels of evidence (p = .027).

Type of study

Many publications (63%) developed a prognosis and history, followed by economic and decision analysis studies (14.4%), therapeutic, prevention, aetiology and damage studies (13%), and diagnosis studies (9.5%). In terms of the relationship between type of study and journal, BJSM and SM published most of the therapeutic, prevention, and aetiology and damage studies. Most of the economic and decision analysis studies were published in BJSM, followed by AJSM and SM. In addition, it is noteworthy that most MSSE studies concerned prognosis and the history of injuries (p = .002), see Table 3.

No statistically significant associations between the variables were found when type of study was compared with evidence level (p = .872).

Sex

A total of 125 (56.3%) studies were conducted with males, 79 studies (35.5%) included both male and female, and 18 (8.1%) included only females.

Of the publications selected for this study, SM published football-related studies involving only males or both sexes but published no studies involving only females. Most of the studies published in MSSE involved only males, with only a few investigating both sexes or only females. Regarding the studies in BJSM, most involved only males, followed by studies involving both sexes, with the least number involving only females; however, it is noteworthy that BJSM published the most studies pertaining to only females. Most of the studies published in AJSM included both sexes, followed by male-only studies and a few that only involved females (p= .005).

After examining the association between sex and years of publication, when considering for the analysis the division into two quinquennium, it was found that studies involving only males were more numerous in the second quinquennium than in the first. In contrast, studies involving both sexes or only females were less numerous in the second quinquennium than in the first (p = .002).

Table 4. Anatomical location of injuries.

Anatomical Location	Frequency	Percentage
Muscle	29	13.06%
Bone	6	2.70%
Tendon	13	5.86%
Joint	17	7.66%
Ligament	21	9.46%
Multiple, others	136	61.26%

Anatomical location

More than half of the articles (61.3%) described injuries in multiple locations. Reports about specific injury locations ordered by frequency were as follows: muscle injuries 13.1%, ligament 9.5%, joint 7.7%, tendon 5.9%, and bone 2.7%; (p = .037), see Table 4.

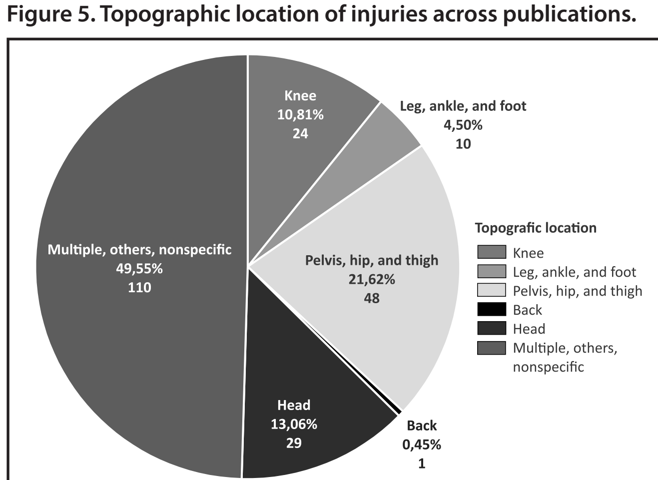
There was a statistically significant association between the variables, implying that studies on injuries to tendons and bones presented higher levels of evidence than studies regarding injuries to muscles, joints, ligaments, and multiple locations (p = .037). There was no significant statistical association between the level of evidence and the anatomical location of the injury (p = .057).

Topographic location

Almost half of the articles (49.5%) described injuries in multiple locations; injuries in the hip and thigh comprised 21.6% publications; injuries to the head make up 13.1% of the publications; injuries to the knee were studied in 10.8% publications; and injuries to the leg, ankle, and foot were studied in 4.5% publications, see Figure 5.

Regarding associations between topographic location and country of publication, British journals published more studies involving multiple injuries and injuries to the pelvis, hip, and thigh, while American journals

Figure 5. Topographic location of injuries across publications.



published more studies about injuries to the knee and head. Studies pertaining to leg, ankle and foot injuries were equally represented in British and American journals (p = .009).

An analysis of the relationship between sex and topographic location indicated that most of the studies that included only females investigated multiple injuries, followed by injuries to the knee, and then the head. Most of the studies that included only males in their sample reported multiple injuries, followed by injuries to the pelvis, hip, and thigh; knee; head; and leg, ankle and foot, (p = .002).

Discussion

The data shows that there is an overall trend to rise in article production over the past 10 years. This shows that there is a growing interest in developing knowledge around the understanding of football injuries (their prognosis, location, and treatment). The United States had the highest number of studies (23.9%). Nonetheless, most of the articles in this study were published in high-impact British journals (65.31%). This finding coincides with other bibliometric studies in traumatology[16,17], in which the United States was found to be the country with the highest levels of authorship.

Europe developed 59.46% of the total academic production considered in this analysis, followed by America (27.03%), Asia (6.76%), and Oceania (6.76%). It is noteworthy that countries with an important football tradition, such as Spain and Italy, only developed 4.1% of the total production of studies relating to football injuries.

During the decade considered for this analysis, more than half of the articles were published by BJSM (p = .013) with a peak in production in 2013 (20 publications). This shows a global tendency to increase publications across the four journals. This coincides with the 2012 London Olympics, European Football Championship 2012 (Eurocup)[18], and increased scientific production in football commented on in other bibliometric studies[10,19].

With respect to the number of authors, the journal with the highest number of authors per article was SM, M = 8.73; AJSM had the lowest number, M = 5.00 (p = .025). In other bibliometric studies, it has been observed that having many authors can be interpreted in different ways: it can reflect a high degree of collaboration or an aggrandizement of the number of authors as a consequence of having the presence of honorific or phantom authors, and other studies have reported a 21% prevalence of these types of authors[20].

Regarding levels of evidence, 56.7% of the studies reviewed had a low level of evidence. This asymmetry in evidence levels may be explained by differences in categories and scenarios regarding the sport of football which affects research infrastructure. Consequently, large studies are limited to the footballing elite. However, this study included meta-analysis and randomized controlled trials (RCTs) in the areas of training endurance and performance, with special focus on the prevention of injuries[21–23]; it also comprised studies that evaluated the efficacy of football programmes, such FIFA's 11+ Kids[24,25], along with SRs corresponding to FIFA studies in young football players[26]. This constitutes valuable input for medical teams and technicians responsible for managing the training loads and attending to the mental health of football players.

As stated elsewhere, 'where RCTs are often not available, a systematic literature review of other published studies is the next 'best' form of evidence'[27]. Given the low number of RCTs, this could be applied to football. In relation to the SRs analyzed during this study, some of them with meta-analyses, it was found that they refer to topics related to risk factors for injuries and injury prevention and the treatment of sports injuries[28–33]. However, there were 56.7% articles with low levels of evidence; this represents an opportunity for improvement in the area for researchers who are making an incursion into football.

With respect to study type, the majority were prognosis and natural history studies (63%), while the minority were diagnostic studies (9.5%). Most of the studies described injury behaviour and its influence on football players' fulfilment[34–40], and few investigations were dedicated to the utility of diagnostic tests in pathologies such as tendinopathies or groin pain[41–44]. The high prevalence of economic studies is striking[45–47] (14.4%). As observed in other publications, there is an increase in studies of innovation in football[19,26], in aspects such as the use of tools for injury prediction[48], decision-making about the continuity of prevention programmes[25], analysis of beneficial effects generated by preventive programs[49,50], adaptations derived from specific skills training[51], and talent identification[46].

In relation to sex, there were a greater number of studies involving only males (56,3%) than only females (8.1%). Further, studies reported a lower number of football studies involving females compared to males and an even greater scarcity of publications involving elite female football players, despite an increase in the popularity of females football[13,52,53]. In this study, we observed a lower number of publications about injuries in females; nevertheless, these publications have a high level of evidence. It was found that there was a higher rate of studies with female participants in the first five years[29,36,54], with a special focus on knee injuries in adolescent football players[36]; however, there was an unfortunate downward trend in the second five-year period. This suggests a commitment to scientific quality in this field. As a consequence, it is necessary to expand the number of studies with female participants in order to improve their availability to carry out comparative studies with males, which in the end strengthens the possibility of decision-making.

Regarding the anatomical location of injuries, a greater presence of muscle injuries was found, followed by injuries to the ligaments, joints, tendons, and bones. It is striking that tendon and bone studies have a higher level of evidence than those involving other anatomical structures: evaluating their content, it has been observed that they are also epidemiological studies[38,55–58], or that they evaluate the effectiveness of injury prevention programmes involving structures that are not exclusively tendons, such as the hamstrings[56]. In addition, many of these studies were performed with support from large organizations such as Union of European Football Associations, providing for large population samples[56,58].

With respect to topographic locations, the distribution found in this study coincides with the epidemiologic distribution described in other reports that noted a general prevalence of muscle and thigh injuries, followed by head injuries[8,20,58]. Furthermore, this study's finding of a high frequency of research reporting hip, joint, and thigh injuries in males coincides with injury patterns reported by UEFA studies, with a higher incidence of such injuries in elite football players[7,59,60]. Regarding female football, there has been a higher presence of articles reporting head and knee injuries; this finding is coherent with the report of the Football Association (FA) highlighting the importance of knee injuries and the injury profile for females described by Spanish authors in a SR[52,53], although in the present study there was no special emphasis on head injuries. In contrast with the previous studies, a study conducted with college female football players by the National Collegiate Athletic Association (NCAA) exposes a concern about the rate of this type of injury in females, mentioning that 'the concussion rate in NCAA female soccer is almost twice as high as the rate in male soccer'[59]. In football, head injuries have been the object of analysis in the field of biomechanics research in order to propose evidence-based rules and policies, as well as guide developments based on agreed criteria regarding return to play after suffering a concussion[61–63]. In this field, American journals stand out in the number of reports about head injuries, with a particular focus on neurocognitive symptoms after concussion[63,64].

Study limitations

This study was limited to 222 papers selected from the WOS database, and thus there may be valuable information in other publications outside the scope of this study. The exclusion of surgery and exercise physiology journals can be considered a limitation as well, since we could have rejected articles related to football injuries. Nevertheless, this report performed a detailed evaluation to exclude articles about Gaelic, Australian, and American football to increase the quality of the study; at the same time, an entirely quantitative approach was avoided and a qualitative assessment of evidence levels in terms of CEBM criteria was included. This approach is intended to contribute to current and future research in this field.

Conclusions

In conclusion, this review found that during the decade from 2010 to 2019, the frequency of football and sports studies grew, reflecting an increasing interest in this area. We found that BJSM was the journal with the highest number of publications, followed by AJSM, and the United States was the country with the highest level of authorship. A noteworthy finding was that there were more studies involving males than females. Finally, we found that football injury studies in general present a low level of evidence while female football studies exhibit a higher level of evidence.

Registration

This review was not registered.

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Conflict of interest

The authors do not declare a conflict of interest.

Availability of data

Data is available at Repositorio Institucional de la Consejería de Sanidad de la Comunidad de Madrid (https://hdl.handle.net/20.500.12530/54436).

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Consumption of energy drinks on cardiovascular and metabolic response and performance. Is there an effect?

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Summary

Over the years, the search for nutritional strategies that promote improved sports performance has increased. Among the available options, energy drinks appear as potential nutritional resources for this purpose, because they offer, in addition to caffeine, substances that act synergistically to improve performance, such as taurine, carbohydrates, amino acids, vitamins and minerals, promoting improved performance for both amateur and professional athletes. The aim of the study was to verify the effects of ingesting energy drinks with (ED1) and without carbohydrates (ED0) containing 2 mg·kg^{-1} of caffeine, and a decaffeinated placebo (PL) on cardiovascular, metabolic and performance parameters during cycling. Twelve male cyclists (age = 24.4 ± 6.6 years old) volunteered to participate in this study. The protocol consisted of three experimental sessions of 60 min of continuous cycling (65-75% of VO_{2maxE}) followed by time-trial 6 km. The subjects ingested ED1, ED0 or a placebo drink (PL) 40 min before beginning the exercise. The heart rate (HR), blood pressure (BP), plasma glucose and lactate concentrations, and the time taken to complete the 6 km time-trial were evaluated. The time taken to complete the time-trial was significantly higher ($p < 0.05$) in the PL group than in the groups ED1 and ED0. This time significantly decreased after the ED1 consumption relative to that for the ED0 consumption. Heart rate, systolic and diastolic arterial pressure and in the plasma glucose and lactate concentrations were similar in all the considered groups. These results demonstrate that ED1 consumption appears to be more effective at maximizing performance during the last 6 km.

Key words:
Caffeine. Taurine. Sport drinks. Sports performance. Cycling

Consumo de bebidas energéticas sobre la respuesta cardiovascular, metabólica y rendimiento. ¿Hay efecto?

Resumen

Con el paso de los años, se ha incrementado la búsqueda de estrategias nutricionales que promuevan un mejor rendimiento deportivo. Entre las opciones disponibles, las bebidas energéticas aparecen como potenciales recursos nutricionales para este fin, pues ofrecen, además de la cafeína, sustancias que actúan sinérgicamente para mejorar el rendimiento, como taurina, carbohidratos, aminoácidos, vitaminas y minerales, promoviendo un mejor rendimiento para atletas tanto aficionados como profesionales. El objetivo del estudio fue verificar los efectos de la ingestión de bebidas energéticas con (ED1) y sin carbohidratos (ED0) que contienen 2 mg · kg^{-1} de cafeína y un placebo descafeinado (PL) sobre los parámetros cardiovasculares, metabólicos y de rendimiento durante el ciclismo. Doce ciclistas varones (edad = 24,4 ± 6,6 años) participaron voluntariamente en este estudio. El protocolo consistió en tres sesiones experimentales de 60 min de ciclismo continuo (65-75% del VO_{2max}) seguidas de una prueba contrarreloj de 6 km. Los sujetos ingirieron ED1, ED0 o una bebida placebo (PL) 40 minutos antes de comenzar el ejercicio. Se registró la frecuencia cardíaca (FC), la presión arterial (PA), las concentraciones plasmáticas de glucosa y lactato y el tiempo necesario para completar la prueba contrarreloj de 6 km. El tiempo necesario para completar la contrarreloj en el grupo PL fue significativamente mayor ($p <0,05$) que en los grupos ED1 y ED0. Este tiempo disminuyó significativamente después del consumo de ED1 en relación con el consumo de ED0. La frecuencia cardíaca, la presión arterial sistólica y diastólica y las concentraciones plasmáticas de glucosa y lactato fueron similares en todos los grupos. Estos resultados demuestran que el consumo de ED1 parece ser más eficaz para maximizar el rendimiento durante los últimos 6 km.

Palabras clave:
Cafeína. Taurina. Bebidas deportivas. Rendimiento deportivo. Ciclismo

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Introduction

In the last decade, the consumption of energy drinks (EDs) has become popular especially among athletes[1] due to the possibility of an ergogenic effect[2] during competitions.

Most EDs contain caffeine, taurine, carbohydrates and vitamins[3]. Caffeine has often been used as an acute ergogenic substance before performing physical exercise to postpone fatigue and consequently to improve performance[4]. In addition, some studies have also shown the positive effect of an acute ingestion of taurine on physical performance in humans[5,6].

The presence of carbohydrates in EDs appears to be essential for aerobic events, particularly those that are longer than one hour. Carbohydrates decrease the need to consume muscle glycogen and consequently delay the onset of muscle fatigue[7]. Some studies have shown positive results of a possible enhancement in the ergogenic effect during physical exercise after addition of carbohydrates in caffeinated drinks[8,9], in contrast, other studies did not observe any effect[10].

It is becoming quite popular to consume EDs without carbohydrates (sugar free) before physical activity[11]. However, the benefits of these beverages on physical performance are not clear. Some studies with divergent results [12,13] have evaluated performance after the ingestion of this type of EDs. One study reported an increase in the number of sprints during a soccer game[13] and others did not find improvement in the exercise time to exhaustion[12].

Only the studies by Reis *et al.*,[14] and Reis *et al.*[9] verified and compared the impacts of energy drinks ingestion with and without carbohydrates, confirming that the consumption of these drinks does not affect the hydro-electrolyte balance and promotes an improvement in the performance of runners.

Considering both the scarcity of studies that compare the effects of EDs with and without carbohydrates on physical performance and the increased consumption of both types of drink before sport practice, identifying which drink has greater ergogenic benefits is important. Therefore, the aim of this study was to investigate the effects of pre-exercise ingestion of EDs with and without carbohydrates on cardiovascular and metabolic parameters and on performance on a cycle ergometer during an aerobic effort.

Material and method

Participants

Twelve male cyclists (age = 24.4 ± 6.6 years, body mass = 72.7 ± 7.2 kg, estimated VO_{2max} (VO_{2maxE}) = 54.5 ± 4.8 ml.kg^{-1}.min^{-1}), volunteered to participate in this study. Participants were amateurs who were participating to regional competitions, and trained at least three times per week for a minimal duration of 2 hours, for at least two years.

All subjects were considered healthy, as assessed by the PAR-Q questionnaire[15]. The participants were non-smokers, did not consume any alcohol or drugs that could affect food intake and energy metabolism, and did not have a previous history of hypertension, heart disease or diabetes mellitus. The daily caffeine intake of the volunteers was also low (<200 mg/day), as determined from their response to a food frequency questionnaire that was adapted for caffeine intake[16].

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and approved by local Institutional Review Board for Human Subject Protection (no. 154/2011).

The sample size was calculated on the basis of the formulas proposed by Mera *et al.*[17]. The time taken to complete time-trial (in seconds) was considered the main variable, with a statistic strength of 95%. Standard Deviations values were applied in these calculations, adopting a difference of 15% for the average value of time-trial based on the study realized by Rankin *et al.*[18]. The women were not included in the sample due to hormonal alterations resulting from the menstrual cycle, because the luteal phase can promote alterations in the metabolism of caffeine[18] which could affect the results.

Preliminary test

The exercise protocol to determine the maximal consumption of oxygen (VO_{2max}) was composed of 3 minutes of warm-up with a charge proportional to the body weight (BW) of each participant in the cycle ergometer (SCIFIT ISSO 1000, Oklahoma, USA). Once finalized, 30 W were added each minute until 85% of heart rate (HR) was reached, which had been calculated through the THR equation (training heart rate = % ($HR_{max} - HR_{rest}$) + HR_{rest})[19], where HRmax is calculated with the equation validated for exercise on cycle ergometer*: HR_{max} = 202 - 0,72 x (age)[19].

The VO_{2max} was estimated on the basis of recommendations of Marsh[20] using the um submaximal cycle ergometer test, aiming to preserve the safety of the subjects. According to this method, individual equations to estimate the VO_{2max} were formulated by linear regression using the HR (bpm) and the consumption of oxygen (VO_2) (ml.kg.min^{-1}) values obtained during exercise through the analysis of respiratory gas exchange.

The metabolic gas analyzer (Medical Graphics Corporation®, VO2000) was used to evaluate VO_2, the cardiac monitor (Polar® RS800cx) was utilized to evaluate the HR, and a software (SigmaPlot®, 11.0) was used to determine the linear regressions. The charge corresponding to the range of 65 a 75% of the VO_{2max} was also determined by the software in order to use it in the main part of the experimental protocol.

After the preliminary test, the volunteers were instructed to refrain from consuming caffeine or alcohol or performing physical activity for 48 hours before their visit to the laboratory to perform the test.

Experimental protocol

For the double-blind, randomized crossover design, each subject performed three experimental tests that were separated by at least 2 days. The participants arrived at the laboratory between 6:00 and 9:00 AM after fasting for 10 to 13 hours, and the volunteers then consumed a breakfast (including grape juice, sliced white bread, mozzarella cheese and an apple). The breakfast was based on the recommendations of the Institute of Medicine[21] and provided 15% of the estimated energy requirements (EER), which were calculated for the nutritional needs of each participant. The variables used in this calculation were: age, weight, height and level of physical activity.

The volunteers were instructed to standardize their meals on the previous day and for the remaining days between the three tests. The actual consumption was monitored by a 24-hour dietary recall, which was collected before each experimental protocol.

One hour after breakfast, the subjects consumed their drinks. The EDs differed only in the presence (ED1) or absence (ED0) of carbohydrates, and the placebo solution (PL) was prepared with lemon juice (absence of sugar) dissolved in 500 ml of carbonated water. Table 1 shows the nutritional composition of each drink.

Considering that the flavor placebo was not identical to other energy drinks, the subjects were informed that all drinks had ergogenic substances mixed in their composition.

The beverages were ingested 40 minutes before starting the experimental tests; thus, the caffeine peaks in the bloodstream occur within 30 to 60 minutes of ingestion[22]. The drinks were supplied in opaque plastic bottles to prevent identification.

The amount of liquid consumed (454.7 ± 44.2 ml) was calculated for each individual to provide a dose of 2 mg caffeine/kg of BW. The dosage was selected based on previous studies[23,24] that showed improved physical performance in populations that were similar to the volunteers of the present study.

The exercise consisted of an initial 5-minute warm-up at 45 - 55% of VO_{2maxE} and the main exercise for 60 min at continuous speed and 65 - 75% of VO_{2maxE}. All subjects maintained the spinning/cycling rate between 65 to 75 rpm during the 60 minutes of continued exercise. Immediately after the 60 minutes of exercise, subjects realized 6 km time-trial with the same charge carried in the entire test. The verbal encouragement was given to all participants during time-trial, where speed was selected self- selected.

The hydratation procedure adopted during experimental sessions were exclusively realized with water, which corresponds to an individual calculation of 3ml/kg of PC, before exercise and every 15 minutes during exercise, as well as after the time-trial. At those times, the blood pressure (BP) was measured using a Tycos® sphygmomanometer. Additionally, the HR was monitored using a Polar® RS800cx (Polar Electro Ltd., Kempelen, Finland) with recordings every 15 seconds, and the value was averaged every 5 minutes.

Table 1. Nutritional composition (per 250 ml) of the beverages used in experimental trials.

Ingredients	Energy Drink (ED1)	Energy Drink sugar free (ED0)	Placebo Drink (PL)
Calories (kcal)	110	10	6.37
Carbohydrates (g)	28	3	0
Protein (g)	0	0	0
Fat (g)	0	0	0
Caffeine (mg)	80	80	0
Taurine (mg)	1000	1000	0
Other ingredients	Glucuronolactone, inositol, sodium, water, and vitamins of group B	Glucuronolactone, inositol, sodium, water, and vitamins of group B	Sodium

ED1: Energy Drink in the presence of carbohydrates. ED0: Energy Drink in the absence of carbohydrates. PL: Placebo solution, prepared with lemon juice (absence of sugar) dissolved in 500 ml of carbonated water.

Every 15 minutes during continued exercised and after the time-trial, participants were asked to provide the index of perceived exertion (IPE) which variants from 6 to 20[25].

For each experimental test, blood samples were collected before breakfast (fasting), before the drink ingestion, immediately before the beginning of the exercise, every 20 minutes during the continuous exercise and at the end of the time-trial. After each blood collection, the catheter was filled with 0.9% saline solution to prevent blood coagulation and preserve access for subsequent collections. From each blood sample, 1 ml was removed and immediately transferred to an eppendorf tubes. An automatic pipette was used to select 100 μL of this blood, which was injected into a single-use disposable cartridge and analyzed "in situ" by a portable blood analysis system for glucose measurements (i-STAT, Abbott®, Illinois, United States). A drop of blood was collected from the eppendorfs and placed into a portable lactate analyzer (Accutrend®, Roche, Mannheim, Germany) to determine the value of this metabolic variable.

All experimental tests were performed under similar ambient conditions of temperature and relative humidity (23.2 ± 0.91ºC and 69.5 ± 5.56%; p> 0.05), as measured by a Hygro Thermometer®.

Statistical analysis

All results are reported as the mean and standard deviation. The Shapiro-Wilk test was used to verify the normality. To compare the time-trial duration between the different treatments, a one-way ANOVA test for repeated measures with a post-hoc Tukey HSD test was used. To verify the interaction between the treatments over time, a two-way ANOVA test for repeated measures (split-plot ANOVA test) was used while applying a Mauchly test and a Greenhouse-Geisser correction when the assumption of sphericity was violated. Significant p-values were identified for interaction effects (time x treatment); simple analyses were performed when an influence from the energy drinks was found. Significant values for certain moments were investigated using paired comparisons with Bonferroni-adjusted confidence intervals. The statistical analysis was performed using SPSS (v17.0, USA) and assuming $p<0.05$ as the significance level.

Results

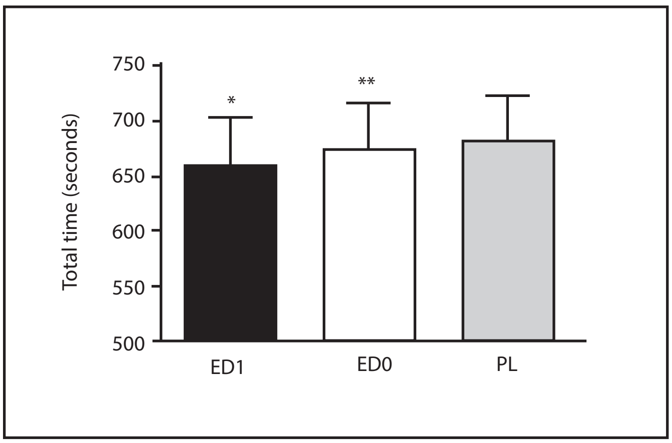
Evaluation of physical performance

The time required to complete the 6 km time-trial was significantly higher for the PL group than for the groups that the consumed energy drinks, ED1 ($p<0.001$) and ED0 ($p<0.01$) (see Figure 1). The time-trial time after consuming ED1 was significantly lower ($p<0.001$) than the time after consuming ED0. The mean performance time for the last 6 km was 2.01% and 2.78% faster after ingesting ED1 than after ingesting ED0 and PL, respectively.

Cardiovascular parameters

The cardiovascular responses are shown in Table 2. For all treatment groups, there was a significant increase ($p<0.001$) in the HR and systolic arterial pressure (SAP) during the time-trial relative to the values during the continuous exercise. The diastolic arterial pressure (DAP) remained stable throughout the exercise at 65-75% of VO_{2maxE} ($p<0.05$) and increased significantly ($p<0.001$) during the time-trial for all treatments. No differences were observed in HR, SAP and DAP between the treatments either at rest, during the 60 minutes of continuous exercise, or during the time-trial.

Figure 1. Sprint duration for the three treatments.



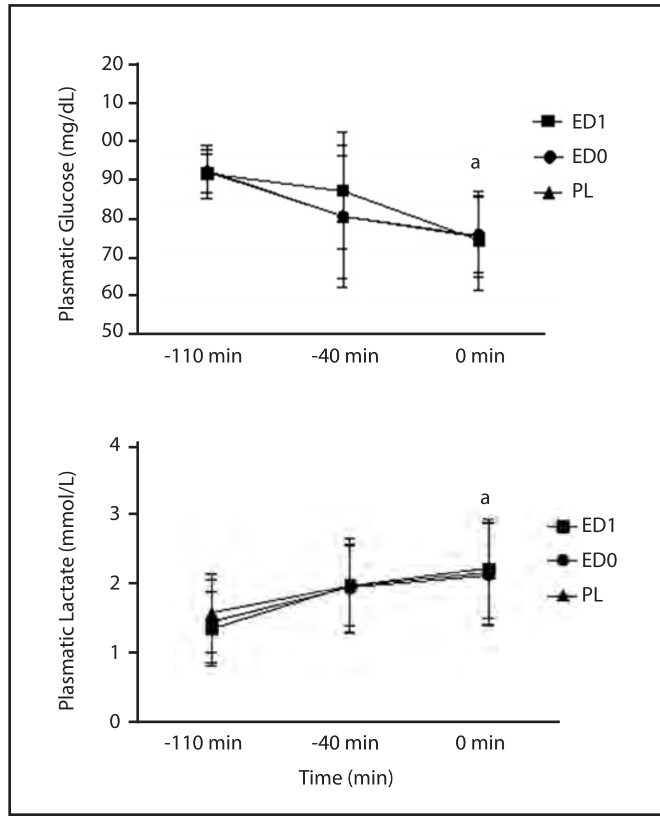
* Significant difference compared with ED0 ($p<0.001$) and PL ($p<0.001$). ** Significant difference compared with ED1 ($p<0.001$) and PL ($p<0.01$).

Table 2. Average ± Standard deviation values of the cardiovascular responses at rest, during exercise 65-75% of the VO_{2maxE} and sprint.

	Type of Treatment		
Condition	**ED1**	**ED0**	**PL**
SAP			
Resting	114.50 ± 9.65	113.00 ± 9.04	115.30 ± 6.51
Exercise	147.50 ± 14.04*	148.00 ± 16.06*	150.54 ± 14.51*
Sprint	197.33 ± 19.22§	198.50 ± 19.13§	200.00 ± 17.06§
DAP			
Resting	70.83 ± 7.93	74.83 ± 9.96	75.16 ± 6.68
Exercise	73.95 ± 5.58	71.62 ± 9.11	77.29 ± 9.38
Sprint	90.83 ± 13.11§	90.83 ± 16.21§	93.45 ± 19.23§
HR (beats/min)			
Resting	55.75 ± 7.16	55.08 ± 7.77	56.75 ± 9.38
Exercise	145.82 ± 8.93*	148.06 ± 7.77*	146.44 ± 12.17*
Sprint	173.71 ± 7.37§	171.57 ± 7.05§	173.27 ± 9.86§

* Significant differences compared to resting and sprint ($p<0.001$). § Significant differences compared to resting and exercise ($p<0.001$).
SAP = Systolic arterial pressure; DAP = Diastolic arterial pressure; HR = Heart rate.

Figure 2. Average ± standard deviation of the plasma glucose and lactate levels during fasting (-110 min), before the drink intake (-40 min) and immediately before the beginning of the exercise (0 min).



Plasma metabolites

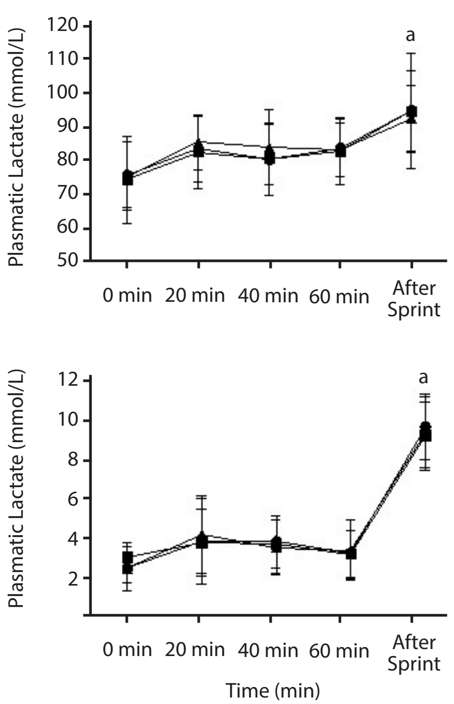
The plasma concentrations of glucose and lactate before breakfast (fasting), before the drink intake and immediately before the beginning of the exercise are shown in Figure 2. No significant differences ($p>0.05$) were observed between the treatments, indicating that the subjects started the exercise under similar metabolic conditions.

The plasma concentrations of glucose and lactate at rest (0 min), during exercise at 65-75% of VO_{2maxE} and after the time-trial are shown in Figure 3. For all treatments, the plasma concentrations of glucose and lactate were significantly higher ($p<0.001$) after the time-trial than those at rest and during the continuous exercise. No significant differences were observed in the plasma levels of glucose and lactate between the treatments at rest, during the continuous exercise and after the time-trial.

Index of perceived exertion (IPE)

The IPE remained stable throughout continued exercise (13.41 ± 0.59 for ED1, 13.41 ± 0.44 for ED0 and 13.48 ± 0.65 for PL) and increased significantly ($p<0.001$) after time-trial in all treatments (18.25 ± 1.35 for ED1, 18.5 ± 1.62 for ED0 and 19.15 ± 1.07 for PL). The IPE value at the end of the time-trial was higher in the treatment with PL compared to ED1 ($p=0.012$) and to ED0 ($p=0.022$).

Figure 3. Average ± standard deviation of the plasma glucose and lactate concentrations during the experimental protocol. (a) Significant difference (p<0.001) compared with the other conditions (0-60 min) for all treatments.



Discussion

The aim of this study was to verify the effects of pre-exercise ingestion of an ED with and without carbohydrates on cardiovascular, metabolic and performance parameters during an aerobic effort on a cycle ergometer.

The main finding of this study was that the use of EDs with and without carbohydrates decreased the time to complete a 6 km time-trial after 60 minutes of aerobic training relative to the PL time-trial time (Figure 1). This improvement in performance after the ED ingestion is consistent with other previous studies[8].

The mechanisms by which EDs improve performance are not fully understood. Some authors believe that caffeine is the main active ingredient of EDs and is responsible for the ergogenic effects on physical performance[12]. Several mechanisms may be involved in these effects. These mechanisms include the following: action on the sarcoplasmic reticulum by increasing the availability of calcium to potentiate muscle contraction[26] an antagonist effect on adenosine receptors, leading to increased activation of the central nervous system and plasma epinephrine[26]; and changes in potassium concentrations that assist in the maintenance of the membrane excitability of contractile muscle during exercise[27].

Although caffeine is considered the main active ingredient in energy drinks, taurine may also contribute to the ergogenic effect on exercise[28]. Some studies reported that taurine supplementation can increase the ability to prolong exercise[5,6], possibly by stabilizing the phospholipids of the membrane and increasing the availability of calcium in the muscle[29].

The combination of the ingestion of caffeine and taurine in the same formulation showed significant improvements in the ventricular function, increasing the stroke volume[6] compared to drinks only containing caffeine. This way, these components can act synergistically and improve the performance in training as well as in competitions.

ED1 seems appears to increase performance more effectively because it reduced the 6 km time-trial time by 2.01% relative to the time for ED0. The results corroborate those of other studies indicating that the combination of caffeine and carbohydrates can improve the ergogenic effect during exercise[30]. Caffeine has also been linked with increased intestinal glucose absorption and utilization of exogenous carbohydrates[31] thus minimizing the depletion of muscle glycogen and delaying the onset of fatigue during aerobic exercise.

The HR values gradually increased during the 60 minutes of continued exercise and during time-trial, although no significant difference was observed between the treatments (Table 2). Caffeine inducts the liberation of adrenaline during exercise, higher HR values were expected in treatment with energy drinks. However, some studies reported a decrease in HR during submaximal exercise after the ingestion of an ED containing taurine[32] suggesting that taurine could alter cardiovascular physiology.

Corroborating this hypothesis, Baum[6] observed that taurine in combination with caffeine significantly increases the volume of ejection in athletes after endurance exercise. This is due to the greater end diastolic volume and to the decrease of the end systolic volume of the left ventricle, as the fractional shortening increases significantly, and contributes to lower values of HR. If confirmed, these responses in the cardiovascular system can have an important effect after a training session in athletes who train for extended durations, since it acts like a factor of cardioprotection.

As found in a previous study[33], our mean values of SAP were lower, but not significantly, after the consumption of ED1 and ED0 compared with those in the PL group. Besides, no significant differences between treatments were observed in the DAP values.

Ragsdale[34] analyzed the effects of two energy drinks on cardiovascular function during two hours of rest. Those drinks were similar to the drinks used in this study (ED1 and ED0), and those researchers reported that ingesting EDs did not cause a significant difference in BP relative to the BP after ingesting PL.

The lack of studies that has analyzed BP during exercise after the consumption of energy drink brings difficulties in the comparison and the interpretation of the results. Consequently, additional studies are necessary to verify if the consumption of ED effects the pressure values both during rest and exercise, principally when consumed chronically and not as acute in this study.

The IPE significantly increased after the time-trial compared with the values obtained during the continuous exercise. The IPE for the time-trial was significantly higher after PL consumption than after ED1 and ED0 consumption (Table 2). Similar results were observed in the study realized by Hahn *et al.*,[35] after the ingestion of drinks comparable to placebo.

It is believed that caffeine reduces the feeling of pain through its antagonist effect on adenosine[36]. Due to the similarity between the molecular structures of adenosine and caffeine, caffeine occupies some adenosine receptors and minimizes the effect of this neurotransmitter on the body[36]. Thus, dopamine becomes less inhibited, increasing the dopamine concentrations during exercise. Another ergogenic mechanism of caffeine is to decrease the expression of tryptophan hydroxylase (TPH); the degradation of tryptophan modulates the amount of serotonin that crosses the blood-brain barrier[37]. A lower serotonin/dopamine ratio reduces central fatigue and improves performance[38].

Our results show no differences among the treatments in the plasma glucose levels during the continuous exercise and the time-trial (Figure 3). Thus, the energy drinks were equally effective at maintaining plasma glucose levels during the continuous exercise and the time-trial. The maintenance of blood glucose is crucial because hypoglycemia causes fatigue, leading to exhaustion and forcing an individual to stop the exercise[39]. Our results indicate that the presence or absence of carbohydrates in the ED did not affect the plasma glucose kinetics, which were most likely influenced by the breakfast that was consumed before the exercise.

No differences were observed in the plasma lactate concentrations between the treatments (Figure 3). Lactate has an important role in the onset of fatigue during high-intensity exercise[40], as shown for the 6 km time-trial in the present study. The results indicated better performance after ED consumption than after PL consumption but did not show significant differences in lactate concentration. Therefore, it is possible that this improved performance could be linked to specific cellular adaptations.

Consuming an ED can also cause ergolytic effects. The most common problem in these beverages appears to be associated with the high levels of caffeine, rather than the other substances in these drinks. Doses above 6 mg/kg of BW can be toxic to the body, decreasing the stability of the upper limbs and causing insomnia, irritability, anxiety, nausea and gastrointestinal discomfort[41]. Campbell[22] indicated that ingesting a dose of caffeine of 2 mg/kg of BW between 10 and 40 minutes prior to exercise increased performance without ergolytic effects or any risk for the athlete, as was further confirmed in this study.

The limitations of the present study include the absence of either a muscle biopsy to analyze the levels of muscle glycogen or an electromyographic examination that could provide relevant information about the different muscle responses to the work load.

Conclusion

Considering the assessed population group (regular cyclists with a low daily intake of caffeine) and the conditions of the exercises performed in this study, it can be concluded that consuming ED1 (2 mg of caffeine/kg of BW) 40 minutes before 60 minutes of moderate aerobic exercise improved the performance in a 6 km time-trial. Further research that uses other doses and other population groups (such as women and consumers of caffeine) and that measures the effects in other sports should be undertaken to expand upon the scientific evidence presented in this study.

Conflict of interest

The authors do not declare a conflict of interest.

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Estudio de la variabilidad de la frecuencia cardiaca tras la exposición a la hipoxia normobárica

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Resumen

La variabilidad de la frecuencia cardiaca (VFC) es una herramienta capaz de analizar y valorar la actividad vegetativa sobre el corazón ante diversas actividades y situaciones. Consiste en medir el tiempo que trascurre entre cada dos latidos cardiacos durante un periodo de tiempo y expresarlo en función de ecuaciones matemáticas y estadísticas. Otros autores han analizado la influencia de diferentes estresores sobre la VFC. En este trabajo buscamos la acción de la hipoxia normobárica (HN) sobre la misma. La HN consiste en respirar aire empobrecido de oxígeno simulando el entrenamiento en altitud. El objetivo del estudio es determinar la influencia de la HN sobre los dominios de tiempo y frecuencia de la VFC. Sometimos a 13 sujetos sanos (deportistas recreacionales) a dos sesiones de HN. Usamos el simulador iAltitude Trainer v2.7®. La primera mediante un test de tolerancia a la hipoxia (TTH) (10 minutos, 11% O_2, equivalente a 5.050 m) y, la segunda, con una exposición intermitente (HNI) (14% O_2, 3.250 m) en la que se alternaron periodos de 4 minutos de hipoxia con 4 de normoxia durante 64 minutos. Para el análisis de VFC se utilizó un pulsómetro Polar H10®, la aplicación HRV-elite® y el software Kubios-Standard®. Se tomaron los datos de los 5 minutos previos y posteriores a cada sesión, comparándose estos valores mediante el test de T-student para datos pareados. Ninguna de las variables de los dominios de tiempo (RRmedio, SDNN, rMSSD, pNN50) ni de frecuencia (VLF, LF, HF, LF/HF) de la VFC mostró cambios significativos ante ninguna de las dos situaciones. La HN no provocó modificaciones en los niveles de estrés de estos sujetos, siendo bien tolerada, clínica y electrocardiográficamente. Un test de tolerancia y una sesión de exposición a hipoxia normobárica intermitente no son estímulos suficientes para provocar cambios agudos en la VFC.

Palabras clave:
Variabilidad de la frecuencia cardiaca. Hipoxia normobárica intermitente. Tolerancia a la hipoxia.

Study of heart rate variability after exposure to normobaric hypoxia

Summary

Heart rate variability (HRV) is a tool capable of analysing and assessing the vegetative activity of the heart in various activities and situations. It consists of measuring the time that elapses between every two heartbeats over a period of time and expressing it in terms of mathematical and statistical equations. Other authors have analysed the influence of different stressors on HRV. In this work we are looking for the action of normobaric hypoxia (NH) on HRV. NH consists of breathing oxygen-depleted air simulating altitude training. The aim of the study is to determine the influence of HN on the time and frequency domains of HRV. We subjected 13 healthy subjects (recreational athletes) to two HN sessions. We used the iAltitude Trainer v2.7® simulator. The first was a hypoxia tolerance test (HTT) (10 minutes, 11% O_2, equivalent to 5050m) and the second was an intermittent exposure (HNI) (14% O_2, 3250m) in which periods of 4 minutes of hypoxia alternated with 4 minutes of normoxia for 64 minutes. For HRV analysis, a Polar H10® heart rate monitor, the HRV-elite® application and the Kubios-Standard® software were used. Data were taken 5 minutes before and after each session, and these values were compared using the Student´s t- test for paired data. None of the variables in the time (RRmean, SDNN, rMSSD, pNN50) or frequency (VLF, LF, HF, LF/HF) domains of HRV showed significant changes in either situation. HN did not cause changes in the stress levels of these subjects and was well tolerated, clinically and electrocardiographically. A tolerance test and a session of exposure to intermittent normobaric hypoxia are not sufficient stimuli to cause acute changes in HRV.

Key words:
Heart rate variability. Intermittent normobaric hypoxia. Hypoxia tolerance.

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Introducción

La variabilidad de la frecuencia cardiaca (VFC) (HRV, *Heart Rate Variability*), se ha definido como la variación de los intervalos de tiempo entre latido y latido cardiaco, conocidos como intervalos R-R[1]. La VFC se puede evaluar mediante métodos lineales, analizados a través de los dominios de tiempo y de frecuencia, y métodos no lineales[2,3]. En el dominio de tiempo se destacan los índices estadísticos: RRmedio (media de los intervalos RR); SDNN (desviación estándar de los intervalos RR); rMSSD (raíz cuadrada del valor medio de la suma de las diferencias al cuadrado de todos los intervalos RR sucesivos), pNN50 (porcentaje total de las diferencias entre los intervalos R-R adyacentes, mayores de 50 ms) y, en el dominio de frecuencia: VLF (muy baja frecuencia); HF (alta frecuencia); LF (baja frecuencia); LF/HF (cociente de baja frecuencia entre alta frecuencia)[4-6].

Tradicionalmente, la VFC ha sido utilizada en el ámbito del deporte, con la finalidad, entre otras, de mejorar la adaptación o el rendimiento de los atletas[7]. Además del deporte, tiene otras utilidades en el campo de la medicina, pues ha sido utilizada en distintas patologías como la cardiaca[8], la depresión ansiosa[9] y, actualmente, en la enfermedad COVID-19 como posible marcador de inflamación aguda[10] o como método para detectar los efectos que desencadenó el confinamiento sobre esta variable[11].

Múltiples y variados factores pueden influir sobre la frecuencia cardiaca y, por ende, en el análisis de la variabilidad de la frecuencia cardiaca. Estos factores pueden dividirse en intrínsecos o extrínsecos al organismo. En relación con los primeros se establecen: la edad (la FC disminuye con la edad)[12], el sexo (en general, la FC es mayor en las mujeres)[13], la posición del cuerpo (la FC es menor en posición supina)[14] o el estrés laboral[15]. En relación con los factores extrínsecos se destacan: la humedad[16], la hora del día a la que se realice la medición (la FC es más alta en las primeras horas de la mañana)[14], la temperatura ambiental[17] o la ingesta de sustancias como la cafeína[18,19]. Un estímulo sobre el que se ha investigado poco es sobre la influencia de la hipoxia normobárica (respirar un aire con una proporción de oxígeno disminuido a una presión atmosférica constante) en la VFC.

Con el aumento de la altitud, la presión barométrica disminuye exponencialmente, lo que da lugar a una reducción progresiva de la presión parcial del oxígeno (pO_2) del ambiente, denominándose a este tipo hipoxia hipobárica[20]. Sin embargo, con el avance de la tecnología se han desarrollado simuladores de altitud que permiten reducir la proporción de oxígeno en el aire sin cambiar la presión atmosférica, dando lugar a la llamada hipoxia normobárica (HN)[21].

Entrenar en zonas donde el porcentaje de oxígeno esté disminuido ha sido un recurso de especial relevancia en el ámbito del deporte. Puede suponer un estímulo para nuestro organismo, mejorando los sistemas de adaptación a la hipoxia y, en consecuencia, actuando como un mecanismo de supercompensación[22].

Según el tiempo de exposición a la hipoxia podemos diferenciar la exposición crónica, aquella que se realiza durante largos periodos de tiempo o la aguda y, dentro de esta última, la hipoxia normobárica intermitente (HNI) que consiste en aplicar periodos de hipoxia seguidos de periodos de normoxia (proporción de oxígeno normal).

En este estudio nos planteamos conocer las variaciones que se producen en los dominios de la variabilidad de la frecuencia cardiaca después de la exposición a hipoxia normobárica.

Material y método

Esta investigación es un estudio prospectivo de intervención. Los participantes fueron seleccionados bajo un criterio no probabilístico por conveniencia. Cada uno de ellos firmó el consentimiento informado de forma previa a la toma de datos. En él, se exponían los objetivos del estudio, las condiciones en las que se realizarían las mediciones, la confidencialidad y seguridad de la información obtenida. Previamente, se contó con la aprobación del Comité de Ética de Investigación de la Universidad de Murcia. En todos los casos se cumplieron los requisitos exigibles por el Código de Ética de la Asociación Médica Mundial (Declaración de Helsinki) para experimentos con seres humanos.

Participantes

Trece sujetos conforman nuestro estudio (53,3% mujeres). La edad de los participantes estaba comprendida entre los 20 y los 29 años. No padecían ninguna enfermedad cardiaca o respiratoria previa.

Los criterios de inclusión fueron: 1) Expresar la voluntad de querer participar en el estudio habiendo comprendido los alcances del mismo, los riesgo y beneficios de la intervención, confirmando la voluntad de participar a través de la firma del consentimiento informado 2) Presentar una edad entre los 20 y 30 años. Se excluyeron a aquellos que tuvieran patologías que contraindicaran la realización de la prueba; la presencia de una temperatura corporal superior a 37 ºC y/o un test de anticuerpos positivo. 3) Haber pasado la enfermedad COVID-19 y no tener en el momento actual una prueba PCR negativa o no concluir alguna de las dos pruebas de hipoxia por razones ajenas a la misma.

Instrumentos

Para el estudio antropométrico se registró la talla (SECA 213®) y el peso (In Body 120®). El perímetro de cintura y cadera se obtuvo con una cinta metálica flexible Holtain® y el nivel de hemoglobina en sangre a través del dispositivo Lux®. La tensión arterial y la auscultación se realizó con un fonendoscopio y esfigmomanómetro tradicionales (Littmann Clasic®).

El test de tolerancia y la sesión de entrenamiento se realizó con un simulador de hipoxia iAltitude Trainer v2.7® conectado a una mascarilla específica. Durante ambas pruebas, a todos los participantes se les monitorizó la oxigenación muscular mediante el dispositivo Humon Hex® en el recto anterior del muslo derecho, la saturación de oxígeno con un pulsioxímetro (Nonin®) en el lóbulo de la oreja izquierda y la variabilidad de la frecuencia cardiaca con un pulsómetro Polar H10®.

Además, por las circunstancias especiales a causa de la COVID-19, se tomó la temperatura mediante el termómetro digital Yuwell® y el test de anticuerpos "2019-nCoV IgG/IgM®" se usó para descartar la presencia del virus SARS-CoV-2.

Procedimiento previo

Cada participante, después de firmar voluntariamente el consentimiento informado, se sometía a la medición de distintos parámetros antropométricos y, en segundo lugar, a una exploración médica para descartar cualquier alteración que contraindicara la realización de las pruebas. Los procedimientos previos y ambas pruebas de hipoxia se llevaron a cabo en el Laboratorio de Investigación Biosanitaria (LAIB) de la Universidad de Murcia. La temperatura de la sala fue siempre constante, de 25 ºC.

Se comenzaba tomando la temperatura corporal, seguidamente se realizaba el test de anticuerpos, el nivel de hemoglobina y el estudio antropométrico. A continuación, el participante cumplimentaba un cuestionario sobre enfermedades y/o antecedentes familiares. Este era revisado por un facultativo a través de una entrevista directa.

En segundo lugar, se tomaba la tensión arterial en decúbito supino, se auscultaba y se realizaba un electrocardiograma en reposo (Figura 1).

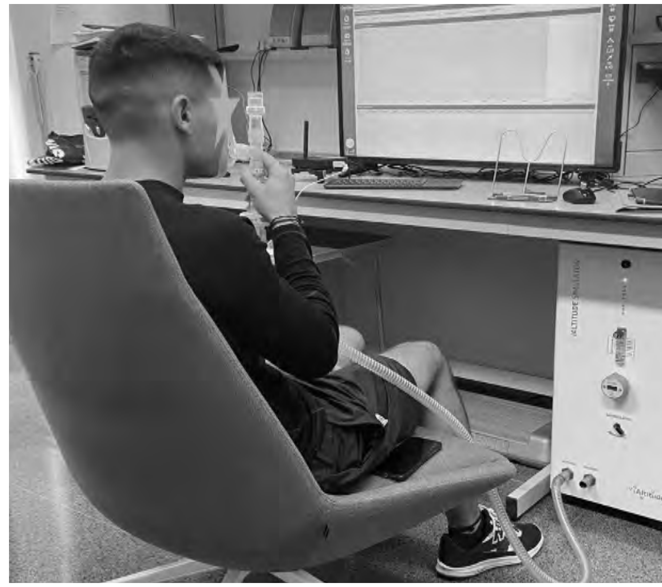
Realización de las pruebas de hipoxia

Comprobada la inexistencia de patologías que contraindicaran la prueba, el participante se sometía a respirar un aire empobrecido de oxígeno monitorizando de manera continua su variabilidad de la frecuencia cardiaca. Se comenzaba con un test de tolerancia para comprobar la adaptación de la persona a la hipoxia para, después, realizar una sesión de exposición a la misma. En ambas pruebas, si el simulador de hipoxia detectaba valores en la saturación arterial de oxígeno inferiores a un 83% indicaba, a través de señales visuales y auditivas, la retirada de la mascarilla, respirando así en condiciones normóxicas y recuperando la concentración de oxígeno normal.

Para ambas pruebas, el participante se sitúa en sedestación en un sillón, permitiéndole este el apoyo de cabeza y una flexión de cadera y rodilla de 90°. Se coloca una cuña de gomaespuma para el correcto apoyo lumbar, siendo una postura cómoda y relajada (Figura 2). El paciente lleva colocada una banda de pecho Polar H10®, vinculada a una tablet por conexión Bluetooth y, a través de la aplicación HRV elite®, se registraban los datos de la misma.

Figura 1. Exploración previa de un participante.

Figura 2. Un participante realizando una prueba de hipoxia.



Test de tolerancia a la hipoxia

En la posición anteriormente descrita, el paciente permanecía sentado y relajado 5 minutos antes de empezar el test de tolerancia para el registro de su VFC, en reposo y en normoxia.

Seguidamente, comenzaba el test de tolerancia. Consistía en respirar de manera ininterrumpida en condiciones hipóxicas (11% de oxígeno, equivalente a 5.050 m de altitud) durante un tiempo máximo de 10 minutos. Después de concluir el test, el sujeto seguía permaneciendo sentado para registrar los 5 minutos posteriores a la finalización del test de tolerancia.

Por tanto, se realizan dos medidas de la VFC, ambas en condiciones de normoxia. La primera muestra los cinco minutos previos a someter al sujeto al test de tolerancia a la hipoxia y, la segunda, registra los cinco minutos posteriores al finalizar dicho test.

Sesión de exposición

Una vez finalizado el test de tolerancia, el voluntario sigue sentado en la posición anteriormente descrita para comenzar la segunda prueba de hipoxia. Se registran los 5 minutos previos de la variabilidad de la frecuencia cardiaca. Trascurridos estos minutos, comienza la sesión de exposición a hipoxia intermitente. La duración de la sesión fue de 64 minutos, con un porcentaje de oxígeno del 14% (equivalente a 3.250 m de altitud). El modo de aplicación es de forma interrumpida, es decir, se realizaban periodos de hipoxia (4 minutos) seguidos de periodos de normoxia (4 minutos) hasta completar la sesión, de 64 minutos de duración. Al concluir dicha sesión se registraban los 5 minutos posteriores a la misma para analizar la VFC.

Por tanto, el registro de VFC se realiza en dos ocasiones, ambas en condiciones de normoxia. El primer registro corresponde a los 5 minutos previos al inicio de la sesión de exposición a la hipoxia y, el segundo, inmediatamente al acabar dicha sesión. Ambos registros tenían una duración de 5 minutos de duración.

Análisis estadístico

Con los datos extraídos de las distintas aplicaciones y software informáticos, se elaboró una hoja de cálculo a través del programa Excel® y, a su vez, fueron analizados con el software estadístico SPSS 24.0®.

Las variables cuantitativas se describieron mediante la media y la desviación típica. Se usó el coeficiente de variación para comprobar la dispersión de los datos. Mediante la prueba de Levene se verificó la igualdad de varianzas. Las comparaciones intraindividuo se hallaron mediante el test de la T pareada y las intergrupo con el test de T Student. Se consideraba que había diferencias o relaciones significativas cuando p<0,05.

Resultados

6 varones y 7 mujeres conforman la población de estudio. En la Tabla 1 se describen las características de la población en general y separadas por sexo. Se evidencian diferencias significativas (p<0,05) entre sexos en las variables de talla, peso y contorno de cintura, obteniéndose en los varones valores superiores.

Al comparar los valores de la VFC previos y posteriores a la realización del test de tolerancia no se han encontrado diferencias significativas en ninguno de los dominios: tiempo (Tabla 2) y frecuencia (Tabla 3).

En la sesión de hipoxia intermitente no se obtuvo diferencias significativas al comparar los valores del dominio de tiempo previos a la intervención de HNI con los obtenidos al final de la misma (Tabla 4). En el dominio de frecuencias (Tabla 5) tampoco se encontraron cambios significativos (p>0,05).

Tabla 2. Diferencias en el componente de dominio de tiempo de la variabilidad de la frecuencia cardiaca antes y después al test de tolerancia (n=13).

Variables de dominio de tiempo	Media	SD	Media de las diferencias	SD de la media de las diferencias	t	Sig. (bilateral)
Inicio RRmedio	869,35	143,16	4,20692	60,03661	0,253	0,805
Final RRmedio	865,14	109,06				
Inicio SDNN	73,21	21,19	-6,59908	24,80853	-0,959	0,356
Final SDNN	79,81	35,09				
Inicio RMSSD	50,40	23,73	1,11462	11,52709	0,349	0,733
Final RMSSD	49,29	24,03				
Inicio pNN50	26,09	19,76	1,56176	9,44434	0,596	0,562
Final pNN50	24,53	19,70				

RRmedio: media de los intervalos RR; SDNN: desviación estándar de los intervalos RR; rMSSD: raíz cuadrada de las diferencias medias al cuadrado entre intervalos RR sucesivos; pNN50: porcentaje de RR sucesivos > 50 ms; SD: desviación estándar.

Tabla 1. Características de la población global y separada por sexo.

Variable	Población	Media	SD	CV (%)	t	Sig. (bilateral)
Edad (años)	Global (n=13)	23	2,58	11,22	-1,41	0,194
	Varones (n=6)	22,0	1,26	5,73		
	Mujeres (n=7)	23,86	3,19	13,37		
Talla (cm)	Global (n=13)	173,75	9,24	5,32	6,129	0,000
	Varones (n=6)	182,18	4,97	2,72		
	Mujeres (n=7)	166,51	4,25	2,55		
Peso (Kg)	Global (n=13)	72,72	12,80	17,60	4,270	0,001
	Varones (n=6)	83,21	5,27	6,33		
	Mujeres (n=7)	63,72	10,01	15,71		
C. cintura (cm)	Global (n=13)	77,02	8,33	10,82	3,411	0,006
	Varones (n=6)	83,21	4,99	6,00		
	Mujeres (n=7)	71,71	6,82	9,51		
C. cadera (cm)	Global (n=13)	98,13	6,40	6,52	1,667	0,124
	Varones (n=6)	101,11	4,69	4,63		
	Mujeres (n=7)	95,57	6,87	7,19		
IMC (kg/m^2)	Global (n=13)	23,94	2,74	11,45	1,45	0,176
	Varones (n=6)	25,08	1,44	5,74		
	Mujeres (n=7)	22,97	3,30	14,37		

C. cintura: contorno de cintura; C. cadera: contorno de cadera; CV: coeficiente de variación; SD: desviación estándar; Sig. (bilateral): significación bilateral.

Tabla 3. Diferencias del dominio de frecuencia de la variabilidad de la frecuencia cardiaca antes y después al test de tolerancia (n=13).

Variables de dominio de frecuencia	Media	SD	Media de las diferencias	SD de la media de las diferencias	t	Sig. (bilateral)
Inicio VLF	2299,84	1664,02	-1866,11	5979,313	-1,125	0,282
Final VLF	4165,95	5925,52				
Inicio LF	2341,87	1972,07	-25,82077	1580,123	-0,059	0,954
Final LF	2367,69	2039,74				
Inicio HF	980,11	668,23	29,19838	249,249	0,422	0,68
Final HF	950,91	716,12				
Inicio LF/HF	3,05	2,45	-0,3728	1,487	-0,904	0,384
Final LF/HF	3,42	2,39				

VLF: muy baja frecuencia; HF: alta frecuencia; LF/HF: cociente de baja frecuencia entre alta; LF: baja frecuencia; SD: desviación estándar

Tabla 4. Diferencias en el de dominio de tiempo de la variabilidad de la frecuencia cardiaca antes y después a la sesión de hipoxia (n=13).

Variables	Media	SD	Media de las diferencias	SD de la media de las diferencias	t	Sig. (bilateral)
Inicio RRmedio	854,55	106,70	36,47	58,58	2,157	0,054
Final RRmedio	891,02	120,05				
Inicio SDNN	81,74	35,92	-1,73	18,81	-0,319	0,756
Final SDNN	80,01	24,45				
Inicio rMSSD	47,09	23,70	0,134	8,83	0,055	0,957
Final rMSSD	47,23	17,47				
Inicio pNN50	21,48	17,06	2,25	5,44	1,436	0,179
Final pNN50	23,73	15,72				

RRmedio: media de los intervalos RR; SDNN: desviación estándar de los intervalos RR; rMSSD: raíz cuadrada de las diferencias medias al cuadrado entre intervalos RR sucesivos; pNN50: porcentaje de RR sucesivos > 50 ms; SD: desviación estándar.

Tabla 5. Diferencias en el dominio de frecuencia de la variabilidad de la frecuencia cardiaca antes y después a la sesión de exposición a HNI (n=13).

Variable	Media	SD	Media de las diferencias	SD de la media de las diferencias	t	Sig. (bilateral)
Inicio VLF	3085,77	2073,66	349,61	3059,15	0,396	0,700
Final_VLF	2736,16	3362,20				
Inicio LF	2289,60	1708,52	-213,92	1068,16	-0,694	0,502
Final LF	2503,52	2068,12				
Inicio HF	731,98	461,18	-146,22	482,91	-1,049	0,317
Final HF	878,19	696,04				
Inicio LF/HF	3,43	2,62	-0,24	1,67	-0,505	0,623
Final LF/HF	3,67	2,31				

VLF: muy baja frecuencia; HF: alta frecuencia; LF/HF: cociente de baja frecuencia entre alta; LF: baja frecuencia; SD: desviación estándar.

Discusión

En este estudio se ha analizado la respuesta de la variabilidad de la frecuencia cardiaca tras realizar un test de tolerancia y una sesión de exposición a la hipoxia normobárica. Se ha evidenciado que la hipoxia, a la altitud y tiempo de exposición descrita, no ocasiona cambios significativos en los dominios de tiempo y frecuencia de la VFC.

La población del presente estudio la componen 13 sujetos, tamaño que está en concordancia con la de otros autores[23-25]. De la misma forma ocurre con la edad media de los sujetos (23±2,58 años) siendo muy similar a la expuesta en otros estudios[24,26]. Este hecho puede ser debido a que, actualmente, hay pocos estudios que analicen este fenómeno y, como paso previo, se ha realizado en personas jóvenes y sanas para, en un futuro, poder realizarlo en otras poblaciones sujetas a mayores riesgos, trabajando así en condiciones de seguridad.

La altitud simulada y el tiempo de exposición que hemos utilizado ha sido distinto dependiendo de si se realiza un test de tolerancia o una sesión de exposición a la hipoxia. En nuestro caso, durante el test de tolerancia se simuló una altitud de 5.050 metros (11% de O_2) durante un máximo de 10 minutos mientras que, Buccheit *et al*[23] sometieron a sus participantes a una altitud ligeramente inferior, 4.800 metros (11,5% O_2) durante dicho test. Sin embargo, el protocolo utilizado por estos autores difiere del nuestro, pues alternaban periodos de hipoxia en descanso con hipoxia durante el ejercicio físico, dificultando la comparación con nuestro estudio.

Dominio de tiempo y frecuencia de la variabilidad de la frecuencia cardiaca

Hemos comprobado, a través de otros trabajos, cómo puede variar la respuesta de la VFC según sea: una exposición breve[23,25-27] o más prolongada a la hipoxia[28,29]; la manera de administrar la hipoxia, es decir, de forma gradual[29-31] o súbitamente[23,25]; la intensidad de la altitud: alta[23,29,31], moderada[24] o baja[30]; así como los diferentes tipos de hipoxia utilizados: normobárica[23,26] o hipobárica[31,25], ya que la respuesta del organismo ante cada uno de ellos es distinta y dificulta la comparación. Por ello, es importante determinar qué duración, intensidad y tipo de hipoxia influyen de forma favorable sobre la VFC.

Algunos autores coinciden en que una exposición a hipoxia normobárica genera una disminución en la rMSSD y un aumento del cociente LF/HF, es decir, una mayor activación del sistema nervioso simpático[25,32] mientras que otros autores defienden un aumento del sistema nervioso parasimpático[24,31]. Sin embargo, en el test de tolerancia que realizamos en el presente estudio, no se encontró diferencias significativas en los dominios de tiempo y frecuencia de VFC. Este hallazgo puede corroborar lo que otros autores sugerían y es que, para inducir cambios significativos en algunos dominios, como en el cociente LF/HF, es necesario duraciones más prolongadas, al menos de 30 minutos[33]. No obstante, Botek *et al*[26] estipularon 10 minutos de exposición, pero con la diferencia que sometieron a sus participantes a una altitud mayor de la que describía la bibliografía, a 6.200 m (9,6% O_2). Estos autores[26] obtuvieron una disminución en la LF y un aumento en la HF. Por lo tanto, parece que mientras que en 2001 Bernardi *et al*[33] indicaban que era necesario más de 30 minutos de exposición a hipoxia para generar cambios en los dominios de VFC, Botek *et al*[26], años más tarde, han conseguido influir sobre los dominios de VFC manteniendo exposiciones agudas (10 minutos), pero aumentando el estímulo de la altitud. Por esta razón, nuestro estudio evidencia que 5.050 metros durante diez minutos no es altitud suficiente para incidir sobre la VFC, siendo necesario disminuir más la proporción de oxígeno respirado.

Durante la sesión de entrenamiento se realizó un tiempo de exposición más prolongado (64 minutos) que en el test de tolerancia, pero disminuyendo la altitud y de manera interrumpida (hipoxia normbárica intermitente). Los 3.250 metros en los que se realizó la segunda prueba de hipoxia en este estudio pueden ser insuficientes para generar cambios en la variabilidad de la frecuencia cardiaca pese a realizar una exposición con una duración más prolongada. De esta manera, coincidirían estos hallazgos con Yamatho *et al*[34], quienes tampoco encontraron cambios significativos en su estudio. Estos autores[34] preveían que una altitud inferior a los 3.500 metros no era suficiente, apoyando esta hipótesis los datos de nuestro estudio ahora.

En algunos trabajos se emplea la exposición a la hipoxia de manera simultánea a la práctica de ejercicio físico[34,35]. En este caso sí parece haber más unanimidad en que los dominios de tiempo y frecuencia absolutos varían más que al administrar la hipoxia en reposo. Sin embargo, esto puede ser debido al estímulo propio del ejercicio físico y no debido a la hipoxia. Por eso, consideramos que debe esclarecerse qué tiempos y qué altitudes son necesarias para generar un efecto beneficiario sobre la variabilidad de la frecuencia cardiaca antes de incluir otro estímulo de manera sincrónica como puede ser el ejercicio físico.

Conclusión

La variabilidad de la frecuencia cardiaca no evidencia cambios significativos en el dominio de tiempo ni en el de frecuencia después de la exposición a hipoxia normobárica. Por ello, consideramos que estos estímulos no son lo suficientemente estresantes para ocasionar cambios de forma aguda.

Conflicto de interés

Los autores no declaran conflicto de interés alguno.

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