ISSN: 0212-8799

220
Volume 41 (2)
March - April 2024

Archivos de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

ORIGINALS

UCAM Universidad Católica San Antonio de Murcia

Campus de los Jerónimos,
Nº 135 Guadalupe 30107

(Murcia) - España

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

UCAM
UNIVERSIDAD
CATÓLICA DE MURCIA

Sociedad Española de Medicina del Deporte

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

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

Publicidad
ESMON PUBLICIDAD
Tel. 93 2159034

Publicación bimestral
Un volumen por año

Depósito Legal
Zaragoza. Z 988-2020

ISSN
0212-8799

Soporte válido
Ref. SVR 389

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

Archivos de medicina del deporte

Revista de la Sociedad Española de Medicina del Deporte

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

Archivos
de medicina del deporte
Volume 41(2) - Num 220. March - April 2024 / *Marzo - Abril 2024*

Summary / Sumario

The roots of return to sport

Las raíces de la vuelta al deporte

Giulio Sergio Roi

Postgraduated School of Sports Medicine and Physical Exercise. University of Bologna. Italy.

doi: 10.18176/archmeddeporte.00158

Training and sports rehabilitation are based on the same rules, originating from the Theory and Methodology of Training[1]. In both cases it is the results that matter. Unlike training, sports rehabilitation does not develop through multi-year programming, but it is unluckily inserted into the athlete's life for a limited span of time. Hence, in sports rehabilitation the training theory must adapt to the limitations imposed by the pathology and its evolution, so for sports physicians and athletic trainers it is necessary the acquisition of a sound knowledge regarding the different pathologies and their treatments together with a sound knowledge of the Theory and Methodology of Training.

Some years ago, the concept of *"functional outcome"* was introduced to point out *"the functional result of a treatment process"*[2]. This concept implies that the physical condition of an injured athlete must be periodically measured conducting specific tests and analyzed to implement the corrections imposed by the evolution of the pathology, from the moment of diagnosis to that of discharge[3]. In this way, thinking in terms of *measurable expected results*[4] pushes to raise the threshold of attention of healthcare professionals, improving the quality of therapeutic decisions. This approach increases the awareness of the physician in charge of the patients, stimulating to face the effectiveness of her/his intervention and that of the colleagues and collaborators, which must work together in a team.

The rehabilitation process is a complex phenomenon since it is influenced by multiple factors. However, it is also dynamic[5] since it continually evolves over time because of the interaction of different factors with each other. There is strong evidence for considerable heterogeneity in the responsiveness to regular physical activity and rehabilitation. Age, sex, and ethnic origin are not major determinants of human responses, whereas the pretraining level of a phenotype has a considerable impact in some cases[6]. Familial factors also contribute significantly to variability in training response[5] and in cardiorespiratory fitness[7] affecting the sports rehabilitation process.

Therefore, modern sports rehabilitation must overcome the reductionist approach, based on static and simplistic analyzes[8] without considering not only the complexity, but also the dynamicity of biological phenomena regulated by several delicate feedback mechanisms.

In 1995 Wilson and Cleary[9] proposed a model with five levels of outcome, starting from the cellular one, and moving to that of the individual (the person), up to the interactions of the individual as a member of the society. The conceptual complexity of each level increases proceeding from the cellular to the social level, which therefore becomes of increasing difficulty to define and measure.

Overcoming the reductionist approach can only be achieved by intimately understanding the different components of the *functional outcome*. These components are embodied by the various professionals met by an injured athlete during her/his personal therapeutic journey. These operators too often struggle communicating with each other, since they come from different educational backgrounds, leading to focus on their discipline (or knowledge) and on their specific skills. In this way they *reduce* the human body to a set of individual parts (or functions) and sub-parts (or sub-functions), which cannot necessarily represent the complexity and the unicity of the human being. This attitude leads them to *reduce* the possibilities of impacting the functional recovery and to conceive the injured athlete as a person as a whole, the same way conceiving the rehabilitation as a whole[10].

There is a prerequisite to access the anti-reductionist approach, which derives from the definition of health proposed by the World Health Organization: *"State of complete physical, mental and social well-being and not simply the absence of disease or infirmity"*. By adopting this

Correspondence: Giulio Sergio Roi
E-mail: giuliosergio.roi@unibo.it

definition, the post-injury recovery process cannot be limited to the *restitutio ad integrum* of the affected zone of the body, but must consider also the psychological and social aspects, increasing the complexity of the intervention. Despite the variability in the definition of return to sport (RTS) used in the literature[11,12], RTS is actually a very complex process developed along a continuum that includes the return to training (RTT), the return to competitions (RTC) and finally, the return to performance (RTP)[13]. It follows that to establish whether an athlete can return to sport, both in training and/or in competition, we should adopt almost five criteria. 1) Clinical criteria: consisting of absence of pain, swelling, other signs of inflammation, complete healing process, complete range of motion, and good joint stability. 2) Functional criteria: investigated by functional assessment tests, including body composition (often ignored), recovery of strength and absence of deficits in the strength tests carried-out in the laboratory and in the field, also including the recovery of endurance and rate of force development; recovery of physical fitness and aerobic and anaerobic power and endurance. 3) Biomechanical criteria: investigated by tests referring to the recovery of motor patterns, certifying the absence of deficits in movement analysis tests. 4) Psychological criteria: fear of reinjury and psychological attitudes of the patients, identifying those who could benefit from psychological support. 5) Specific sport and social criteria: shared with coaches and technicians, reaching specific objectives relating to the sport practiced, including the ability to sustain volumes and intensities of trainings and competitions, but also overall lifestyle indicators including nutrition and sleep, together with other healthy measures (i.e., smoking habit).

Finally, it is interesting to note that there are numerous questionnaires available to evaluate functional outcomes also from the patient's point of view[14]. Even the use of these questionnaires can indicate the adoption of a reductionist or anti-reductionist approach. In fact, there are questionnaires to evaluate *only* the functionality of the injured limb (e.g., the IKDC questionnaire), and questionnaires to evaluate the *overall* state of health and the quality of life (e.g., the SF-36 questionnaire). Obviously, we should use both, working in team to overcome the antireductionist approach to RTS.

Bibliography

1. Bompa TO, Haff GG. Periodization. Theory and methodology of training. *Human Kinetics,* Champaign (IL), 2009.
2. Baumberg L, Long A, Jefferson J. International workshop: culture and outcomes. Barcelona 9-10 June 1995; Leeds: European Clearing House on Health Outcomes.
3. Ekizos A, Santuz A. "Biofeedback-based return to sport": individualization through objective assessments. *Front Physiol.* 2023 Jun 12; 14:1185556.
4. Frattali CN. Measuring outcomes in speech-language pathologies. Thieme, New York, 1998.
5. Davids K, Glazier P, Araújo D, Bartlett R. Movement systems as dynamical systems. *Sports Med.* 2003;33:245-60.
6. Bouchard C, Rankinen T. Individual differences in response to regular physical activity. *Med Sci Sports Exerc.* 2001;33(6 Suppl): S446-51; discussion S452-3.
7. Ross R, Goodpaster BH, Koch LG, Sarzynski MA, Kohrt WM, Johannsen NM, Skinner JS, Castro A, Irving BA, Noland RC, Sparks LM, Spielmann G, Day AG, Pitsch W, Hopkins WG, Bouchard C. Precision exercise medicine: understanding exercise response variability. *Br J Sports Med*. 2019;53(18):1141-53.
8. Quatman CE, Quatman CC, Hewett TE. Prediction and prevention of musculoskeletal injury: a paradigm shift in methodology. *Br J Sports Med*. 2009;43:1100-7.
9. Wilson IB, Cleary PD. Linking clinical variables with health-related quality of life. A conceptual model of patient outcomes. *JAMA*. 1995;273:59-65.
10. Roi GS. Return to competition following athletic injury: Sports rehabilitation as a whole. *Apunts Med Esport*. 2010; 45: 181-184.
11. Doege J, Ayres JM, Mackay MJ, Tarakemeh A, Brown SM, Vopat BG, Mulcahey MK. Defining return to sport: a systematic review. *Orthop J Sports Med*. 2021 Jul 26;9(7):23259671211009589.
12. Loeza-Magaña P, Quezada-González HR, Arias-Vázquez PI. Return to Sport, integrating the process from conventional rehabilitation up to reconditioning: a narrative review. *Arch Med Deporte.* 2021;38(4):253-60.
13. Buckthorpe M, Frizziero A, Roi GS. Update on functional recovery process for the injured athlete: return to sport continuum redefined. *Br J Sports Med*. 2019;53(5):265-7.
14. Andrew NE, Gabbe BJ, Wolfe R, Cameron PA. Evaluation of instruments for measuring the burden of sport and active recreation injury. *Sports Med*. 2010;40:141-61.

Monografías Femede nº 12
Depósito Legal: B. 27334-2013
ISBN: 978-84-941761-1-1
Barcelona, 2013
560 páginas.

Índice

Dep. Legal: B.24072-2013
ISBN: 978-84-941074-7-4
Barcelona, 2013
75 páginas. Color

Índice

Beyond creatine: evaluating guanidino acetic acid as a novel ergonutritional aid for basketball players

Ignacio Escribano-Ott[1], Juan Mielgo-Ayuso[2], Javier Ochóa-Lacar[3], Julio Calleja-González[1], Sergej M. Ostojic[4]

[1]Department of Physical Education and Sport. University of the Basque Country. Vitoria. Spain. [2]Department of Health Sciences. Faculty of Health Sciences. University of Burgos. Burgos. Spain. [3]Queiron CrossFit Navarra. Pamplona. Spain. [4]Department of Nutrition and Public Health. University of Agder. Kristiansand. Norway.

doi: 10.18176/archmeddeporte.00159

Received: 01/04/2023
Accepted: 05/02/2024

Key words:
Ergonutritional. Basketball. Creatine. Guanidino Aceit Acid. Sports Nutrition.

Summary

This study investigates the impact of Guanidinoacetic Acid (GAA) supplementation in basketball, a high-intensity sport requiring optimal nutrition and recovery strategies. Ergogenic aids like Creatine (CRM) are common, but GAA, a creatine precursor, may be more beneficial. Involving 31 semi-professional male and female players, the study compared GAA, CRM, and placebo groups. Results showed significant physical performance improvements in females using GAA, particularly in Counter Movement Jump (CMJ) and Handgrip (HG). Male GAA users showed CMJ improvements, while CRM enhanced cognitive functions in males. The study suggests GAA's potential in enhancing physical performance, especially in women, and highlights the need for further research on GAA and CRM effects, considering gender differences.

Más allá de la creatina: análisis del potencial del ácido guanidino acético como nueva ayuda ergogénica de interés para el baloncesto

Palabras clave:
Ergonutrición. Baloncesto. Creatina. Ácido guanidino acético. Nutrición deportiva.

Resumen

Este estudio examina el impacto de la suplementación con Ácido Guanidinoacético (GAA) en el baloncesto, un deporte de alta intensidad que demanda estrategias de recuperación nutricional óptimas. Aunque la Creatina Monohidrato (CRM) es una ayuda ergogénica muy utilizada para este fin, se ha hipotetizado que, el GAA, precursor de la creatina, podría ofrecer mayores beneficios. La investigación, que involucra a 31 jugadores semiprofesionales de ambos sexos, compara grupos que recibieron GAA, CRM y placebo. Los resultados revelan mejoras significativas en el rendimiento físico de las mujeres que utilizaron GAA, especialmente en el Salto con contra movimiento (CMJ) y la Fuerza Manual (HG). Por otro lado, los hombres que emplearon GAA experimentaron mejoras en el CMJ, mientras que la CRM potenció sus funciones cognitivas. Este estudio señala el potencial del GAA para mejorar el rendimiento físico, destacando su relevancia particular en mujeres, y subraya la necesidad de investigaciones adicionales sobre los efectos del GAA y la CRM, considerando las particularidades de género.

SEMED Research Award 2023

Correspondence: Ignacio Escribano-Ott
E-mail: Ignacio.escribano.ott@gmail.com

Introduction

In basketball, players must manage intense, fast-paced play with minimal rest, challenging both their physical and mental capacities. They also contend with external pressures such as frequent travel, limited sleep, and a dense game schedule. Thus, prioritizing proper nutrition and effective recovery tactics is essential for optimizing their performance and readiness in this demanding sport[1]. In particular, in certain circumstances, the use of ergogenic aids may also be necessary to support players in achieving their performance goals[2]. Among them, one of the most popular ergogenic aids for the past 30 years has been creatine monohydrate (CRM)[1]. It is widely considered safe and reliable for athletes and also, has been associated with potential beneficial effects on physical conditioning and cognitive performance[1], as well as promoting recovery[1]. Due to these benefits, basketball players have long used CRM supplementation to improve their physical and cognitive performance and recover. However, CRM presents some limitations such as low solubility in water, transportability issues, and heterogeneous response among individuals (non-responders)[1]. To overcome these limitations, researchers are studying studied other novel formats of CRM[3]. Despite the emergence of various alternative forms of this product, none of them have yet surpassed the efficacy of CRM in enhancing muscle uptake and high-intensity exercise performance[4]. While creatine citrate, creatine pyruvate, and magnesium creatine chelate have shown some potential, they do not exceed CRM in terms of muscle uptake and their evidence base is less robust[4]. Other forms, such as creatine ethyl ester, buffered creatine, and creatine nitrate, lack substantial supportive evidence. However, guanidinoacetic acid (GAA), a precursor of creatine, has been proposed as an advantageous and interesting alternative for CRM supplementation[5].

The first evidence of its performance-enhancing effects dates back to the early 1950s[6]. The GAA is naturally synthesized in the kidney and pancreas through an enzyme-catalyzed step from L-arginine and glycine, ultimately leading to the formation of creatine. It is theorized that oral administration of GAA is easily absorbed from the gastrointestinal tract and rapidly metabolized to creatine[6], improving cellular bioenergetics[6] and acting as fuel in high-energy-demand tissues such as skeletal muscle and the brain[7].

Additionally, the response to GAA seems to be more significant in terms of performance for individuals compared to non-responders[8]. The administration of guanidinoacetic acid (GAA) is widely recognized as safe and has been associated with beneficial effects that outweigh its potential side effects[9]. While caution must be exercised regarding potential neurotoxicity[10], GAA has demonstrated its efficacy even at low doses, typically ranging from approximately 1.2g/d1.2 g/d to around 5g[6]. In male athletes, GAA was associated with enhanced high-intensity anaerobic performance and increased body creatine levels[11], suggesting its potential as an ergogenic aid. Meanwhile, women with Chronic Fatigue Syndrome experienced improvements in muscular strength and aerobic power following GAA supplementation[12]. Moreover, GAA has been linked to enhanced brain performance, suggesting its potential cognitive benefits[7].

While these outcomes are significant across various athletic disciplines, they hold particular importance in high-intensity, intermittent sports like basketball. In basketball, the fundamental importance of lower body power and force production, particularly for actions such as jumping, is well recognized. This is often measured using the Counter Movement Jump (CMJ) test, which closely mirrors in-game jumping demands. The outcomes from this test highlight the essential role of ample creatine reserves in the lower body for optimal basketball performance[1]. Similarly, the capacity to generate force through explosive upper body movements, crucial for actions like throwing, shooting, and passing, underscores the importance of creatine stores in facilitating strength and power output. Equally, the Medicine Ball throw test provides valuable insights into these upper body strength requirements in basketball. Moreover, cerebral creatine reserves are vital to support cognitive abilities in sports performance[7], including maintaining focus, activating/inhibiting automatic responses, and adapting to changing situations on the court. These cognitive demands can be assessed using specific tests such as reaction time or Stroop On/Off, potentially indicating the use of cerebral creatine reserves. The potential of CRM to facilitate recovery is increasingly recognized, not confined to the court but extending to post-exercise recuperation, which is essential for an ergogenic aid in the context of basketball[2]. This includes its capacity to aid in glycogen restoration and attenuate increases in creatine kinase and delayed-onset muscle soreness[13]. Despite the limited data on GAA's role in recovery, it is postulated to contribute to recovery by enhancing insulin sensitivity, modulating GABA neurotransmission, promoting vasodilation, or being utilized in an unidentified metabolic pathway instigated by intense exercise[11].

The outcomes observed in prior research, in alignment with the unique requirements of basketball, invite the hypothesis that GAA may have a potential ergogenic effect in basketball players. To the best of the authors' knowledge, this study is the first examining the effectiveness of GAA supplementation in the area of basketball performance. The main aim of this study is to investigate the potential effects, of GAA as an effective ergo nutritional in basketball. As a secondary aspect, and parallel to this research, a comparative study will be conducted against CRM to investigate potential differences between these supplementation strategies. Finally, this work also aims to provide detailed information specifically for female basketball players. This is important because most studies in this field are conducted on men, and the data is subsequently extrapolated to the female population. This approach often overlooks the possibility that women's responses could be different.

Design

Thirty-one non-vegetarian basketball players, originally 33 but reduced due to team change and COVID-19, participated in this study. The group comprised 17 semi-professional female players from various Spanish divisions (average 24 years, 1.78m, 67.85kg) and 14 male players (average 23 years, 1.92m, 85.81kg). Inclusion criteria included players aged 16-40 in Spanish divisions, attending most practice sessions, no recent injuries, and no drug/supplement use. Vegetarians, those with metabolic disorders, or recent injuries were excluded.

The study, approved by the Basque Country University Ethics Committee and adhering to the Declaration of Helsinki and EU data regulations, was a simple-blind, placebo-controlled trial during the 2021-2023 seasons. Participants were divided into three groups: guanidinoacetic acid (GAA), creatine Monohydrate (CRM), and placebo, with detailed demographics provided for each group.

Participants were administered either a GAA product (comprising 2g of CRM and 2g of GAA, sourced from CreGAAtine, Applied Bioenergetic Lab and Carnomeda), CRM (4g, Nutrisport), or a Placebo (4g Maltodextrine, Decathlon). The selected doses were based on the safety and efficacy of GAA and CRM in exercise, sport, and medicine. Each product was provided to the participants in sachet form prior to the commencement of the experiment. Instructions were given to consume the product during main meals, allowing them to choose either lunch or dinner to better fit their daily routines. This was done to enhance adherence and minimize the risk of gastrointestinal issues[1].

Each participant underwent two trials and was assessed before and after 4 weeks of supplementation. Physical, cognitive, and body composition variables were measured to evaluate differences induced by the interventions across the three groups (Figure 1).

During testing days, participants warmed up at their basketball court for 15 minutes, led by a coach. The warm-up routine included 8 minutes of jogging, 5 minutes of full-body stretches, and 3 minutes of intense running[14].

After warming up, participants performed tests including Medicine Ball throw, Handgrip, Counter Movement Jump, Stroop tests, and LED Reaction time. They were familiar with these tests and practiced each three times. Staff demonstrated correct techniques. Recovery periods of 5 minutes were given between some tests, with 3 minutes for others. No break was provided between Handgrip and Counter Movement Jump tests. Feedback was given during tests to maximize performance.

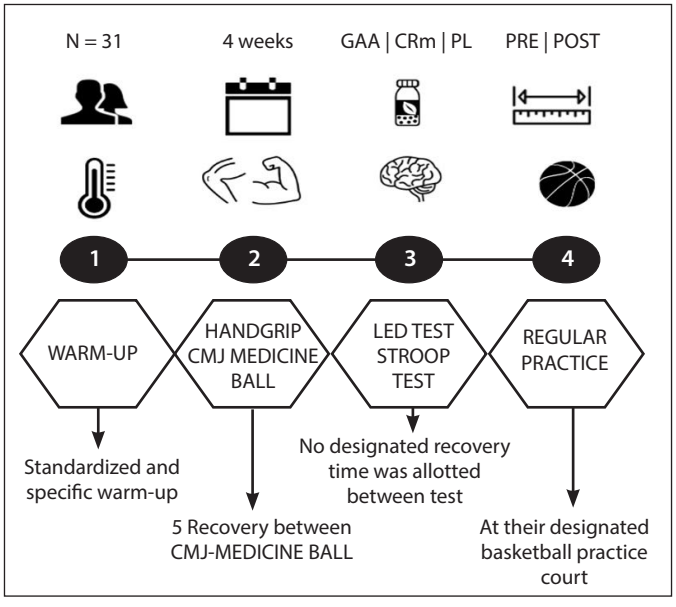
Material and method

To assess lower neuromuscular performance: the CMJ test, a widely used field test in basketball research[15], was employed to assess lower body neuromuscular performance. Each participant performed three maximal jumps with a two-minute rest interval between jumps[15]. To ensure accurate measurement, the validated and reliable smartphone app My Jump Lab®[16] was utilized to record and analyze the jumps. To asses upper Neuromuscular Performance, the Handgrip (HG) test, a widely used method to assess upper body dynamic strength[17], was performed by participants. They executed three maximal handgrip contractions with their dominant hand, and the best attempt was recorded. The Medicine Ball (MB) test, another common test in basketball research, was also conducted. Participants were instructed to perform a horizontal medicine ball throw using a two-hand chest pass movement, following established protocol instructions[18]. Female participants used a 3kg medicine ball, while male participants used a 5 kg medicine ball. To ensure accurate measurement, the throws were recorded using two strategically positioned video cameras for clear visibility. Subsequently, each throw was analyzed by two researchers using the Kinovea analysis software, achieving a high intra-class correlation coefficient of 0.99[19].

Regarding cognitive performance, to assess psychomotor Speed and Cognitive Flexibility, the SO and SOFF tests were employed. These tests have proven to be sensitive in detecting cognitive impairment[20]. To ensure accurate measurement, a validated and reliable smartphone app, the Stroop Smartphone App, was utilized. The test[21] consisted of two tasks: 1) "Stroop Off" (the easier task), where participants matched a color name to the displayed color; and 2) "Stroop On" (the more challenging task), where participants matched the color of the word presented in discordant coloring (e.g., the word "blue" displayed in red color). In both Stroop modes, the test concluded after five consecutive correct runs. However, if a mistake was made, the run was interrupted, and the player had to restart. To assess perceptual and decision-making skills (reaction time), LED test was used to provide insights into the speed and accuracy of player responses[22]. A reliable and validated test designed for fast-action sports such as basketball was administered[22]. Three light sensors with LED indicators were positioned at fixed heights on the left, center, and right side of the player's defensive position (mass center). Players assumed the starting position and promptly touched the illuminated LED indicator with either hand, aiming to react as quickly as possible.

Dietary intake and training protocols were closely monitored throughout the study. To assess dietary habits, players completed a validated Food Frequency Questionnaire (FFQ) that has been utilized in previous sports nutrition research[23]. Through a self-administered questionnaire, participants were queried about their health status, dietary style, their perception of the adequacy of their nutritional habits in relation to recommendations, and their perception of their fitness level (Anex 1). To minimize potential interference from dietary changes or the use of other nutritional supplements[23], participants were instructed to maintain their usual dietary intake throughout the study period and avoid the consumption of any dietary supplements that could potentially provide ergogenic benefits. To track their training activities, participants completed a self-administered questionnaire detailing their weekly team practice duration and frequency of resistance training

Figure 1. Chronology of Research Events.



sessions[24]. Additionally, to evaluate the potential side effects associated with GAA, CRM, or PL supplementation, players were asked to report any adverse effects on their gastrointestinal system through an online survey (https://form.typeform.com/to/fks2Xck8). The survey was available until 1st December 2022, with the last access to the link recorded on 10th January 2023 (Survey Close Date: 1-12-2022; Last access to the link 10-01-2023). Participants were also requested to provide subjective assessments of their overall health status, dietary habits, eating patterns, and physical fitness level.

Statistical analysis

Data was analyzed using descriptive statistics (mean, standard deviation) for normality and homoscedasticity. Student's t-tests were applied to normal data, and Wilcoxon rank-sum tests for non-normal data. Group comparisons were conducted, categorizing effect sizes (trivial <0.20 to very large >2.0).

Players' outcomes were classified into responders (>10% difference), quasi-responders (5%–10% difference), and non-responders (<5% difference) based on previous research. Categories included non-responders (≥50% variables reported as "non-responders"), responders (≥50% variables reported as "responders"), and quasi-responders. Significance was set at P <0.05, analyzed with SPSS® 26.0 and R 4.2.2.

The study used a 2-way ANOVA (group × trial) with Bonferroni-corrected post-hoc tests to analyze changes. Effect size was measured using partial eta squared. Responders surpassed the smallest worthwhile change (SWC), set at 0.2 times the between-participant deviation, signifying the minimum change above measurement error at 95% confidence.

Results

A total of 31 semiprofessional basketball players (17 female players from the 1st, 2nd, 3rd, and Spanish Basketball Divisions and 14 male players from the 2nd and 4th divisions) completed the study. No differences were found among groups regarding their health status, diet type, eating habits, fitness level, weekly team practice minutes, or weekly resistance frequency. Only one player (CRM group: 3.2%, P >0.05) reported gastrointestinal adverse symptoms whereas the other volunteers (96.8%) reported no major side effects after they participated in the study. Eleven players (52%) were categorized as responders, five as quasi-responders (24%), and five as non-responders (24%). The secondary outcomes for: 1) Anaerobic neuromuscular performance (MB, HG, CMJ) (Table 1); 2) cognitive performance (SO, SOFF, LED) (Table 2) were assessed at baseline (pre-intervention; T1) and 4-week follow-up (post-intervention; T2).

Table 1. Physical condition outputs in the three study groups at the baseline (T1) and after 4 weeks (T2).

Sex	Group	T1	T2	Delta	%VAR	p	D	P	n2p	MBI
								(TXG)		
MB										
Female	GAA	2.79 ± 0.28	2.81 ± 0.24	0.02 ± -0.04	1.02 ± 3.35	0.530	-0.32; small	0.05 [B]	0.18	Most Likely Trivial Increase.
	CRM	3.07 ± 0.44	3.06 ± 0.37	-0.04 ± -0.01	0.03 ± 5.36	0.900	-0.36; small			Most Likely Large Increase.
	PL	3.86 ± 1.87	3.84 ± 1.94	-0.01 ± 2.62	-1.22 ± 2.49	0.500	0.12; very small			Unclear Difference.
Male	GAA	3.47 ± 0.16	3.52 ± 0.14	0.05 ± 0.02	1.47 ± 1.81	0.200	-0.09; very small	0.65 [B] 0.13 [A]	0.15	Likely Trivial Increase.
	CRM	3.77 ± 0.38	3.91 ± 0.37	0.14 ± 0.1	3.62 ± 1.83	0.010	0.02; very small			Most Likely Trivial Increase.
	PL	3.73 ± 0.41	3.67 ± 0.47	0.06 ± 0.06	-1.52 ± 3.59	0.430	0.01; very small			Most Likely Trivial Decrease.
HG										
Female	GAA	38.71 ± 6.65	41.71 ± 5.77	3 ± -0.88	**8.32 ± 5.19**	**0.003**	-0.38; small	0.743	0.16	Likely Trivial Increase.
	CRM	34.8 ± 3.56	37.2 ± 2.59	-0.88 ± 2.4	7.35 ± 7.56	0.09	-0.18; small			Almost Certainly Very Large Increase.
	PL	41.2 ± 4.97	41 ± 4.95	0.2 ± 0.2	-0.45 ± 2.49	0.700	-0.14; medium			Almost Certainly Very Large Increase.
Male	GAA	55.75 ± 7.23	58.5 ± 7.33	2.75 ± 0.10	5.03 ± 3.02	0.040	-0.48; small	0.072	0.10	Most Likely Trivial Increase.
	CRM	57.6 ± 9.02	59.2 ± 8.56	2.4 ± 0.46	**2.95 ± 3.74**	**0.150**	-0.77; very small			Most Likely Trivial Increase.
	PL	53.4 ± 4.34	54 ± 4.18	0.6 ± 0.16	1.15 ± 1.05	0.070	0.04; very small			Most Likely Trivial Increase.
CMJ										
Female	GAA	28.84 ± 4.36	30.47 ± 3.85	1.63 ± -0.51	**6.01 ± 3.37**	**<0.001**	-0.22; small	0.850	0.16	Most Likely Trivial Increase.
	CRM	30.63 ± 3.06	32.45 ± 5.15	-0.51 ± 1.82	5.55 ± 6.65	0.160	-0.13; very small			Likely Moderate Increase.
	PL	26.83 ± 5.71	26.56 ± 5.74	0.27 ± 0.3	-1.04 ± 1.51	0.200	0.03; very small			Likely Moderate Increase.
Male	GAA	39.4 ± 2.94	40.14 ± 3.77	0.74 ± 0.83	1.79 ± 2.57	0.260	-0.4; small	0.013 [B] 0.263 [A]	0.28	Most Likely Trivial Increase.
	CRM	36.26 ± 4.26	36.88 ± 5.05	0.94 ± 0.79	1.52 ± 4.08	0.410	-0.43; small			Most Likely Trivial Decrease.
	PL	34.17 ± 3.55	34.07 ± 4	0.10 ± 0.45	-0.4 ± 2.68	0.790	0.05; very small			Most Likely Trivial Decrease.

Data are expressed as mean ± standard deviation. Two-factor repeated-measures ANOVA. [A] GAA *Vs* CRE; [B]GAA *Vs* CONT; [C]CRE *Vs* GAA; [D]CRE *Vs* CONT.
*Significantly different between study points (T1 *Vs* T2) P <0.05.
MB: Medicine Ball; HG: Handgrip; CMJ: Counter Movement Jump; GAA: Guanidinoacetic acid group; CRM: Creatine Monohydrate group; PL: Placebo group; %VAR: Percentage of variation; D: Cohen's D; VS: Very Small; S: Small; P (TxG): Group-by-time interaction.

Table 2. Cognitive performance outputs in the three study groups at the baseline (T1) and after 4 weeks (T2).

Sex	Group	T1	T2	Delta	%VAR	p	D	P	n2p	MBI
								(TXG)		
SON										
Female	GAA	47.14 ± 6.15	46.95 ± 6.05	-0.19 ± -0.1	-0.4 ± 0.9	0.370	0.01; very small	0.008[A]	0.27	Most Likely Trivial Decrease.
	CRM	52.21 ± 2.14	54.66 ± 6.78	-0.1 ± 2.45	4.49 ± 9.34	0.340	0.69; medium			Possibly Small Increase.
	PL	48.14 ± 2.42	47.66 ± 2.34	0.48 ± 0.10	-0.81 ± 6.6	0.750	0; very small			Possibly Moderate Increase.
Male	GAA	50.05 ± 4.78	49.99 ± 4.5	0.06 ± 0.28	-0.07 ± 1.79	0.900	-0.04; very small	0.001[A]	0.33	Most Likely Trivial Decrease.
	CRM	57.38 ± 2.05	54.99 ± 4.47	2.39 ± -2.42	-4.08 ± 8.01	0.310	-0.47; small			Possibly Small Decrease.
	PL	51.3 ± 4.43	51.3 ± 4.67	0 ± -0.24	0 ± 2.73	0.990	0.6; medium			Most Likely Trivial Increase.
SOFF										
Female	GAA	44.96 ± 4.59	45.12 ± 4.44	0.16 ± -0.15	0.39 ± 0.94	0.320	0.01; very small	0.338	0.26	Most Likely Trivial Increase.
	CRM	52.12 ± 0.95	54.18 ± 6.16	-0.15 ± 2.06	3.84 ± 10.14	0.440	0.36; small			Possibly Small Increase.
	PL	45.1 ± 2.54	36.4 ± 2.48	8.7 ± 0.6	-19.72 ± 44.89	0.380	0.06; very small			Unclear Difference.
Male	GAA	45.45 ± 4.01	45.39 ± 4.15	0.06 ± -0.14	-0.15 ± 1.98	0.900	0.03; very small	0.001[D]	0.59	Most Likely Trivial Decrease.
	CRM	57.81 ± 3.2	55.77 ± 7.47	2.04 ± -4.27	-3.82 ± 9.02	0.390	-0.49; small			Possibly Trivial Decrease.
	PL	47.44 ± 4.21	47.22 ± 3.32	0.22 ± 0.89	-0.35 ± 1.79	0.621	0.2; small			Most Likely Trivial Decrease.
LED										
Female	GAA	69.43 ± 9.61	64.86 ± 6.72	-4.57 ± -2.89	**-6.03 ± 6.6**	**0.040**	0.02; very small	0.637	0.14	Possibly Trivial Decrease.
	CRM	74.8 ± 6.46	71.2 ± 4.21	-2.89 ± -3.6	-4.45 ± 6.89	0.220	0.41; small			Likely Moderate Decrease.
	PL	70 ± 4	70.4 ± 3.13	0.4 ± 0.87	0.64 ± 1.72	0.470	0.32; small			Likely Trivial Increase.
Male	GAA	68 ± 3.74	67.94 ± 3.2	0.06 ± 0.54	-0.05 ± 1.32	0.900	0.55; medium	0.857	0.37	Most Likely Trivial Decrease.
	CRM	67.4 ± 6.5	64.16 ± 9.02	3.24 ± -2.52	-4.52 ± 12.58	0.430	0.66; medium			Possibly Trivial Decrease.
	PL	76.2 ± 6.61	74.49 ± 3.89	1.71 ± 2.72	-1.99 ± 4.21	0.350	-0.11; very small			Likely Trivial Decrease.

Data are expressed as mean ± standard deviation. Two-factor repeated-measures ANOVA. [A] GAA *Vs* CRE; [B]GAA *Vs* CONT; [C]CRE *Vs* GAA; [D]CRE *Vs* CONT.
*Significantly different between study points (T1 *Vs* T2) *P* <0.05.
SON: Stroop On; SOFF: Stroop Off; LED: Reaction Time; GAA: Guanidinoacetic acid group; CRM: Creatine Monohydrate group; PL: Placebo group; %VAR: Percentage of variation; D: Cohen's D; VS: Very Small; S: Small; P (TxG): Group-by-time interaction.

In terms of anaerobic neuromuscular performance, female group players who supplemented with GAA exhibited notable and statistically significant enhancements in their CMJ results (6.01+3.37%; *P* <0.001; ES = 0.22, small), and HG (8.32+5.19%; *P* = 0.003; ES = 0.38; small) performance. No differences were found in the MB (1.02 + 3.35%; *P* = 0.53; ES = 0.32; small). However, for the MB, ANOVA revealed a significant effect of the group, regarding treatment *Vs.* time. Post-hoc comparisons indicated that the GAA group showed significant (0,05) improvements in the MB compared to the control and CRM groups. In contrast, CRM supplementation did not yield significant improvements in any measured anaerobic neuromuscular performance variables. Comparatively, the PL group did not show any significant differences. Regarding male group, while no significant differences were initially comparing GAA, CRM and PL groups, the application of one-way ANOVA tests revealed statistically significant differences. Specifically, these differences favored the GAA group when compared to the PL group in CMJ (0.,013). Furthermore, effect size calculations using eta squared (η^2) showed a significant interaction (0.28) effect for CMJ.

When it comes to cognitive performance, the inclusion of GAA supplementation in the female group also yielded a beneficial effect on LED (-6.03+6.6%; *P* = 0.040; ES = 0.02; very small) whereas SOFF (0.39 + 0.94%; *P* = 0.32; ES = 0.01; very small) and SO (-0.4 + 0.9; *P* = 0.37; ES = 0.01; very small) did not show significant differences. Regarding SO, the ANOVA did detect significant interactions regarding treatment *Vs.* time, and the posterior Bonferroni corrected post hoc test revealed significant improvements in favor of the GAA group (0.008). No differences were found in both the CRM and PL group. In the male group, initial raw data analysis did not reveal any noticeable differences in cognitive performance among the GAA, CRM, and PL groups, further analysis using one-way ANOVA tests revealed nuanced variations. Specifically, the ANOVA tests detected a significant difference in the SOFF, favoring the CRM group over the PL group (0,001), and the GAA group over the CRM group (0,001).

Discussion

This study investigated the ergogenic effects of GAA in basketball players, comparing its impact on males and females and against CRM. Results indicate GAA enhances anaerobic performance in females (MB, HG, CMJ) and CRM improves cognitive functions in males. However, varied gender responses suggest more research is needed to understand GAA and CRM effects and to optimize supplementation strategies in sports performance, particularly exploring gender-specific impacts.

Basketball is a sport characterized by many intermittent high-intensity actions[1] in which the aerobic energetic system is quantitatively higher, but the anaerobic pathways are qualitatively decisive[1]. Both male and female basketball players must deal with numerous situations requiring their maximum physical effort throughout a game, leading to high levels of fatigue. Consequently, to cope with these demands, proper physical condition is crucial to develop optimal performance. Specific actions based on jumps or throws are usually measured to describe the players' physical readiness because the tests involve physical demands like those of the game.

In the context of the MB test, the effects of GAA and CRM supplementation showed distinct differences between male and female groups. The GAA group demonstrated significant improvements over time, hinting at a positive impact of GAA supplementation on upper body neuromuscular performance in basketball players, irrespective of gender. For the female group, the possibility of a heightened sensitivity to GAA[12] supplementation may have underpinned these improvements. This holds substantial implications given that upper body strength is a pivotal aspect of basketball performance, primarily in actions such as rebounding and shooting, which necessitate robust arm and shoulder movements. The male group also exhibited a positive response to GAA supplementation, albeit less pronounced than their female counterparts. This may be attributable to the typically higher initial muscle mass and strength in male athletes[25], potentially resulting in a less noticeable impact of GAA supplementation.

Comparatively, between the GAA and CRM groups, GAA appeared to have a superior effect on MB performance, suggesting that GAA might offer additional ergogenic benefits in the context of basketball performance.

The CMJ test is one of the most commonly used field tests in the basketball literature to assess lower body neuromuscular performance. Our findings suggest that supplementing with GAA may improve it, particularly among female athletes. The male group, on the other hand, showed only marginal improvements after CRM supplementation.

Dietary GAA has been observed to improve cellular bioenergetics by stimulating creatine biosynthesis, which may be the primary mechanism[6] driving the observed enhancements in CMJ performance. This mechanism has been widely observed in CRM supplementation reporting explosive/strength gains in the lower body and aerobic power. Creatine raises levels of intramuscular PCr, in combination with a phosphoryl group (Pi) via the enzymatic reaction of creatine kinase (CK)[26]. This rephosphorylation of the adenosine diphosphate acceleration resynthesis and maintain ATP bioavailability which as result allows muscle fiber to develop fast and strong muscle contractions. Another mechanism that would explain these results is, the role of creatine in calcium recapture in the sarcoplasmic reticle, leading to a more rapid actin-myosin cross-cycle, and therefore enhancing muscle strength and endurance[26]. However, the physiological roles of GAA extend beyond creatine synthesis. It has been found to stimulate hormonal release and neuromodulation, alter the metabolic utilization of arginine, and adjust oxidant-antioxidant status[6]. This hypothesis is supported by creatine´s ability to reduce the formation of reactive oxygen species through an ADP-recycling mechanism via mitochondrial CK[27]. Also, regarding the protective effect on glycogen storage, oral CRM supplementation increases GLUT4 protein content[28] and therefore increases the ability to uptake glucose[29]. This way, GAA may promote faster recovery and better performance.

For instance, the stimulation of hormonal release could induce higher levels of growth hormone or testosterone, which are known to enhance muscle strength and power. The neuromodulator role of GAA[30] could potentially improve the efficiency of neuromuscular transmission, leading to more effective force production during the CMJ. The physiological mechanisms underlying this observation could be multiple and complex. Dietary and pre-existing muscle creatine status can influence the efficacy of CRM supplementation[1]. Given that males typically have higher baseline creatine levels due to higher muscle mass[25] it's plausible that they might not experience the same degree of benefit from CRM supplementation as females do from GAA. Finally, it's unclear whether GAA offers a superior benefit in terms of enhancing handgrip strength and the differences between males and females.

The reasons for this difference are not fully understood but may relate to neural, muscular, or motor learning traits.

Basketball places significant cognitive demands on players, requiring quick, accurate responses to unpredictable events in high-uncertainty conditions. This leads to psychobiological fatigue, impacting motor skills and decision-making. Our study on GAA supplementation offers insights to address these challenges.

Female participants who took GAA showed notable improvements in LED task performance, indicating better reaction time and eye-hand coordination. This aligns with the fact that females typically have a smaller creatine pool in the upper body compared to males, highlighting the potential benefits of increased creatine synthesis from GAA supplementation in such situations.

Another possible mechanism that may explain the improvement is the elevation of GAA concentrations in specific brain regions such as cerebellum[31]. While CRM supplementation increases muscle storage to a greater degree than in brain tissue[32], this small contribution seems to protect athletes from mental fatigue[33].

When mental fatigue occurs (low PCr among other things), a feedback signal controls the suppression of the excitatory transmission, preventing exhaustion and fatal damage. In periods of high neuronal activity, adenosine, acting through A1R and A2AR receptors, plays a key role in brain function by balancing excitatory and inhibitory signals, and fostering synaptic plasticity[34]. In the event of a brain insult, A1R initiates a protective response, but prolonged activation can lead to desensitization. Conversely, A2AR is upregulated potentially triggering adaptive changes, yet this might worsen brain damage, making A2AR blockade a potential neuroprotective strategy[34]. GAA's ability to raise the brain's total creatine storage, and particularly in the cerebellum[31] can acts as a rapidly accessible energy reserve for the regeneration of ATP, leading to a protective neural excitability effect, showing, therefore, meaningful differences when compared with CRM.

In contrast, the male participants did not initially exhibit any significant cognitive performance improvements following supplementation. However, deeper analysis using a one-way ANOVA revealed significant enhancements in the SOFF task performance in the groups supplemented with CRM and GAA, with GAA displaying a superior efficacy. This difference could be rooted in the metabolic role of GAA, thereby

enhancing energy metabolism in high-energy demand tissues such as the brain[31].

Furthermore, GAA may also stimulate nitric oxide production, improving cerebral blood flow, and consequently, oxygen and nutrient delivery to the brain, bolstering cognitive function[35].

The observed gender-based differences in the responses to GAA supplementation underscore the role of physiological characteristics and gender-specific creatine distribution in influencing cognitive performance. The evidence that females, typically characterized by lower upper body creatine levels[25], may stand to benefit more from GAA supplementation, stresses the potential utility of gender-tailored supplementation strategies in sports performance. Our findings invite us to hypothesize that GAA may also be superior to CRM to facilitate cognitive recovery in basketball players who are typically exposed to chronic mental fatigue, such as sleep deprivation. However, new research lines would be necessary to support this hypothesis.

This article acknowledges limitations, including a small sample size, challenging to increase in elite sports and amid the COVID-19 pandemic. Despite this, the study's strength lies in its real-world setting during the 2020-2022 competitive period, adding ecological validity to the GAA and CRM behavior analysis. A notable drawback is the inability to track women's hormonal phases, yet the research still contributes valuable insights for female basketball players. The study duration was limited to four weeks.

The study's findings are relevant for high-level sports requiring quick results. While it didn't use biological techniques like blood tests for primary outcomes, it utilized non-invasive, cost-effective methods for assessing nutritional interventions. A key strength is the study's ecological validity and its replicable methodology, beneficial for sports scientists, trainers, nutritionists, and coaches.

Future research should focus on comparing GAA and CRM, particularly their cognitive effects, for more conclusive evidence. More studies are needed to understand GAA and CRM's impact in basketball, uncover their mechanisms, and refine supplementation strategies. It's important for researchers and sports professionals to consider gender and individual differences in exploring these supplements to enhance basketball performance.

Conclusions

GAA supplementation improved physical performance in females, notably in CMJ, handgrip strength, and medicine ball throw. CRM showed cognitive benefits for males, enhancing attention and control. Further research should examine these supplements' specific effects in basketball, considering gender differences. Thus, female players could use GAA to boost physical abilities, particularly lower body and upper body strength. Male players might also benefit from CRM and GAA's cognitive enhancements.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

- SMO serves as a member of the Scientific Advisory Board on Creatine in Health and Medicine (AlzChem LLC).
- Applied Bioenergetic Lab and Carnomed provided the GAA product for the completion of this work.

Bibliography

1. Escribano-Ott I, Ibañez-Santos J. Nutrición Hospitalaria. *Nutr Hosp.* 2020;37:160-8.
2. Escribano-Ott I, Calleja-González J, Mielgo-Ayuso J. Ergo-Nutritional Intervention in Basketball: A Systematic Review. *Nutrients*. 2022;14(3):1-18.
3. Fazio C, Elder CL, Harris MM. Efficacy of Alternative Forms of Creatine Supplementation on Improving Performance and Body Composition in Healthy Subjects: A Systematic Review. *J Strength Cond Res.* 2022;36(9):2663-70.
4. Kreider RB, Jäger R, Purpura M. Bioavailability, Efficacy, Safety, and Regulatory Status of Creatine and Related Compounds: A Critical Review. *Nutrients.* 2022;14(5):1035.
5. Forbes SC, Cordingley DM, Cornish SM, Gualano B, Roschel H, Ostojic SM, *et al. Health.* 2022;1-16.
6. Ostojic SM, Drid P, Ostojic J. Guanidinoacetic acid increases skeletal muscle creatine stores in healthy men. *Nutrition* [Internet]. 2016;32(6):723-4. Disponible en: http://dx.doi.org/10.1016/j.nut.2015.11.006
7. Roschel H, Gualano B, Ostojic SM, Rawson ES. Creatine supplementation and brain health. *Nutrients.* 2021;13(2):1-10.
8. Ostojic SM. Short-term GAA loading: Responders versus nonresponders analysis. *Food Sci Nutr.* 2020;8(8):4446-8.
9. Ostojic SM, Forbes SC. Perspective: Creatine, a Conditionally Essential Nutrient: Building the Case. *Adv Nutr*. 2022;13(1):34-7.
10. Ostojic SM. Safety of dietary guanidinoacetic acid: A villain of a good guy? *Nutrients.* 2022;14(1):1-9.
11. Semeredi S, Stajer V, Ostojic J, Vranes M, Ostojic SM. Guanidinoacetic acid with creatine compared with creatine alone for tissue creatine content, hyperhomocysteinemia, and exercise performance: A randomized, double-blind superiority trial. *Nutrition.* 2019;57:162-6.
12. Ostojic SM, Stojanovic M, Drid P, Hoffman JR, Sekulic D, Zenic N. Supplementation with guanidinoacetic acid in women with chronic fatigue syndrome. *Nutrients.* 2016;8(2):1-9.
13. Yokota Y, Yamada S, Yamamoto D, Kato K, Morito A, Takaoka A. Creatine Supplementation Alleviates Fatigue after Exercisethrough Anti-Inflammatory Action in Skeletal Muscle and Brain. *Nutraceuticals.* 2023;3(2):234-49.
14. Brini S, Boullosa D, Calleja-González J, Delextrat A. Construct validity and reliability of a new basketball multidirectional reactive repeated sprint test. *Int J Environ Res Public Health*. 2021;18(20).
15. Mancha-Triguero D, García-Rubio J, Calleja-González J, Ibáñez SJ. Physical fitness in basketball players: A systematic review**.** *J Sports Med Phys Fitness*. 2019;59(9):1513-25.
16. Bishop C, Jarvis P, Turner A, Balsalobre-Fernandez C. Validity and Reliability of Strategy Metrics to Assess Countermovement Jump Performance Using the Newly Developed My Jump Lab Smartphone Application. *J Hum Kinet.* 2022;83(1):185-95.
17. Cildan Uysal S, Tonak HA, Kitis A. Validity, reliability and test-retest study of Grip strength measurement in two positions with two dynamometers: Jamar® Plus and K-Force® Grip. *Hand Surg Rehabil* [Internet]. 2022;41(3):305-10. Disponible en: https://doi.org/10.1016/j.hansur.2022.02.007
18. Stockbrugger BA, Haennel RG. Validity and Reliability of a Medicine Ball Explosive Power Test. *J Strength Cond Res*. 2001;15(4):431-8.
19. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med* [Internet]. 2016;15(2):155-63. Disponible en: http://dx.doi.org/10.1016/j.jcm.2016.02.012
20. Takahashi S, Grove PM. Impact of acute open-skill exercise on inhibitory control and brain activation: A functional near-infrared spectroscopy study. *PLoS One* [Internet]. 2023;18(3 March):1-17. Disponible en: http://dx.doi.org/10.1371/journal.pone.0276148
21. Bajaj JS, Heuman DM, Sterling RK, Sanyal AJ, Siddiqui M, Matherly S, *et al.* Validation of EncephalApp, Smartphone-based Stroop Test, for the Diagnosis of Covert Hepatic Encephalopathy. *Physiol Behav.* 2017;176(1):139-48.
22. Pojskic H, Pagaduan J, Uzicanin E, Separovic V, Spasic M, Foretic N, *et al.* Reliability, validity and usefulness of a new response time test for agility-based sports: A simple vs. complex motor task. *J Sport Sci Med.* 2019;18(4):623-35.

23. Mielgo-Ayuso J, Calleja-González J, Urdampilleta A, León-Guereño P, Córdova A, Caballero-García A, *et al.* Effects of vitamin D supplementation on haematological values and muscle recovery in elite male traditional rowers. *Nutrients*. 2018;10(12).
24. Douchet T, Paizis C, Babault N. Physical Impact of a Typical Training Session with Different Volumes on the Day Preceding a Match in Academy Soccer Players. *Int J Environ Res Public Health*. 2022;19(21).
25. Haizlip KM, Harrison BC, Leinwand LA. Sex-based differences in skeletal muscle kinetics and fiber-type composition. *Physiology*. 2015;30(1):30-9.
26. Bazzucchi I, Felici F, Sacchetti M. Effect of short-term creatine supplementation on neuromuscular function. *Med Sci Sports Exerc*. 2009;41(10):1934-41.
27. Kreider RB, Kalman DS, Antonio J, Ziegenfuss TN, Wildman R, Collins R, *et al.* International Society of Sports Nutrition position stand: Safety and efficacy of creatine supplementation in exercise, sport, and medicine. *J Int Soc Sports Nutr*. 2017;14(1):1-18.
28. Op 'T Eijnde B, Ursø B, Richter EA, Greenhaff PL, Hespel P. Effect of oral creatine supplementation on human muscle GLUT4 protein content after immobilization. *Diabetes*. 2001;50(1):18-23.
29. Kraniou Y, Cameron-smith D, Misso M, Collier G, Hargreaves M, Cameron-smith D, *et al. Highlighted topics*. 2023;794-6.
30. Ostojic SM, Ratgeber L, Olah A, Betlehem J, Acs P. Guanidinoacetic acid deficiency: A new entity in clinical medicine? *Int J Med Sci*. 2020;17(16):2544-50.
31. Ostojic SM, Ostojic J, Drid P, Vranes M, Jovanov P. Dietary guanidinoacetic acid increases brain creatine levels in healthy men. *Nutrition* [Internet]. 2017;33:149-56. Disponible en: http://dx.doi.org/10.1016/j.nut.2016.06.001
32. Solis MY, Artioli GG, Gualano B. Potential of creatine in glucose management and diabetes. *Nutrients*. 2021;13(2):1-13.
33. Cao S, Geok SK, Roslan S, Sun H, Lam SK, Qian S. Mental Fatigue and Basketball Performance: A Systematic Review. *Front Psychol*. 2022;12(January):1-10.
34. Cunha RA. How does adenosine control neuronal dysfunction and neurodegeneration? *J Neurochem*. 2016;139(6):1019-55.
35. Balestrino M, Adriano E. Beyond sports: Efficacy and safety of creatine supplementation in pathological or paraphysiological conditions of brain and muscle. *Med Res Rev*. 2019;39(6):2427-59.

Links between Sports Injuries and Mental Health in Elite Athletes: the current state of affairs

Laura Gil Caselles[1], **Aurelio Olmedilla Zafra**[2]

[1]Facultad de Ciencias del Deporte. Campus Mare Nostrum. Universidad de Murcia. [2]Departamento de Personalidad, Evaluación y Tratamiento Psicológicos. Universidad de Murcia.

doi: 10.18176/archmeddeporte.00160

Received: 11/06/2023
Accepted: 21/02/2024

Summary

Currently, the studies that have been carried out on sports injuries are mostly focused on physical factors as the main cause; however, empirical evidence shows the importance of psychological factors. Therefore, we must focus on identifying the most relevant variables surrounding sports injuries, that is, those that can influence their appearance and/or rehabilitation. Mental health disorders have become one of the most relevant problems today, and with it, the risk of suffering an injury is increasing. The objective of the present study is to carry out a systematic review of the scientific literature to know which mental health indicators are the most common in relation to sports injuries in elite athletes. A systematic review of the scientific literature will be carried out in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. For this purpose, various databases have been used, such as: Scopus, Scielo, ResearchGate, MedlinePlus, Dialnet and Google Scholar. The selected documents were 6, all of them review articles published between 2016 and 2022. The results indicate that: there is a relationship between mental health and sports injuries; the prevalence of mental health symptoms in sport increases the risk of injury and delays rehabilitation; the number of injuries negatively affects the athlete's mental health; Injuries can increase the risk of mental health problems and adverse behaviors. In conclusion, this review shows how mental health indicators are significantly related to sports injuries, and how their relationship can lead to incorrect recovery for the athlete and/or being more exposed to suffering from it.

Key words:
Mental Health. Athlete. Athletic injuries. Systematic review.

Relación entre lesiones deportivas y salud mental en deportistas de élite: estado actual de la cuestión

Resumen

Actualmente los estudios que se han llevado a cabo sobre las lesiones deportivas están centrados en su mayoría en los factores físicos como causa principal, sin embargo, la evidencia empírica muestra la importancia que ejercen los factores psicológicos. Por ello, debemos incidir en identificar aquellas variables más relevantes en torno a la lesión deportiva, es decir aquellas que puedan influir en su aparición y/o rehabilitación. Los trastornos de salud mental se han convertido en uno de los problemas más relevantes en la actualidad, y con ello, se está incrementando el riesgo de sufrir una lesión. El objetivo del presente estudio es realizar una revisión sistemática de la literatura científica para conocer que indicadores de salud mental son los que más inciden en torno a la lesión deportiva del deportista de élite. Se realizará una revisión sistemática de la literatura científica conforme a las directrices de Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Para ello, se han empleado diversas bases de datos, como son: Scopus, Scielo, ResearchGate, MedlinePlus, Dialnet y Google Scholar. Los documentos seleccionados han sido 5, todos ellos artículos de revisión publicados entre 2016 y 2022. Los resultados indican que: existe relación entre la salud mental y las lesiones deportivas; la prevalencia de síntomas de salud mental en el deporte aumenta el riesgo de padecer lesiones y retrasa su rehabilitación; el número de lesiones afecta negativamente a la salud mental del deportista; las lesiones pueden aumentar el riesgo de problemas de salud mental y comportamientos adversos. En conclusión, esta revisión de revisiones muestra como los indicadores de salud mental se relacionan de manera significativa con las lesiones deportivas, y cómo su relación puede acarrear en el deportista una incorrecta recuperación y/o que esté más expuesto a sufrirla.

Palabras clave:
Salud Mental. Deportistas. Lesiones deportistas. Revisión sistemática.

Accesit to the Best Oral Communication of the XIX International Congress of the Spanish Society of Sports Medicine 2023

Correspondence: Laura Gil Caselles
E-mail: laura.gilc@um.es

Introduction

The analysis of psychological factors that might impact athletic performance should be studied given the currently growing diversion in this sector and we need to consider that the number of athletes claiming to suffer mental health problems is growing every year[1].

The practise of sport and physical exercise can be beneficial activities for the prevention and even treatment of symptoms stemming from mental disorders[2,3]. Nonetheless, elite athletes sometimes seem to be especially susceptible to presenting common mental disorders[4,5] and, in recent years, the number of athletes suffering from one emotional disorder or another seems to be rising considerably.

Consequently, scientific literature reflects the great importance that psychological factors have on both the risk of injury and recovery from injury[6,7]. Furthermore, it also reveals the importance of more integrated assessment of psychological function within the overall preparation of athletes in their training process[8].

The mental conditions of an athlete should be dealt with throughout their sports career so as to achieve optimal performance and avoid injury[9]. Several mental health indicators can de detected during the sports career of an athlete, including generic stress factors and specific factors tied to the sport in question that can increase the risk of mental health symptoms and disorders.

Sports psychology researchers have unanimously agree that sport — at all levels — exposes the athlete to high levels of stress and anxiety[10].

Numerous studies and research projects have shown that elite athletes — both those currently competing and those who have retired from competition — are linked to the deterioration of mental health, and depression in particular[11].

Finally, tools should be used to recognise mental health in athletes and to facilitate the early detection of their symptoms so as to deal with them openly. Such reviews would be justified by the fact that there are no checks that consider mental health as a fundamental factor in the sports injuries suffered by elite athletes. However, there are many partial studies that would make this review necessary for revealing the current situation of the scientific problem and future research needs, as well as psychological intervention recommendations.

The overall objective of this study is to conduct a systematic review of scientific literature to reveal which mental health indicators are most closely tied to sports injury in elite athletes. More specifically: the studies that analyse the links between mental health indicators and their ties to propensity in athletes to injure themselves; and the studies that analyse the links between sports injury and its impact on mental health indicators in athletes.

Material and method

Search Design and Strategy

Review articles have been selected for this study; systematic review, meta-analysis and narrative reviews. Documents in both Spanish and English were used.

This article contains a systematic review of scientific literature in accordance with the guidelines of *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) for greater consistency and scientific rigour.

The following English keywords were used: *athletic injuries, systematic review, elite athletes, mental health*. In Spanish, the keywords were: *lesiones deportistas, revisión sistemática, deportistas élite, salud mental*. To combine them, *and/y were* chosen as Boolean operators. Finally, a total of 28 documents from various databases published between 2016 and 2023 were selected (Table 1).

Inclusion and Exclusion Criteria

A series of inclusion and exclusion criteria were taken into consideration when conducting the systematic review. The criteria for inclusion were:

- Review articles published between 2016 and 2023.
- Review articles written in Spanish or English.
- The articles must contain a methodology section.
- The main topic of the documents must be sports injuries and mental health in elite athletes.

Books, reports, empirical articles, consensus articles and theses were excluded. Figure 1 shows a flowchart with the selection process to choose the documents for systematic review.

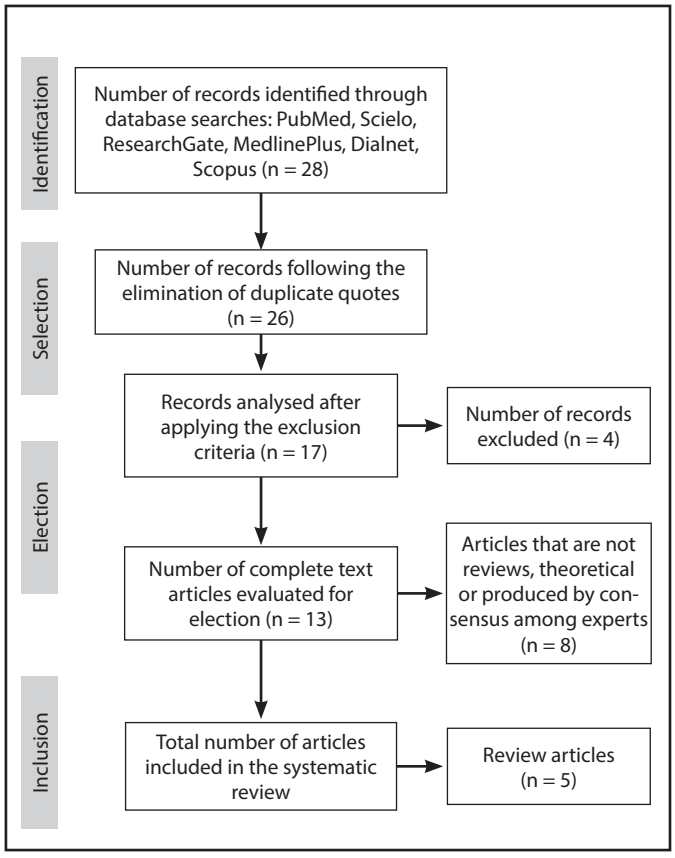
Selection of Studies and Extraction of Data

Study eligibility was determined in two steps. Step 1 involved collecting a total of 28 potentially relevant quotes. Two of them were eliminated for duplicity, leaving a total of 26 quotes. Step 2 involved applying the exclusion criteria. Nine of the quotes were eliminated at this point. We then assessed and revised the complete text of the remaining studies. Verification of the articles led to the elimination of four more quotes due to a lack of access to the complete text, meaning

Table 1. Databases consulted.

Databases	Nº of Results Obtained	Nº of Related Works	Keywords Used
Google Scholar	38	7	Mental health and sports injuries
Dialnet	12	4	Mental health and sports injuries
MedlinePlus	8	3	Mental health, sports injuries, elite athletes
PubMed	15	4	Mental health and sport injuries
Scielo	21	2	Mental health and sport injuries
Scopus	26	8	Mental health and sport injuries

Figure 1. Flowchart.



that no additional relevance could be assigned to them. As a result, our systematic review includes five original studies that provide evidence on mental health in sport and its links to sports injuries.

We searched for information in each original reviewed article on: author, year of publication, sample size, age of the subjects, characteristics of the intervention (groups, type of activity, components, programme duration, number of sessions and their duration, measurement instruments and results obtained).

Study Quality Assessment

The methodological quality of all the primary studies included was assessed. Based on a quality assessment tool used previously[12] and general recommendations on assessing the quality of primary studies, we developed a quality assessment tool designed specifically for this review. We included the following quality dimensions: (I) measurement of multidimensional perfectionism; (II) sample size; (III) research design; (IV) mental health indicators; (V) history of injuries; and (VI) sample design.

Results

Table 2 contains the selection of articles for review. With that, we will be able to examine the available scientific evidence both quantitatively and qualitatively. Furthermore, its analysis will help reveal what was observed and enable us to contribute our own results, which should verify the links between mental health and sports injuries in elite athletes.

Discussion

This study sought to analyse the existing body of knowledge on the links between sports injuries and mental health in elite athletes. Specifically:

1. Determine which studies analyse the links between mental health and the propensity of an athlete to injure themselves.
2. Analyse the links between sports injury and its impact on the mental health of athletes.

The results enable reaffirmation of the claim that injuries constitute a fundamental problem in sport due to the epidemiology thereof, reflecting a high percentage of occurrence. This demonstrates that injuries therefore constitute an inherent phenomenon in the practise of sport, as mentioned by specialised scientific literature[13], meaning that its study should be considered a fundamental issue in training and competency processes.

In terms of the first goal, the results of the review carried out indicate that a link is observed between mental health and sports injuries[14,15]. Rice[3] suggests the need to offer a mental health service to elite athletes. Of the five articles analysed, we found that mental health indicators (sleep, anxiety, stress, eating disorders, etc.) impact athletes by raising their vulnerability to injury and suffering from mental health problems[16] given that these articles provide useful information on preventing and intervening on their appearance or minimising the seriousness of the sports injury[16,17]. These factors grow if an athlete injures themselves, as it has been demonstrated that mental health plays a very important role in the response, rehabilitation and recovery from injury by the athlete[18,19].

A number of authors, such as Åkesdotter[20] and Rice[3], have highlighted risk factors related to the practise of sport at a high level, such as overtraining, exhaustion, injuries and excessive preoccupation with body weight, as well as genetic and environmental factors, and include such others as competitive failure, pain and concussion, among others. In fact, the study by Goutterbarge[2] states that athletes can face up to 600 different stress factors, such as adverse life events, conflicts with the coach or professional dissatisfaction, that can lead to psychological pathologies. On the other hand, Broodryk[21] and other authors studied the effects of competition on stress, mood and anxiety in football players. They found that physiological and psychological variables combine to contribute to the stress response during competition, meaning it is important to concentrate on high-intensity activities and to minimise fatigue as both are linked to elevated levels of cortisol and negative moods.

In terms of the second goal, such authors as Olmedilla[22] claim that footballers manifest greater levels of depression, cognitive anxiety and somatic anxiety after suffering an injury and that this would reflect the

Table 2. Reviews.

Reardon, *et al.* 2019. Various countries					
Goal	**Design**	**Data Collection System**	**Sample**	**Statistical Test**	**Main Findings**
To foster a more standardised and evidence-based approach to mental health symptoms and disorders in elite athletes, a consensus work group of the International Olympic Committee critically evaluated the current scientific situation and offered recommendations.	Systematic review	The PubMed, SportDiscus, PSycINFO, Scopus and Cochrane databases, as well as any other database considered relevant, were used.	Panel of experts consisting of 23 people from 13 countries with experience in the mental health of elite athletes.	None	The current scientific situation regarding the mental health of elite athletes suggests: that there is a lack of access to mental health services; more research and subsequent recommendations are needed to more widely identify the mental health of elite athletes. Within this context, the impact from sleep on recovery and on optimal preparedness should be considered; additional prevention strategies for mental health symptoms and disorders.
Rice, *et al.* 2019. Various countries					
Goal	**Design**	**Data Collection System**	**Sample**	**Statistical Test**	**Main Findings**
To identify and quantify the decisive factors in the anxiety symptoms and disorders experienced by elite athletes.	Systematic review and meta-analysis based on the PRISMA guidelines	Systematic search strategy. The search was conducted in the PubMed, SportDiscus, PsycINFO, Scopus and Cochrane databases.	61 studies were included in the systematic review and 27 of them were suitable for meta-analysis.	Raw data were obtained (average, SD and n) for the decisive factors in anxiety. The general sizes of the effect were estimated by means of the standardised differentiation of averages.	The decisive factors in anxiety among elite populations broadly reflect those experienced by the general population. Doctors should be aware of these general and specific decisive factors in anxiety among elite athletes.
Rice, *et al*. 2018. Australia					
Goal	**Design**	**Data Collection System**	**Sample**	**Statistical Test**	**Main Findings**
To evaluate the base of evidence with regard to the link between sports-related concussion and mental health results in athletes competing at professional and elite levels.	Systematic review based on the PRISMA guidelines	A search was conducted in six databases: PubMed, EMBASE, SportDiscus, PSycINFO, Cochrane and Cinahí.	27 studies	None	Current evidence suggests a link between sports-related concussion and the symptoms of depression in elite athletes. Causality cannot be determined at this stage of the research due to a lack of well designed prospective studies. More research is required that considers a range of mental health results in various samples of elite athletes/sports.
Souter, *et al.* 2018. UK					
Goal	**Design**	**Data Collection System**	**Sample**	**Statistical Test**	**Main Findings**
To explore the problems that affect men and mental health within the context of elite sport.	Literary review	Not reported	Review of the areas: injuries, stress, depression, anxiety, overtraining, eating disorders...	None	Major negative events in life, including injuries, can increase the risk of mental health problems in elite athletes. The risk of injury can increase when men suffer emotionally. As suggested by the literature, injuries can increase the risk of mental health problems and adverse behaviours.

(continues)

Table 2. Reviews *(continuation)*.

Putukian M, *et al.* 2016. United States					
Goal	**Design**	**Data Collection System**	**Sample**	**Statistical Test**	**Main Findings**
To reveal the current state of knowledge on the psychological response to an injury in order to direct the injured athlete to a mental health care service provider when necessary.	Narrative review	Not reported	Elite athletes aged 16-23	None	The psychological response to injury can lead to more serious mental health problems, such as depression, anxiety, eating disorders and substance abuse. Obstacles exist to the treatment of mental health problems in athletes, and track and field coaches, team doctors and other medical service providers play an essential role in the recognition and identification of athletes at risk of mental health problems.

existence of an impact from the injury on mood and pre-competition anxiety.

All the processes through which an injured athlete pass represent an adaptive effort and that effort will mean they live through specific situations of overcoming adversity without the physical capacity to which they are accustomed, especially in elite athletes who are accustomed to sport being a part of life and part of their day-to-day activity. Various negative behaviours can arise following a sports injury, such as isolating oneself, not soliciting the services of the right professional, failure to adhere to recommendations and pain[23], behaviours that can be controlled once an injury occurs. In that sense, just as stress makes a person more vulnerable to injury, the injury itself makes the subject more fragile vis-à-vis the possibility of suffering from stress[24-26]. Besides stress, other psychological and emotional processes are linked to sports injuries and directly impact the rehabilitation process in athletes[27].

The study by Zurita, *et al.,* reaffirms that injuries constitute a fundamental problem in sport due to the epidemiology thereof, reflecting a high percentage of occurrence. This demonstrates that injuries therefore constitute an inherent phenomenon in the practise of sport, as mentioned by specialised scientific literature[28,29].

In essence, we were able to detect in numerous publications how the terms "mental health", "anxiety", "sleep quality", "depression" and "stress" are mentioned by athletes, coaches and relatives within the field of sport with regard to discomfort in athletes at both psychological and physical levels.

Conclusions

This systematic review reveals that sports injuries significantly affect mental health and how they can lead to incorrect recovery in athletes and/or make them more vulnerable to further injury. Mental health is essential for correct development in athletes and is vital to their performance. Furthermore, we were able to identify how the studies researched some of their indicators separately (stress and injuries, anxiety and injuries, quality of sleep and injuries, depression and injuries) but not together. Mental health should be observed from a global perspective and its indicators should be analysed given that stress leads to anxiety, anxiety can lead to depression and all that combined can lead to poor rest and incorrect recovery due to a lack of sleep quality caused by the unease or restlessness that may manifest in athletes. Finally, mental health in athletes should be strengthened and action should be taken before problems arise through prevention programmes and the use of sports psychology as a fundamental tool for combating and/or treating it.

Conflicts of Interest

The authors declare no conflict of interest whatsoever.

Bibliography

1. Gouttebarge V, Backx FJG, Aoki H, Kerkhoffs GMMJ. Symptoms of common mental disorders in professional football (soccer) across five European countries. *J Sports Sci Med.* 2015;14:811–8.
2. Gouttebarge V, Aoki H, Lambert M, Stewart W, Kerkhoffs G. A history of concussions is associated with symptoms of common mental disorders in former male professional athletes across a range of sports. *Br J Sports Med*. 2017;51:324.2-324.
3. Rice SM, Gwyther K, Santesteban-Echarri O, Baron D, Gorczynski P, Gouttebarge V, *et al.* Determinants of anxiety in elite athletes: a systematic review and meta-analysis. *Br J Sports Med*. 2019;53:722–30.
4. Foskett RL, Longstaff F. The mental health of elite athletes in the United Kingdom. *J Sci Med Sport*. 2018;21:765–70.
5. Kilic Ö, Aoki H, Haagensen R, Jensen C, Johnson U, Kerkhoffs GMMJ, *et al.* Symptoms of common mental disorders and related stressors in Danish professional football and handball. *EJSS (Champaign)*. 2017;17:1328-34.
6. Salim J, Wadey R. Using gratitude to promote sport injury–related growth. *J Appl Sport Psychol.* 2021;33:131-50.
7. Wadey R, Roy-Davis K, Evans L, Howells K, Salim J, Diss C. Sport psychology consultants' perspectives on facilitating sport-injury-related growth. *Sport Psychol.* 2019;33:244-55.
8. Sonesson S, Kvist J, Ardern C, Österberg A, Silbernagel KG. Psychological factors are important to return to pre-injury sport activity after anterior cruciate ligament reconstruction: expect and motivate to satisfy. *Knee Surg Sports Traumatol Arthrosc*. 2017;25:1375-84.
9. Fossati C, Torre G, Vasta S, Giombini A, Quaranta F, Papalia R, *et al.* Physical exercise and mental health: The routes of a reciprocal relation. *Int J Environ Res Public Health*. 2021;18:12364.

10. Ford J, Ildefonso K, Jones M, Arvinen-Barrow M. Sport-related anxiety: current insights. *Open Access J Sports Med.* 2017;8:205-12.
11. Rice S, Parker A, Rosenbaum S, Bailey A, Mawren D, & Purcell R. Sport-related concussion and mental health outcomes in elite athletes: a systematic review. *Sports medicine.* 2018;48:447-465.
12. Grugan MC, Hill AP, Madigan DJ, Donachie TC, Olsson LF, Etherson ME. Perfectionism in academically gifted students: A systematic review. *Educ Psychol Rev*. 2021;33:1631-73.
13. Pujals C, Rubio VJ, Márquez MO, Sánchez-Iglesias I, Ruiz R. Comparative sport injury epidemiological study on a Spanish sample of 25 different sports. *Journal of Sport Psychology.* 2016;25:271-9.
14. Haugen E. Athlete mental health & psychological impact of sport injury. *Oper Tech Sports Med.* 2022;30:150898.
15. Souter G, Lewis R, Serrant L. Men, mental health, and elite sport: a narrative review. *Sports Med Open.* 2018;4:57.
16. Putukian M. The psychological response to injury in student athletes: a narrative review with a focus on mental health. *Br J Sports Med.* 2016;50:145–8.
17. Garit, JR, Surita YP, Zafra AO, Gómez-Espejo V. Psicología y lesiones deportivas: un estudio en lanzadores de béisbol. *Cuad Psicol Deporte*. 2021;21(1):102-118.
18. Cox R. *Psicología del deporte: conceptos y sus aplicaciones*. Ed. Médica Panamericana. 2008.
19. Weinberg RS, Gould D. *Foundations of sport and exercise psychology*. 2023.
20. Åkesdotter C, Kenttä G, Eloranta S, Franck J. The prevalence of mental health problems in elite athletes. *J Sci Med Sport.* 2020;23:329-35.
21. Broodryk A, Pienaar C, Edwards D, Sparks M. Effects of a soccer tournament on the psychohormonal states of collegiate female players. *J Strength Cond Res.* 2021;35: 1873-84.
22. Olmedilla A, Ortega E, Gómez JM. Influencia de la lesión deportiva en los cambios del estado de ánimo y de la ansiedad precompetitiva en futbolistas. *Cuad Psicol Deporte*. 2014;14:55–62.
23. Moo JC, Góngora EA. La lesión deportiva desde una perspectiva psicológica positiva en Yucatán (México). *Enseñanza e Investigación en Psicología*. 2017;22:127-134.
24. Ortín FJ, Garcés de los Fayos EJ, Olmedilla A. Influencia de los factores psicológicos en las lesiones deportivas. *Papeles del Psicol.* 2010;31:143–54.
25. Schinke RJ, Stambulova NB, Si G, Moore Z. International society of sport psychology position stand: Athletes' mental health, performance, and development. *Int J Sport Exerc Psychol*. 2018;16:622-39.
26. Wadey R, Day M, Cavallerio F, Martinelli L. Multilevel Model of Sport Injury (MMSI): can coaches impact and be impacted by injury? En: En R, Thelwell M, editores. *Professional Advances in Sports Coaching.* 2018.
27. Abenza L, Olmedilla A, Ortega E, Ato M, García-Mas A. Analysis of the relationship between mood states and adherence behavior in injured athletes. *Anales de Psicología*. 26(1):159-68.
28. García C, Albaladejo R, Villanueva R, Navarro E. Deporte de ocio en España: epidemiología de las lesiones y sus consecuencias *Apunts Educ. Fís. Deporte*. 2015;119:62-70.
29. Padegimas EM, Stepan JG, Stoker GE, Polites GM, Brophy RH. Epidemiology and severity of sports and recreation injuries presenting to a tertiary adult emergency department. *Phys Sportsmed.* 2016;44:263-8.

Links between Eccentric Hamstring Strength and a History of Lower Limb Injury in Colombian High-performance Athletes

Javier F. Bonilla-Briceño[1], Brayan E. Patiño-Palma[2], Mauricio Serrato Roa[3]

[1]Biólogo. MSc en Fisiología. Médico con Especialidad en Medicina del Deporte. Fundación Universitaria Sanmartín. Bogotá. Colombia. [2]Fisioterapeuta. MSc en Actividad Física y Deporte. Especialista en Estadística Aplicada. Fundación Universidad del Área Andina. Pereira. Colombia. [3]Médico con Especialidad en Medicina del Deporte. Director de la Especialidad en Medicina del Deporte. Departamento de Medicina Interna. Escuela de Medicina de la Universidad Nacional de Colombia. Bogotá. Colombia.

doi: 10.18176/archmeddeporte.00161

Received: 24/05/2023
Accepted: 10/02/2024

Summary

The main cause of injury in athletes is of muscular origin and of all those of the hamstrings it is the most important. The inadequate eccentric strength of these is a factor that is related to lower limb injuries. At the Sports Science Center of the Ministry of Sports, the eccentric strength of the hamstrings is evaluated with the Nordic test. In Colombia, it is not known if this is related to lower limb injuries in the different world-class high-performance athletes who attend there. A descriptive work was proposed with a quantitative approach and analytical phase, evaluating the pre-participation medical records of 195 athletes who underwent the Nordic test during the year 2021. The athletes analyzed were 56% men, with ages for both sexes on average of 21.5 years, with body mass indexes of approximately 22.1 k/m^2. The most frequent injury to the lower limbs was muscle (38.5%), followed by tendinopathies (27%). Of the muscle, the hamstrings were injured in 69%. An average maximum force was found for all athletes of 292.4 ± 67.06 N and a relative force of 4.52 ± 1 N/kg. The bivariate analyzes show an association between the presence of injury and lower maximum eccentric hamstring strength for both sexes. Furthermore, it was found that asymmetries less than 15% of the maximum eccentric hamstring strength were associated with a lower presence of injury. From a multivariate analysis, normative reference curves were constructed for weight, sex, and maximum eccentric strength of these athletes. It contributes to the conceptual gap of the behavior of eccentric hamstring strength and its relationship with the presence of lower limb injuries in different Colombian elite athletes.

Key words:
Sports. Performance. Leg injuries. Hamstrings. Strength. Eccentric.

Asociación entre la fuerza excéntrica de isquiotibiales con historia de lesión en miembros inferiores de atletas colombianos de alto rendimiento

Resumen

La principal causa de lesión de los deportistas es de origen muscular y de todas la de los isquiotibiales es la más importante. La inadecuada fuerza excéntrica de éstos es un factor que se relaciona con lesión de miembros inferiores. En el Centro de Ciencias del Deporte del Ministerio del Deporte se evalúa la fuerza excéntrica de los isquiotibiales con el test Nórdico. En Colombia, no se sabe si esta se relaciona con lesión de miembros inferiores en los diferentes deportistas de alto rendimiento de talla mundial que allí asisten. Se planteó un trabajo descriptivo con enfoque cuantitativo y fase analítica evaluando las historias clínicas preparticipativas de 195 deportistas a los que se les realizó el test Nórdico durante el año 2021. Los deportistas analizados 56% fueron hombres, con edades para ambos sexos en promedio de 21,5 años, con índices de masa corporal de aproximadamente 22,1 k/m^2. La lesión más frecuente en miembros inferiores fue la muscular (38,5%), seguida por las tendinopatías (27%). De la muscular, los isquiotibiales se lesionaron en el 69%. Se encontró un promedio de fuerza máxima para el total de deportistas de 292,4 ± 67,06 N y una fuerza relativa de 4,52 ± 1 N/kg. Con los análisis bivariados se evidencia una asociación entre la presencia de lesión y menor fuerza máxima excéntrica de isquiotibiales para ambos sexos. Además, se encontró que las asimetrías menores al 15% de la fuerza máxima excéntrica de isquiotibiales se asociaron con menor presencia de lesión. A partir de un análisis multivariado se construyeron las curvas de referencia normativas para peso, sexo, fuerza excéntrica máxima de estos deportistas. Se aporta al vacío conceptual del comportamiento de la fuerza excéntrica de isquiotibiales y su relación con la presencia de lesión de miembros inferiores en diferentes atletas élite colombianos.

Palabras clave:
Deportes. Rendimiento. Lesión de extremidades. Isquiotibiales. Fuerza. Excéntrica.

SEMED Research Award 2023

Correspondence: Javier F. Bonilla-Briceño
E-mail: fbonillaj@unal.edu.co

Introduction

Skeletal muscle tissue in non-athlete humans accounts for 40-50% of body weight in men and 25-35% in women. However, this figure is usually far higher in athletes and, in weightlifters, can reach up to 65%[1]. Athletes are highly susceptible to injury due to their number of daily training or competition hours, and muscle is the most commonly compromised tissue[2,3]. That said, the susceptibility of each muscle group will depend on the characteristics and demands of the specific sport being practised[2,4,5].

Muscle injury in athletes is associated with numerous risk factors. It occurs in the lower limbs for a sizeable proportion of athletes, mainly the hamstrings, and significant attention is given to this matter due to the high incident rates and prevalence. In light of the above, hamstring muscle injury (HMI) has aroused strong interest in the scientific community due to the evidence pointing to especially high occurrence in team sports[3,6,7]. This type of injury accounts for 12% of all injuries reported by 17 teams of the various European football (soccer) leagues during the first decade of this century[6]. More recently, that figure doubled to 24% for the seasons running from 2016-202[18]. Furthermore, it accounts for 16% in rugby[9] and 13% in Australian football[10]. For the various sports clubs involved, this represents a high financial cost due not only to the rehabilitation and salary of players but also to the lack of availability in these athletes at key moments because they are unfit to play due to injury[6]. In addition, a recurrence rate of up to 18% has been reported at two months[8], which only aggravates the problem.

Because it is a multicausal event, answers are sought to the questions of how and to what extent for each sport and population group certain risk factors may impact most heavily. A lack of eccentric strength is one of those factors, as it has been identified as creating a risk of muscle injury; especially in those sports with high intensity running requirements such as football[11] (soccer) and basketball[12]. Various devices currently exist for the assessment of eccentric hamstring strength that exceeds the limitations of isokinetic dynamometry[13]. One of them is the NordBord from VALD Performance®. With the Nordic hamstring exercise, the device can register the maximal eccentric hamstring strength and the imbalance between limbs with an assessment time of less than five minutes per athlete. Although this device is a reliable measure of eccentric knee flexor strength during Nordic hamstring exercise[13], no literature currently exists that examines whether the measurements produced by this device predict future HMI risk in an athlete. Nonetheless, it is recognised as a factor that reduces injury[14] when training with this exercise.

Nordic exercise used to work the hamstrings eccentrically is currently one of the most closely studied exercises in literature, establishing it as a suitable exercise for HMI prevention[14,15] and it could be reasonably expected that the measurement of eccentric hamstring strength during this exercise can provide information on HMI risk in the future.

Finally, this study sought to determine whether the magnitude of eccentric hamstring strength and imbalance thereof between limbs is associated with a history of injury in high-performance athletes in different sports. Furthermore, it also sought to determine the benchmark values for eccentric strength in this population type. The main hypothesis was that the athletes who suffered an HMI would show lower levels of strength and greater imbalance between the limbs in terms of eccentric hamstring strength when compared with their counterparts with no history of such injury.

Material and method

A retrospective study is proposed under a quantitative approach with an analytical stage that was approved by the ethics committee of the National University of Colombia in minutes 018-165 of 29 September 2021. All the preparticipation assessments conducted on high-performance athletes attending the Sports Science Centre of the Colombian Ministry of Sport between 1 January and 30 November 2021 were analysed.

Of the 350 preparticipation assessments, 198 records were selected as they included a detailed history of injury, complete results from the Nordic test and the medical diagnosis reached by an orthopaedic and/or sports medicine professional in those athletes with a history of injury.

Assessment of Eccentric Hamstring Strength

The assessment of eccentric hamstring strength was determined via the NordBord Hamstring Testing System from VALD® Performance. Participants knelt on the NordBord platform with their ankles secured immediately over the lateral malleolus using individual ankle braces that link to uniaxial load cells on the device. Following a warm-up series, participants performed a series of three maximal repetitions of the Nordic exercise, with 20-second rests between the various attempts. The athletes were told to gradually lean forwards as slowly as possible while resisting this movement as much as possible with both legs, maintaining their core and hips in a neutral position and their hands crossed over their chest[13]. Participants were vocally urged to make the maximum effort in each repetition. A test was considered acceptable when the production of force reached a defined peak (indicative of maximum eccentric strength), followed by a rapid reduction in force, which would occur when the athlete could no longer apply or generate more force.

Data Analysis

The data on eccentric hamstring strength for each limb were exported from the online platform of VALD Performance® where peak strength for the three repetitions of each limb (left and right) was identified. Eccentric hamstring strength was reported in absolute terms (N) and in relative terms vis-à-vis body mass (N·kg-1), helping to determine an average of the maximum force levels in the three repetitions for each limb[13].

The imbalance between limbs in terms of eccentric hamstring strength was calculated as a proportion of the force differences between the limbs (left and right). This was carried out using the method recommended by Impellizeri, *et al*.[16]. A negative percentage imbalance indicated that the left limb was stronger than the right, while a positive percentage indicated the opposite.

Statistical analysis

Central tendency and dispersion measurements were determined for those variables of a quantitative nature and frequency distributions for those variables of a categoric or qualitative nature, all with their respective confidence intervals of 95%. A bivariate analysis was conducted to compare age, height, weight, limb imbalance percentage and eccentric strength between athletes with and without a history of injury. The T student and Mann–Whitney U statistics were used to determine the differences based on the distribution of the data for analysis, which were determined using the Kolmogorov-Smirnov statistic.

The magnitude of effect for the differences revealed was calculated using the Cohen's D statistic, which was determined using G Power software version 3.1. The following convention was used for analysis: values below 0.2 were considered to reflect no effect; between 0.21 and 0.49 reflect a small effect; between 0.5 and 0.7 indicate a moderate effect; and, finally, values over 0.8 indicate a major effect[17].

Finally, the benchmark values proposed in this study were constructed from the Box-Cox Cole and Green (BCCG) distribution using the method known as minimums squared[18], which can be found in the library of additive models generalised by location, scale and form[19] in the R Studio statistics software.

Results

The characteristics of the athletes who were assessed can be found in Table 1. In short, the sample mostly consisted of male athletes aged on average 21 + 4.6 years, with an average height of 171.9 + 9.5 centimetres, an average weight of 65.7 + 12.8 kilograms and a body mass index (BMI) of 22.1 + 3 kg/m^2.

Different sports were included in the analysis. However, athletics, volleyball and ultimate (73.7%) accounted for the majority of the sample included in this study.

Finally, a history of lower limb injury was reported in 97 of the 198 preparticipation assessments reviewed, with muscle injury being the most prevalent (38.5%) followed by tendinopathies (27%).

Figure 1 shows the behaviour in terms of peak strength or maximum strength, relative maximum strength and asymmetry with regard to the history of injury and gender. It is clear that the male gender presents higher levels of strength and similar symmetry values when compared with the female gender. However, when disregarding this factor in terms of history of injury, it can be seen that both men and women show statistically significant differences in peak strength, thereby determining that the athletes with no history of injury present higher levels of strength than those with a history of lower limb injury. Nonetheless, when analysing relative strength, significant differences can only be seen in the male gender; revealing that the athletes presenting a history of injury perform worse in terms of strength when compared with those having no history. In contrast, when analysing asymmetry, it can be seen that significant differences exist in the female gender only, thereby showing that there is greater asymmetry in female athletes with a history of injury.

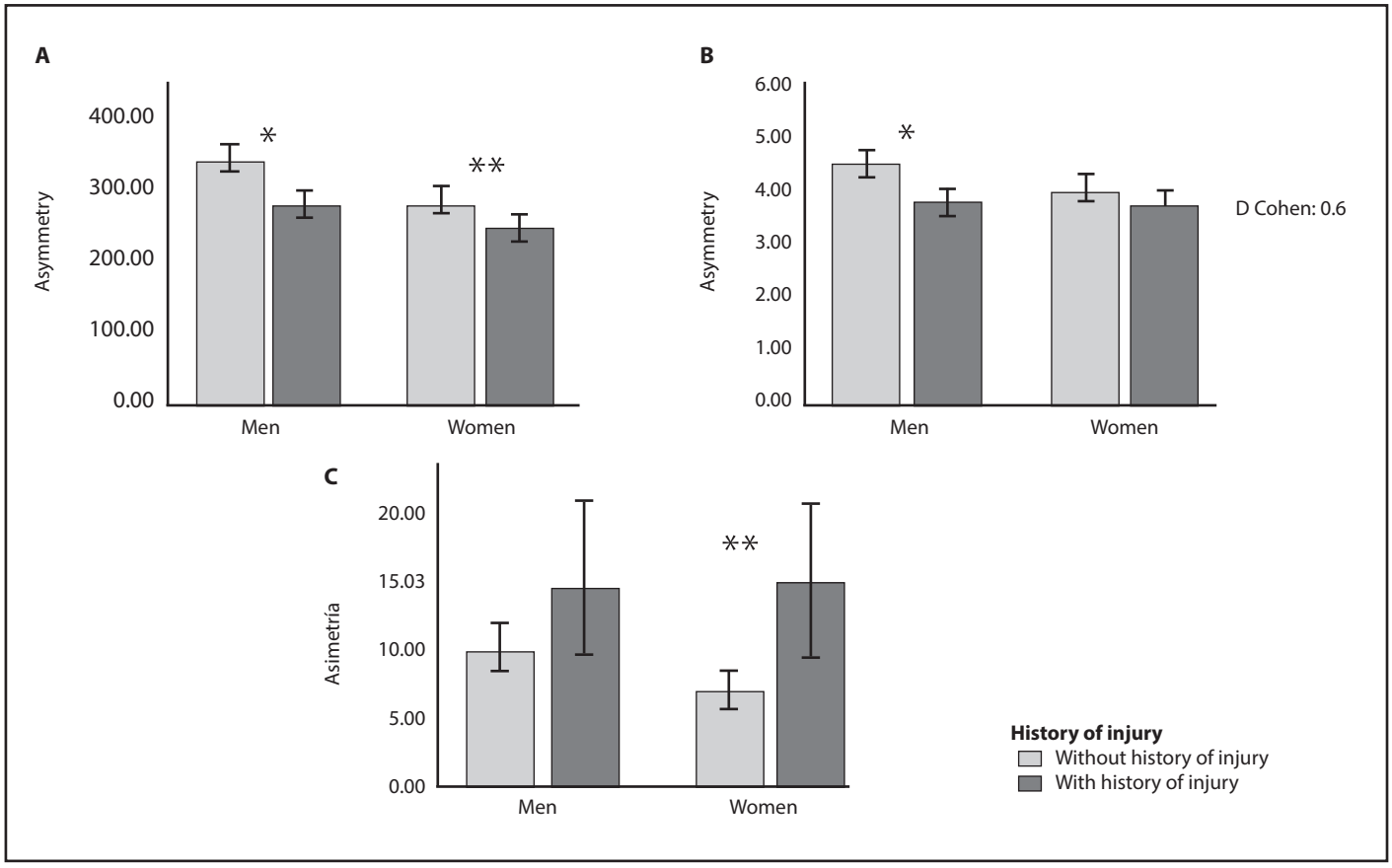
Table 2 shows the results obtained from the assessment of eccentric hamstring strength, the age and the BMI when taking the history of injury into account. An average maximum strength for all the athletes was determined at 292.4 + 67.06 N and a relative strength of 4.52 + 1 N/kg. However, it is worth noting that performance in strength (maximum strength, average strength across the three Nordbord test attempts and relative strength) is considerably lower in the athletes with a history of injury, observing worse performance results when compared with the athletes without a history of injury.

Table 1. Characteristics of the sample.

Variable		Frequency	%	CI 95%
Gender	Male	110	55.6	48.3 - 62.5
	Female	88	44.4	37.4 - 51.6
History of injury	Yes	97	49	41.8 - 56.1
	No	101	51	43.8 - 58.1
Dominance	Right	172	86.8	81.3 - 91.2
	Left	26	13.1	8.7 - 18.6
Type of injury	Bone	7	7.35	2.9 - 14.4
	Muscle	32	38.5	24.0 - 43.6
	Ligament	18	18.8	11.5 - 28.0
	Cartilage	8	8.3	3.6 - 15.7
	Tendon	26	27.1	18.5 - 37.1
Sport	Martial arts	1	0.5	0.01 - 2.7
	Athletics	76	38.4	31.5 - 45.5
	Basketball	1	0.5	0.01 - 2.7
	BMX	7	3.5	1.4 - 7.1
	Boxing	12	6.1	3.1 - 10.3
	Cycling	9	4.5	2.0 - 8.4
	Fencing	1	0.5	0.01 - 2.7
	Football	1	0.5	0.01 - 2.7
	Gymnastics	4	2.0	0.5 - 5.0
	Skating	2	1.0	0.12 - 3.6
	Weightlifting	9	4.5	2.0 - 8.4
	Squash	4	2.0	0.5 - 5.0
	Taekwondo	1	0.5	0.01 - 2.7
	Ultimate	41	20.7	15.2 - 27.0
	Volleyball	29	14.6	0.01 - 2.7

Source: Authors.
%: percentage; IC 95%: Confidence interval at 95%.

Figure 1. Comparison of eccentric strength and asymmetry with history of injury and gender. 1A. Comparison of maximum eccentric strength with history of injury and gender. 1B. Comparison of relative maximum eccentric strength with history of injury and gender. 1C. Comparison of asymmetry with history of injury and gender.



Source: Authors
*Indicates statistical significance for the Mann-Whitney U test statistic; **Indicates statistical significance for the T student statistic; Cohen's D: Magnitude of effect for the statistical differences.

Table 2. Strength characteristics based on history of injury.

Variable	With a history of injury			Without a history of injury			P value	Cohen's D	Total		
	Average	SD	CI 95	Average	SD	CI 95			Average	SD	CI 95
Maximum strength (N)	267.3	50.29	257.1 - 277.4	316.5	72.34	302.5 – 330.8	0.000**	0.78	292.41	67.06	283.0 - 301.8
Relative strength (N/kg)	4.2	0.89	4.0 - 4.3	4.8	1.01	4.6 - 5.0	0.000*	0.63	4.52	1.00	4.3 - 4.6
Average strength (N)	275.1	63.7	262.3 - 288.0	298.1	68.8	284.5 – 311.7	0.012**	0.34	286.91	67.22	277.4 - 296.3
BMI (kg/m^2)	22.0	2.8	21.5 - 22.6	22.1	3.2	21.5 - 22.8	0.854	0.003	22.11	9.57	21.6 - 22.5
Age (Years)	22.6	5.1	21.6 - 23.7	20.1	3.7	19.4 - 20.9	0.001**	0.56	21.41	4.6	20.7 - 20.0

Source: Authors.
*T student; **Mann-Whitney U test.
N: Newton; N/kg: Newton per kilogram of weight; CI 95: Confidence interval at 95%; SD: Standard deviation.

Table 3. Link between history of injury and asymmetry.

		History of injury		P value	RR
		With a history (%)	Without a history (%)		
Asymmetry	Asymmetry > 15%	20.6	9.9	0.035	1.45
	Asymmetry > 15%	79.4	90.1		

Source: Authors.
RR: Relative risk; %: Percentage.

Table 4. Benchmark values for maximum eccentric strength.

Benchmark values for men (N)							
Weight (kg)	**-3SD**	**-2SD**	**-1SD**	**0**	**1SD**	**2SD**	**3SD**
40 – 59	67.0	165.5	242.9	301.6	349.9	391.9	429.4
60 – 79	103.5	209.1	285.4	344.7	394.4	438.1	477.4
80 – 100	110.6	189.0	305.9	394.8	466.7	528.2	538.7
+ 100	115.5	196.6	352.6	473.6	570.1	651.8	723.7
Benchmark values for women (N)							
Weight (kg)	**-3SD**	**-2SD**	**-1SD**	**0**	**1SD**	**2SD**	**3SD**
40 – 59	123.3	166.9	209.4	251.0	292.0	332.3	372.2
60 – 79	119.7	175.1	228.7	281.0	332.4	383.0	433.0
+ 80	183.0	207.3	231.2	294.9	335.2	390.4	441.3

Source: Authors.
SD: Standard deviation; N: Newton; Kg: Kilograms.

Table 3 shows the asymmetry and history of injury variables, which present a statistically significant link. Based on the calculated relative risk (RR), it can be determined that having asymmetry of more than 15% is linked to having a history of injury. Hence, this result allows us to state that asymmetries of over 15% may become a risk factor for HMI in high-performance athletes.

As is common in this kind of studies, a combination of different processes was used that involve subjective reasoning, statistical analysis and a literary review to establish the various benchmark values for eccentric hamstring strength (cut-off points) in the population of high-performance athletes. Figure 2 shows the percentiles for maximum hamstring strength measured with the NordBord while considering the body weight of the athletes. These data were the basis for the benchmark values shown later.

After adjusting the data, the hyperparameters were determined and selected using the BCCG model, via which the values for eccentric strength according to body weight were standardised and predicted.

In light of the above, Table 4 shows the benchmark values in N discriminated by gender and determined according to the percentile behaviour of maximum eccentric hamstring strength in the sample assessed (Figure 2). For a better understanding of the results shown in the Table, it is proposed that the values located between +/- one SD be values considered as normal. Based on the above information, a male athlete of over 100 kg with a maximum hamstring strength of 300 N is proposed as an example. Based on the determined values, this athlete would be below normal performance of the population.

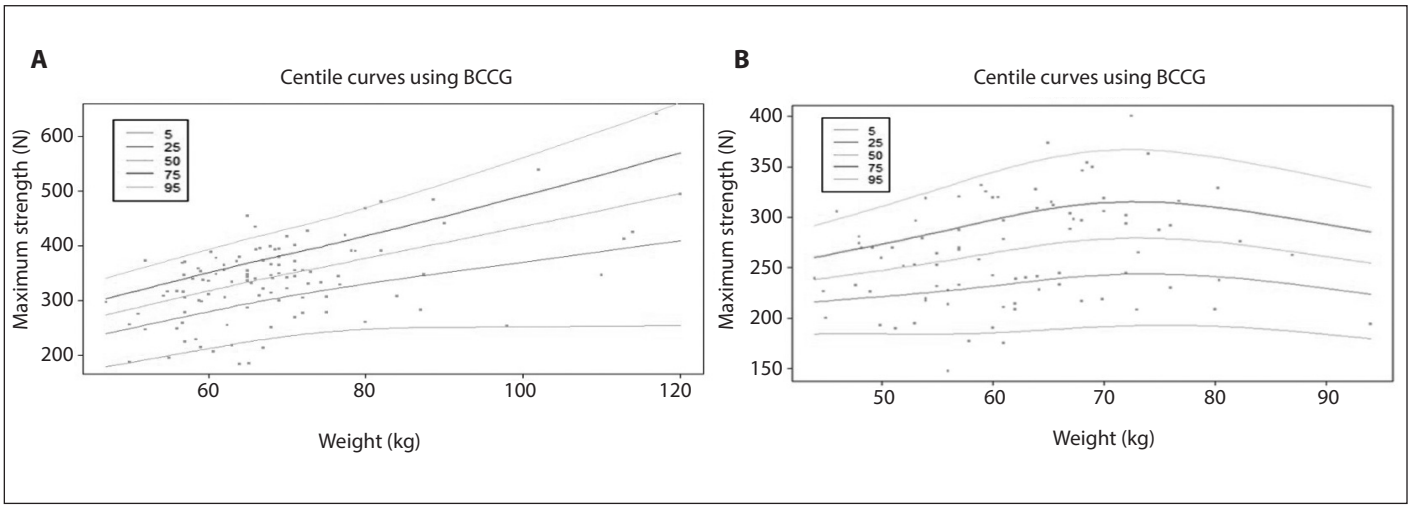
Discussion

This project was conducted with high-performance athletes forming part of the Colombian national teams for the period January-November 2021. The main findings were: firstly, that athletes with no history of injury present higher levels of strength when compared with those with a history of lower limb injury. Secondly, women with asymmetries of over 15% are those female athletes with a history of injury. Thirdly, that performance in strength (maximum strength, average strength across the three Nordbord test attempts and relative strength) is considerably lower in those athletes with a history of injury given that worse performance results were observed when compared with those athletes with no history of injury. Furthermore, by virtue of the need to have benchmark hamstring strength values in sports other than football, an initial approach is provided to benchmark tables for maximum hamstring strength in men and women for our population.

57% of all the assessments conducted in this period were taken into consideration. The others were mainly discarded due to errors in performing the Nordic exercise or due to incomplete information.

15 different sports are represented, with volleyball, ultimate and athletics accounting for 74.3%. It is worth mentioning that only one

Figure 2. Eccentric strength percentiles. 2A. Maximum eccentric strength percentiles for men. 2B. Maximum eccentric strength percentiles for women.



Source: Authors.
BCCG: Box Cox Cole and Green model.

footballer was assessed, thereby lending added relevance to this project because this is the sport in which the most studies on lower limb muscle injury are conducted[7] and even more so when considering that the small amount of information published in countries such as Colombia relates to football[20] (Table 1).

The athletes assessed in this study were young people with an average age of 21 + 4.6 years, with a balanced distribution in terms of gender similar to that reported in the study by Schmidt-Olsen, *et al.*[21]. The number of injuries in young footballers seems to increase with age. The 17-18 years age group seems to have a similar or even higher incident rate when compared with adults, this result coinciding with that reported by numerous authors[22,23]. The same finding was reported in a study of injuries during 12 international tournaments in players from different age and ability level categories[24]. Within this context, it can be seen that the famous "sport specialisation" in children and teenagers is linked to a greater risk of injury, with muscle injury remaining the most significant[25]. In light of the above, it is worth linking the age at which training begins in a single sport with the increase in risk of muscular injury and, more specifically, hamstring injuries in South American countries, where the development of this type of research in high-performance sport is precarious.

In this study, the main injuries were muscular (38.5%) (data not shown) as reported by, Alonso *et al.* (48%)[26] and Zahínos, *et al.* (2010)[27], among others, in football, where the highest frequency of injury was muscular, and up to 80% of the total, followed by joint, tendon and bone[27].

In this research, hamstring injury accounted for 69% of all lower limb muscle injuries; i.e. the most common by far. This has been clearly shown by numerous studies around the world and for many athletes[28], such as Judo[29], basketball[30], beach football[31], baseball[32], and, as stated above, football, where it continues to increase, which is why growing attention is being paid to the topic[8].

In terms of the physical qualities, strength and muscle power are the physiological basis for action in each muscle-bone unit. Furthermore, training these qualities increases performance and reduces the risk of injury in an athlete[33]. One of the main functions of the muscle group at the back of the thigh has been recognised as tied to the development of eccentric contraction. This type of contraction is associated with a higher risk of injury[34]. Describing and establishing the behaviour behind the causes of hamstring injuries through the assessment of eccentric strength will in turn help, to some extent, resolve one of the main causes of lower limb muscle injury for a good number of athletes.

The eccentric hamstring muscle strength in N that was found via the Nordic test was higher in men (328.48 N) than in women (260 N) (Figure 1). In men, it was similar to that reported by Quiceno, *et al*. in a professional football team (339 N) in Colombia[20].

A number of postulated risk factors exist for injury of muscular origin but few have been studied as in depth as strength. As stated above, strength is one of the physical qualities that, when trained, reduces the risk of injury and improves performance in athletes[35]. However, in the case of lower limbs, strength symmetry is another factor that is tied to injury[36]. Better tools are therefore needed that are capable of not only reporting unilateral strength but also bilateral strength so as to enable an ongoing assessment of the various expressions of strength and thus conduct adequate monitoring of an athlete over the course of a season.

Within these expressions of strength, maximum strength (the ability to provide maximum strength with a simple action and under specific conditions)[37] — which, for this project, was recorded using the Nordic

test — has been recognised as a characteristic of strength susceptible to constant assessment and with sufficient evidence to be considered as an injury risk factor, such as is the case when it is diminished for a type of specialist sport and a type of athlete in particular. There is a large body of literature supporting the use of the Nordic test and one of the variables — maximum strength, obtained from the software — to assess hamstring muscles[12].

In this research, it was possible to establish that a history of weakness or asymmetric activation in hamstring strength was linked to injury in this same muscle group (Table 2). Other authors, such as Opar, *et al.*, 2013[13] and Lee, *et al.*, 2009[38] have been able to show how a reduction in maximum or isometric eccentric strength is tied to injury risk or re-injury in footballers. Similarly, asymmetry continues to be a factor that should be taken into consideration and should always be examined whenever lower limb muscle strength is assessed. It was possible to link asymmetry values of over 15% to injury.

Finally, an initial approach is offered for local athletes in various sports, with which a series of benchmark values was established for maximum eccentric hamstring strength (Figure 2, Table 4) using the internationally widespread Nordic test and from which a few measurements already exist, only for professional football in Colombia[20,39]. Producing benchmark values is always a challenge. However, the intention is to use athletes from the national teams as a model in order to enable the highly necessary assessment and evaluation process to be begun for monitoring athletes before, during and after the season.

This research provides a context for the complex dynamic model for injury in sport, in which changes to strength form part of the already recognised "predisposed athlete". It also seeks to highlight the relevance of engaging in local research to establish behaviours by the various factors in athletes, both intrinsic and extrinsic, which should be continuously monitored so as to underpin good performance by our high-performance athletes.

In conclusion, a suitable support process should be created among players, coaches and biomedical teams so that proper work can be done on the process to prevent muscle injury, which continues to be a major reason why a high number of training and competition hours are lost, in turn impacting the health of high-performance athletes.

More studies like this one are needed to develop high-performance sport, ranging from the reserves through to professional medallists.

Conflict of Interest

The authors declare no conflict of interest whatsoever.

Bibliography

1. Spenst LF, Martin AD, Drinkwater DT. Muscle mass of competitive male athletes. *J Sports Sci*. 1993;11(1):3–8.
2. Heiderscheit BC, Sherry MA, Silder A, Chummanov ES, Thelen DG. Hamstring strain injuries: Recommendations for diagnosis, rehabilitation, and injury prevention. *J Orthop Sports Phys Ther.* 2010;40(2):67–81.
3. Liu H, Garrett WE, Moorman CT, Yu B. Injury rate, mechanism, and risk factors of hamstring strain injuries in sports: A review of the literature. *Journal of Sport and Health Science*. 2012;1:92-101.
4. Chavarro-Nieto C, Beaven M, Gill N, Hébert-Losier K. Hamstrings injury incidence, risk factors, and prevention in Rugby Union players: a systematic review. *Physician and Sportsmedicine.* 2023;51:1-19.
5. Chu SK, Rho ME. Hamstring injuries in the athlete: Diagnosis, treatment, and return to play. *Curr Sports Med Rep.* 2016;15(3):184-90.
6. Ekstrand J, Hägglund M, Waldén M. Injury incidence and injury patterns in professional football: The UEFA injury study. *Br J Sports Med.* 2011;45(7):553-8.
7. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). *Am J Sports Med*. 2011;39(6):1226-32.
8. Ekstrand J, Bengtsson H, Walden M, Davison M, Hagglund M. Still poorly adopted in male professional football: but teams that used the Nordic Hamstring Exercise in team training had fewer hamstring injuries-a retrospective survey of 17 teams of the UEFA Elite Club Injury Study during the 2020-2021 season. *BMJ Open Sport Exerc Med.* 2022;8(3):e001368.
9. Brooks JHM, Fuller CW, Kemp SPT, Reddin DB. Epidemiology of injuries in English professional rugby union: Part 1 match injuries. *Br J Sports Med*. 2005;39(10):757-66.
10. Elliott MCCW, Zarins B, Powell JW, Kenyon CD. Hamstring muscle strains in professional football players: A 10-year review. American Journal of Sports Medicine. *Am J Sports Med.* 2011;39:843-50.
11. Chebbi S, Chamari K, Van Dyk N, Gabbett T, Tabben M. Hamstring Injury Prevention for Elite Soccer Players. *J Strength Cond Res*. 2020.
12. Okoroha KR, Conte S, Makhni EC, Lizzio VA, Camp CL, Li B, *et al*. Hamstring Injury Trends in Major and Minor League Baseball: Epidemiological Findings From the Major League Baseball Health and Injury Tracking System. *Orthop J Sport Med.* 2019;7(7).
13. Opar DA, Piatkowski T, Williams MD, Shield AJ. A novel device using the nordic hamstring exercise to assess eccentric knee flexor strength: A reliability and retrospective injury study. *J Orthop Sports Phys Ther.* 2013;43(9):636-40.
14. Cuthbert M, Ripley N, McMahon JJ, Evans M, Haff GG, Comfort P. The Effect of Nordic Hamstring Exercise Intervention Volume on Eccentric Strength and Muscle Architecture Adaptations: A Systematic Review and Meta-analyses. *Sports Medicine*. 2020;50:83-99.
15. Šarabon N, Marušič J, Marković G, Kozinc Ž. Kinematic and electromyographic analysis of variations in Nordic hamstring exercise. *PLoS One.* 2019;14(10).
16. Impellizzeri FM, Bizzini M, Rampinini E, Cereda F, Maffiuletti NA. Reliability of isokinetic strength imbalance ratios measured using the Cybex NORM dynamometer. *Clin Physiol Funct Imaging*. 2008;28(2):113-9.
17. Ledesma R, Macbeth G, de Kohan NC. Tamaño del efecto: Revisión teórica y aplicaciones con el sistema estadístico vista. *Rev Latinoam Psicol.* 2008;40(3):425-39.
18. Cole TJ, Green PJ. Smoothing reference centile curves: The lms method and penalized likelihood. *Stat Med*. 1992;11(10):1305-19.
19. Stasinopoulos DM, Rigby RA. Generalized additive models for location scale and shape (GAMLSS) in R. *J Stat Softw*. 2007;23(7):1-46.
20. Quiceno C, Mantilla A, Iván J, Samudio MA, del Castillo D. Perfil de la Fuerza Muscular de Isquiotibiales en Jugadores de Fútbol de la Liga Profesional Colombiana Monitorizado con Tecnología Nordbord. *Rev Kronos*. 2020;19(2):1.
21. Schmidt-Olsen S, Jørgensen U, Kaalund S, Sørensen J. Injuries among young soccer players. *Am J Sports Med*. 1991;19(3):273-5.
22. Peterson L, Junge A, Chomiak J, Graf-Baumann T, Dvorak J. Incidence of football injuries and complaints in different age groups and skill-level groups. *Am J Sports Med.* 2000;28(5 SUPPL).
23. Inklaar H, Bol E, Schmikli SL, Mosterd WL. Injuries in male soccer players: Team risk analysis. *Int J Sports Med.* 1996;17(3):229-34.
24. Junge A, Dvorak J. Soccer injuries: a review on incidence and prevention. *Sports Med.* 2004;34(13):929-38.
25. Jayanthi NA, Post EG, Laury TC, Fabricant PD. Health consequences of youth sport specialization. *J Athl Train*. 2019;54:1040-9.
26. Alonso JM, Edouard P, Fischetto G, Adams B, Depiesse F, Mountjoy M. Determination of future prevention strategies in elite track and field: Analysis of Daegu 2011 IAAF Championships injuries and illnesses surveillance. *Br J Sports Med*. 2012;46(7):505-14.
27. Zahínos JI, Salinero Martín JJ. Epidemiological study of the injuries, the processes of readaptation and prevention of the injury of anterior cruciate ligamento in the professional football. *J Sport Heal Res.* 2010;2(2):7.
28. Silvers-Granelli HJ, Cohen M, Espregueira-Mendes J, Mandelbaum B. Hamstring muscle injury in the athlete: State of the art. *Journal of ISAKOS*. 2021;6:170-81.
29. Kurosawa H. Complete avulsion of the hamstring tendons from the ischial tuberosity. a report of two cases sustained in judo. *Br J Sports Med.* 1996;30(1):73-4.

30. Meeuwisse WH, Sellmer R, Hagel BE. Rates and risks of injury during intercollegiate basketball. *Am J Sports Med*. 2003;31(3):379-85.
31. Elliott MCCW, Zarins B, Powell JW, Kenyon CD. Hamstring muscle strains in professional football players: A 10-year review. *Am J Sports Med.* 2011;39:843-50.
32. Zachazewski J, Silvers H, Li B, Pohlig R, Ahmad C, Mandelbaum B. Prevalence of hamstring injuries in summer league baseball players. *Int J Sports Phys Ther*. 2019; 14(6):885-97.
33. Llurda-Almuzara L, Labata-Lezaun N, López-De-celis C, Aiguadé-Aiguadé R, Romaní-Sánchez S, Rodríguez-Sanz J, *et al.* Biceps femoris activation during hamstring strength exercises: A systematic review. *Int J Environ Res Public Health*. 2021;18(16).
34. Silvers-Granelli HJ, Cohen M, Espregueira-Mendes J, Mandelbaum B. Hamstring muscle injury in the athlete: State of the art. *J ISAKOS*. 2021;6:170-81.
35. Suchomel TJ, Nimphius S, Stone MH. The Importance of Muscular Strength in Athletic Performance. *Sports Med*. 2016; 46:1419-49.
36. Yanci J, Camara J. Bilateral and unilateral vertical ground reaction forces and leg asymmetries in soccer players. *Biol Sport.* 2016;33(2):179-83.
37. James LP, Talpey SW, Young WB, Geneau MC, Newton RU, Gastin PB. Strength Classification and Diagnosis: Not All Strength Is Created Equal. *Strength Cond J*. 2023;45(3):333–41.
38. Lee MJC, Reid SL, Elliott BC, Lloyd DG. Running biomechanics and lower limb strength associated with prior hamstring injury. *Med Sci Sports Exerc.* 2009;41(10):1942–51.
39. Franchi M V., Ellenberger L, Javet M, Bruhin B, Romann M, Frey WO, *et al.* Maximal eccentric hamstrings strength in competitive alpine skiers: Cross-sectional observations from youth to elite level. *Front Physiol*. 2019;10(88).

Impact of CrossFit® practice on pelvic floor dysfunction: a systematic review

Nuria Romero-Parra[1], Mónica Rodríguez-Faggionato[2], Miguel A. Rojo-Tirado[3]

[1]Doctor in Physical Activity and Sports Science. Department of Physical Therapy, Occupational Therapy, Rehabilitation and Physical Medicine. Faculty of Health Sciences. Universidad Rey Juan Carlos. LFE Research Group. Department of Health and Human Performance. Faculty of Physical Activity and and Sport Sciences (INEF). Universidad Politécnica de Madrid. [2]Graduated in Physical Activity and Sports Science. Faculty of Physical Activity and Sport Sciences (INEF). Universidad Politécnica de Madrid. [3]Doctor in Physical Activity and Sports Science. LFE Research Group. Department of Health and Human Performance. Faculty of Physical Activity and Sport Sciences (INEF). Universidad Politécnica de Madrid.

doi: 10.18176/archmeddeporte.00162

Received: 02/06/2023
Accepted: 22/02/2024

Summary

Introduction: CrossFit® is an sport modality that involves high-impact and intense exercise, gymnastic movements and weightlifting, whose practice has achieved great popularity in recent years, despite the high prevalence of urinary or fecal incontinence (UI e FI) associated to this practice. Therefore, the objective of this study was to conduct a systematic review of the literature to understand the impact of CrossFit® on pelvic floor dysfunction compared to other exercise modalities.
Material and method: Following PRISMA (Preferred Reported Items for Systematic Reviews and Meta-Analysis) guidelines, a search was conducted in scientific databases. A total of 7 studies out of the 53 obtained were qualitatively evaluated and selected for the systematic review.
Results: Stress UI seemed to be greater in female CrossFit® participants, than in female kickboxing, bootcamp, aerobic exercise and no CrossFit® practitioners, and also in comparison to sedentary women ($P<0.05$). Running was suggested to produced higher FI than CrossFit® ($P<0.001$), while no differences were observed in intra-abdominal pressure and pelvic floor contraction capacity through pelvic examination between female CrossFit® participants and women who practice light exercise, non-CrossFit® practitioners and sedentary women ($P<0.05$).
Conclusion: CrossFit® practice appears to favor IU in a greater extent than other exercise modalities but not FI which seem to be more prevalent with running practice, although differences between exercise modalities were not observed through direct examination of pelvic floor contraction. Further studies are needed to clarify these findings, defining more accurately the assessment instruments, influencing factors and control groups.

Key words:
Urinary incontinence. Fecal incontinence. Exercise training. High-intensity interval training. Pelvic floor disorders.

Impacto de la práctica de CrossFit® en la disfunción del suelo pélvico: una revisión sistemática

Resumen

Introducción: CrossFit® es una modalidad deportiva que engloba ejercicio de alta intensidad e impacto, movimientos gimnásticos y halterofilia, cuya práctica ha alcanzado una gran popularidad en los últimos años, a pesar de la elevada prevalencia de incontinencia urinaria y fecal (IU e IF) a la que se asocia esta práctica. Por ello, el objetivo de este trabajo fue realizar una revision sistemática de la literatura para examinar el impacto del CrossFit® en la disfunción del suelo pélvico comparado con otras modalidades de ejercicio.
Material y método: Siguiendo las directrices PRISMA (Preferred Reported Items for Systematic Reviews and Meta-Analysis) se realizó una búsqueda en bases de datos científicas. De un total de 53 estudios, 7 fueron evaluados cualitativamente y seleccionados para la revisión sistemática.
Resultados: La IU de esfuerzo pareció ser mayor en mujeres que practicaban CrossFit® que en aquellas que practicaban kickboxing, bootcamp, ejercicio aeróbico o que no practicaban CrossFit®, y también mayor que en mujeres sedentarias ($p<0,05$). Correr parecía provocar mayor IF que la práctica de CrossFit® ($p<0,001$), mientras que no se observaron diferencias en la presión intra-abdominal y en la capacidad de contracción del suelo pélvico a través de examen físico entre mujeres que practicaban CrossFit® y aquellas que no practicaban CrossFit® o que practicaban ejercicio ligero o eran sedentarias ($p<0,05$).
Conclusión: La práctica de CrossFit® parece favorecer la IU en mayor medida que otras modalidades de ejercicio, pero no la IF, que pareció ser mayor con la práctica de carrera, aunque no se observaron diferencias entre modalidades de ejercicio mediante el examen directo de la capacidad de contracción del suelo pélvico. Se necesitan más estudios para aclarar estos resultados, definiendo con mayor precisión los instrumentos de evaluación, los factores influyentes y los grupos de control.

Palabras clave:
Incontinencia urinaria. Incontinencia fecal. Entrenamiento físico. Entrenamiento interválico de alta intensidad. Alteraciones del suelo pélvico.

Correspondence: Nuria Romero Parra
E-mail: nuria.romero@urjc.es

Introduction

The pelvic floor is a structure formed by muscles, fascia, and ligaments whose main mission is to support other pelvic structures (urinary bladder, urethra, rectum, and anus, and additionally in women uterus and vagina) and fix them to the pelvis, allowing functions of the aforementioned organs such as urination, defecation or intercourse[1] . However, all these structures are especially vulnerable to certain risk factors such as pregnancy, vaginal delivery, multiparity, age, menopause, and all the hormonal changes associated with these processes, as well as vulnerable to certain situations that chronically increase intra-abdominal pressure, such as constipation, chronic bronchitis, obesity or high-impact repetitive exercises[2,3]. All this can trigger an involuntary contraction or relaxation of the pelvic floor muscles known as pelvic floor dysfunction (PFD), which entails a series of anatomical-functional disorders in this region, the most evident being voiding dysfunction or urinary incontinence (UI) and fecal incontinence (FI), followed by other anorectal or pelvic dysfunctions such as obstructive defecation syndrome, pelvic organ prolapse (POP), sexual dysfunction and perineal pain[4]. According to the International Continence Society, UI is the manifestation of any involuntary loss of urine[5] which also represents a social, hygienic and even economic problem. The most frequent types are[6,7]: (1) stress UI, which is the involuntary loss of urine since the sphincter is not able to support it, which is associated with an increase in abdominal pressure, due to underlying physical efforts such as coughing, laughing or running; (2) urgent UI, which is the involuntary loss of urine due to the inability to hold it long enough to go to the bathroom and; (3) mixed UI, which would be the association of involuntary urine loss to both effort and urgency. Regarding FI, this includes, from least to most serious, respectively, any involuntary escape of gases and/or feces through the anal orifice, which can be[3]: (1) passive or unconscious; (2) urgent due to inability to contain defecation; (3) mixed; (4) post-defecation but with normal continence the rest of the time; and (5) during urination. However, there is less agreement on its precise definition and severity criteria than on UI.

Weakness of pelvic floor muscles is one of the possible causes of genitourinary tract problems[6], and the prevalence is higher in women, with ratios of up to 20:1 for IU compared to men. Therefore, men could be more reluctant to report this problem[4]. Despite fluctuating between countries, the percentages of women who have experienced some urine loss range between 25% and 45%, while the percentages of adults who manifest FI range between 0.4% and 18%, increasing up to 24% if gas incontinence is considered[3]. However, the future estimate is not much more encouraging. According to a 2019 study, one in three women will experience UI, while one in two will present POP and one in ten will report FI[8]. On the other hand, it is also estimated that sexual dysfunction will increase from 50% to 83% in women with DSP[8]. Altogether, this implies a clear deterioration in psychological, social and sexual well-being.

Interestingly, in the 1990s a review of the literature suggested a 44% prevalence of UI in physically active women, especially those involved in high-impact sport activities[9,10], predominantly involving jumping or running[2,11,12]. In spite of this, the practice of high-impact exercise has recently become popular among the general population[12], with CrossFit® being one of the high-impact exercise modalities or disciplines that has received great interest and recognition since its formal establishment in 2000[13]. This fitness program initially developed for military training, provides a sense of community, fun, personal satisfaction, and motivation[14] and optimizes physical competence in 10 aspects: cardiorespiratory endurance, muscular endurance, muscular strength, flexibility, power, speed, coordination, agility, balance and precision[15]. CrossFit® sessions combine: (1) exercises with a traditional cardiovascular component and metabolically stimulating impacts such as running, jumping, rowing or climbing rope; (2) exercises based on sports gymnastics skills such as handstands or rings; and (3) weightlifting exercises[13,15]. These three elements make up what is called "Work Of the Day" (WOD), which must be performed with high intensity and speed, repetitively and with limited rest time[13,15].

The presence of women in CrossFit® competitions has grown from approximately 28,000 participants in 2016 to around 75,000 in 2019[15], which according to several studies, has led to a decrease in body dissatisfaction or eating disorders, favoring body positivity and providing women with the possibility of improving their strength and physical perception through sport enjoyment[16]. Some women also highlight the possibility of helping to undo the traditional hegemony of the male gender in terms of cultivating strength and muscularity, which allows them to enhance the functionality of their body and improve their self-concept and confidence in daily life[16]. However, despite the recognized benefits of practicing CrossFit® , it is worth highlighting its potential to produce musculoskeletal injuries, mainly associated with the speed of execution, especially in novice practitioners[15], and the increase of intra-abdominal pressure that is linked to PFD, especially in terms of stress UI. Specifically, in female CrossFit® practitioners, UI prevalence rates between 32.1% and 44.5% were observed, with stress UI being the most common type reported[17,18]. The disorder is greater among women over 35 years of age, with previous pregnancies and vaginal deliveries and the exercises associated with greater stress UI were jumping rope, double under, weightlifting, and box jumping[17]. Nonetheless, although it has recently received more visibility, PFD is a pathology of contemporary appearance and most review studies on the topic focus mainly on UI, so it is necessary to address the entire spectrum of disorders under PFD. Furthermore, the impact of CrossFit® on PFD compared to other exercise modalities remains unclear, as not only high-impact exercise but also significant weightlifting have been linked to high rates of PFD[19] as reflected in a study carried out with powerlifting and weightlifting athletes, where 50%, 80% and 23.3% of women analyzed presented, respectively UI, FI and POP[20]. Therefore, the objective of this study was to conduct a systematic review of the literature to examine the studies evaluating the impact of CrossFit® on PFD based on exercise modality.

Material and method

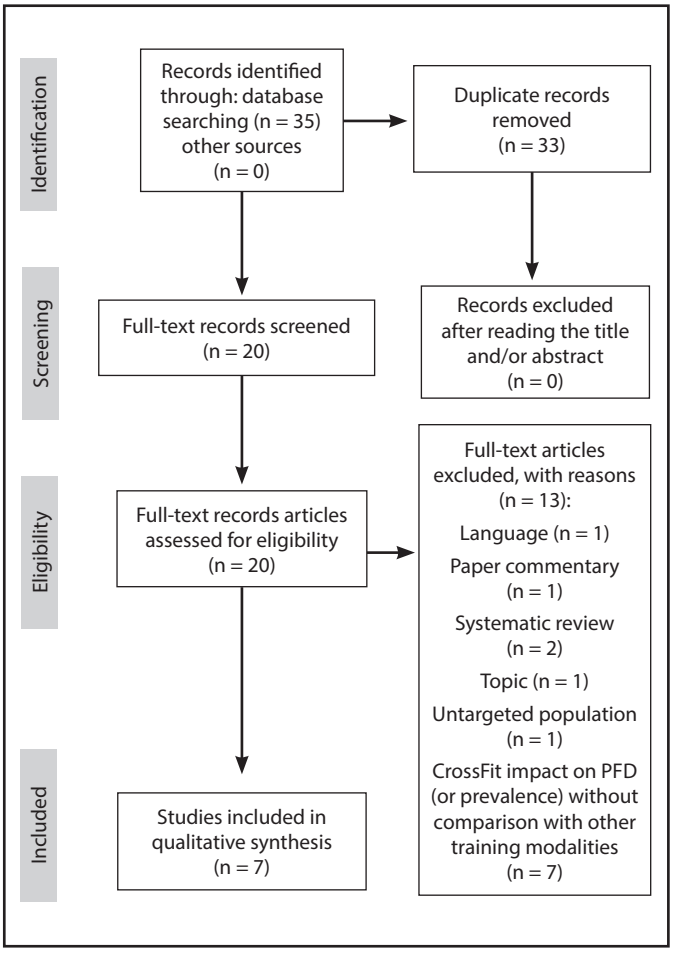
The methodological process carried out was based on the recommendations indicated by the PRISMA (Preferred Reported Items for Systematic Reviews and Meta-Analysis) guidelines[21]. A comprehensive database search was conducted (PubMed, Web of Science, Scopus and Cochrane) up to June 12, 2023, by two authors independently (NRP and

MART). The search strategy was as follows: "pelvic floor" AND "CrossFit®" indicating the combination of these terms in the title, abstract or keywords. To construct the search phrase, the PICO (population, intervention, comparison and outcome) strategy was considered[22], which in the case of this study would have been: females (population), CrossFit® (intervention) vs. other modalities (comparison) and DSP (outcome). However, according to previous literature, the different scenarios that occur in the clinical or social setting mean that the formulation of the question cannot always be adapted to this strategy[23]. In this case, with the initial search phrase, the results obtained were already quite limited, so it was decided, on the one hand, not to include 'females' in the search phrase so that if a study with male participants appeared, it could at least be screened to have a more comprehensive view of pelvic floor pathology. On the other hand, it was also decided not to include different sports disciplines in the search phrase, since this search strategy guaranteed that at least those studies where CrossFit® participants had been evaluated would appear, regardless of whether they were compared with other sport disciplines and even with sedentary participants.

The inclusion criteria were: (1) studies with people in which the impact of CrossFit® on the pelvic floor had been evaluated; and (2) studies accessible in full text in English, published in scientific journals. Opinion articles, conference communications, book chapters or review articles were excluded, as well as those that evaluated the state of the pelvic floor in women during pregnancy and those that studied the prevalence of PFD in CrossFit® without comparing this training modality with others. The search yielded a total of 53 articles (16 in Pubmed, 17 in Web of Science, 20 in Scopus and 0 in Cochrane). After removing the 33 duplicates, 20 potentially eligible articles were obtained and included to consult the full document and evaluate their eligibility. Of these, 13 studies were excluded for the aforementioned reasons: full text found in a language other than English (n = 1), opinion article (n = 1), evaluation of DSP during pregnancy (n = 1), not evaluating the impact of CrossFit® on the pelvic floor but rather the use of an insertable device, although the sample was composed of CrossFit® participants (n = 1), systematic review (n = 2), sPFD prevalence studies in CrossFit® which not compare this training modality to others (n = 7). Therefore, 7 articles were included in the qualitative analysis. The flow chart of the selection process is reflected in Figure 1.

Regarding the tool used for qualitative analysis, it was the following: McMaster University Guidelines and Critical Review Form for Quantitative Studies[24], which has been previously used in recent systematic reviews in the Sports Science field[25] and was considered the most appropriate for evaluating quantitative methods. With it, in each study, issues related to the following aspects were analyzed: 1) clearly stated objective of the study; 2) appropriately reviewed relevant literature; 3) type of design; 4.1) sample described in detail; 4.2) justified sample size; 5.1) reliable outcome measures; 5.2.) valid outcome measures; 6.1) intervention described in detail; 6.2) contamination in the intervention was avoided; 6.3) co-intervention was avoided; 7.1) results reported in statistical terms; 7.2) appropriate analysis; 7.3) clinical relevance was indicated; 7.4) the dropout rate was reported; 8) conclusions consistent with the methodology and results. Each of these 15 items was valued with a "1" if the answer was affirmative and with a "0" if it was negative, giving a value of "low" if the result was less than or equal to 5, "moderate" if the result was between 6 and 10, and "high" if it was greater than 10. From the included studies, the following information was extracted in a previously designed data sheet: authors and year, study design (data obtained through questionnaire or direct measurement) and characteristics of the participants (sex, age, height and weight, training state). Regarding exercise, information related to the activities or exercises performed and training load (sets and repetitions, duration, rest between sets and exercises, intensity...) were extracted, as well as information related to findings about pelvic floor involvement.

Figure 1. Flowchart of the study selection process.



Results

The qualitative analysis of the selected studies is shown in Table 1. The 7 selected studies[12,13,26-30] were included in the qualitative analysis. The characteristics of the studies included in the review are summarized in Tables 2 and 3. The included studies that analyzed the impact of PFD in CrossFit® practitioners compared to other sports disciplines is reflected in Table 2, while a study that compared the PFD between female CrossFit® practitioners and sedentary females is shown in Table 3.

Table 1. Qualitative analysis of the selected studies.

Nº	Authors and year	1. Purpose of the study (0/1)	2. Literature (0/1)	3. Design (0/1)	4. Sample (0/2)	5. Outcome measures (0/2)	6. Interven-tion (0/3)	7. Results (0/4)	8. Conclu-sion (0/1)	Sum of quality criteria (0/15)	Assessment according to score (Poor / Moderate / High)
1	Elks, *et al.,* 2020	1	0	1	2	2	1	3	1	11	High
2	Forner, *et al.,* 2021	1	1	1	1	2	2	3	1	12	High
3	Gephart, *et al.,* 2018	1	0	1	1	2	1	2	1	9	Moderate
4	Khowailed, *et al.,* 2020	1	1	1	1	1	2	3	1	11	High
5	Machado, *et al.,* 2021	1	1	1	2	2	3	3	1	14	High
6	Middlekauf, *et al.,* 2016	1	1	1	1	2	2	3	1	12	High
7	Yang, *et al.,* 2020	1	1	1	1	2	2	2	1	11	High
										11.43	High

Table 2. Results of studies that compare women practicing CrossFit® with women practicing other sports.

Authors and year	Characteristics of the participants and the physical activity practiced	Evaluation instrument and exercise protocol performed (if any)	Main findings
Elks, *et al.*, 2020	**n = 403 women** **n = 303 CrossFit practitioners** 38 (30-45) years BMI: 23.9 (22.4-26.9) kg/m^2 2 (1-3) vaginal deliveries n = 33 ± 10 menopausal **n = 100 non practitioners** 31 (26.5-39.5) years BMI: 23.9 (21.6-26.2) kg/m^2 2 (1-2) vaginal deliveries n = 8 ± 8 menopausal	ISI Questionnaire (Sandvik, *et al.*, 2000): UDI-6 Questionnaire (Barber, *et al.*, 2001). POPDI-6 Questionnaire (Barber, e*t al.,* 2001). UI log during training and competition, and type of exercises.	Higher prevalence and severity of UI in women who participate in CrossFit compared to those who do not: 84% of CrossFit participants (256 ± 84) vs. 48% of non-participants (48 ± 48) (*P* <0.001) reported UI on some occasion. Higher UI severity score in CrossFit participants. 20.8 (8.3-37.5) vs. 12.5 (2.1-27.1) (*P* <0.001). No differences between groups for pelvic prolapse (*P* >0.05). The exercises that reflected higher percentages of urine loss in CrossFit practitioners and in which differences seem to be reflected with respect to the control group were double jumping ropes (65%), rope climbing (50%) and weightlifting (40%).
Forner, *et al.,* 2020	**n = 1379 women** **n = 858 CrossFit practitioners** (Lifting >15 kg of weight in training) 38.5 ± 8.8 years BMI: 25.77 ± 4.48 kg/m^2 n = 452 vaginal deliveries (52.7%) n = 87 ± 10 menopausal **n = 521 runners** (That they did not lift >15 kg of weight in training) 38.4 ± 9.2 years BMI: 24.19 ± 3.91 kg/m^2 n = 295 (56.6%) vaginal deliveries n = 50 ± 10 menopausal	PFDI-20 Questionnaire (Barber, *et al.,* 2005) made up of questionnaires: UDI-6, POPDI-6 y CRADI-8.	The group of runners presented higher scores than the group of CrossFit practitioners in the total PFDI questionnaire (22.9 *vs* 17.7; *P* <0.001), in the POPDI (4.2 *vs* 0; *P* <0.001), and in the CRADI (6.3 *vs* 3.1; *P* <0.001). No differences between groups in the UDI-6 questionnaire (*P* >0.05). Scores were relatively low in both groups.

(continued)

Table 2. Results of studies that compare women practicing CrossFit® with women practicing other sports *(continuation)*.

Gephart, *et al.*, 2018	**n = 10 women** (26–48 years, half of them nulliparous) **n = 5 CrossFit practitioners** (>2 sessions per week, minimum 6 months) **n = 5 non-CrossFit practitioners** (for at least 1 year)	Intravaginal catheter: Goby Laborie wireless system (Laborie Medical Technologies, Mississauga, ON, Canada) to measure intra-abdominal pressure during a CrossFit class with 10 repetitions of the following exercises (weight chosen by each participant): weightless squats, front (front bar) and back (back bar) squats, burpees, deadlifts, kettlebell swings, lunges, pull-ups, push-ups, crunches, thrusters, wall balls, and jumping jacks jump rope with doubles if possible.	There was no difference in intra-abdominal pressure observed between the group of female CrossFit practitioners and the non-practice group. The highest intra-abdominal pressure was generated during jump rope, arm dips, front barbell squats, thrusters, and wall balls (P <0.0001). As the repetitions performed increased, the intra-abdominal pressure increased for the back squat (P = 0.003) while it decreased for the abdominals (P = 0.04).
Khowailed, *et al.*, 2020	**n = 14 women** (18-40 years, 10 of them nulliparous, 3 vaginal delivery) n = 2 training <2 h/week n = 9 training 3-6 h/week n = 3 training >6 h/week **n = 9 CrossFit practitioners** BMI: 22.4 ± 2.3 kg/m^2 **n = 5 Kickboxing or Bootcamp practitioners** BMI: 24.5 ± 2.7 kg/m^2	Questionnaire "The Female Athlete Survey: Urinary Incontinence Survey" (Carls, 2007). This questionnaire includes questions addressed to: a) identify symptoms of SUI during high-impact activities. b) Evaluate the willingness of the participants to try exercises to improve the UI (not included). c) Assess willingness to seek treatment for UI and their awareness of it.	Urine losses were higher in the participants who performed CrossFit than in those who performed Kickboxing or Bootcamp (P = 0.023). 64.2% of the participants reported some loss of urine. 78% of the participants associated urine loss with jumping activities (jump rope, drawer), and with abdominal contraction activities such as sneezing or laughing. 67% of the participants associated urine loss with running.
Middlekauf, *et al.*, 2016	**n = 61 women (26.8 ± 3.79 years), nulliparous** BMI: 24.06 kg/m^2 **n = 32 intense exercise practitioners** (>6 months practicing CrossFit >3 sessions/week) **n = 29 light exercisers** (not participating in any intense or impact strength or conditioning exercise in the previous 6 months) 22.7 ± 3.9 años BMI: 22.8 kg/m^2	Pelvic exam from a registered nurse through: Exam (POP-Q) (Bump, *et al.*, 1996), Pelvic floor muscle strength through a perinometer (Peritron 9300 V vaginal perineometer, Laborie, Mississauga, Ontario, Canada), with which 3 MVC of the pelvic floor were measured (contract and relax and the vaginal rest pressure or VRP). 15 minutes before and after performing: a) Intense exercise group: 15 funds, 5 deadlifts at 80% of 3RM, 5 push-presses at 80% of 3RM, 15 burpees, and 20 sit-ups. b) Non-intense exercise group: 20 minutes walking at your preferred intensity and pace.	There were no significant differences between groups in terms of vaginal support. Both vaginal tone and resting vaginal pressure decreased slightly after performing both exercises (P >0.05). Only one participant reported POP. 27.7% of participants in the intense exercise group vs. 8.57% of the non-intense exercise group reported urine loss in relation to physical activity, coughing, sneezing. 68.6% of participants did not perform pelvic floor strengthening exercises, compared to 17.1% who did and 14.28% who were unaware of their existence.
Yang, *et al.*, 2018	**n = 105 CrossFit practitioners** (4-5 sessions/week) 36.9 ± 10.4 years BMI: 24.9 ± 3.7 kg/m^2 36.2% nulliparous. Of the 63.8% with a history of childbirth, 47.6% reported vaginal delivery **n = 44 aerobic exercise practitioners** BMI: 25.6 ± 2.7 kg/m^2 63.6% nulliparous. Of the 36.4% with a history of childbirth, 68.8% reported vaginal delivery	ISSI questionnaire (Terai, *et al.*, 2004).	The incidence of SUI was higher in CrossFit participants (27.8%) than in aerobic exercise participants (0%) (P <0.003). 47.6% of CrossFit participants reported SUI. The exercises with the most pronounced urine loss were jump ropes, both double (47.7%) and simple (41.3%), and box jumps (28.4%). None of the aerobic exercise practitioners reported SUI during the exercise. The most commonly used prevention strategies were emptying the bladder before training, wearing dark pants, and performing Kegel exercises during training.

BMI: Body Mass Index; DSP: Pelvic Floor Dysfunction; POP: Pelvic Organ Prolapse; IF: Fecal incontinence; UI: Urinary incontinence. PFDI: Pelvic Floor Distress Inventory; UDI-6: Urinary Distress Inventory; POPDI-6: Pelvic Organ Prolapse Distress Inventory; CRADI-8: Bowel Dysfunction Scale; ISI: Incontinence Symptoms Index, SUI: Stress Urinary Incontinence; ICIQ-SF: International Consultation on Incontinence Questionnaire – Short Form; POP-Q: POP-Quantification; MVC: Maximal Voluntary Contraction; RM: Maximum Repetition; VRP: vaginal rest pressure; ISSI: Incontinence Symptom Severity Index.

Table 3. Results of studies that compare women practicing CrossFit® with sedentary women.

Authors and year	Characteristics of the participants and physical activity practiced	Evaluation instrument and exercise protocol performed (if any)	Main findings
Machado, *et al.,* 2021	**n = 42 women** (26.6 ± 3.6 years, BMI: 23.7 ± 2.9 kg/m²) **n = 21 CrossFit practitioners.** (*Minimum* 6 months and 3 sessions/ week à 22 (6-60) months and 4.45 ± 0.8 sessions/week) More menstrual irregularities **n = 21 sedentary women.** (No practice of systematic physical activity for at least 6 months). Increased use of contraceptives	ICIQ-SF Questionnaire (International Consultation on Incontinence Questionnaire – Short Form) (Tamanini, *et al.,* 2004). Assessment (0-5) of a MVC of the pelvic floor by a physiotherapist by means of palpation, following the Modified Oxford Scale (Pereira, *et al.*, 2014). Miotool 400 electromyography (Miotec Equipamentos Biomédicos Ltda, Brazil) with protocol adapted from previous study (Glazer & Hacad, 2012).	Higher prevalence of UI (6 times more) in the group of CrossFit practitioners (P <0.001). 75% of the CrossFit group associated the losses with exercise, specifically in activities that involved jumping (rope, box...) and weightlifting. There were no differences between groups in pelvic floor strength (P >0.05) or electromyographic variables, although MVC from electromyography tended to be higher in the CrossFit group (P = 0.069).

BMI: Body Mass Index; ICIQ-SF: International Consultation on Incontinence Questionnaire–Short Form; MVC: Maximal Voluntary Contraction; UI: Urinary incontinence.

Discussion

The purpose of this study was to conduct a systematic review of the literature to find out if CrossFit® favors PFD to a greater extent than other sports disciplines. Of the seven studies included in the systematic review, six compared the impact of CrossFit® with other disciplines on one or more PFD disorders. However, we will discuss, on the one hand, the studies in which PFD was evaluated using different validated questionnaires and, on the other hand, the studies that evaluate the pelvic floor through direct exploration. In the first group, the results indicate that CrossFit® causes greater stress UI than 1) kickboxing or bootcamp, 2) practicing aerobic exercise and 3) 'no practicing' CrossFit®[12,19,30]. One factor that could influence this result is the higher percentage of vaginal deliveries in the study sample[30], which has been suggested as a risk factor for suffering UI[31-33], although slightly higher UI results (60% *vs*. 40%) have also been observed among participants with a history of vaginal deliveries and nulliparous participants[34]. Another factor previously associated in the literature with greater UI is the higher percentage of postmenopausal participants[19] among CrossFit® practitioners[2,3,13]. Finally, all the reviewed literature indicated greater urine losses in these high-impact exercises: rope jumping, box jumping and running[12-14,19,27-30,32,34]. In contrast to the UI results, female runners were found to have a higher incidence of POP and FI, but not UI, than female CrossFit® practitioners[13], which could suggest that running may be more negative for FI than CrossFit®, although this should be taken with caution to avoid speculation about suggesting that CrossFit® is healthy for the pelvic floor or that running is strictly a cause of anorectal dysfunction[13].

Regarding the studies that evaluated the contraction and relaxation capabilities of the pelvic floor muscles through direct pelvic examination, the results revealed no differences in intra-abdominal pressure and vaginal tone during the same exercises, neither between female CrossFit® and non-CrossFit® practitioners[27], nor between CrossFit® and light exercise practitioners[29]. Interestingly, this lack of differences in PFD between female CrossFit® practitioners and non-practitioners / light exercisers is observed despite the existence of differences between CrossFit® and control groups in BMI or training volume, which are factors traditionally linked to PFD in the literature[3,13,14,19,32,35]. Therefore, it could be thought that this lack of differences between CrossFit® and the control groups in both studies can be attributed to the similarities in terms of the gynecological history of participants' vaginal deliveries, the majority being nulliparous[27,29,] or the fact that, in both studies, more than 30% of participants did not perform pelvic floor strengthening exercises[27,29]. However, the explanation that seems to gain more strength is that the absence of differences between study groups when pelvic floor is evaluated by direct examination instead of using questionnaires is precisely the assessment methodology. This is observed in the only study of the seven that compares female CrossFit® practitioners and sedentary women[28]. This research analyzes both questionnaires and pelvic floor tone by direct examination and electromyography, and revealed a UI up to six times greater in CrossFit® practitioners, but nevertheless, there are no differences in the contraction capacity of the pelvic floor between groups[28]. This could suggest a greater reliability of questionnaires to detect PFD than pelvic examinations, and could explain the greater number of studies that use questionnaires, in addition to the high percentage of women (76%) who, even reporting UI, indicated that they had never received pelvic floor assessment[34]. In fact, despite the presence of eight different questionnaires in the total of seven analyzed studies referring to different PFD symptoms, all of them are based on simple severity scales (none, some, moderate, severe), which seems to guarantee the reliability of the questionnaires as instrument.

Finally, several of the included studies agreed on low percentages of POP, less than 4%, generally observed in all participants[13,14,29,32], although it seems that the prevalence of sexual dysfunction was studied to a much lesser extent. In fact, other research that coincided with the low prevalence of POP yielded an intriguing percentage of 48.7% of participants reporting pain during sexual intercourse[14]. Therefore, sexual dysfunctions should be further explored in future studies, as they may contribute to worsening females' well-being.

Despite addressing a topic of recently increasing attention such as PFD, which seems to underlie a relatively novel and highly practiced

sport modality through a solid methodology, some limitations must be mentioned. There is a great variability in exercise modalities considering the number of studies (7) finally included in the review, which not only impairs the development of a meta-analysis that would provide more robustness, but also the correct interpretation of findings. In fact, of the six studies that compared CrossFit® practitioners with a control group, only two detailed the physical activity carried out by the control group, this activity being running (n = 1) or kickboxing/bootcamp (n = 1). Out of the other six studies, two indicate that the control group was composed of non-CrossFit® practitioners, without specifying whether they performed other types of physical activity, while in two other studies the control group consisted of aerobic exercise practitioners without including details on impact or intensity. Further studies comparing CrossFit® with other exercise modalities should include an accurate description of control group's physical activity practice to reduce heterogeneity and potentially confounding factors. Additionally, other aspects such as the timing of data collection (immediately after training or not), participants' history of vaginal strengthening exercises or the development of strategies to reduce UI before training, such as urinating or reducing water intake, should be carefully described, as they may influence the results[34] and, finally, the consideration of different subtypes of UI and FI may be a key aspect to clarify the findings and facilitate therapists and trainers adjust PFD rehabilitation.

In conclusion, when PFD is assessed through validated questionnaires, CrossFit® seems to cause greater UI than (1) kickboxing and bootcamp, (2) aerobic exercise, (3) not practicing CrossFit® and (4) sedentary lifestyle. In contrast, running seems to trigger more FI than CrossFit®. On the other hand, when the information comes from a direct pelvic examination, no differences are observed between women who practice CrossFit® and 1) women who practice light exercise, 2) women who do not practice CrossFit®, and 3) sedentary women. However, due to methodological differences, the results should be taken with caution and future studies should specify in detail the physical activity practices of the control group, as well as potentially influential factors, such as gynecological history.

Bibliography

1. Lacima G, Espuña M. Patología del suelo pélvico. *Gastroenterología y Hepatología*. 2008;31:587-95.
2. Casey EK, Temme K. Pelvic floor muscle function and urinary incontinence in the female athlete. *Phys Sportsmed.* 2017;45:399-407.
3. Lacima G, Espuña M. Patología del suelo pélvico. *Gastroenterol Hepatol*. 2008;31:587-95.
4. Torres J, Delgado J, Adams E. Incontinencia urinaria en pacientes atendidos en consulta de disfunciones del suelo pélvico. Prevalencia y factores de riesgo. *Revista Cubana de Medicina Física y Rehabilitación*. 2016;8:1-12.
5. Abrams P, Cardozo L, Fall M, Griffiths D, Rosier P, Ulmsten U, Van Kerrebroeck P, Victor A, Wein A. The standardisation of terminology in lower urinary tract function: report from the standardisation sub-committee of the International Continence Society. *Urology.* 2003;61:37-49.
6. Aoki Y, Brown HW, Brubaker L, Cornu JN, Daly JO, Cartwright R. Urinary incontinence in women. *Nat Rev Dis Primers.* 2017;3:17042.
7. González Sánchez B, Rodríguez-Mansilla J, Toro García A, González López-Arza M. Eficacia del entretenimiento de la musculatura del suelo pélvico en incontinencia urinaria femenina. *An Sist Sanit Navar.* 2014;37:381-400.
8. Verbeek M, Hayward L. Pelvic floor dysfunction and its effect on quality of sexual life. *Sex Med Rev.* 2019;7:559-64.
9. Nygaard IE. Does prolonged high-impact activity contribute to later urinary incontinence? A retrospective cohort study of female olympians. *Obstet Gynecol.* 1997;90:718-22.
10. Nygaard IE, Thompson FL, Svengalis SL, Albright JP. Urinary incontinence in elite nulliparous athletes. *Obstet Gynecol.* 1994;84:183-7.
11. Eliasson K, Larsson T, Mattsson E. Prevalence of stress incontinence in nulliparous elite trampolinists. *Scand J Med Sci Sports*. 2002;12:106-10.
12. Khowailed IA, Pinjuv-Turney J, Lu C, Lee H. Stress incontinence during different high-impact exercises in women: a pilot survey. *Int J Environ Res Public Health.* 2020;17.
13. Forner LB, Beckman EM, Smith MD. Do women runners report more pelvic floor symptoms than women in CrossFit®? A cross-sectional survey. *Int Urogynecol J.* 2021;32:295-302.
14. Pisani GK, de Oliveira Sato T, Carvalho C. Pelvic floor dysfunctions and associated factors in female CrossFit practitioners: a cross-sectional study. *Int Urogynecol J.* 2020.
15. Claudino JG, Gabbett TJ, Bourgeois F, Souza HS, Miranda RC, Mezêncio B, Soncin R, Cardoso Filho CA, Bottaro M, Hernandez AJ, *et al.* CrossFit overview: systematic review and meta-analysis. *Sports Med Open*. 2018;4:11.
16. Podmore M, Ogle JP. The lived experience of CrossFit as a context for the development of women's body image and appearance management practices. *Fashion and Textiles.* 2018;5:1.
17. Álvarez-García C, Doğanay M. The prevalence of urinary incontinence in female CrossFit practitioners: a systematic review and meta-analysis. *Arch Esp Urol.* 2022;75:48-59.
18. Dominguez-Antuña E, Diz JC, Suárez-Iglesias D, Ayán C. Prevalence of urinary incontinence in female CrossFit athletes: a systematic review with meta-analysis. *Int Urogynecol J.* 2023;34:621-34.
19. Elks W, Jaramillo-Huff A, Barnes KL, Petersen TR, Komesu YM. The stress urinary incontinence in CrossFit (SUCCeSS) study. Female Pelvic *Medicine and Reconstructive Surgery.* 2020;26:101-6.
20. Skaug KL, Engh ME, Frawley H, Bø K. Prevalence of pelvic floor dysfunction, bother and risk factors and knowledge of the pelvic floor muscles in Norwegian male and female Powerlifters and Olympic Weightlifters. *J Strength Cond Res*. 2020.
21. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, Clarke M, Devereaux PJ, Kleijnen J, Moher D. The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of studies that evaluate health care Interventions: explanation and elaboration. *PLoS Med*. 2009;6:e1000100-e1000100.
22. da Costa Santos CM, de Mattos Pimenta CA, Nobre MR. The PICO strategy for the research question construction and evidence search. *Rev Lat Am Enfermagem.* 2007;15:508-11.
23. Cañón M, Buitrago-Gómez Q. The research question in clinical practice: a guideline for its formulation. *Rev Colomb Psiquiatr* (Engl Ed). 2018;47:193-200.
24. Law M, Stewart D, Pollock N. Guidelines for critical review form-quantitative studies: McMaster University: Occupational Therapy Evidenced-Based Practice Research Group. 1998 http://srs-mcmaster.ca/wp-content/uploads/2015/05. Guidelines-for-Critical-Review-Form-Quantitative-Studies pdf (accessed 4 Apr 2016).
25. Thompson B, Almarjawi A, Sculley D, Janse de Jonge X. The effect of the menstrual cycle and oral contraceptives on acute responses and chronic adaptations to resistance training: a systematic review of the literature. *Sports Med*. 2019.
26. Elks W, Jaramillo-Huff A, Barnes KL, Petersen TR, Komesu YM. The stress urinary incontinence in CrossFit (SUCCeSS) study. *Female Pelvic Med Reconstr Surg.* 2020;26:101-6.
27. Gephart LF, Doersch KM, Reyes M, Kuehl TJ, Danford JM. Intraabdominal pressure in women during CrossFit exercises and the effect of age and parity. *Proc (Bayl Univ Med Cent).* 2018;31:289-93.
28. Machado LDS, Marques Cerentini T, Laganà AS, Viana da Rosa P, Fichera M, Telles da Rosa LH. Pelvic floor evaluation in CrossFit® athletes and urinary incontinence: a cross-sectional observational study. *Women Health.* 2021;61:490-9.
29. Middlekauff ML, Egger MJ, Nygaard IE, Shaw JM. The impact of acute and chronic strenuous exercise on pelvic floor muscle strength and support in nulliparous healthy women. *Am J Obstet Gynecol.* 2016;215:316.e311-7.
30. Yang J, Cheng JW, Wagner H, Lohman E, Yang SH, Krishingner GA, Trofimova A, Alsyouf M, Staack A. The effect of high impact crossfit exercises on stress urinary incontinence in physically active women. *Neurourol Urodyn*. 2019;38:749-56.
31. Dominguez-Antuña E, Diz JC, Ayán C, Suárez-Iglesias D, Rodríguez-Marroyo JA. Prevalence and severity of urinary incontinence among male and female competitors and recreational CrossFit® practitioners. *Eur J Obstet Gynecol Reprod Biol.* 2022;276:144-7.
32. High R, Thai K, Virani H, Kuehl T, Danford J. Prevalence of pelvic floor disorders in female CrossFit athletes. *Female Pelvic Med Reconstr Surg.* 2020;26:498-502.
33. Pisani GK, de Oliveira Sato T, Carvalho C. Pelvic floor dysfunctions and associated factors in female CrossFit practitioners: a cross-sectional study. *Int Urogynecol J.* 2021; 32:2975-84.
34. Wikander L, Kirshbaum MN, Gahreman DE. Urinary incontinence and women CrossFit competitors. *Int J Womens Health.* 2020;12:1189-95.
35. García-Fernández J, Gálvez-Ruiz P, Sánchez-Oliver AJ, Fernández-Gavira J, Pitts BG, Grimaldi-Puyana M. An analysis of new social fitness activities: loyalty in female and male CrossFit users. *Sport in Society.* 2020;23:204-21.

The usefulness of sports medical examinations to detect and prevent eating disorders

Antonio Rodríguez Martínez

Diplomado Universitario en Enfermería. masQsano Salud y Deporte S.L.P. Almería.

doi: 10.18176/archmeddeporte.00163

Received: 12/07/2023
Accepted: 01/03/2024

Summary

Introduction and objectives: Eating disorders are a growing problem in our society, especially among young people. The aim of this study is to know which are the individual and social factors that support and perpetuate the danger of suffering from eating disorders, and their possible consequences on the sports and academic performance of individuals.
Material and method: The sample consisted of 395 athletes between 12 and 16 years of age (M = 14.07; SD = 1.35), of whom 142 (35.9%) were female and 253 (64.1%) male. A questionnaire was administered to collect information on sociodemographic data, body image, use of social networks, social relationships, sports practice, risk of eating disorders, and academic and sports performance. In the analysis, firstly, cross-tabulations were carried out to observe the body distortion of the respondents according to body mass index; secondly, a linear regression was performed to analyze the factors influencing the risk of eating disorders. In addition, correlations were performed to find out the relationship between risk of manifesting eating disorders and academic and sports performance.
Results: The main result shows that there is a high risk of eating disorders among young athletes, due to a high distortion of body image, which becomes the main determinant factor. In addition, relationships with family and friends have a significant influence on this danger. On the other hand, behaviors related to eating disorders cause academic and sports performance to decrease.
Conclusión: Due to these data, it is necessary to generate and promote prevention and early detection guidelines during adolescence.

Key words:
Eating disorders. Body image. ocial networks. Athletes.

Utilidad del reconocimiento médico deportivo para detectar y prevenir trastornos de la conducta alimentaria

Resumen

Introducción y objetivos: Los trastornos alimenticios son un problema creciente en nuestra sociedad, en especial entre los jóvenes. El objetivo de este estudio es conocer cuáles son los factores individuales y sociales que apoyan y perpetúan el peligro de padecer trastornos de la conducta alimenticia, y sus posibles consecuencias en el rendimiento deportivo y académico de los individuos.
Material y método: La muestra la componen 395 deportistas entre 12 y 16 años (M = 14,07; DT = 1,35), de los cuales 142 (35,9%) son mujeres y 253 (64,1%) hombres. Se administró un cuestionario para recabar información sobre datos sociodemográficos, imagen corporal, uso de redes sociales, relaciones sociales, práctica deportiva, peligro de padecer trastornos de la conducta alimenticia y rendimientos académico y deportivo. En el análisis se llevaron a cabo, en primer lugar, tablas cruzadas para observar la distorsión corporal de los encuestados en función del índice de masa corporal; en segundo lugar, una regresión lineal para analizar los factores influyentes en el peligro de padecer trastornos de la conducta alimenticia. Además, se realizaron correlaciones para averiguar la relación entre peligro de manifestar trastornos de la conducta alimenticia y el rendimiento académico y deportivo.
Resultados: El resultado principal muestra que existe un peligro alto de trastornos de la conducta alimenticia por parte de los jóvenes deportistas, a partir de una elevada distorsión de la imagen corporal que se convierte en el factor mayormente determinante. Además, las relaciones con la familia y amigos tienen influencia significativa ante este peligro. Por otro lado, las conductas relacionadas con los trastornos alimenticios hacen que el rendimiento académico y deportivo baje.
Conclusión: Debido a estos datos, se hace necesario generar y promocionar pautas de prevención y detección temprana durante la adolescencia.

Palabras clave:
Trastornos alimentarios. Imagen corporal. Redes sociales. Deportistas.

Correspondence: Antonio Rodríguez Martínez
E-mail: antorodri8@gmail.com

Introduction

Eating disorders (EDs) are a public health problem (Gómez *et al.*, 2018)[1]. Such disorders can be classified into several groups with very diverse characteristics (see American Psychiatric Association, 2013)[2]. However, anorexia and bulimia nervosa have received the greatest attention in the scientific literature because they present similar behaviours in terms of body image, social relationships, interaction with food, etc., and their perpetuation may be due to similar causes (Modica, 2020)[3]: dissatisfaction with body image, fear of gaining weight and obsessive thoughts about eating, leading to serious modifications in the daily diet, sometimes eating small amounts and sometimes in excess or performing purging behaviours (American Psychiatric Association, 2013[2]; Behar *et al.*, 2014[4]; Ponce *et al.*, 2017[5]).

Even before their manifestation and clinical detection, these disorders affect the individual's self-esteem, social relationships and academic and work performance (Avila *et al.,* 2019)[6]. In the face of this situation, health professionals rely on different standardised measurement scales to observe the incipient condition: SCOFF, BITE, BES, BULT, EAT-40, EAT-26, TFEQ/EI, etc. (Vela *et al.*, 2017)[7], detection instruments which they use as screening and study tools.

The scientific literature and professionals that focus on people suffering from these disorders argue that we are facing multifactorial phenomena: biological, psychological, family and social. Therefore, the social-ecological model of analysis is especially important (Wang *et al.*, 2013)[8]. This model is organised around three factors: one, the sociocultural factor, in which the different settings in which the subject operates are taken into account; two, the sociodemographic factor, defined by sex or age; and three, the psychological factor, inherent in each subject. Consequently, three aspects come into play: personal characteristics, social characteristics and how the individual reacts to them through self-assessment and social comparison (Festinger, 1954)[9].

EDs had, until now, been considered an almost exclusively female problem (Fitzsimmons-Craft *et al.*, 2014[10]; Torres, 2019[11]; Schaefer *et al.,* 2014[12]); however, there is an increasing prevalence among men (Ferreiro *et al.,* 2012[13]; Veses *et al.,* 2014[14]). Meanwhile, the bulk of sufferers is still found in adolescents between the ages of 12 and 18*[15] (Villegas-Moreno, 2021)[16], a critical stage for developing body image and greater susceptibility to possible body dysmorphic and eating disorders (Gaete *et al.,* 2020[17]; Klump, 2013[18]).

Adolescents and young people who do sport are not immune to this situation, especially so considering that in addition to the pressure and ideals of beauty observed in their social environments and/or peer groups, they are also under physique-related pressure to improve their athletic performance (see, among others, Fitzsimmons-Craft *et al.,* 2014[10]; Monserrat *et al.*, 2021[19]; Villar, 2017[20]). This is so to the point that the term *athletic anorexia* has been coined to refer to the set of subclinical eating behaviours manifested by athletes to arrive at a physique which comes as close as possible to the desirable image associated with their particular sport (Baquero, 2020)[21].

And that is not all, because young athletes are not just exposed to environmental and sports-related pressure. They also have to deal with the Internet, where, on the one hand, they have ready access to content on famous personalities/athletes with whom they can compare themselves and, on the other, they are bombarded with advertising which, on certain occasions, does not correspond to reality or is misleading. According to AHAB (Associació Contra l'Anorèxia i la Bulímia; Association against Anorexia and Bulimia) (2020)[22], social networks, together with the need to adapt to and preoccupation with a slim body ideal associated with social, family and professional success, could be a factor which explains physiological vulnerability to presenting an ED. How individuals use the Internet plays an important role in both the prevention and development of EDs. In adolescence, Instagram, Facebook or YouTube, whose main content consists of images, can negatively affect body self-perception (Pérez and Cassany, 2018)[23], whether one just views images or actually creates content, since they can generate dissatisfaction with one's physique, due to the mismatch between the ideal of beauty and one's own reality (Romo del Olmo, 2020)[24], even leading to the use of filters and/or retouching to modify the physique in order to publish a supposedly perfect image to please as many people as possible (Romo del Olmo, 2020)[24].

In short, bearing in mind the different scenarios which can act as predisposing factors and triggers for EDs, we decided to study this phenomenon with young athletes in a Spanish province, focusing on social and individual factors. Taking into account the preceding literature, an emphasis was placed on comparisons based on sex (Fitzsimmons-Craft *et al.,* 2014[10]; Schaefer *et al.*, 2014[12]) and age in a sports environment (Ferreiro *et al.,* 2012[13]; Chardon *et al.*, 2016[25]).

Materials and methods

The sample was selected from among those taking part in a sports injury prevention and medical examination programme run by a company specialising in sports clubs in a Spanish province. The sample consisted of 395 athletes (all of whom agreed to participate voluntarily) between the ages of 12 and 16 (M = 14.07; SD = 1.35), of which 142 (35.9%) were female and 253 (64.1%) male. Their sports were football (47.1%), basketball (19.2%), handball (19%), swimming (1.8%), rugby (4.1%) and volleyball (6.3%).

The report that the participants completed, with the help of a professional, consisted of several sections: socio-demographic data, data related to body image, use of social networks, sports activity, social relationships and questions related to academic and athletic performance.

* However, these conditions are increasingly affecting the adult population (Letelier, 2021)[15].

The *Sick, Control, One, Fat, Food* (SCOFF) questionnaire (Morgan *et al.,* 1999)[26] was also used to analyse the presence of warning signs signalling the presence of Eating Disorders (Anorexia Nervosa or Bulimia Nervosa). The original questionnaire consists of five dichotomous (yes, no) questions. The respondents get one point for every "yes" answer. A score of 2 or more indicates a highly likely case of anorexia or bulimia. For our study, because all the questions on the questionnaire required an answer on a scale of 0 to 5, the Scoff score ranged from 0 to 25. Consequently, 10 points meant risk of an ED and more than 15 indicated a high risk.

The questionnaire was computerised and answered anonymously through the Limesurvey platform. The data was collected between September and November 2022. The respondents were interviewed individually in the presence of professionals, with the prior consent of their sports clubs and/or those responsible for them.

Initially, descriptive statistics (mean and standard deviation) were calculated to observe the prevalence of EDs. Next, to study the respondents' body image disturbance, the BMIs of the study subjects and the subjective diagnoses that they themselves gave were cross-tabulated.

Subsequently, following the social-ecological model (Wang *et al.,* 2013)[8], we performed a linear regression analysis to discover the different factors that influence the development of ED risk. Given the high number of initial variables and high correlations between some of them, a factor analysis with orthogonal rotation (maximum-likelihood method) was conducted beforehand (varimax: KMO = 0.818; ig. = 0.000) to reduce dimensionality and avoid multicollinearity problems.

Finally, to calculate the possible consequences of the risk of developing an ED, we made correlations between Scoff and the variables related to hours of sleep, concentration when studying and physical and mental fatigue.

Data analysis was performed using SPSS-27 for Windows.

However, the study had limiting factors which need to be taken into consideration. First, the sampling was not random. Therefore, it did not give representative data for each group of athletes. This information is crucial, especially for elite athletes, due to the demands of different sports in terms of weight and/or muscle mass (see Baile *et al.*, 2021)[27].

Second, there may be non-observation errors (Groves, 1989)28 due to the impossibility of obtaining all the influential variables, such as, for example, psychological variables.

Third, the possibility of measurement errors, due to the fact that the surveys were carried out during the medical examinations, which, although the questionnaire was short, meant that the attitude and cooperation of the subjects were subject to haste.

Fourth, BMI is not a fully objective tool to diagnose normal, insufficient or excess weight and even less so in the sports population, given that the index only takes into account weight and height, ignoring information as useful as muscle mass and its percentage with respect to fat mass.

Fifth, we consider age a limiting factor, since the subjects surveyed were passing through a stage of life in which numerous changes in body composition occur, typically as a result of growth and social influence.

And, sixth, there was no non-athletic control group to be able to compare the level of significance of the variables in the two populations.

Results

According to the data in Table 1, 77.7% showed some type of risk of suffering an ED and 22.3% showed a high risk (M = 13.3; SD = 3.33). If we look at sex, we observed that 76.7% of the females and 78.1% of the males revealed some type of risk. And, analysing this according to age (Figure 1), we saw that most of the "risk" scores came between 14 and 15 years, and most of the "high risk" scores were at the age of 16. 12-year-olds got the most "no risk" scores.

To recode the participants' Body Mass Index (weight/height^2), we took into account their age range (12-16 years) and the considerations that this entails. For children under 14 years of age, a BMI under 15 kg/m^2 was considered underweight; a BMI between 15 and 21 kg/m^2 was considered normal weight; a BMI between 21 and 25 kg/m^2 was considered overweight; and a BMI over 25 kg/m^2 was considered obesity. For participants aged between 14 and 16, a BMI under 16 kg/m^2 was underweight; a BMI between 16 and 24 kg/m^2 was normal weight; a BMI between 24 and 27 kg/m^2 was overweight; and a BMI over 27 kg/m^2 was obesity (Alvero *et al.,* 2010)[29].

The mean BMI of the sample analysed was M = 21.3 (SD = 2.1). With the recoded data, we observed that 4.1% were overweight, 0.3% were

Table 1. Risk of EDs in the surveyed population. Differentiation by sex and age.

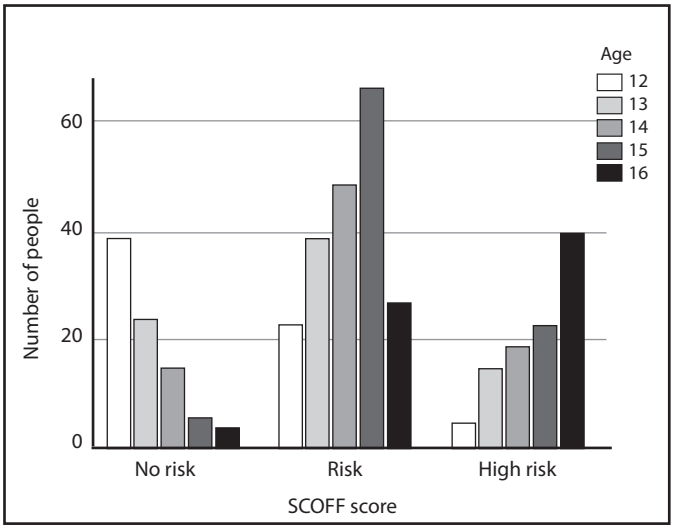
SCOFF	Female n (%)		Male n (%)		Total n (%)	
No risk	33 (23.2)		55 (21.7)		88 (22.3)	
Risk	77 (54.2)		128 (50.5)		205 (51.9)	
High risk	32 (22.5)		70 (27.6)		102 (25.8)	
Age	**12**	**13**	**14**	**15**	**16**	**Total**
No risk	39 (56.9)	24 (30.8)	15 (18.1)	6 (5.3)	4 (4.5)	88
Risk	23 (35.4)	39 (50)	49 (59)	67 (70.5)	27 (38.8)	205
High risk	5 (7.7)	15 (19.2)	19 (22.9)	23 (24.2)	40 (56.7)	102

*X^2= 1.251[a]; p = 0.001; **X^2 = 111,384[a]; p = 0.001.

Table 2. Response to the statement "I think I'm fat".

	N	%
Never	51	12.9
Rarely	143	36.2
Sometimes	120	30.4
Almost always	67	17
Always	13	3.3

Figura 1. Riesgo de TCA en la población encuestadas.



obese, 84.3% were normal weight and 11% were healthily underweight. None of the participants were unhealthily underweight.

Although most of the population surveyed had BMIs considered within their "normal" range and only 4.4% were overweight or obese, it was observed that 20.3% "considered themselves fat" always or almost always, and as many as 30.4% considered themselves fat sometimes (Table 2).

Because the data were considered disparate between objective BMI value and perception by the respondents, we cross-tabulated BMI and the answer to the question "I think I'm fat" to see the extent of body image disturbance among the respondents (Table 3). The Chi-square values accept the null hypothesis and, therefore, there is no relationship between feeling fat and BMI. In all, of the athletes with a BMI considered "normal", 16.1% said they feel fat almost always and 3.6% always. And of the athletes with a BMI considered "underweight", 23.3% feel fat almost always and 2.3% always.

In order to find out which variables predict the variability of the risk of suffering an ED through linear regression, we first reduced the

Table 3. Response to the statement "I think I'm fat" and its relationship with BMI.

I think I'm fat	Body Mass Index			
	Low Weight	Normal weight	Overweight	Obese
Never	5	45	1	0
Rarely	11	126	4	1
Sometimes	16	94	7	
Almost always	10	53	4	0
Always	1	12	0	0
Total	43	330	16	1

$X^2 = 9.201^a$; $p = 0.686$.

Table 4. Total Variance Explained.

	Initial eigenvalues			Extraction sums of squared loadings		
Component	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.09	29.22	29.22	2.68	19.14	19.14
2	2.87	20.51	49.73	1.84	13.14	32.28
3	1.29	9.22	58.95	1.83	13.04	45.32
4	1	7.13	66.09	1.15	8.22	53.54

Extraction method: maximum likelihood.

Table 5. Degree of saturation of the items in each factor.

	Factor 1	Factor 2	Factor 3	Factor 4
I would like clothes to look better on me	-0.069	0.166	0.730	0.114
I would like a different physique	0.065	0.235	0.757	0.047
I follow someone on social media if they are nice and make me feel good	0.137	0.694	0.260	0.131
I follow someone on social media if they are good-looking and have a good physique	0.104	0.799	0.145	0.044
I would like to interact with more people	0.194	0.582	0.204	0.035
I would like to be the centre of attention in the team	0.003	0.282	0.165	0.205
I would like to be slimmer	-0.067	0.232	9.670	0.112
In the last few weeks, I've spent time with my friends	0.253	0.118	0.163	0.790
In the last few weeks, I've had fun with my friends	0.428	0.135	0.115	0.568
My friends and I help each other	0.569	0.084	-0.222	0.253
I have enough money to do the same things as my friends	0.743	0.023	-0.008	0.175
I get enough money for my expenses	0.765	-0.033	0.083	0.103
I can talk to my parents whenever I need to	0.695	0.220	-0.094	0.068
My parents have enough time for me	0.638	0.272	-0.097	0.065

different behavioural variables into factors through the percentage of total variance explained (TVE). 66.09% was reached in the extraction (Table 4), which is an acceptable result because the minimum threshold of 60% was exceeded (Hair *et al.,* 2010)[30].

4 factors were extracted (Table 5). We called Factor 1 social and economic cooperation. It is saturated with the following variables: my friends and I help each other; I have enough money to do the same

things as my friends; I get enough money for my expenses; I can talk to my parents whenever I need to; my parents have enough money for me.

We call Factor 2 social networks. It is saturated with the following variables: I follow someone on social media if they are nice and make me feel good; I follow someone on social media if they are good-looking and have a good physique; I would like to interact with more people; I would like to be the centre of attention in the team.

Factor 3 takes the name of body image because it is saturated with related variables: I would like my clothes to look better on me; I would like a different physique; I would like to be slimmer.

And finally, Factor 4 is called relationship with friends. It contains: in the last few weeks I've spent time with my friends; in the last week I've had fun with my friends.

Linear regression was determined using the stepwise variable selection procedure with the dependent variable Scoff score and the four factors defined above and the individual variables age and BMI as independent variables. Table 6 shows the descriptive statistics of the variables entered. No data are given on sex because it was entered as a dummy variable.

Table 7 summarises the model. It should be noted that the R2 reaches 76%, which indicates the goodness of fit of the model and the

Table 6. Descriptive statistics of the variables entered in the linear regression.

	N	Mean (SD)	Skewness	Standard Error	Kurtosis	Standard Error
Age	395	14.07 (1.353)	-0.95	0.123	-1.202	0.245
Body Mass Index	391	21.349 (2.199)	0.296	0.123	0.757	0.246
Factor 1	393	0.00 (0.903)	-0.065	0.123	-0.537	0.246
Factor 2	393	0.00 (0.874)	-0.066	0.123	-0.246	0.246
Factor 3	393	0.00 (0.873)	-0.061	0.123	-0.498	0.246
Factor 4	393	0.00 (0.840)	-0.373	0.123	-0.003	0.246
SCOFF score	390	13.35 (3.334)	-0.090	0.124	-0.586	0.247

Table 7. Summary of the model (dependent variable SCOFF score).

Model	Input variables	R	R-squared	Adjusted R-squared	Durbin-Watson
1	Factor 3	0.841	0.707	0.706	
2	Factor 3 Factor 1	0.854	0.730	0.729	
3	Factor 3 Factor 1 Age	0.862	0.751	0.749	
4	Factor 3 Factor 1 Age BMI	0.866	0.764	0.762	1.892

Figure 2. SCOOF index dispersion.

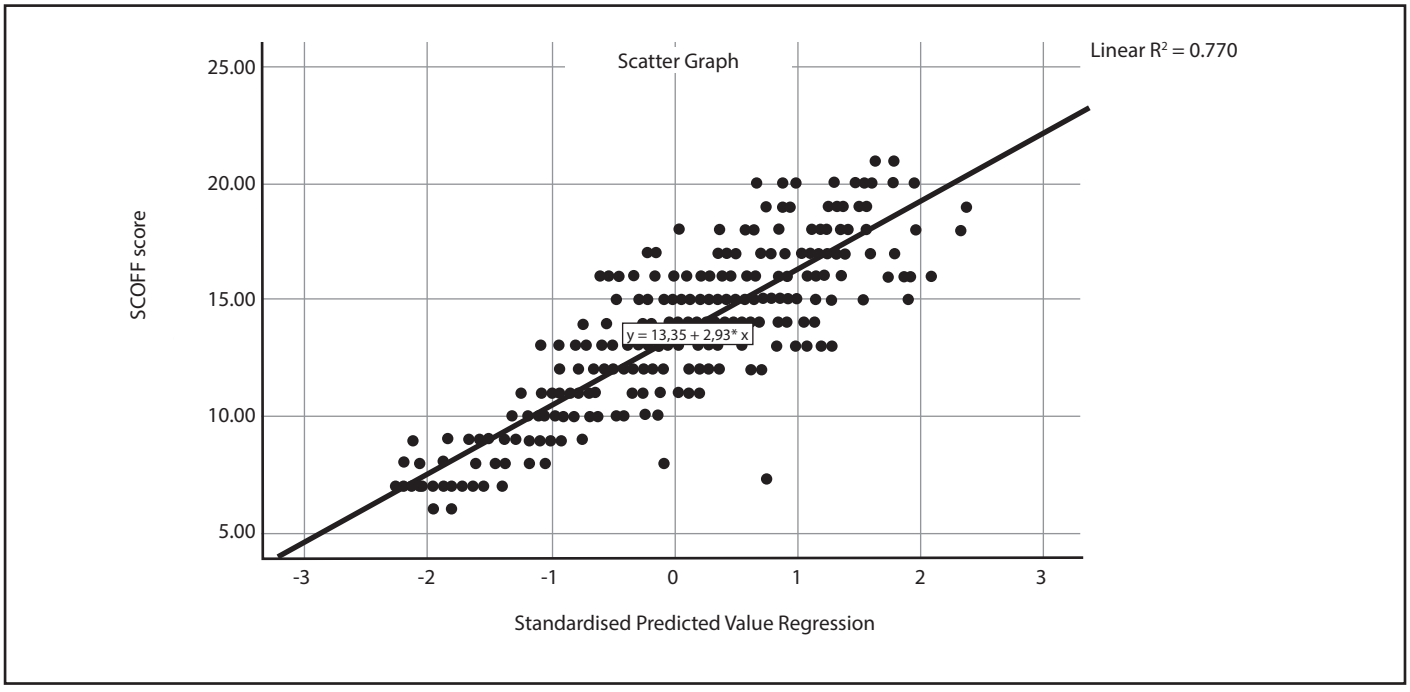


Table 8. Linear regression analysis.

Variables	Model 1	Model 2	Model 3	Model 4
Body image	0.841**	0.832**	0.779**	0.780**
Social and economic cooperation with family and friends		-0.152**	-0.139**	-0.145**
Age			0.128**	0.108**
BMI				0.081**

**The correlation is significant at the 0.001 level
*The correlation is significant at the 0.005 level

high capacity of the independent variables to explain the variance of the Scoff score.

Similarly, taking the Durbin-Watson statistic as a reference with the reference values for our sample and the number of variables considered in the linear regression, it can be understood that there is no autocorrelation (positive or negative) (Figure 2).

Table 8 shows the linear regression bringing in different models:

In model 1 (sig. = 0.000), the variables related to body image (factor 3) (sig. <0.001) appear with a positive sign, so those who are significantly interested in how their clothes look on them, would change their physique and would like to be slimmer are more likely to have an ED.

Model 2 (sig. = 0.000) contains the variables related to body image (factor 3) (sig. <0.001) and social and economic cooperation (negative) (factor 1) (sig. <0.001). In this case, when there is no intergroup peer support, the individual has less money than their peers or does not talk to their parents when faced with problems, the danger of suffering an ED increases.

Model 3 adds age (sig. < 0.001) to the previous factors (sig. < 0.000), showing that there is a greater risk of suffering an ED as the study population becomes more adult.

Finally, model 4 (sig. <0.001) adds BMI (sig. = 0.002), showing that the higher this indicator, the greater the risk of having an eating disorder.

In summary, it can be seen that concern about body image has the greatest explanatory weight regarding the danger of developing an ED, followed by social and economic cooperation with family and friends, age and BMI. Sex and the relationship with friends factor were excluded from the model because they did not significantly increase the variance explained.

Table 9. Correlations between Scoff score and athletic and academic performance (N = 393).

	Scoff	Hours of sleep per day	Do you have trouble concentrating?	Do you feel tired?	Do you feel tired in training?
Scoff					
Pearson correlation	1	-0.251**	-0.122**	-0.193**	-0.376**
Sig. (2-tailed)		<0.001	0.01	<0.001	<0.001

*The correlation is significant at the 0.05 level
**The correlation is significant at the 0.005 level

The last objective of the study was to find out the degree to which the danger of suffering from an ED is related to the athletic and academic performance of adolescents. The answers to the questions posed were on a Likert-type scale from "yes, usually" to "no, never".

Table 9 shows that there is a significant correlation between positive Scoff scores and not sleeping much, concentration problems and physical and psychological fatigue. The variable with the highest correlation was fatigue after training; the more tired the individual felt as a result of physical activity, the greater the risk of EDs.

Discussion and conclusions

The aim of this study was to pinpoint the individual and social factors which pave the way towards and perpetuate the danger of suffering from eating disorders, and to analyse the consequences such disorders may have on the sports and academic performance of adolescent athletes.

When held up against other studies for the same age group (Villegas-Moreno, 2021)[16], the chief findings of this study show a higher prevalence of danger of developing EDs in the young population that does sport. And not just that; the prevalence of danger of presenting EDs in the athlete population is also related to the type of sport. There are studies that claim that this is a consequence of the requirements or norms considered beneficial for performance (see, among others, Baile *et al.,* 2021[27]; Monserrat [et al.], 2021[19]).

This study does not expose any difference between the sexes. Unlike other studies, which point towards a greater rate of disorder in the female population (Torres, 2019[11]; Schaefer and Thompson, 2014[12]), neither the descriptive data nor the significance values in the linear regression support such a distinction. Therefore, we stress a need to work on prevention from a more age-based rather than sex-based perspective, considering age a more predictive factor. This may be because both the males and the females are in a stage of constant growth and development, and are continuously evaluating themselves and comparing themselves with their peers, be it in their class, school or sports team, and/or with famous people they see on social networks. However, due to the results found, we believe that it would be important and interesting for prevention work to be carried out prior to the adolescent stage (before the age of 12 or 13).

Another aspect to highlight is the lack of relationship between objective and subjective body image values. The fact that a large part of the respondents say they feel fat despite the fact that BMI data show that the vast majority are at normal weight highlights two main ideas supported by the data from the study: 1) the presence of body image disturbance; 2) body dissatisfaction. Both are related to current beauty standards (see Villegas-Moreno, 2021)[16], where body dissatisfaction is related to body fat (Neves *et al.*, 2017)[31].

Consequently, there is a well-defined relationship between danger of ED and body image. The result of the linear regression clearly shows this, dissatisfaction with body image having the greatest explanatory weight despite the normal weights found. Secondly, although they explain the danger of EDs to a lesser extent, social and economic co-operation relationships are another factor that go some way towards explaining the model insomuch as the less social and economic cooperation young people experience with their peers and family members, the more likely they are to suffer from eating disorders.

Similarly, the data show, in our case, that social networks, as a whole, do not show a significant relationship with the danger of developing an ED. However, that it is not the most determining factor in the danger of developing EDs highlights the fact that it is not simply consumption of networks that is a factor when it comes to determining EDs but rather using them as tools for relationships and aspiration. That is to say, following someone who is attractive in itself does not pose a danger, but it can be dangerous when following someone is used for comparison and as a model to follow and/or imitate because "I express dissatisfaction with my body and I want to look like him/her" (Aznar *et al*., 2020[32]; Romo del Olmo, 2020[24]).

As for the relationship between developing an ED and sports and academic performance, we find that there is a relationship between the danger of developing EDs and feeling tired in day-to-day life, getting little rest and having problems concentrating. This demonstrates, as other studies highlight, the relationship between physiological and psychological problems and EDs (AHAB, 2020; American Psychiatric Association, 2013[2]; Contreras *et al.,* 2021[33]).

In our case, feeling tired and danger of developing an ED is not related to the number the hours of sport, unlike previous studies where the time dedicated to sport is positively related to the danger of developing an ED (Baquero, 2020[21]; Ventura-Cruz *et al.*, 2022[34] and Márquez S, 2008[35]). This situation can be explained because in our case the subjects' exercise is guided and supervised by coaches with a focus on competition. However, if in addition to the activities scheduled by their club, the subjects engage in more sports activity and suffer greater fatigue, they are at risk, because this "excess" has a more narcissistic rather than competitive component.

In short and in conclusion, despite the limitations, we believe that this study is of high explanatory and probative value, allowing us to list several proposals for action:

One, implement prevention programmes from an early age because, as has been seen, the danger increases with age.

Two, implement health promotion programmes where, in addition to working on eating and sports-related habits, aspects related to body image are also addressed.

Three, design interventions based on age, in addition to sex, given that the data on body image dissatisfaction and risk of EDs are becoming increasingly similar between the sexes.

Four, when designing interventions, pay particular attention to the athlete population because, as we have observed, there is a very high risk of EDs among athletes. We even recommend differentiating between athletes according to type of sport both for diagnosis and for prevention and intervention.

By means of conclusion, we would like to highlight two points: first, that the young participants in the study have not been diagnosed, which shows that excessive preoccupation for the physique can lead to behaviour or attitudes that can affect the health before any disorder is diagnosed. Even more, if these co-morbidities are never diagnosed, they can persistently affect lifestyle. And second, the results support the undertaking of longitudinal studies in which the variability of the different dimensions analysed and their degree of influence on danger of developing EDs are observed over time.

Funding

Funding support received by the University of Almería through the "UAL TRANSFIERE 2022" programme.

Conflict of interest

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

Bibliography

1. Gómez C, Mijan de la Torres A, Palma S, Rodriguez P, Matia P, Loria V, *et al.* Consenso sobre la evaluación y el tratamientonutricional de los trastornos de la conducta alimentaria: anorexia nerviosa, bulimia nerviosa, trastorno por atracón y otros. *Nutrición Hospitalaria.* 2018;35(2):489-94.
2. Asociación Estadounidense de Psiquiatría. DSM-V. *Diagnostic and Statistical Manual of Mental Disorder.* Arlington: Washinton, EEUU, 2013.
3. Modica CA. The associations between Instagram use, selfie activities, appearance comparison, and body dissatisfaction in adult men. *Cyberpsychology, Behavior, and Social Networking*. 2020;23(2):90-9.
4. Behar R, Arancibia M. DSM-V y los trastornos de la conducta alimentaria. *Revista Chilena de neuro-psiquiatría*. 2014;52(1):22-33.
5. Ponce C, Turpo K, Salazar C, Viteri-Condori L, Carhuancho J, Taype Á. Trastornos de la conducta alimentaria en estudiantes de medicina de una universidad de Perú. *Revista Cubana de Salud Pública.* 2017;43(4):1-12.
6. Ávila J, Park K, Golden N. Trastornos de la alimentación en adolescentes. R*evista Médica del Instituto Mexicano del Seguro Social.* 2019;52(S1):48-57.
7. Vela BL, Alarcón SH, Rodríguez AM. Revisión de las herramientas en español para la detección de los trastornos del comportamiento alimentario en adultos. *Rev Esp Nutr Comu*. 2014;20(3):109-17.
8. Wang ML, Peterson KE, McCormick MC, Austin SB. Environmental factors associated with disordered weight-control behaviours among youth: A systematic review. *Public Health Nutrition.* 2013;17(7):1-14. http://doi.org/10.1017/S1368980013001407
9. Festinger L. A theory of social comparison processes. *Human Relations.* 1954;7:117-40.
10. Fitzsimmons-Craft EE, Bardone-Cone AM, Bulik CM, Wonderlich SA, Crosby RD, Engel SG. Examining an elaborated sociocultural model of disordered eating among college women: The roles of social comparison and body surveillance. *Body Image.* 2014;11(4):488-500. http://doi.org/10.1038/jid.2014.371.
11. Torres V. Trastornos de la conducta alimentaria: anorexia y bulimia nerviosa. *Inteligencia Epidemiológica.* 2019;9(1):33-8.
12. Schaefer LM, Thompson JK. The development and validation of the Physical Appearance Comparison Scale-Revised (PACS-R). *Eating Behaviors*. 2014;15(2):209-17. http://doi.org/10.1016/j.eatbeh.2014.01.001.
13. Ferreiro F, Seoane G, Senra C. Gender-related risk and protective factors for depressive symptoms and disordered eating in adolescence: A 4-year longitudinal study. *Journal of Youth and Adolescence.* 2012;41(5):607-622. http://doi.org/10.1007/s10964-011-9718-7.

14. Veses AM, Gómez-Martínez S, Pérez de Heredia F, Esteban-Cornejo I, Castillo R, Estecha S, *et al.* Cognition and the risk of eating disorders in Spanish adolescents: The AVENA and AFINOS studies. *European Journal of Pediatrics.* 2014;174(2):229-36. http://doi.org/10.1007/s00431-014- 2386-3.
15. Letelier V. *Predictores de severidad en trastornos de conducta alimentaria en población clínica adulta.* Universidad Católitca de Chile: Santiago, Chile, 2021.
16. Villegas-Moreno MJ, Londoño-Pérez C. *Modelo predictivo de insatisfacción con la imagen corporal.* Universidad Católica de Colombia: Bogotá, Colombia, 2021.
17. Gaete V, Lopez, C. Trastornos de la conducta alimentaria en adolescentes. Una mirada integral. *Revista Chilena de Pediatría.* 2020;91(5):784-93.
18. Klump KL. Puberty as a critical risk period for eating disorders: A review of human and animal studies. *Hormones and Behavior.* 2013;64(2):399-410.
19. Monserrat Hernández M, Arjona Garrido Á, Checa Olmos JC, Salguero García D. Relationship between Negative Running Addiction and Eating Disorder Patterns in Runners. *Nutrients.* 2021;13(12):43-4.
20. Villar MG. Relación entre una práctica excesiva de ejercicio físico y los trastornos de la conducta alimentaria: Una revisión sistemática. *Trastornos de la conducta alimentaria.* 2017;25:2766-94.
21. Baquero F. *Trastornos de la conducta alimentaria en adolescentes: Hospital Infantil Universitario de San José Carrera.* 2020. Disponible en: https://www.hospitalinfantildesanjose.org.co/pediatria/trastornos-de-la-conducta-alimentaria-en-adolescentes
22. Associació Contra l'Anorèxia i la Bulímia *¿Qué son los TCA?* 2020 https://www.acab.org/es/los-trastornos-de-conducta-alimentaria/que-son-los-tca. (Acces 09/01/23).
23. Pérez Sinusía M, Cassany Comas D. Escribir y compartir: Prácticas escritas e identidad en los adolescentes en Instagram. *Aula de Encuentro.* 2018;20(2). https://doi.org/10.17561/ae.v20i2.5
24. Romo del Olmo M. *Influencia de las redes sociales en la satisfacción de la imagen corporal de las adolescentes. Un proyecto de prevención*. Trabajo de Grado en Psicología. Universidad de Cádiz: Cádiz, Spain, 2020.
25. Chardon ML, Janicke DM, Carmody JK, Dumont-Driscoll MC. Youth internalizing symptoms, sleep-related problems, and disordered eating attitudes and behaviors: A moderated mediation analysis. *Eating behaviors.* 2016;21:99-103.
26. Morgan JF, Reid F, Lacey JH. The SCOFF questionnaire: assessment of a new screening tool for eating disorder. *British of Medicine Journal.* 1999;319:1467-18.
27. Baile Ayensa JI, Villamediana A. Factores de riesgo en trastornos de la conducta alimentaria en deportistas de alto rendimiento. Revisión sistemática. *Clínica Contemporánea.* 2021;12(2).
28. Groves RM. Survey errors and survey cost. New York: John Wiley & Sons. Jáñez, L. F*undamentos de Psicología Matemática*. Madrid: Pirámide; 1989.
29. Alvero-Cruz JR, Carnero EÁ, Fernández-García JC, Expósito JB, de Albornoz Gil MC, Sardinha LB. Validez de los índices de masa corporal y de masa grasa como indicadores de sobrepeso en adolescentes españoles: estudio Esccola. *Medicina Clínica.* 2010;135(1):8-14.
30. Hair JF Jr., Black WC, Babin BJ, Anderson RE. *Multivariate data analysis.* Prentice Hall: New York, EEUU, 2010.
31. Neves CM, Cipriani FM, Meireles JFF, da Rocha Morgado FF, Ferreira MEC. Body image in childhood: An integrative literature review. *Revista Paulista de Pediatría.* 2017;35(3):331.
32. Aznar Díaz I, Kopecký K, Romero Rodríguez JM, Cáceres Reche MP, Trujillo Torres JM. Patologías asociadas al uso problemático de Internet. Una revisión sistemática y metaanálisis en WOS y Scopus. *Investigación bibliotecológica.* 2020;34(82):229-53.
33. Contreras Moreno SY, Arias Moreno NV. *Adolescentes con características asociadas a los trastornos de conducta alimentaria y estrategias de afrontamiento: revisión sistemática.* Universidad de Tunja: Tunja, Colombia, 2021.
34. Ventura-Cruz VA, Pacheco LM, Peña-Polanco JJ, Cruceta-Gutiérrez JF, Arias-Ureña JL, Bennasar-García MI. Relación entre imagen corporal e índice de actividad física en adolescentes. *Polo del Conocimiento.* 2022;7(6):743-55.
35. Márquez S. Trastornos alimentarios en el deporte: factores de riesgo, consecuencias sobre la salud, tratamiento y prevención. *Nutrición Hospitalaria*. 2008;23(3):183-90.

POSTGRADOS OFICIALES:
SALUD Y DEPORTE

UCAM
UNIVERSIDAD
CATÓLICA DE MURCIA

- **Actividad Física Terapéutica** *(2)*
- **Alto Rendimiento Deportivo: Fuerza y Acondicionamiento Físico** *(2)*
- **Performance Sport: Strength and Conditioning** *(1)*
- **Audiología** *(2)*
- **Balneoterapia e Hidroterapia** *(1)*
- **Desarrollos Avanzados de Oncología Personalizada Multidisciplinar** *(1)*
- **Enfermería de Salud Laboral** *(2)*
- **Enfermería de Urgencias, Emergencias y Cuidados Especiales** *(1)*
- **Fisioterapia en el Deporte** *(1)*
- **Geriatría y Gerontología: Atención a la dependencia** *(2)*
- **Gestión y Planificación de Servicios Sanitarios** *(2)*
- **Gestión Integral del Riesgo Cardiovascular** *(2)*
- **Ingeniería Biomédica** *(1)*
- **Investigación en Ciencias Sociosanitarias** *(2)*
- **Investigación en Educación Física y Salud** *(2)*
- **Neuro-Rehabilitación** *(1)*
- **Nutrición Clínica** *(1)*
- **Nutrición y Seguridad Alimentaria** *(2)*
- **Nutrición en la Actividad Física y Deporte** *(1)*
- **Osteopatía y Terapia Manual** *(2)*
- **Patología Molecular Humana** *(2)*
- **Psicología General Sanitaria** *(1)*

(1) Presencial *(2) Semipresencial*

MÁS INFORMACIÓN: **968 27 88 01** · **ucam.edu**

About "energy" drinks
Sobre las bebidas energéticas

Sociedad Española de Medicina del Deporte (SEMED)

The media has recently reported that seven Spanish autonomous communities have plans to regulate the sale of what are known as "energy" drinks to under-18s. Galicia has taken the first steps to prohibit under-18s from buying them as of 2024, but does any legislation currently regulate the consumption of stimulant drinks? What medical risks does consuming them involve?

Almost all "energy" drinks contain different stimulant ingredients (high caffeine content, minimum amounts of taurine, ginseng, guarana and so on), but they do not all contain sugar. There are "sugar free" options which, seeing that they do not provide energy, should not be classed as "energy" drinks at all.

If the ingredient that defines the classification is caffeine, for example, and this is a stimulant, the name should reflect the composition and use given to these drinks, that is to say, they should be called stimulant drinks.

To date, the European Union (EU) has no regulations dealing with stimulant or ill-defined "energy" drinks. Some countries regulate their composition, as is the case with Austria, Lithuania, Latvia and Germany.

Spain has legislation on soft drinks (RD 650/2011), this being the classification in which they would be included, but it is not specific enough.

If the EU does not regulate, the Spanish Society of Sports Medicine (SEMED) believes that Spain should regulate the naming of these beverages at national level, even though some aspects are the competence of the EU,, such as warning labels:

- Composition: Beverages with a content of more than 15 mg of caffeine/100 ml, including energy shots in the regulation.
- Maximum size. "Energy" drinks should not exceed 250 ml.
- Regulate sale to under-18s.
- No free product samples at sports competitions, so as not to associate their consumption with physical activity, exercise and sport, or in school environments (primary, secondary and high school).
- Finally, as EU Regulation 1169/2011 governs labelling for products with high caffeine content other than coffee, tea or their derivatives, in which the name of the product includes the word "coffee" or "tea", Spain, as holder of the Presidency of the European Union, should ask the European Commission to initiate modification of the information given so that the warning reads: "High caffeine content. Not recommended for minors or pregnant or breastfeeding women" in the same visual field as the name of the drink, followed by a reference, in brackets, to the amount of caffeine per 100 ml.

The 2023 nutrient profiles of the WHO Regional Office for Europe classifies energy drinks in a subgroup within non-alcoholic beverages, as it does with juices and juices reconstituted from concentrate, dairy milk drinks, plant-based milks, water and flavoured soft drinks.

The recommendation of the European Food Safety Authority (EFSA) is not to exceed 400 mg of caffeine/person/day, but this should be understood as an amount to be spread out over 24 hours. Stimulant drinks are consumed in 10-30 minutes and so their physiological effect is completely different. The problem is not the amount of caffeine a person consumes per day, where the calculation is made for consumption distributed over 24 hours, but when it is consumed in concentrated form (160 mg) in a single act in a very short space of time.

High caffeine content per 100 ml is potentially the most dangerous factor for the health. To make matters worse, the containers used for these drinks are usually large, 500 ml, and the contents are drunk quickly.

The side effects can include: gastrointestinal discomfort, anxiety, restlessness, nervousness, tremor, headache, irritability, dependence, psychomotor agitation, peptic ulcer, epileptic seizure and the list goes on.

At the cardiological level, the increase in catecholamine levels facilitates cytoplasmic calcium overload, which can trigger atrial and ventricular arrhythmias. There is also a risk of coronary vasospasm, increased platelet aggregation and endothelial dysfunction, all of which are conducive to acute myocardial ischaemia, and ventricular arrhythmias as a result of that ischaemia.

On top of everything, stimulant drinks are often drunk in combination with alcohol, which favours dehydration by increasing diuresis, more so in conditions which induce sweating (outside and inside premises), and this can pave the way to arrhythmias.

These drinks can even mask hereditary channelopathies such as long QT syndrome through the release of catecholamines or Brugada syndrome through the sodium-channel-blocking effect of taurine.

For all these reasons, the Spanish Society of Sports Medicine (SEMED) calls on the competent authorities to regulate the supply and naming of drinks of this kind, with the ultimate aim of protecting the health of the population in general and under-18s in particular.

Correspondence: Sociedad Española de Medicina del Deporte
E-mail: femede@femede.es

Guidelines of publication Archives of Sports Medicine

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

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

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

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

Submit of manuscripts

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

b. **REVIEWS ARTICLES:** The text will be divided in as much paragraphs as the author considers necessary for a perfect compre-hension of the topic treated.
c. **LETTERS TO THE EDITOR:** Discussion about published papers in the last two issues, with the contribution of opinions and experiences briefed in 3 pages, will have preference in this Section.
d. **OTHERS:** Specific sections commissioned by the Journal's Editorial Board.

6. **Bibliography:** it will be presented on pages apart and will be ordered following their appearance in the text, with a correlative numeration. In the text the quote's number will be presented between parentheses, followed or not by the authors' name; if they are mentioned, in case the work was made by two authors both of them will figure, and if there are more than two authors only the first will figure, followed by "et al".
There will not be personal communication, manuscripts or any unpublished information included in the bibliographical appointments.
The official citation for the journal Archives of Sports Medicine is Arch Med Sport.
References will be exposed in the following way:
   - **Journal: order number;** surnames and name's initial of the article authors with no punctuation and separated with a comma (if the number of authors is higher than six, only the six first will figure, followed by "et al"); work's title in its original language; abbreviated journal name, according to the World Medical Periodical; year of publication; volume number; first and last page of the quoted extract. Example: Calbet JA, Radegran G, Boushel R and Saltin B. On the mechanisms that limit oxygen uptake during exercise in acute and chronic hypoxia: role of muscle mass. *J Physiol.* 2009;587:477-90.
   - **Book chapter**: Authors, chapter title, editors, book title, city, publishing house, year and number of pages. Example: Iselin E. Maladie de Kienbock et Syndrome du canal carpien. En : Simon L, Alieu Y. Poignet et Medecine de Reeducation. Londres : Collection de Pathologie Locomotrice Masson; 1981. p162-6.
   - **Book**. Authors, title, city, publishing house, year of publication, page of the quote. Example: Balius R. Ecografía muscular de la extremidad inferior. Sistemática de exploración y lesiones en el deporte. Barcelona. Editorial Masson; 2005. p 34.
   - **World Wide Web**, online journal. Example: Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis (revista electrónica) 1995 JanMar (consultado 0501/2004). Available in: http://www.cdc.gov/ncidod/EID/ eid.htm
7. **Tables and figures.** Tables and figures will be sent on separate files in JPEG format. Tables must be sent in word format.
Tables shall be numbered according to the order of appearance in the text, with the title on the top and the abbreviations described on the bottom. All nonstandard abbreviations which may be used in the tables shall be explained in footnotes.
Any kind of graphics, pictures and photographies will be denominated figures. They must be numbered correlatively by order of appearance in the text and will be sent in black and white (except in those works in which colour is justified). Color printing is an economic cost that has to be consulted with the editor.
All tables as well as figures will be numbered with Arabic numbers following the order of appearance in the text.
At the end of the text document the tables and figures captions will be included on individual pages.
8. The Journal's Editorial Staff will communicate the reception of submitted articles and will inform about its acceptance and possible date of publication.
9. After hearing the reviewers' suggestions (journal uses peer correction system), may reject the works which are not suitable, or indicate the author the modifications which are thought to be necessary for its acceptance.
10. The Editorial Board is not responsible for the concepts, opinions or affirmations supported by the authors.
11. Submissions of the papers: Archives of Sports Medicine. By e-mail to FEMEDE'S e-mail address: femede@femede.es. The submission will come with a cover letter on which the work's examination for its publication in the Journal will be requested, article type will be specified, and it will be certified by all authors that the work is original and has not been partially or totally published before.

Conflicts of interests

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

Ethics

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

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

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

Campaña de aptitud física, deporte y salud

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

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

BIOLaster

Analizador de Lactato Biosen C-line

Medición de glucosa y lactato con precisión de laboratorio en una sola prueba

CLINIC

20 muestras de manera automática
Disponible en:
1 canal de medición: lactato o glucosa
2 canales de medición: lactato y glucosa

GP+

5 muestras de manera automática
Disponible en:
1 canal de medición: lactato o glucosa
2 canales de medición: lactato y glucosa

COSTE REDUCIDO DE OPERACIÓN

FÁCIL DE UTILIZAR

- Pantalla táctil multilingüe con instrucciones paso a paso
- Sólo se necesitan 20 µl de sangre, plasma o suero
- Resultados entre 20 y 45 segundos en función del modo de calibración
- Hasta 120 resultados por hora
- Detección automática de las cubetas a analizar
- Sensores de chip fácilmente intercambiables

EXACTO Y CONFIABLE

- Método enzimático amperométrico con tecnología de sensor de chip
- Intervalo de medición: **glucosa 0,5 - 50 mmol/L; lactato 0,5 - 40 mmol/L**
- Precisión Im: CV ≤1,5 % (12 mmol/L)
- Las cubetas de reacción suprimen la necesidad de dilución manual
- El innovador diseño de aguja y permutador elimina el riesgo de contaminación cruzada
- 3 modos de calibración

MÁXIMA EFICACIA Y COMODIDAD

- Opción de canal doble: resultados de glucosa y/o lactato a partir de una sola muestra
- Sensor de larga duración: glucosa 60 días / 7.500 pruebas; lactato 50 días / 6.000 pruebas
- Muestras estables en cubeta hasta 5 días (refrigeración recomendada)

MANEJO EFICAZ DE LOS DATOS

- Conectividad con PC, red e impresora mediante la interfaz RS232C
- Guarda hasta 1.000 resultados
- Lector de códigos de barras integrado (opcional)

CLINIC

GP+

BIOLaster www.biolaster.com 943 300 813 | 639 619 494