ISSN: 0212-8799

221

Volume 41 (3)

May - June 2024

Archivos de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

ORIGINALS

REVIEW

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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(3) - Num 221. May - June 2024 / ***Mayo - Junio 2024***

Summary / Sumario

Body Composition, Body Mass Index and Relative Fat Mass

Composición corporal, índice de masa corporal y masa grasa relativa

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doi: 10.18176/archmeddeporte.00164

Ever since Sports Medicine emerged as a specific field, one of its main purposes has been to assess body size, build, proportionality and composition. A number of different goals are sought through this speciality, including the recruitment of sports talent, the optimisation of training activities, the improvement of performance in sport and the assessment of cardiovascular risk. Anthropometry was therefore adopted as a tool to lend scientific method to the taking of measurements and the interpretation of those measurements. This is often referred to as kinanthropometry and various consensuses have been reached for standardisation purposes[1].

Multiple anthropometric techniques and procedures have been developed and perfected over the years to quantify issues relating to body composition and build[2]. These include the classic Sheldon somatotype, the Phantom model for body segment proportionality, skinfold measures and the various equations for calculating fat percentage (Siri, Faulkner, Carter, Yuhasz…). Regarding the latter — the calculation of fat percentage — several dozens of equations have been published; some more generic and others for more specific populations with numerous variables, coefficients and constants that make comparisons and interrelationships between them complicated. Meanwhile, technology has steadily produced numerous procedures for determining fat mass and muscle mass with minimal intervention from the examining physician but with significant preparation by the patient, including bioelectrical impedance, magnetic resonance, tomography and densitometry. These technical and technological advancements, which could be considered a favourable result, complicate the collection of data, the interpretation of that data and comparison between different studies. The broad range of equipment, brands, models and techniques plus the existence of different benchmark values and equations based on each one means that we cannot all have everything and that each centre or researcher has their own benchmark values. Moreover, this situation has led to many studies looking to find relationships between techniques and procedures, as well as complex value conversions. Ultimately, and from a practical point of view, this means they can only be reliably compared with others of a similar nature and that the potentially precise is relegated to something approximate.

In an attempt to simplify things and to find a broad benchmark, the World Health Organisation adopted Quetelet's Index (mass/height^2) as a measurement to assess nutritional status and its links to health, calling it the Body Mass Index (BMI). The WHO classification for the BMI is mainly focused on identifying and classifying overweight tied to excess fat[3]. What some consider an advantage (the same benchmark values for men and women, regardless of age and level of physical activity) of this index is the clearest source of criticism for others. The calculation of this index has been used in the vast majority of scientific works related to public health, nutrition, and sports medicine and science. Besides the corresponding "WHO label", this is perhaps due to inertia in the traditional description of the populations used in our studies and the ease with which it can be calculated and interpreted. Regrettably, most readers of these studies have not been critical with what we are shown alongside a BMI value in a population of healthy, not obese and athletic subjects. For example, what does knowing the BMI of a population of triathletes contribute to a project? or how does knowing their BMI value help a young judoka? It is logical to expect an athlete with an acceptable muscle mass to have a high BMI (muscle has weight and the scales do not distinguish what they are weighing) but that does not mean they are overweight or obese. For that reason, BMI values and their interpretation according to the WHO classification are of no interest or usefulness in athletes.

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An inappropriate tool is being used whenever a population of athletes is described using the BMI, especially when not complemented with other data. Those data might be the fat mass percentage or the musculoskeletal mass percentage. For this percentage to be valid, it should be simple to obtain and reliable. I believe that this premise rules out anthropometric techniques with skinfold measurement as their technical complexity and inter-observer variability make them barely credible in poorly trained hands. Furthermore, the multitude of usable formulas makes it extremely difficult to compare data. The other, increasingly more popular alternative would be to rely on data obtained from bioelectrical impedance in which inter-observer variability is low. However, the differences between the data provided by the various devices make the possibility of intrinsic errors high. A third alternative has also been available for a number of years now, which is to determine relative fat mass (RFM). This is a slightly more sophisticated evolution of the classic waist-to-height ratio.

The RFM concept was described by Woolcott and Bergman in 2018 and provides distinct equations for each gender[4]. Its generic equation is: RFM = 64 – (20*height/waist) + (12*gender) [1 in women; 0 in men)]. To determine the RFM formulas, the authors considered different population groups and the correlation with dual-energy X-ray absorptiometry (DXA) as a benchmark[4]. One major advantage is that, for calculation purposes, only the waist circumference needs to be measured (as well as height). This means that measurement errors are few and far between when compared with the measurement of skinfolds. Geometric vision of what is being linked is far more logical for interpreting obesity than it is when using BMI. The RFM concept can be thought of as a cylinder, meaning that fat percentage in individuals of the same height is higher in those with a larger waist, and vice-versa; the same waist measurement indicates a larger fat component when the height measurement is smaller. Whereas the BMI is a mass divided by a surface, something that is difficult to visualise. A formula adapted to children and adolescents has also been described[5] and a growing body of benchmark data is being produced for different populations while the number of studies to validate its use is increasing[6], as is the number of those who prefer it over the BMI[7,8]. I believe it is a cheap, fast and reliable option for describing our populations, with or without the BMI, and one worthy of more attention in the field of sports medicine.

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Original article

The Effects of Aquatic Exercise on Variables related to Body Composition in Children and Adolescents: a systematic review

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doi: 10.18176/archmeddeporte.00165

Received: 08/08/2023
Accepted: 08/03/2024

Summary

Objective: The aim of this study was to analyse the current scientific evidence on the effects of aquatic exercise on variables related to body composition in children and adolescents.
Material and method: Articles published up to March 2022 were identified in six databases using the following search strategy: ["aquatic exercise"] OR ["water based exercise"] AND ["children"] OR ["weight loss"] OR ["body composition"]. Methodological quality was evaluated using the Physiotherapy Evidence Database, Methodological Index for Non-Randomized Studies, and "Quality Assessment Tool for Before-After Studies with No Control Group" scales. Additionally, the Consensus on Exercise Reporting Template was applied to analyse the quality of the interventions.
Results: Finally, 8 studies (349 participants) were selected. Six of them were considered "high" quality and two were "low" quality. After applying the Consensus on Exercise Reporting Template to assess the quality of intervention descriptions, four were rated as "good," while the other four were rated as "poor" or "unreliable." Aquatic exercise programs were found to be effective in improving variables related to body composition such as body weight, body mass index, and body fat percentage. Additionally, variables related to the physical capacity of participants were also found to benefit.
Conclusion: The implementation of aquatic exercise programs appears to be useful in improving variables related to body composition in children and adolescents. Additionally, they could be a valuable intervention to improve their physical capabilities. However, given that the methodological quality of the interventions was not high, further exploration of these relationships is necessary.

Key words:
Adiposity. Aquatic therapy. Body composition. Child. Weight loss.

Efectos del ejercicio acuático en variables relacionadas con la composición corporal en niños y adolescentes: revisión sistemática

Resumen

Objetivo: El objetivo de este estudio fue analizar la evidencia científica actual sobre los efectos del ejercicio acuático en variables relacionadas con la composición corporal de niños y adolescentes.
Material y método: Se identificaron artículos publicados hasta marzo de 2022 en seis bases de datos utilizando la siguiente estrategia de búsqueda y palabras clave: [*"aquatic exercise"*] OR [*"water based exercise"*] AND [*"children"*] OR [*"weight loss"*] OR [*"body composition"*]. Se evaluó la calidad metodológica utilizando las escalas de *Physiotherapy Evidence Database, Methodological Index for Non-Randomized Studies* y *"Quality Assessment Tool for Before-After Studies with No Control Group"*. Además, se aplicó la escala *Consensus on Exercise Reporting Template* para analizar la calidad de las intervenciones.
Resultados: Se seleccionaron finalmente 8 artículos (349 participantes). Seis de ellos fueron considerados como artículos de "alta" calidad y dos de "baja" calidad. Tras aplicar la escala *Consensus on Exercise Reporting Template* para conocer la calidad de la descripción de las intervenciones, cuatro de ellas fueron calificadas como "buenas", mientras que las otras cuatro fueron calificadas como "malas" o "poco fiables". Los programas de ejercicio acuático demostraron ser eficaces para mejorar variables relacionadas con la composición corporal como el peso, el IMC o el porcentaje graso. Además, las variables relacionadas con la capacidad física de los participantes también se encontraron beneficiadas.
Conclusión: La realización de programas de ejercicio acuático parece ser útil para mejorar variables relacionadas con la composición corporal de niños y adolescentes. Además, también podrían ser una intervención valiosa para mejorar las capacidades físicas de estos. Sin embargo, dado que la calidad metodológica de las intervenciones no era alta, es necesario seguir explorando estas relaciones.

Palabras clave:
Adiposidades. Composición corporal. Ejercicio acuático. Niños. Pérdida de peso corporal.

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Introduction

Obesity and overweight in children and adolescents have important health consequences, both in the short and long term. Children and adolescents with overweight and obesity are at greater risk of developing obesity, premature death and disability in adulthood. However, besides the increased future risks, obese children experience breathing difficulty, greater risk of fractures, high blood pressure, early cardiovascular disease markers, resistance to insulin and psychological effects[1].

Child and adolescent obesity and overweight are a global problem that is on the rise. According to the World Health Organisation, the amount of young people with overweight or obesity has multiplied ten-fold in the last four decades, and the number is expected to keep growing[1]. In Spain, it is estimated that more than 30% of children and adolescents have overweight or obesity[2].

For this reason, finding effective strategies to prevent and treat obesity and overweight in children and adolescents is essential. Regular physical exercise is one of the main tools for dealing with this situation, and it is recommended that children and adolescents engage in at least 60 minutes of moderate or vigorous physical activity per day[3]. With that in mind, aquatic exercise can be a beneficial and interesting option for promoting physical activity in this group due to a series of advantages. Physical exercise in the water has a reduced impact on joints and lowers the risk of injury, which would also encourage motivation and adherence[4]. Furthermore, water offers a natural resistance that increases the intensity of effort and energy expenditure, potentially favouring a body fat reduction and improved muscle strength and cardiovascular capacity[5,6].

Despite the potential advantages of aquatic exercise in the prevention and treatment of obesity and overweight in children and adolescents, a systematic review of existing studies on this topic is necessary. This would enable analysis of the effectiveness of aquatic exercise in the prevention and treatment of obesity and overweight, as well as identification of possible factors capable of impacting its effectiveness.

This systematic review of literature sought to analyse the scientific evidence in this regard on the effects of aquatic exercise on variables tied to body composition in children and adolescents.

Material and method

This systematic review was carried out according to the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[7]. This review was registered on the Open Science Framework (OSF), https://doi.org/10.17605/OSF.IO/HY385

Search strategy

Articles published up to March 2022 were identified using the following databases: Scopus® (Elsevier B.V.), PubMed (United States National Library of Medicine), and SPORTDiscus (EBSCO Industries Inc.). Other secondary databases were also used, such as Google Scholar, Dialnet and ERIC (Education Resources Information Centre). The following search strategy and keywords were used: ["aquatic exercise"] OR ["water based exercise"] AND ["children"] OR ["weight loss"] OR ["body composition"].

Eligibility criteria

The research articles were included or excluded using the criteria defined with the PICO (*P*opulation, *I*ntervention, *C*omparison, *O*utcome) method (Table 1), and the bibliographic literature searches were limited to those articles that provided information on the effects of aquatic exercise on variables related to body composition in children and adolescents. Theses, dissertations and conference proceedings and summaries were also excluded. No restrictions were imposed on language, but the studies needed to be written in English, Portuguese or Spanish.

Study selection

Two authors reviewed the titles and summaries of the identified articles to check their eligibility. After independently reviewing the studies selected for inclusion, the two authors compared them to reach an agreement. Upon reaching an agreement, a copy of the full text of each potentially relevant study was obtained. If it was unclear whether a study met the criteria for inclusion, a third author was consulted to reach a consensus. Furthermore, the full texts of the studies that met the criteria for inclusion and various systematic reviews were reviewed manually in search of other relevant references.

Table 1. Search strategy and criteria for inclusion/exclusion based on PICO.

Database	Search terms	PICO	Criteria for inclusion	Criteria for exclusion
Scopus PubMed SPORTDiscus Google Scholar Dialnet ERIC	["aquatic exercise"] OR ["water based exercise"] AND ["children"] OR ["weight loss"] OR ["body composition"]	Population	Children and adolescents	Middle-aged adults or senior citizens.
		Intervention	Aquatic exercise strategies	The aquatic intervention proposal was combined with other therapies. The interventions did not take place in neutral environments.
		Comparison	Aquatic exercise strategies/conditions	There is no comparison between the structured strategies or the control condition with previous and subsequent results.
		Outcome	Variables related to body composition	The results did not consider those related to body composition. Data is lacking on the effects of the aquatic exercise strategies.

Data extraction

General details on the study title, the authors and the design were extracted. Any available data on the participants, the characteristics of the intervention, the variables analysed, the tests used, the results obtained and the adherence/dropout rate were also obtained. All this information was extracted from the original articles by two of the authors and a descriptive table was created (Table 2). A third researcher supervised this process.

Methodological quality assessment

The methodological quality of the studies was assessed using three different scales. The methodological quality of each randomised controlled trial (RCT) was obtained from Physiotherapy Evidence Database (PEDro). If a trial was not included in PEDro, two authors assessed its quality and any disagreements were resolved by consensus. The suggested cut-off points for categorising the studies based on quality were: excellent (9-10), good (6-8), standard (4-5) and poor (≤3)[8]. The Methodological Index for Non-Randomised Studies (MINORS)[9] was used to determine the methodological quality of comparison studies. They were considered to be of high quality if the total MINORS score was ≥17, while a total score of <17 was considered low quality[10]. The Quality Assessment Tool for Before–After Studies with No Control Group of the National Heart, Lung and Blood Institute (NHLBI) was used for uncontrolled interventions[11]. The levels of evidence were considered to be high, moderate or low[12]. The methodological quality of comparison and uncontrolled studies was assessed by one author and then checked by a second author. In the event of a disagreement, a third author was consulted.

Furthermore, the quality of the information reported in the interventions was assessed using the Consensus on Exercise Reporting Template (CERT). A decision was made to use this tool due to the differences found in the design of the articles. A final score of ≤8 was considered low quality and a final score of ≥9 was considered high quality[13].

Results

2,011 records were obtained from the database search. After excluding duplicates and examining the titles and summaries, 62 articles were recovered for assessment of the full text. Finally, eight studies met the criteria for inclusion and were included in the systematic review (Figure 1).

Table 2. Descriptive summary of the randomised and controlled articles.

Author (Year), Design, Participants and Adherence/Dropout Rate	Intervention	Variables (Test)	Results
Irandoust *et al.* (2020) **Design:** RCT **Participants (n; condition; gender):** 71 (59); children; M (G1 = 20; G2 = 19; CON = 20) *Age, years (average; SD):* G1 = 8.91 ± 1.21; G2 = 9.30 ± 1.30; CON = 8.95 ± 1.15 *Height, cm (average; SD):* G1 = 135.40 ± 7.38; G2 = 133.82 ± 5.17; CON = 133.87 ± 5.66 *Weight, kg (average; SD):* G1 = 39.92 ± 6.62; G2 = 39.52 ± 6.16; CON = 39.20 ± 4.49 *Fat percentage, % (range):* >25 BMI, kg/m² (average; SD): G1 = 29.39 ± 3.84; G2 = 29.44 ± 3.67; CON = 29.28 ± 2.95 **Dropout rate (n; reasons):** 12; (9 = do not meet inclusion criteria and 3 for missing the sessions)	**Frequency:** 3 sessions/week **Duration:** 4 weeks **G1:** Video games group **Description:** *Combination of games (Wii Sports, Kinect Ultimate Sports, Wii Fit and Just Dance)* **Volume:** 60 min **Intensity:** 50–70 % FCR (11–13 RPE) **G2:** Aquatic exercise group **Description:** – 5 min. Warm-up: Stretching movements, static walking, jogging on the spot, side-to-side steps. – 50–60 min. Main part: Jumping jacks, high knees, jabs, quick kicks, backward kicks, running laps and jumps with rotation. – 10 min. Return to rest: Stretching, ball game, relaxation and deep breathing. **Volume:** 65-75 min **Intensity:** Warm-up: 40–50% HRR (7–9 RPE): Main part: 50–70% HRR (11–13 RPE), Return to rest: 40–50% HRR (7–9 RPE) **CON** **Description:** No organised PE was performed	**Anthropometric measurements** Body weight (kg) Fat percentage (%) WHR BMI (kg/m²) **Physical capacity measurements** *Muscle function:* – FVC (ml) – FEV_1 (ml) **Perceptive measurements** RPE- Borg Scale (6-20)	**Intra-group** (*P* <0.05) Body weight ↓ in G1 (pre-intervention *vs.* monitoring and post intervention *vs.* monitoring) Body weight ↓ in G2 (pre-intervention *vs*. monitoring and pre-intervention *vs.* post-intervention) BMI ↓ in G1 (pre-intervention *vs.* monitoring, pre-intervention *vs*. post-intervention and post-intervention *vs.* monitoring) BMI ↓ in G2 (pre-intervention *vs*. monitoring, pre-intervention *vs*. post-intervention) FVC ↑ in G1 (pre-intervention *vs*. monitoring and pre-intervention *vs.* post-intervention) FVC ↑ in G2 (pre-intervention *vs*. monitoring and pre-intervention *vs.* post-intervention) **Inter-group (P <0.05)** > Body weight in CON that in G1 and G2 in the monitoring and post-intervention > WHR in CON that in G1 and G2 > BMI in CON that in G1 and G2 in the monitoring and post-intervention > FVC in G1 and G2 that in CON in the monitoring and post-intervention > FEV_1 in CON that in G1 and G2 in the monitoring and post-intervention

(continued)

Table 2. Descriptive summary of the randomised and controlled articles *(continuation)*.

Author (Year), Design, Participants and Adherence/Dropout Rate	Intervention	Variables (Test)	Results
Honório *et al.* (2018) **Design:** RCT **Participants (n; condition; gender):** 28; children who practised swimming; NR (G1 = 9; G2 = 19) *Age, years (range):* 6-12 *Height, cm (average; SD):* G1 = NR; G2 = 130.32 ± 7.80 *Weight, kg (average; SD):* G1 = 23.7 ± 3.64; G2 = 29.6 ± 6.15 *Fat percentage, % (average; SD):* G1 = 18.4 ± 2.66; G2 = 17.6 ± 3.57 *BMI, kg/m² (average; SD):* G1 = 15.4 ± 1.72; G2 = 17.3 ± 2.37 **Dropout rate (n; reasons):** NR	**Frequency:** 2 sessions/week **Duration:** 12 weeks **G1:** Swimming group **Description:** Swimming classes **Volume:** 45 min **Intensity:** NR **G2:** Swimming + aquatic walking group **Description:** 39 min., swimming classes + 6 min. aquatic walking at the end of each session (water at chest height) **Volume:** 45 min. **Intensity:** NR	**Anthropometric measurements** Body weight (kg) Fat percentage (%) Muscle mass (kg) Water percentage (%) Waist circumference (cm) BMI (kg/m²) BMI percentiles (kg/m²) **Physical capacity measurements** *Muscle function:* – FVC (ml) – FEV_1 (ml) – PEF (ml) **Perceptive measurements** RPE (Borg Scale, 6-20)	**Intra-group (*P* <0.05)** Body weight $\uparrow$ in G1 at week 12 compared with at the start (23.7 ± 3.64 *vs.* 25.5 ± 4.38 kg) Body weight $\uparrow$ in G2 at week 6 (30.1 ± 6.01 kg) and 12 (30.4 ± 6.05 kg) compared with at the start (29.6 ± 6.14 kg) Fat percentage $\uparrow$ in G2 at week 12 compared with at the start (17.6 ± 3.57 *vs.* 17.9 ± 3.70%) Water percentage $\uparrow$ in G2 at week 12 compared with at the start (56.7 ± 4.21 *vs*. 56.0 ± 4.24%) Waist circumference $\uparrow$ in G1 at week 6 compared with at the start (54.4 ± 5.17 *vs*. 56.3 ± 5.73 cm) BMI $\uparrow$ in G1 at week 12 compared with at the start (15.4 ± 1.72 *vs.* 16.7 ± 2.70 kg/m²) BMI $\uparrow$ in G2 at week 6 (17.6 ± 2.22 kg/m²) and 12 (17.8 ± 2.30 kg/m²) compared with at the start (17.3 ± 2.37 kg/m²) BMI percentiles $\uparrow$ in G2 at week 12 compared with at the start (59.4 ± 32.4 *vs*. 68.0 ± 29.8 kg/m²) FVC $\uparrow$ in G2 at week 6 (1.83 ± 0.42 ml) and 12 (1.81 ± 0.41 ml) compared with at the start (1.63 ± 0.49 ml) FEV_1 $\uparrow$ in G2 at week 6 (1.68 ± 0.42 ml) and 12 (1.71 ± 0.39 ml) compared with at the start (1.55 ± 0.47 ml) **Inter-grup (*P* <0.05)** > Body weight - in G2 that in G1 at week 6 (30.1 ± 6.01 *vs.* 24.9 ± 4.54 kg) and at week 12 (30.4 ± 6.05 *vs.* 25.5 ± 4.38 kg) > FVC in G2 that in G1 at week 6 (1.83 ± 0.42 *vs*. 1.47 ± 0.31 ml) > FEV1 in G2 that in G1 at week 6 (1.68 ± 0.42 *vs*. 1.33 ± 0.23 ml) and at week 12 (1.71 ± 0.39 *vs.* 1.41 ± 0.26 ml) > PEF in G2 that in G1 at week 6 (3.77 ± 1.00 *vs*. 2.88 ± 0.43 ml) ant at week 12 (3.87 ± 1.02 *vs*. 3.19 ± 0.44 ml)

(continued)

Table 2. Descriptive summary of the randomised and controlled articles *(continuation)*.

Author (Year), Design, Participants and Adherence/Dropout Rate	Intervention	Variables (Test)	Results
Lopera *et al.* (2016) **Design:** *Comparative* **Participants (n; condition; gender):** 210 (150); adolescents; G1 = 28 (11 M + 27 F); G2 = 57 (29 M + 28 F); CON = 66 (36 M + 30 F) *Age, years (average, SD):* G1 = 13.0 ± 1.4; G2 = 13.1 ± 1.9; CON = 13.3 ± 1.9 *Height, cm:* NR *Weight, kg (average, SD):* G1 = 78.3 ± 17.5; G2 = 81.0 ± 17.8; CON = 77.8 ± 16.0 *Fat percentage, % (average, SD):* G1 = 40.1 ± 7.6; G2 = 44.4 ± 6.6; CON = 43.5 ± 6.4 *BMI, kg/m^2 (average; SD):* G1 = 29.2 ± 5.0; G2 = 31.2 ± 4.7; CON = 29.4 ± 4.3 **Dropout rate (n; reasons):** 80; 59 did not complete the protocol due to transport problems (G1 = 7; G2 = 33; CON = 19), 25 preferred other activities (G1 = 2: G2 = 23); 10 lost motivation (G1 = 2; G2 = 8) and 19 did not attend the last session (CON = 19)	**Frequency:** 3 sessions/week **Duration:** 16 weeks **G1:** Aquatic exercise group **Description:** Psychological intervention + nutritional intervention + educational programme on physical activity + training session. – interval walking/running training in water. – endurance exercise with aquatic equipment to simulate endurance exercises. – swimming exercises (mainly crawl and backstroke) and diving to pick up dumbbells and other objects. – continuous recreational exercises. **Volume:** 60 min **Intensity:** NR **G2:** On-land exercise group **Descripction:** Psychological intervention + nutritional intervention + educational programme on physical activity + training session – endurance training (sit-ups, push-ups, squats and exercises with medicine balls). – aerobic exercises (walking and running). – group games. **Volume:** 60 min **Intensity:** NR **CON** **Description:** Performed no organised PE	**Anthropometric measurements** Body weight (kg) Fat percentage (%) Fat-free weight (kg) Waist circumference (cm) Waist circumference (cm) BMI (kg/m^2) **Physical capacity measurements** Abdominal strength/endurance (rep) - Maximum curl-ups in 1 min. Flexibility (cm)- Sit-and-reach test. VO_{2max} (ml/min/kg) - 20 m Shuttle Run Test or Cooper Test adapted to the pool (m) **Perceptive measurements** Quality of life - Paediatric Quality of Life Inventory™ – Physical – Emotional – Social – School – Psychosocial – Total	**Intra-group (P <0.05)** Body weight ↑ in CON (77.8 ± 16 *vs.* 78.6 ± 16.2 kg) Fat percentage ↓ in G1 (40.1 ± 7.6 *vs.* 36.3 ± 8.5%) Fat percentage ↓ in G2 (44.4 ± 6.6 *vs.* 42.0 ± 7.6%) Fat-free weight ↑ in CON (41.6 ± 8.7 *vs.* 42.6 ± 8.8 kg) Waist circumference ↓ in G1 (87.7 ± 10.5 *vs.* 86.5 ± 10.9 cm) Waist circumference ↓ en G2 (91.4 ± 10.9 *vs.* 89.3 ± 10.7 cm) Hip circumference ↓ in G1 (106.9 ± 9.5 *vs.* 105.5 ± 8.8 cm) Hip circumference ↓ in G2 (109.6 ± 10.9 *vs.* 108.5 ± 10.8 cm) BMI ↓ in G1 (29.2 ± 5 *vs.* 28.1 ± 5.1 kg/m^2) BMI ↓ in G2 (31.2 ± 4.7 *vs.* 30.6 ± 4.8 kg/m^2) Abdominal strength/endurance ↑ in G1 (18.8 ± 10.4 *vs.* 24.1 ± 10.9 rep) Abdominal strength/endurance ↑ in G2 (20.4 ± 10.8 *vs.* 29.1 ± 11.7 rep) Flexibility ↑ in CON (22.1 ± 9.1 *vs.* 24.4 ± 9.8 cm) Flexibility ↑ in G1 (21.0 ± 10.1 *vs.* 24.3 ± 9.4 cm) Flexibility ↑ in G2 (22.9 ± 11.7 *vs.* 25.7 ± 8.6 cm) VO_{2max} ↑ in G1 (24.2 ± 4.8 *vs.* 26.5 ± 5.7 ml/min/kg) VO_{2max} ↑ in G2 (25.2 ± 5.4 *vs.* 27.9 ± 6.4 ml/min/kg) Physical (perceived) ↑ in G1 (75.8 ± 11.5 *vs.* 81.6 ± 10.5) Physical (perceived) ↑ in G2 (77.7 ± 14.0 *vs.* 83.2 ± 12.6) Social (perceived) ↑ in G2 (77.1 ± 21.7 *vs.* 82.1 ± 17.8) Psychosocial (perceived) ↑ in G2 (73.1 ± 14.5 *vs.* 75.9 ± 14.1) Total quality of life (perceived) ↑ in G2 (74.3 ± 13.2 *vs.* 78.0 ± 12.6) **Inter-group (P <0.05)** > Body weight reduction in G2 that in CON (–1.7% ± 5.3 *vs.* 1.2% ± 3.3) > Fat percentage reduction in G2 and G1 that in CON (–1.1 ± 4.3%), and > G2 *vs.* G1 (–9.8 ± 7.2 *vs.* –6.1 ± 6.2%) > Fat-free weight increase in G1 (4.6 ± 4 kg) and G2 (4.4 ± 4.1 kg) that in CON (2.5 ± 3.9 kg) > VO_{2max} increase in G1 (7.3%) and G2 (10.7%) that in CON (2%) > Abdominal strength/endurance increase in G2 *vs.* G1 (34.7 *vs.* 26.1%)

(continued)

Table 2. Descriptive summary of the randomised and controlled articles *(continuation).*

Author (Year), Design, Participants and Adherence/Dropout Rate	Intervention	Variables (Test)	Results
Pan (2011) **Design:** Comparative **Participants (n; condition; gender):** 30 (G1 = 7; ASD; M, G2 = 7; No-ASD; 1M + 6F, G3 = 8; ASD; 8M, G4 = 8; No-ASD; 4M + 4F) *Age, years (average, SD):* G1 = 9.31 ± 1.67; G2 = 8.89 ± 1.98; G3 = 8.75 ± 1.76; G4 = 7.39 ± 2.94 *Height, cm (average, SD):* G1 = 134.89 ± 7.82; G2 = 133.14 ± 16.39; G3 = 135.05 ± 11.27; G4 = 125.11 ± 2.94 *Weight, kg (average, SD):* G1 = 29.16 ± 3.53; G2 = 28.76 ± 12.59; G3 = 36.05 ± 12.35; G4 = 30.25 ± 15.07 *Fat percentage, %: NR* *BMI, kg/m^2 (average; SD):* G1 = 16.03 ± 1.36; G2 = 15.56 ± 2.18; G3 = 19.41 ± 5.06; G4 = 18.18 ± 3.69 **Dropout rate (n; reasons):** NR	**Duration:** 32 weeks; 14 (Stage 1) + 14 (Stage 2) + 4 transition Aquatic programme **Description:** – 10 min. Social and floor warm-up. – 35 min. Main part: they practised the training objectives individually or in pairs. – 15 min. Main part: group games/ activities. – 10 min. Return to rest: cool-down activities. **Volume:** 70 min **Intensity:** NR **Frecuency:** 2 sessions/week **G1:** Aquatic programme (Stage 1) + CON (Stage 2) **G2:** Aquatic programme (Stage 1) + CON (Stage 2) **G3:** CON (Stage 1) + Aquatic programme (Stage 2) **G4:** CON (Stage 1) + Aquatic programme (Stage 2)	**Anthropometric measurements** Body weight (kg) Fat percentage (%) Fat weight (kg) Fat-free weight (kg) BMI (kg/m^2) **Physical capacity measurements** Abdominal strength/ endurance (rep) - Curl-up test Flexibility (cm) - Sit-and-reach test. $VO_{2máx}$ (ml/min/kg) - PACER (m) *Aquatic skills* - HAAR checklist – Mental adaptation – Introduction to the aquatic medium – Turns – Balance and control – Free movement in the water	**Inter-group (*P* <0.05)** > Curl ups (30 s) in G1 that in G3 and G4 (12.29 ± 2.93 *vs.* 8.25 ± 3.88 and 8.00 ± 2.62) at the end of Stage 1 > Curl ups (30 s) in G2 that in G4 (12.71 ± 3.99 *vs.* 8.00 ± 2.62) at the end of Stage 1 > Curl ups (60 s) in G1 and G2 that in G4 (22.57 ± 7.04 and 23.43 ± 7.41 *vs.* 13.63 ± 5.71) at the end of Stage 1 > Curl ups (60 s) in G2 that in G3 (22.57 ± 7.04 *vs.*14.88 ± 6.56) at the end of Stage 1 > Score in introduction to the aquatic medium in G1 and G2 that in G4 (100 ± 0 and 100 ± 0 *vs.* 91.25 ± 8.35) at the end of Stage 1 > Score in balance and control in G1 and G2 that in G3 and G4 (96.43 ± 9.45 and 100 ± 0 *vs.* 73.44 ± 24.49 and 57.81 ± 28.30) at the end of Stage 1 > Score in free movement in the water in G1 that in G3 and G4 (83.33 ± 21.52 *vs.* 43.75 ± 36.66 and 33.33 ± 39.84) at the end of Stage 1 > Score in free movement in the water in G2 that in G4 (78.57 ± 23.00 *vs.* 33.33 ± 39.84) at the end of Stage 1
Lee & Oh (2014) **Design:** Comparative **Participants (n; condition; gender):** 24 (20); children (G1 = 10; CON = 10) *Age, years (average, SD):* G1 = 11.45 ± 2.87; CON = 11.11 ± 1.69 *Height, cm (average, SD):* G1 = 127.46 ± 5.37; CON = 126.74 ± 3.25 *Weight, kg (average, SD):* G1 = 44.53 ± 8.83; CON = 46.73 ± 8.86 *Fat percentage, % (average; SD):* G1 = 34.45 ± 3.24; CON = 33.92 ± 2.70 *BMI, kg/m^2:* NR **Dropout rate (n; reasons):** 4; personal reasons or physical limitations	**Frequency:** 3 sessions/week **Duration:** 12 weeks **G1:** Aquatic exercise group **Description:** – 10 min. Warm-up: Stretching. – 40 min. Main part: 1) side kick, 2) free kick, 3) free pull, 4) pull and kick, 5) freestyle swim, 6) back kick, 7) back pull, 8) pull and kick, 9) freestyle and back simulation, 10) interval swimming. – 10 min. Return to rest: Stretching, ball game, relaxation and deep breathing. **Volume:** 60 min **Intensity:** Warm-up: 7–9 RPE; Main part: 1-6 weeks 50–60% HR_{max} (11–13 RPE) and 7-12 weeks 60–70% HR_{max} (13–15 RPE), Return to rest: 7–9 RPE **CON** **Description:** Performed no organised PE	**Anthropometric measurements** Body weight (kg) Fat percentage (%) Fat-free weight (kg) **Physiological measurements** Vascular distention in hands and feet **Physical capacity measurements** Abdominal strength/endu-rance (rep) - *Sit-ups* Grip strength Flexibility (cm) - *Sit-and-reach test* Cardiovascular endurance 20 m *Shuttle Run Test*	**Intra-group (*P* <0.05)** Body weight ↓ in G1 (44.53 ± 4.56 *vs.* 40.80 ± 2.11 kg) Fat percentage ↓ in G1 (34.45 ± 2.28 *vs.* 29.90 ± 1.75%) Fat-free weight ↑ in G1 (30.64 ± 1.41 *vs.* 35.34 ± 1.91 kg) Vascular change in right leg ↑ in G1 (361.34 ± 25.66 *vs.* 381.93 ± 16.87) *Sit-ups* ↑ in G1 (49.49 ± 15.73 *vs.* 60.1 ± 11.54 rep) Flexibility ↑ in G1 (6.11 ± 6.34 *vs.* 18.71 ± 9.58 cm) Cardiovascular endurance ↑ in G1 (13.72 ± 2.45 *vs.* 17.45 ± 2.22 cm) **Inter-group (*P* <0.05)** > Body weight in CON that in G1 (44.38 ± 4.75 *vs.* 40.80 ± 2.11 kg) at 12 weeks > Fat percentage in CON that in G1 (35.1 ± 1.65 *vs.* 29.90 ± 1.75%) at 12 weeks < Fat-free weight in CON that in G1 (30.94 ± 1.66 *vs.* 35.34 ± 1.91%) at 12 weeks < Vascular change in right leg in CON that in G1 (349.16 ± 28.24 *vs.* 381.93 ± 16.87) at 12 weeks < *Sit-ups* in CON that in G1 (47.6 ± 10.29 *vs.* 60.1 ± 11.54) at 12 weeks < Flexibility in CON that in G1 (11.1 ± 5.89 *vs.* 18.71 ± 9.58 cm) at 12 weeks < Cardiovascular endurance in CON that in G1 (13.67 ± 2.17 *vs.* 17.45 ± 2.22) at 12 weeks

(continued)

Table 2. Descriptive summary of the randomised and controlled articles *(continuation)*.

Author (Year), Design, Participants and Adherence/Dropout Rate	Intervention	Variables (Test)	Results
Lopes *et al.* (2021) **Design:** Uncontrolled **Participants (n; condition; gender):** 22 (18); adolescents; 13M, 5F *Age, years (average, SD):* 13.26 ± 1.27 *Height, cm (average, SD):* 164.61 ± 8.85 *Weight, kg (average, SD):* 85.09 ± 20.81 *Fat percentage, % (average; SD):* 36.99 ± 5.19 *BMI, kg/m^2 (average; SD):* 31.25 ± 6.35 **Dropout rate (n; reasons):** 2; due to illness; 2 did not complete all the activities	**Frequency:** 3 sessions/week **Duration:** 12 weeks HIITAQ programme **Description:** – 10 min. Warm-up. – 12-24 min. Main part: HIIT series (static running, front kicks and ski) with active rests. – Return to rest: recreational exercises. **Volume:** NR **Intensity:** 80-95% HR_{max} and 50% HR_{max} during the rest periods; RPE 7-9	**Anthropometric measurements** Height (cm) Body weight (kg) Fat percentage (%) Fat-free weight (kg) WHR Waist circumference (cm) BMI (kg/m^2) Z-BMI **Physiological measurements** Glucose (mg/dl) Insulin (mg/dl) TC (mg/dl) HDL-C (mg/dl) LDL-C (mg/dl) **Physical capacity measurements** VO_{2max} (ml/kg/min^{-1}) RHGS (kg) LHGS (kg) BMR (kcal/day)	**Intra-grupo (p <0,05)** Height ↑ at the end of the 12 weeks (164.61 ± 8.85 *vs.* 167.81 ± 8.80 cm) Body weight ↑ at the end of the 12 weeks (85.08 ± 20.80 *vs.* 87.41 ± 21.37 kg) Fat-free weight ↑ at the end of the 12 weeks (52.99 ± 10.54 *vs.* 55.17 ± 12.45 kg) Waist circumference ↑ at the end of the 12 weeks (107.27 ± 14.10 *vs.* 109.48 ± 14.95 cm) Z-BM I ↓ at the end of the 12 weeks (2.75 ± 0.95 *vs.* 2.62 ± 0.95) TC ↓ at the end of the 12 weeks (175.08 ± 25.95 *vs.* 163.97 ± 22.71 mg/dl) LDL-C ↓ at the end of the 12 weeks (107.46 ± 21.79 *vs.* 97.29 ± 23.80 mg/dl) VO_{2max} ↑ at the end of the 12 weeks (32.2 ± 5.24 *vs.* 33.90 ± 4.93 ml/kg/min^{-1}) BMR ↑ at the end of the 12 weeks (1644.22 ± 341.16 *vs.* 1765.94 ± 356.87 kcal/day)
Pal & Sarkar (2019) **Design:** Uncontrolled **Participants (n; condition; gender):** 20; adolescents; M *Age, years (range):* 8-14 *Height, cm:* NR *Weight, kg:* NR *Fat percentage, % (average; SD):* 38.27 ± 4.52 *BMI, kg/m^2:* NR **Dropout rate (n; reasons):** NR	**Frequency:** 5 sessions/week **Duration:** 6 weeks Aquatic exercises and swimming **Description:** – Dynamic warm-up. – 30-45 min. Main part: Aquatic exercises and swimming. Small field games. **Volume:** NR **Intensity:** NR	**Anthropometric measurements** Fat percentage (%) **Physical capacity measurements** 6 min *Run and Walk Test* - adapted to the pool (m)	**Intra-group (*P* <0.05)** Fat percentage ↓ at the end of the 6 weeks (38.27 ± 4.52 *vs.* 37.07 ± 4.50%) Distance travelled during the 6 min. *Run and Walk Test* ↑ at the end of the 6 weeks (3.0550E2 ± 31.49 *vs.* 3.7725E2 ± 29.40)
Stan (2012) **Design:** Uncontrolled **Participants (n; condition; gender):** 7, children; NR *Age, years (range):* 5-8 *Height, cm (range):* 112-126 *Weight, kg (range):* 37-46 *Fat percentage, %:* NR *BMI, kg/m^2:* NR **Dropout rate (n; reasons):** NR	**Frequency:** 2 sessions/week **Duration:** 12 weeks Aquatic aerobic exercises **Description:** running in shallow water (static and in motion), running in deep water, crawl swimming, modified arm, backstroke legs with float on the chest. **Volume:** 60 min. **Intensity:** NR	**Anthropometric measurements** BMI (kg/m^2)	**Intra-group (*P* <0.05)** Average BMI ↓ at the end of the 12 weeks (29.14 *vs.* 28.23 kg/m^2)

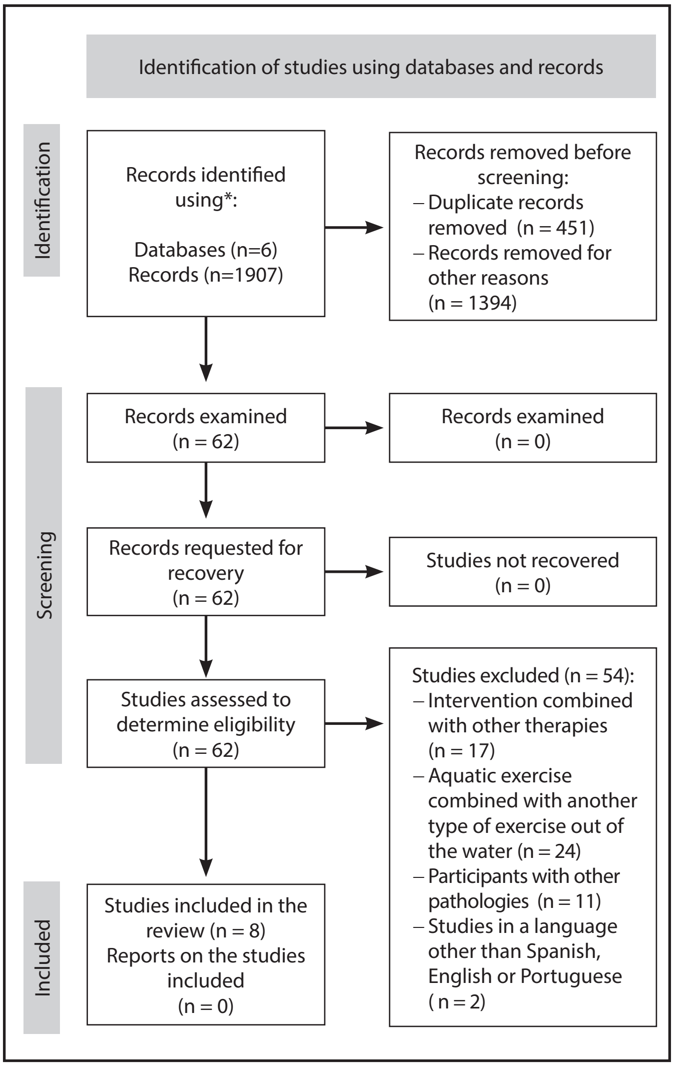
>: Greater than; <: Less than ↑: Increase; ↓: Decrease; PE: Physical exercise; BMR: Basal metabolic rate; CON: Control group; RCT: Randomised controlled trial; F: Female; HR: Heart rate; HR_{max}: Maximum heart rate; HRR: Heart rate reserve; FEV_1: Forced expiratory volume in the first second; FVC: Forced vital capacity; G: Experiment group; HDL: High-density lipoproteins; HIITAQ: Programme of High-Intensity Interval Training in Aquatic Medium; BMI: Body mass index; LDL: Low-density lipoproteins; LHGS: Left hand grip strength; M: Male; NR: Not reported; PACER: *Progressive Aerobic Cardiovascular Endurance Run*; PEF: Maximal expiratory flow; RHGS: Right hand grip strength; RPE: Rate of perceived exertion; TC: Total cholesterol; ASD: Autism spectrum disorders; VO_2: Oxygen volume; VO_{2max}: Maximum oxygen volume: WHR: Waist-to-hip ratio; Z-BMI: Body mass index Z-score.

Design and samples

Of the eight studies included, two were described as RCTs[14,15], three as comparison studies[16-18] and three as uncontrolled studies[19–21]. Table 2 shows a summary of the characteristics of all eight studies reviewed.

In total, 349 participants were included in the studies. The samples used in the studies varied from 7 to 210 participants, with ages ranging from 5 to 18 years. Of the articles analysed, seven showed the sample distribution in terms of gender. Of those seven, four reported mixed

Figure 1. PRISMA diagram (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) for the study.



samples while the other three only conducted the exercise programmes with children (ranges of 228-256 boys and 93-121 girls).

Quality assessment

The RCT articles[14,15] were considered of "high" quality after being analysed using the PEDro scale. The three comparison studies assessed using the MINORS scale were also considered of "high" quality[16–18]. Finally, the NIHL scale was used to assess the methodological quality of the uncontrolled articles, of which two were considered "low" quality[20,21] and one "high" quality[19]. A full description of the quality analysis is provided (Table 3).

The eight interventions were assessed using the CERT scale and four of them were classified as "high" quality[14,18,19,21]. The other four were classified as "low quality" or unreliable. No harmful effects were reported by the participants in any of the interventions (Table 4).

Intervention

Generally, the interventions were conducted over a period of 3 to 16 weeks, with a frequency of 2 to 5 sessions per week and a duration of 30 to 70 minutes. The content of the interventions mainly included aerobic exercise (n = 6), aerobic exercise combined with strength training (n = 1) or aerobic exercise combined with the development of aquatic skills (n = 1).

Two studies compared the effects of the aquatic exercise using a control group[16,17]. The effects of two types of aquatic exercise were compared in one study, with the two groups engaging in swimming sessions but only one of them combined that with aquatic walking[15]. Finally, two articles were reviewed in which the sample was divided into three groups: the control group engaged in regular daily activity; another group engaged in aquatic exercises; and another group engaged in an alternative intervention[14,18]. In this regard, both the interventions based on aquatic exercises and the proposed alternatives were shown to be more effective than the control conditions at reducing body weight.

Main results

We classified the variables into four large groups: anthropometric measurements (n = 8), physiological measurements (n = 2), physical capacity measurements (n = 7) and perceptive measurements (n = 3).

Anthropometric measurements

All the studies assessed variables related to anthropometric measurements. Aquatic exercise presented favourable results in terms of body weight[14,15,17–19,21], BMI[14,15,18,21], body fat percentage[15–18,20], fat-free mass[17–19], waist circumference[15,18] and hip circumference[18,19] after the interventions when compared with before them.

The body weight variable was studied in six articles[14,15,17–19,21]. Three of the six articles[14,17,18] revealed that the control group was less effective than the interventions at reducing body weight. In this regard, Honório *et al.*[15] also discovered differences between the swimming group and the swimming combined with aquatic walking group, the latter being more effective at reducing body weight. The BMI was also studied in six articles, with inter-group differences being found in three of them[14,15,18]. In the studies by Lopera *et al.*[18] and Irandoust *et al.*[14], it was observed that the BMI was higher in the control group than in the intervention groups.

Furthermore, Lopera *et al.*[18] reported improvements in fat percentage and fat-free weight in the aquatic exercise group and on-land exercise group when compared with the control group. Similar results were obtained in the work by Lee & Oh[17], showing lower fat percentages and higher fat-free weight in the aquatic exercise group when compared with the control group.

Waist circumference was studied in two articles[15,18]. Honório *et al.*[15] only found significant differences in the initial assessment of this variable between the swimming group and the swimming combined with aquatic walking group. However, Lopera *et al.*[18] found significant

Table 3. Methodological quality assessment of the studies included.

Authors	Assessment Components												
PEDro scale (randomised and controlled articles)	**0. Eligibility criteria**	**1. Random allocation**	**2. Concealed allocation**	**3. Comparability baseline**	**4. Participant blinding**	**5. Therapist blinding**	**6. Assessor blinding**	**7. Results from 85% assigned**	**8. Intention to treat analysis**	**9. Comparison between groups analysis**	**10. Point measures and variability**	**Total (0-11)**	
Irandoust *et al.* (2020)	1	1	0	1	0	0	1	1	0	1	1	7/11	
Honório *et al.* (2018)	0	1	0	1	0	0	0	1	1	1	1	6/11	
MINORS scale (comparative articles)	**1. Clearly stated aim**	**2. Inclusion of consecutive patients**	**3. Prospective data collection**	**4. Endpoints appropriate to study aim**	**5. Unbiased assessment of study endpoint**	**6. Follow-up period appropriate to study aim**	**7. <5% lost to follow-up**	**8. Prospective calculation of study size**	**9. Adequate control group**	**10. Contemporary groups**	**11. Baseline equivalence of groups**	**12. Adequate statistical analysis**	**Total (0-24)**
Lopera *et al.* (2016)	2	2	2	2	2	2	0	2	2	2	2	2	22/24
Pan (2011)	2	2	2	2	2	2	2	1	2	2	1	2	22/24
Lee & Oh (2014)	2	2	1	2	2	2	0	1	2	2	2	2	20/24
NHLBI scale (uncontrolled articles)	**1. Study aim**	**2. Criterios de elección**	**2. Eligibility criteria**	**4. Elected participants**	**5. Adequate sample**	**6. Intervention and application described**	**7. Result measures**	**8. Assessor blinding**	**9. Loss to follow-up (<20%)**	**110. Statistical values**	**11. Uninterrupted series of data**	**12. Individual data / group result**	**Total (0-12)**
Lopes *et al.* (2021)	1	1	1	1	1	1	1	0	1	1	0	0	9/12
Pal & Sarkar (2019)	1	1	0	1	0	0	0	0	1	1	0	0	5/12
Stan (2012)	1	0	0	0	0	1	0	0	1	1	0	0	4/12

changes in the intervention groups when compared with the control group and also reported a smaller hip circumference in the physical exercise groups when compared with the control group.

Physiological measurements

Two studies included physiological measurements as a result[17,19]. Lopes *et al.*[19] observed that total cholesterol and low-density lipoproteins levels fell after a 12-week programme of high-intensity interval training in an aquatic environment. Furthermore, a change in the vascular distention of the right leg was found in the group engaging in aquatic exercises when compared with the levels recorded prior to the intervention and when compared with the control group[17].

Physical capacity measurements

Seven of the eight studies assessed variables related to the physical capacity of the participants. Aquatic exercise presented favourable results in forced expiratory volume in one second[15], maximal expiratory flow[15], forced vital capacity[14,15] and maximal oxygen uptake[17–20]. In this regard, Honório *et al.*[15] showed that the swimming combined with aquatic walking group was more effective than the only swimming group at improving forced expiratory volume in one second, forced vital capacity and maximal expiratory flow.

Abdominal strength/endurance[16–18], flexibility[17] and the basal metabolic rate[17] were also positively affected by the training programmes, while hand grip strength showed no significant change[17,19]. Furthermore, a programme of aquatic exercise led to significant improvements in aquatic skill scores[16].

Perceptive measurements

Both a 16-week programme of aquatic exercises and one of exercises on land led to a significant increase in perceived fitness among participants when compared with levels prior to the intervention. On the other hand, no significant changes were recorded in fitness among the control group. Nonetheless, only the programme of exercises on land generated an increase in the perceived levels of social status, psycho-social status and quality of life among adolescents[18].

Discussion

This review sought to research the effects of aquatic exercise on variables related to body composition in children and adolescents. The results obtained would indicate its potential interest when reducing body weight, BMI and fat percentage, as well as positively impacting the physical capacity of participants. Nonetheless, the scientific evidence found is not sound.

Table 4. Results of CERT methodological assessment.

Criteria	Irandoust *et al.* (2020)	Honório *et al.* (2018)	Lopera *et al.* (2016)	Pan (2011)	Lee & Oh (2014)	Lopes (2021)	Pal & Sarkar (2019)	Stan (2012)
1. Description of the type of equipment used in the exercise.	1	0	0	0	0	0	0	1
2. Description of the qualifications, experience and/or training.	1	1	1	1	1	1	1	1
3. Describes whether the exercises are individual or group-based.	0	1	0	1	1	0	0	0
4. Describes whether the exercises are supervised or not, how they are taught.	1	1	1	1	0	0	0	1
5. Detailed description of how adherence is measured and reported.	1	0	1	1	1	1	0	1
6. Detailed description of the motivation strategies.	1	0	1	1	0	1	0	0
7a. Detailed description of the rule(s) for deciding on determining exercise progression.	0	0	0	0	0	0	0	0
7b. Detailed description of how the exercise programme is progressing.	0	0	1	0	0	1	0	1
8. Detailed description of each exercise to enable replication.	1	0	1	0	1	1	0	1
9. Detailed description of any component of the programme at home.	0	0	0	0	0	0	0	0
10. Describes any component that is not an exercise.	1	0	1	1	0	0	0	0
11. Describes the type and number of adverse events during the exercise.	0	0	0	0	0	0	0	0
12. Describes the environment in which the exercises take place.	0	1	0	1	0	1	0	1
13. Detailed description of the exercise intervention.	1	0	1	0	1	1	1	1
14a. Describes whether the exercises are generic (the same for all) or personalised.	1	0	1	0	1	1	0	1
14b. Description of how the exercises are adapted to each person.	0	0	0	0	0	0	0	0
15. Describes the rule for determining initial level.	1	1	1	0	0	1	1	1
16a. Describes how adherence or faithfulness are measured.	1	0	1	0	1	0	0	0
16b. Describes the extent to which the intervention went according to plan.	1	1	1	1	1	1	1	1
Final score	**12/19**	**6/19**	**12/19**	**8/19**	**8/19**	**10/19**	**4/19**	**11/19**

Based on the studies included in this review, aquatic exercise seems to be a successful intervention for reducing weight, BMI, fat percentage, fat-free mass, waist circumference and the waist-to-hip ratio in children and adolescents. These results are in line with previous studies on aquatic exercise programmes in adults, which have reported reductions in body weight[22,23], BMI[24], fat percentage[25], fat-free mass[26] or waist circumference and waist-to-hip ratio[27].

One important aspect to take into consideration is that, generally speaking, the groups in the studies included for this review that engaged in some form of physical exercise outside of water also showed benefits in the majority of these variables, while the control groups generally remained unchanged. All the studies included that examined body weight as a variable showed improvements in the exercise groups both in and out of the water. According to the results from the studies by Stan[21], Honório *et al.*[15], Irandoust *et al.*[14] and Lopera *et al.*[18], those participants who engaged in some form of intervention obtained reductions to their BMI regardless of whether the exercise was aquatic, on land or with videogames. In the work by Honório *et al.*[15], there was a small difference in the BMI at the start of the intervention between the swimming group and the swimming plus aquatic walking group. However, this inter-group difference after the intervention was insignificant and both groups saw a reduction to BMI levels. Similarly, fat percentage reductions were found in the groups engaging in exercise out of the water in all the studies that examined this variable. These results seem to indicate that, in general, physical exercise favours the loss of adipose tissue, as already indicated by current scientific evidence[28,29]. Nonetheless, more studies of a better quality are needed to identify whether aquatic exercise is more effective than exercise out of the water at preventing or reducing overweight and obesity in children and adolescents.

Excess body weight in children and adolescents is tied to health risks that include respiratory complications[30], metabolic disorders[31] and an inability to exercise[32]. The data from this review indicated that aquatic exercise was more effective than the control group at improving the variables related to physical capacity, which include breathing capacity, cardiovascular endurance, flexibility and abdominal strength/endurance. Hence, this type of interventions could improve some of the problems associated with overweight and obesity. The results from this review can be added to the existing evidence that indicates the need for children and adolescents to engage in physical activity[33].

Furthermore, in order to analyse the methodological quality of the studies included in this review, several different scales (as stated above) were used to assess the randomised and controlled, and comparison and uncontrolled studies. The methodological quality was good, generally speaking, which is positive because it increases the quality of this work and the results obtained are more reliable. As a result, the scientific evidence extracted from the studies could be described as "valid" [14–16,18,19]. However, there are another two studies in which the evidence extracted might be doubtful due to the "poor" quality of the research[20,21]. In terms of the quality with which the physical exercise interventions were reported (assessed using the CERT scale), half of the articles (n = 4) showed a poor quality. The quality of the interventions was affected on numerous occasions because several studies did not report the pace of progress made by the interventions; something that is essential in any kind of intervention. Neither did any of the studies report whether any problem or adverse event arose during the intervention. Finally, the method used to measure adherence to the exercise programme was not reported at all. For these reasons, the interventions were explained in some of the studies in such a way that left many issues unspecified. As a result, their application to other environments with other participants could be more complicated.

This review has a number of limitations that should be considered when interpreting the results obtained. The most significant of them is tied to the differences between the studies included, especially with regard to their methodological quality. Only four of the eight articles included in this review used a control group[14,16–18]. Of those four, two also had a group that engaged in an activity other than the aquatic exercise[14,18], and the study by Honório *et al.*[15] had a group that combined aquatic exercise with aquatic walking. As a result, only five of the eight initial articles allowed the results obtained following the interventions in the water to be compared with other groups. Finally, there are limitations related to linguistic restrictions owing to the fact that grey literature with publication bias was not reviewed, which could have conditioned the results from this review.

Conclusion

Scientific evidence on the effects of aquatic exercise on variables related to body composition in children and adolescents is scarce. The studies included in this review seem to indicate that aquatic exercise could be useful for preventing or reducing certain variables related to adiposity in children and adolescents, as well as for improving their physical capacity. However, future randomised and controlled studies are necessary to assess the effectiveness of aquatic exercise programmes and these studies should provide a more detailed description of the interventions to enable replication.

Financing

The authors received no financial support for the research, authorship and/or publication of this article.

Conflict of interest

The authors declare no conflict of interest.

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Original article

Strength Exercises in Patients who will undergo Knee Arthroplasty via Fast-track Surgery: a randomised controlled study

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doi: 10.18176/archmeddeporte.00166

Received: 25/04/2023
Accepted: 12/03/2024

Summary

Background: One of the most frequent musculoskeletal and degenerative disorders in adulthood and that produces greater disability is knee ostearthritis; this injury produces greater disability and the solution in severe degrees is knee arthroplasty (TKA). In hospital MAZ, TKA is perfomed with the Fast-track a protocol allows patients to move as quickly as posible and whitout any complications. After the ATR, reductions of muscular strength appear, and with the loss of muscular mass associated with age, the risk of disability increases and that is why recovering musular strength is an important goal for orthopedic surgeons and specialists in rehabilitation.
Objective: The purpose of this study was to evalue the effectiveness of a simple resistance exercise program with elastics bands in patients who are going to unergo TKA usin Fast-track surgery.
Material and method: 48 patients scheduled for TKA in the first half of 2021 participated in this randomized controlled trial. A control group that performed the exercises according to the protocol established in the hospital and the intervention group that also performed exercises with elastic bands. The two groups performed the exercises one month before and after surgery and while the investigation lasted. A pain, stiffness and functional capacity were assessed with questionnaire WOMAC (Western Ontario and McMaster Universities) and the SPPB frailty screenung test battery (Short Physical Perfomance Battery). Handgrip strength, the thigh circumference and the body mass index (BMI) was also mesasured. All of this was evaluated in three times: one month before surgery (T1), fifteen days (T2) and one month (T3) after surgery.
Results: Both the intervention group and the control group obtained statistically significant improvements in the evaluations of WOMAC questionnaire and SPPB tests al 15 days and one month after surgery although the group that did resistance exercises with elastic bands obtained better results. Therre were no significant differences in handgrip strength, thigh circumference or BMI.
Conclusion: A pre and postoperative TKA resistance exercise program with elastic bands improves the effectiveness of the traditional program, reducing pain and stiffness, improving functional capacity, balance and gait speed and therefore autonomy and quality of life.

Key words:
Knee. Knee arthroplasty. Aging. Fast-track. Resistance training. Elastic bands.

Ejercicios de fuerza en pacientes que van a ser intervenidos de artroplastia de rodilla mediante cirugía *"Fast-track"*: un estudio aleatorizado controlado

Resumen

Antecedentes: Uno de los trastornos musculoesqueléticos y degenerativos más frecuente en edad adulta y que produce mayor discapacidad es la osteoartrosis de rodilla cuya solución en grados severos es la artroplastia de rodilla (ATR) que es una de las intervenciones más habituales en los últimos años. En el Hospital Mutua de Accidentes de Zaragoza (MAZ) se realiza con protocolo *"Fast-track"* que permite que los pacientes se movilicen lo más rápido posible y con pocas complicaciones. Inmediatamente después de la ATR aparecen importantes reducciones de la fuerza muscular y junto con la pérdida de masa muscular relacionada con la edad, aumenta el riesgo de discapacidad y es por ello qué recuperar la fuerza muscular es un objetivo importante.
Objetivo: El propósito de este estudio fue evaluar la efectividad de un programa de ejercicios de fuerza con bandas elásticas en pacientes que van a ser intervenidos de artroplastia total de rodilla (ATR) mediante cirugía *"Fast-track"*.

SEMED Research Award 2023

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Material y método: 48 pacientes programados para ATR en el primer semestre del 2021 participaron en este ensayo aleatorizado controlado. Un grupo control que realizaba los ejercicios según protocolo establecido en el hospital y el grupo intervención realizaba además unos ejercicios con bandas elásticas, un mes antes de la cirugía y un mes después de la misma, mientras duró la investigación. Se evaluó el dolor, la rigidez y la capacidad funcional mediante el cuestionario *Western Ontario and McMaster Universities* (WOMAC) y se hicieron la batería de pruebas de cribado de fragilidad SPPB *(Short Physical Performance Battery*) en tres momentos: Un mes antes de la cirugía (T1), quince días después de la cirugía (T2) y al mes de la intervención (T3). También se midió la fuerza de agarre manual en ambas extremidades superiores, el perímetro de muslo (tanto en la pierna que iba a ser intervenida como en la sana) y el Índice de masa corporal (IMC) en las tres evaluaciones.

Resultados: Tanto el grupo intervención como el grupo control obtuvieron mejoras estadísticamente significativas en las evaluaciones del cuestionario WOMAC y pruebas SPPB a los 15 días y a mes de la cirugía si bien el grupo que hizo ejercicios de fuerza con bandas elásticas obtuvo resultados mejores estadísticamente significativos. No hubo diferencias significativas en la fuerza de agarre manual, en el perímetro de muslo ni en el IMC.

Conclusión: Un programa de ejercicios de fuerza pre y postoperatorio de ATR con bandas elásticas mejora la eficacia del programa tradicional, disminuyendo el dolor y rigidez, mejorando la capacidad funcional, equilibrio y velocidad de la marcha y por lo tanto su autonomía y calidad de vida.

Palabras clave:
Rodilla. Artroplastia. Envejecimiento. "Fast-track". Entrenamiento fuerza. Bandas elásticas.

Introduction

One of the most common musculoskeletal and degenerative disorders occurring in adults and causing the greatest disability is knee osteoarthrosis (OA)[1,2]. Patients with knee OA suffer constant pain and functional disorders that often make their day-to-day life impossible[3]. Knee arthroplasty or knee replacement surgery (TKR) to reduce the pain and recover functionality is the most effective and most common treatment in severe cases of OA[4]. A prosthetic knee is a mechanical device consisting of various metal and plastic components that replaces the knee joint formed by the tibia and femur. This prosthesis will relieve the pain and improve function in the majority of patients with degenerative disease in this joint[5,6]. The number of knee arthroplasty surgeries in Spain has risen sharply in recent years, as well as in other countries in the same peer group, given that the indication criteria have broadened due to an ageing population and because it is an effect surgery. As a result, there are greater expectations and higher demand for this surgery among patients[7]. This changing situation has led to various studies demonstrating that it is one of the most common interventions in recent years[8]. In Spain, the number of prostheses has risen from 12,500 in 1995 to 25,000 in 2000[9]. There is no national register of knee arthroplasties at present, although work is being done in this regard[10]. However, according to data from the Spanish Federation of Healthcare Technologies (FENIN), approximately 35,000 prostheses were implanted in 2014 and, according to the most recent arthroscopy conference, this figure reached 60,000 in 2019. Considering the progressive ageing of the population, it is estimated that the number of these surgeries will increase significantly in the coming years.

At the Mutua de Accidentes de Zaragoza Hospital (MAZ), knee replacement surgery is undertaken using a "Fast-track" procedure[11]. This concept was introduced by professor Henrik Kehlet and is defined as any surgery that involves a multi-disciplinary team (traumatologist, anaesthesiologist, nursing staff, rehabilitation doctor and physiotherapist) and the treatment concepts of which, based on evidence, enable patients to mobilise as quickly as possible[12] and with few complications[13]; the patient being the most important part of the programme. The major principles of this procedure are listed below:

- The use of tranexamic acid: Therapy with tranexamic acid in knee arthroplasty reduces blood loss and minimises the need for a transfusion without increasing the risk of thrombosis or embolism[14].
- Administration of corticosteroids such as dexametasone (20 mg) or methylprednisolone (125 mg) for beneficial effects without negatively impacting the infection rate or increasing complications[15].
- A urinary catheter is unnecessary, as it is associated with more complications, a more prolonged stay in hospital, higher costs and a higher readmittance rate at 30 days[16].
- Surgery with intradural anaesthesia and, at MAZ, with ischaemia; i.e. without using a tourniquet: existing literature has demonstrated that no ischaemia reduces blood loss and also reduces post-operative inflammation[17], shortening the operation and guaranteeing a better cementation result.
- There is no intra-articular drainage: A femoral catheter was used for a long time and is still used today in some procedures as a treatment for pain after implanting a knee prosthesis[11], providing good treatment for the pain but not allowing for active mobilisation. Instead of a drain, the recommended treatment for pain is multimodal therapy with local infiltration analgesia (LIA) of the capsule and soft tissues with local anaesthetics (a total of 170 ml solution of ropivacaine at 0.2% sometimes accompanied by adrenaline and local anaesthetic) and application of a certain dressing in the operating theatre plus a compression bandage[18]. This minimises dressing changes and, therefore, handling of the wound. The patient can also shower without a problem the day after the operation.
- Early mobilisation stemming from early discharge, enabling faster and more effective recovery than the conventional protocol[19]:

Two hours after the operation, the patient is already performing active exercises and can walk with a walker. Early mobilisation en courages patient autonomy, conveys the immediate success of the operation and, as a result, eliminates fears and concerns[20] and also acts as an effective thrombosis prophylaxis[21].

One very important and key part of this programme is the information provided to the patient. Candidate patients for the programme attend an informative session, which is also referred to as preoperative education, that seeks to improve knowledge and the health results in patients[22]. Recent literature shows that offering an informative session to patients about the protocol to be followed before the surgery means they experience less anxiety, greater control of postoperative pain and greater understanding of their surgery[23], and the clinical protocols included in that preoperative education programme for knee replacement lead to shorter stays in hospital[24,25] and lower healthcare costs[26]. Those informative sessions deal with issues relating to the type of surgery, the chosen anaesthesia, the medication before and after, and exercises are explained and demonstrated for patients to do at home before the surgery. Several studies show that preoperative training programmes improve postoperative results in terms of pain and function[27,28]. These sessions are also attended by a family member acting as "coach" and this person will be the one encouraging and supervising the daily exercises at home. They are essential for obtaining successful results after the surgery[29]. Strong importance is placed on the patient as the centre of the process and they are involved in their own rehabilitation. It is important to use simple language to ensure optimal understanding of what is discussed[30] and to provide simple educational material with illustrations that will help that better understanding while minimising anxiety and improving results[31].

Furthermore, it is known that muscle strength reductions of up to 60%[32] appear after TKR that, together with the loss of muscle mass related to age, increases the risk of disability[33]. Quadricep strength and function is highly important in ensuring the success of the intervention[34]. Evidence shows that patients who undergo a knee arthroplasty operation obtain better results if they strengthen the musculature of both legs before the surgery via a programme of exercise[35]. In fact, it is believed that preoperative quadricep strength is a strong indicator of functional performance one year after the TKR[36], so recovering muscle strength is an important goal for orthopaedic surgeons and rehabilitation specialists[37].

In light of the above, the purpose of this study is to evaluate the effectiveness of a simple home-based pre- and postoperative strength training programme using elastic bands in patients awaiting TKR. Elastic bands were chosen for their ease of use, accessibility and low cost[38].

Hypothesis

The hypothesis was made that a specific strength exercise programme using elastic bands performed before and after knee arthroplasty leads to a postoperative improvement when compared with the control group (which engages in the exercises established for the current protocol).

Material and method

Design of the study

A controlled and randomised trial was conducted to assess the postoperative period and the effectiveness of including a strength training programme with elastic bands in comparison with a control group engaging in mobility exercises and isometrics exercises. The intervention took place at the Traumatology service under the agreement between MAZ and the Spanish Social Security system. Those patients with stage 3 severe or very severe stage 4 knee arthrosis are proposed for arthroplasty, established according to the Ahlbäck classification system[39,40].

Informed consent was obtained from all patients and the study was initially approved by the ethics committee of the MAZ Hospital and by the Ethics and Research Committee of the Regional Government of Aragon (CEICA) under C.I. PI21/220.

The sample size consisted of 48 patients for convenience (surgeries scheduled during the study period).

Inclusion and exclusion criteria

Those patients who meet the criteria for inclusion in the knee arthroplasty protocol are recruited and given an appointment with a relative/companion to attend an informative session one month prior to the intervention, in groups of two patients.

Inclusion criteria

- Patients over 65 years of age who are scheduled to undergo a TKR.
- Patients: ASA (American Society of Anaesthesiologists) I (healthy patient), ASA II with one or more compensated medical pathologies (controlled high blood pressure, controlled diabetes *mellitus*, smoker, controlled asthma, stabilised chronic obstructive pulmonary disease, obesity, cardiac arrhythmia with normal average ventricular heart rate and with antiaggregate-anticoagulant) and ASA III (patient with one or more medical pathologies, with at least one of them catalogued as decompensated but with said decompensation not posing a risk to life).
- They must sign the informed consent tied to the protocol.

Exclusion criteria

- Patients ASA IV (pathology that poses a constant threat to life), ASA V (moribund patient who is not expected to survive without the operation) and ASA VI (brain-dead: organ donor).
- Under 65 years of age.
- Allergy to any of the drugs proposed during the course of the protocol or contraindication for the administration thereof: Tra-

nexamic acid, nonsteroidal anti-inflammatories), paracetamol, COX-2 inhibitors (cyclooxygenase), corticosteroids, tramadol, ropivacaine, pantoprazol, heparins, oral anticoagulants... although they may be included if these drugs can be replaced with others of a similar effect.
- Patients with significant anaemia (haemoglobin below 13 g/dl in both women and men) or with coagulation abnormalities (excluding drug-induced by oral anticoagulants).
- Refusal by the patient to take part in the study.
- Absence of family support.
- Simultaneous participation in another study.

Randomisation and blinding

The selected patients were randomly allocated to the intervention group or the control group in pairs following the theoretical part of the informative session by individually tossing a coin, with heads being the control group and tails being the intervention group. The patients were not informed about which group they were allocated to. The physiotherapist was the only person with this knowledge, who was also the researcher.

Procedure

The patients and their relative/companion were given an appointment to attend the informative session one month before the intervention, in groups of two, at the hospital. The sessions were held by the physiotherapist responsible for the rehabilitation protocol alongside the traumatologist and they took place on the floor of the hospital where arthroplasty patients are admitted, enabling the patient to familiarise themselves with the environment. The sessions are provided in groups so as to foster interaction with other patients with the same pathology, and time is given for them to ask any questions and have any doubts resolved.

The first study assessment (T1) took place individually and via an interview with the researcher after the informative session in the rehabilitation room.

- Demographic data: Gender, age, weight and height, calculating the BMI (body mass index).
- WOMAC questionnaire (Western Ontario and McMaster Universities)[41] to determine the level of pain, stiffness and functional disability in the patient, assessed on a scale from 0 to 4, with 0 being none (absence of pain, functional disability and stiffness) and 4 being a lot (very severe pain, very severe stiffness and very severe disability). The maximum total WOMAC score was 96 points for all 24 item included.
- Frailty screening test using the Short Physical Performance Battery (SPPB), which is one of the star tests for assessing functional capability and frailty in persons of advanced age. Frailty is related to disability, with the risk of falls and the appearance of disease. Using this tool will be vital for detecting and classifying these people[42,43]. They are three simple tests: balance, sitting down and standing up, and walking speed. The score obtained reflects a certain level of frailty. The lower the SPPB score, the higher the risk of suffering adverse situations (0-3 = major limitations; 4-6 = moderate limitation or pre-frail; 7-9 = minor limitation or frail; 10-12 = no limitation or autonomous).
- Handgrip strength using a manual dynamometer (model T.K.K. 5001 GRIP-A, Tokyo, Japan), this being considered among the manual dynamometers with the highest validity and reproducibility[44]. This is performed on the dominant and non-dominant limbs. The patient remains standing with their arm outstretched and their shoulder at a 45º abduction. Each patient performs the test twice, maintaining pressure for two seconds and resting for one minute between measurements, with the dynamometer open position set at 5 cm for both men and women[45]. The best result was recorded, measured in kilograms, starting with the dominant hand.
- Muscle circumference: with the patient seated on the exam table, knee outstretched and exposed, at 10 cm from the kneecap[46]. This measurement was taken from the two limbs.

The second assessment (T2) is conducted 15 days after the surgery, before the staples are removed from the postoperative wound. The same data are collected under the same conditions as T1. The 3-metre walking speed test is conducted without crutches.

The third assessment (T3) is conducted approximately one month after the operation. The wound is checked and the same data are collected as in T1 and T2.

All the assessments are conducted in the same room using the same procedure (iPhone SE chronometer) and by the same assessor at the same time.

Intervention

Patients and their companions are informed during the informative session about the protocol to be followed. The session starts by introducing the medical team and discussing issues related to their stay in hospital, the surgery, the type of anaesthesia, looking after the wounds at home, dealing with postoperative pain, training on transfers, progress on walking after the surgery (with a walker on the day of surgery, with crutches the next day) and how to go up and down stairs. Finally, the physiotherapist shows the exercises (researcher) and this is when the two study groups are combined; the control group and the research group.

Both the control group and the intervention group receive the same information and only belonging to one group or another changes the exercises to be performed.

Intervention on the Control Group

The exercises aimed at maintaining articular range and muscle tone are explained and performed:

- Laying down in the supine position: bending and stretching the knee, bending and stretching the foot, 45º hip bending, quadricep isometrics.
- Seated: active bending and stretching of the knee.
- Standing: active bending and stretching of the knee.

All the exercises are performed slowly and without the appearance of pain, following the protocol. The patient is asked to perform 10 repetitions of each exercise twice a day. After the intervention and now with the prosthesis, the patient is reminded that they should continue to perform the same exercises.

Intervention on the Intervention Group

The same exercises as the control group are shown, performed and supervised, adding other exercises with a medium resistance elastic band (red, Theraband®[47,48]) to work on muscle strength:

- In the supine position with ankle bands: hip flexion with outstretched knee, abduction and extension of the knee with hip and knee flexion.
- Seated with ankle bands: knee extension.
- Seated with ankle bands: hip flexion, abduction and extension.

These exercises are repeated twice a day, maintaining muscle contraction for two seconds, slowly and without pain, 10 repetitions during the first two weeks increasing to 15 repetitions during subsequent weeks until the day of surgery; the exercises continue at home following hospital discharge after the surgery, 15 repetitions twice a day. The elastic band is one metre long and provided to each patient already knotted and ready to perform the exercises correctly.

The patient learns the exercises to perform at home in both groups under supervision by the physiotherapist. Given the age of the patients (all over 65 years), the companion is an essential part of the process because they will need to oversee and supervise correct performance of the exercises. It is stressed that the companion attending the informative session should be the same person who comes to the hospital for the surgery and stays with the patient at home.

Two leaflets are given to the participants; one with all the information from the session and another with the exercises described in detail. This is so the patient is clear on and committed to the exercises they need to perform before and after the surgery. Emphasis is placed on the importance of performing the exercises and they are encouraged to perform them correctly, thereby involving the patient in their own rehabilitation.

On the day of surgery, the physiotherapist will perform the rehabilitation with the patient on the two days they are admitted to hospital based on the protocol. When discharged, the patients in both groups are reminded that they should continue to perform the exercises as explained during the preoperative session.

The WOMAC questionnaire, the SPPB frailty test, handgrip test, knee circumference and patient weight tests are repeated 15 days after the surgery and before the staples are removed.

All the tests and measurements are repeated one month after the surgery when the patient visits the clinic for discharge. Records are made of the rehabilitation sessions conducted at home on both occasions.

All the assessments — the initial assessment during the informative session (T1), at 15 days (T2) and at 30 days (T3) post-surgery — are conducted in the same room and by the same person (researcher) and at the same time.

Statistical analysis

The demographic characteristics were reported as absolute and relative frequencies for the categorical variables and as an average with standard deviation for the continuous variables. Firstly, the normality of quantitative variables was confirmed using the Shapiro-Wilk test. To assess whether significant differences exist between the groups at the start of the intervention, the Student's T-test or Wilcoxon test was performed. The chi-squared test was used for the only categorical variable (gender).

The ANOVA test for repeated measurements with the Bonferroni post hoc test was used to analyse the inter- and intra-group data from the results of the data with normal distribution. The Mann-Whitney U-test was used to analyse inter-group data with a non-normal distribution and the Wilcoxon test to analyse intra-group data with non-normal distribution.

All the data were analysed using SPSS version 20 statistical software and the analyses were conducted by the researcher.

Results

Basal characteristics of the participants

A total of 48 participants were included in the study, who were randomly allocated to one of two groups; an intervention group and a control group. Two patients were excluded from the surgery because they presented cardiac problems incompatible with the inclusion criteria; both of them were in the control group.

Table 1 shows the demographic data of the patients and it can be seen that the starting characteristics of both groups were similar.

Table 1. Initial Characteristics.

	Control Group N = 22	Intervention Group N = 24	*P* value
Gender	50% men	45.8% men	0.777
Age	73.27 ± 6.56	70.96 ± 0.985	0.108
BMI	32.42 ± 4.25	30.58 ± 0.353	0.096

BMI: body mass index.

Table 2. Initial Measurements.

	Control Group N = 22	Intervention Group N = 24	*P* value
Total WOMAC	65.54 ± 8.59	60.75 ± 8.41	0.774
W pain	12.22 ± 2.58	11.41 ± 2.06	0.108
W stiffness	5.13 ± 1.75	5.54 ± 1.02	0.472
W FUN CAP	48.18 ± 6.3	43.79 ± 7.79	0.472
Total SPPB	4.86 ± 1.49 PRE-FRAIL	5.91 ± 1.97 FRAIL	0,208
SPPB BAL	2.36 ± 0.72	2.29 ± 0.76	0.392
SPPB SS	1.68 ± 0.56	1.8 ± 0.76	0.393
SPPB WS	0.86 ± 0.351	1 ± 0.3	0.16
HANDGRIP DL	25.64 ± 9	26.58 ± 11.32	0.986
HANDGRIP NDL	23.73 ± 8.8	24.84 ± 11.63	0.72
CIRCUMFERENCE PL	51.55 ± 4.89	51.33 ± 4.68	0.881
CIRCUMFERENCE NPL	51.73 ± 4.76	51.29 ± 4.61	0.754

W: WOMAC; FUN CAP: Functional capability; BAL: Balance; SS: Sitting and standing; WS: Walking speed; DL: Dominant limb; NDL: Non-dominant limb; PL: Prosthetic limb; NPL: Non-prosthetic limb.

Result measurements

Table 2 shows the initial measurements from all the tests conducted: The WOMAC questionnaire scores in their totality and in the three sections and the scores recorded in the SPPB screening tests. Finally, the measurements of handgrip strength and muscle circumference.

There are no statistically significant differences at the start of the study (*P* >0.05) and we therefore have two groups that are initially similar in terms of functional capability, frailty, strength and overall condition.

As results from the inter-group analysis, we analysed the results in terms of the WOMAC questionnaire and the frailty test in Table 3, and handgrip, muscle circumference and BMI in Table 4.

Table 3. Inter-group results in WOMAC and SPPB variables.

Variable	Group	T1	T2	T3	T2-T1	T3-T1
WOMAC pain	IG	11.41 ± 2.06	3.21 ± 2.08	1.21 ± 1.38		
	CG	12.22 ± 2.58	6.36 ± 3.12	3.13 ± 2.45	<0.001*	0.002*
	DIF	-0.81	-3.15	-1.92		
WOMAC stiffness	IG	5.54 ± 1.02	2.29 ± 1.12	1.17 ± 0.76		
	CG	5.13 ± 1.75	3.68 ± 1.04	2.05 ± 1.29	0.001*	0.008*
	DIF	-0.41	-1.39	-0.88		
WOMAC FUN CAP	IG	43.79 ± 7.79	13.54 ± 5.61	5.75 ± 3.09		
	CG	48.18 ± 6.30	27.27 ± 7.30	16.4 ± 10.32	<0.001**	<0.001**
	DIF	-4.39	-13.73	-10.65		
Total WOMAC	IG	60.75 ± 8.41	19.04 ± 8.02	8.13 ± 3.87		
	CG	65.54 ± 8.59	37.31 ± 9.77	21.59 ± 13.22	<0.001**	<0.001**
	DIF	-4.79	-18.27	-13.46		
SPPB BAL	IG	2.29 ± 0.76	3.50 ± 0.59	3.83 ± 0.38	0.133*	0.841*
	CG	2.36 ± 0.72	3.18 ± 0.73	3.77 ± 0.52		
SPPB SS	IG	1 ± 0.30	1.92 ± 0.65	3.38 ± 0.92	0.004*	0.008*
	CG	0.86 ± 0.35	1.36 ± 0.49	2.55 ± 1.10		
SPPB WS	IG	1.80 ± 0.76	3.46 ± 0.93	3.79 ± 0.51	0.002*	0.190*
	CG	1.68 ± 0.56	2.64 ± 0.95	3.50 ± 0.80		
Total SPPB	IG	5.91 ± 1.97	8.87 ± 1.62	11 ± 1.50	0.001**	0.016**
	CG	4.86 ± 1.48	7.18 ± 1.70	9.91 ± 1.70		

IG: Intervention group; CG: Control group; FUN CAP: Functional capability; BAL: Balance; SS: Sitting and standing; WS: Walking speed; DIF: Difference between groups.
*Mann-Whitney U-test for parametric distributions; **Repeated measurements ANOVA.

Table 4. Inter-group results for the handgrip, muscle circumference and BMI Variables.

Variable	Group	T1	T2	T3	T2-T1	T3-T1
HANDGRIP DL	IG	26.58 ± 11.32	27.37 ± 10.85	27.87 ± 10.70	0.40*	0.15*
	CG	25.64 ± 9	26.90 ± 8.60	27.04 ± 8.74		
HANDGRIP NDL	IG	24.84 ± 11.63	24.95 ± 10.55	25.62 ± 10.67	1*	0.063*
	CG	23.73 ± 8.8	23 ± 9.64	24.81 ± 9.10		
PL circumference	IG	51.33 ± 4.68	51.64 ± 4.86	51.72 ± 4.94	0.180*	0.064*
	CG	51.55 ± 4.89	51.70 ± 4.87	51.77 ± 4.98		
NPL circumference	IG	51.29 ± 4.61	51.47 ± 5.02	51.70 ± 4.83	0.151*	0.015*
	CG	51.73 ± 4.76	52.18 ± 5.05	52 ± 5.09		
BMI	IG	30.58 ± 3.23	30.37 ± 3.11	30.22 ± 3.03	0.079*	0.067*
	CG	32.42 ± 4.08	32.26 ± 3.99	32.16 ± 3.92		

DL: Dominant limb; NDL: Non-dominant limb; PL: Prosthesis limb; NPL: Non-prosthesis limb; BMI: Body mass index.
*Repeated measurements ANOVA.

Table 5. Intra-group Results for the Intervention Group.

Variable	T1	T2	T3	T2-T1	T3-T2	T3-T1
WOMAC pain	11.41 ± 2.06	3.21 ± 2.08	1.21 ± 1.38	0.001	0.018	<0.001
WOMAC stiffness	5.54 ± 1.02	2.29 ± 1.12	1.17 ± 0.76	<0.001	0.023	<0.001
WOMAC FUN CAP	43.79 ± 7.79	13.54 ± 5.61	5.75 ± 3.09	0.001	<0.001	0.001
Total WOMAC	60.75 ± 8.41	19.04 ± 8.02	8.13 ± 3.87	<0.001	<0.001	<0.001
SPPB BAL	2.29 ± 0.76	3.50 ± 0.59	3.83 ± 0.38	<0.001	0.745	<0.001
SPPB SS	1 ± 0.30	1.92 ± 0.65	3.38 ± 0.92	0.012	0.003	<0.001
SPPB WS	1.80 ± 0.76	3.46 ± 0.93	3.79 ± 0.51	<0.001	0.582	<0.001
Total SPPB	5.91 ± 1.97	8.87 ± 1.62	11 ± 1.50	<0.001	<0.001	<0.001

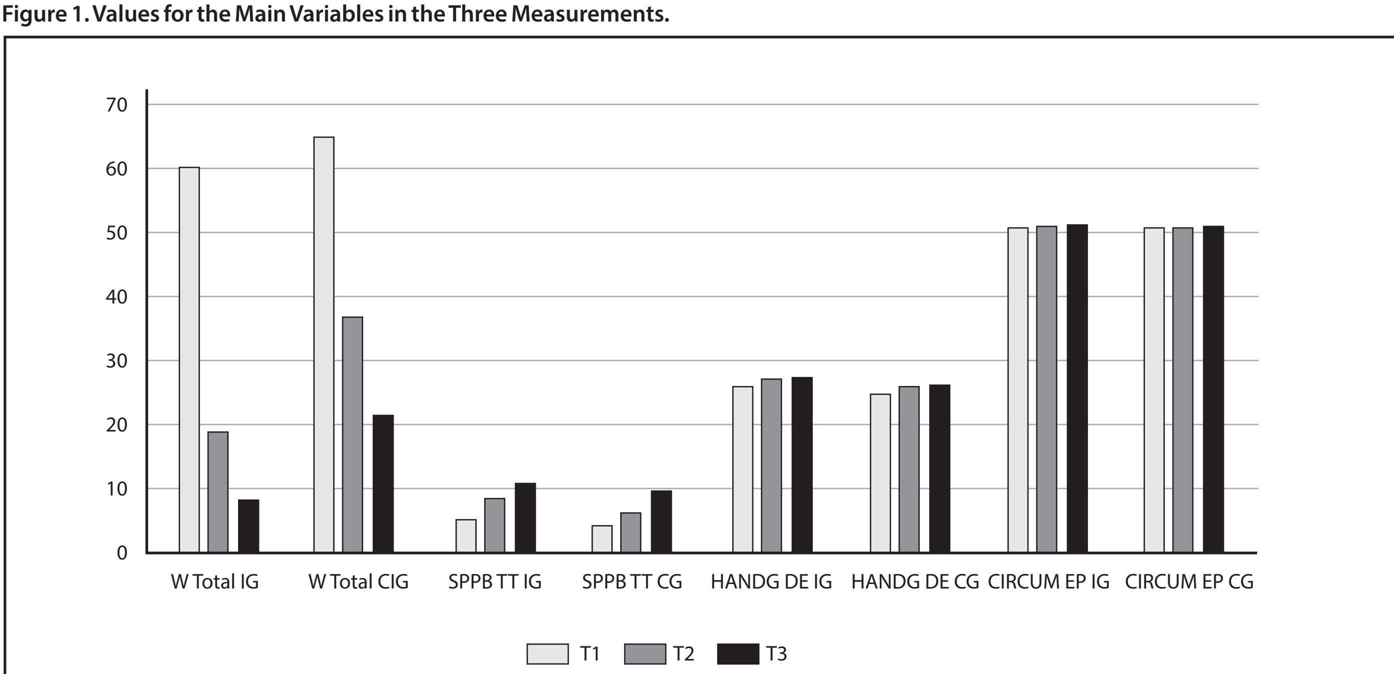
FUN CAP: Functional capability; BAL: Balance; SS: Sitting and standing; WS: Walking speed.

Table 6. Intra-group Results for the Control Group.

Variable	T1	T2	T3	T2-T1	T3-T2	T3-T1
WOMAC pain	12.22 ± 2.58	6.36 ± 3.12	3.13 ± 2.45	<0.001	<0.001	<0.001
WOMAC stiffness	5.13 ± 1.75	3.68 ± 1.04	2.05 ± 1.29	0.031	0.016	<0.001
WOMAC FUN CAP	48.18 ± 6.30	27.27 ± 7.30	16.4 ± 10.32	<0.001	<0.001	<0.001
Total WOMAC	65.54 ± 8.54	37.31 ± 7.77	21.59 ± 13.22	<0.001	<0.001	<0.001
SPPB BAL	2.36 ± 0.72	3.18 ± 0.73	3.77 ± 0.52	0.016	0.104	<0.001
SPPB SS	0.86 ± 0.35	1.36 ± 0.49	2.55 ± 1.10	0.179	0.008	<0.001
SPPB WS	1.68 ± 0.56	2.64 ± 0.95	3.50 ± 0.80	0.010	0.010	<0.001
Total SPPB	4.86 ± 1.48	7.18 ± 1.70	9.91 ± 1.70	<0.001	<0.001	<0.001

FUN CAP: Functional capability; BAL: Balance; SS: Sitting and standing; WS: Walking speed.

Figure 1. Values for the Main Variables in the Three Measurements.



W: WOMAC; IG: Intervention group; CG: Control group; TT: Total; HANDG: Handgrip; DE: Dominant extremity; CIRCUM: Muscle circumference; EP: Extremity with prosthetic; T1: Initial test; T2 and T3: Second and third tests.

Statistically significant differences were observed in all variables with *P* <0.001 in the WOMAC questionnaire, both in the tests at 15 days (T2) after the surgery and at 30 days (T3).

In the results from the tests to assess frailty, we observed no significant differences in the balance test from the second and third measurements; there is a significant difference at 15 days after the surgery in the sitting down and standing up test while this difference disappears at 30 days; and the same can be said about the 3-metre walking test. On the other hand, the total score (which establishes the existence of frailty or not) appears with an initial assessment of "fragile", with an assessment of "pre-frail" at T2 and concludes with "autonomous" in the final measurement one month after surgery (approximately two months following the initial assessment), the scores being statistically significant with a *P* <0.001.

In terms of the inter-group results for handgrip strength, muscle circumference and BMI, there are no statistically significant differences in any of their variables (Table 4).

The results from the intra-group assessments are shown in Tables 5 and 6, observing statistically significant improvements in both groups.

Finally, Figure 1 graphically shows the evolution of the main variables in the three measurements.

Conclusions

Engaging in a programme of exercises both before and after TKR surgery with elastic bands is effective at reducing pain and stiffness, improving functional capability, balance and walking speed, and, therefore, autonomy and quality of life.

Conflict of Interest

The authors declare no conflict of interest whatsoever.

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Original article

Promotion of Extra Virgin Olive Oil as an ergogenic aid for athletes

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doi: 10.18176/archmeddeporte.00167

Received: 23/04/2023
Accepted: 20/03/2024

Summary

Extra virgin olive oil (EVOO) is one of the healthiest and most natural fats that we can provide to our body. EVOO is one of the main foods in the Mediterranean diet, and therefore, its consumption is scientifically recommended, since a multitude of benefits are attributed to it, such as; greater longevity, lower risk of cardiovascular disease, cancer and even cognitive decline. But in addition to these benefits, its direct relationship with sports performance is increasingly being demonstrated thanks to its components, monounsaturated and polyunsaturated fatty acids, and vitamins. The objective of this work is to promote EVOO in athletes as an ergogenic aid, to increase its consumption to be the main addictive fat in the athlete's diet and observe the direct relationship with sports performance.

The method used is a bibliographic search to know the relationship and effects of EVOO on sports performance and to highlight its great anti-inflammatory and antioxidant capacity, together with an experimental study in runners.

In conclusion, the effects of consuming EVOO are considered an ergogenic aid in athletes, more specifically for runners, and its direct relationship with performance means that its consumption must be promoted so that everyone can benefit from the golden fat.

Key words:
Extra virgin olive oil. Sports performance. Ergogenic aid. Athletes.

Promoción del AOVE como ayuda ergogénica en el deportista

Resumen

El aceite de oliva virgen extra (AOVE) es una de las grasas más saludables y naturales que podemos aportar a nuestro organismo. El AOVE es uno de los principales alimentos de la dieta mediterránea, y por tanto, su consumo está recomendado científicamente, ya que, se le atribuyen multitud de beneficios, como por ejemplo; mayor longevidad, menor riesgo de sufrir enfermedades cardiovasculares, cáncer e incluso deterioro cognitivo. Pero además de estos beneficios, se está demostrando cada vez más su relación directa con el rendimiento deportivo gracias a sus componentes: ácidos grasos monoinsaturados, poliinsaturados, vitaminas. El objetivo de este trabajo es promocionar el AOVE en deportistas como una ayuda ergogénica, para aumentar su consumo para siendo la principal grasa de adicción en la dieta del deportista y observar la relación directa con el rendimiento deportivo.

El método utilizado es una búsqueda bibliográfica para conocer la relación y los efectos del AOVE en rendimiento deportivo y poder destacar su gran capacidad antiinflamatoria y antioxidante, junto con un estudio experimental en corredores.

En conclusión, los efectos del consumo de AOVE son considerados como una ayuda ergogénica en los deportistas, más concretamente para los corredores, y su relación directa con el rendimiento hace que se deba promover su consumo para que todos puedan beneficiarse de la grasa dorada.

Palabras clave:
Aceite de oliva virgen extra. Rendimiento deportivo. Ayuda ergogénica. Deportistas.

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Introduction

Our body needs nutrients to stay healthy. Each of these nutrients is obtained from different foods and each of them gives our body a function.

Extra virgin olive oil (EVOO), also known as "liquid gold", is a healthy fat[1]. It is obtained exclusively from olives, the fruit of the olive tree (*Olea europea*). According to the International Olive Council (IOC)[2], EVOO has a high percentage of oleic acid, vitamin E and phytosterols which is obtained through mechanical processes in the first cold pressing, meaning that the product does not lose any of its properties despite being a processed product. It also contains a high percentage of monounsaturated fatty acids, polyunsaturated fatty acids and phenolic compounds, whose antioxidant capacity is significant[3].

We have to be aware these days of the importance of nutrition and have to consume natural foods to maintain a healthy, varied and balanced diet. According to De Pablo *et al.*[4], olive oil is a product of great importance and enormous biological value which also has protective and immune properties when ingested regularly. We should promote the consumption of products that are beneficial for our development and EVOO is one.

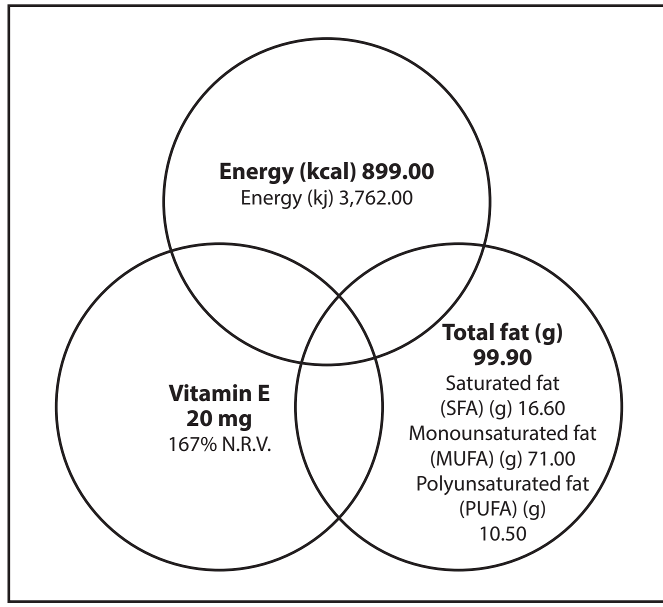
Numerous studies show how the intake of EVOO is beneficial in the prevention and/or reduction of certain health problems, such as: hypercholesterolaemia, atherosclerosis, hypertension, obesity, type 2 diabetes, oxidative stress, inflammatory conditions, cardiovascular diseases and cancer[5,6], and we should, therefore, bring it into our diet and/or increase its intake, thus avoiding the consumption of other more harmful and less nutritious fats.

The Mediterranean diet (MedDiet) is considered one of the diets with the most scientific evidence behind it[7]. The MedDiet is a healthy eating model which uses extra virgin olive oil as its main component[8]. In their study, Ros *et al.* indicate that the scientific community is increasingly interested in studying its preventive and anti-degenerative capacity to treat various pathologies associated with chronic inflammation, such as metabolic syndrome (MS), diabetes, cardiovascular disease (CVD), neurodegenerative diseases and cancer, among others[9-11].

In recent decades, the number of publications on the subject has grown exponentially, reaching nearly 500 articles in Pubmed in 2014.

Therefore, the Mediterranean diet based on the intake of EVOO[12], together with other healthy foods such as fruit and vegetables, is capable of improving health in the general population. Casas *et al.,* Capó *et al.* and Esquius *et al*., among others, study scientific evidence on the consumption of EVOO and performance in athlete[13-15] although we already know some benefits, such as favouring weight control (it has a satiating effect), protecting our bones and joints, its anti-inflammatory effect and, above all, its vitamin E and polyphenol content with its antioxidant effect, a very important factor for runners. Its consumption could also be very beneficial for this type of athlete because, thanks to its multiple properties, it can help the runner over their sporting life.

Figure 1. Extra virgin olive oil composition.



According to FESNAD (Spanish Federation of Nutrition, Food and Dietetics Associations), the quality of dietary fat has a profound influence on health, and therefore, we should replace saturated fatty acids (SFA) with monounsaturated fatty acids (MFA). The composition of olive oil provides us with 98% monounsaturated fat, as well as vitamin A (carotenes), antioxidants (phenolics and chlorophylls), vitamin E (tocopherols) and sterols (intestinal absorption of cholesterol), among others. By ingesting olive oil, we consume a product with a high vitamin, essential fatty acid and natural antioxidant content which allows athletes to function correctly and energetically. The objective of this paper is: to promote the consumption of EVOO as an ergogenic aid for endurance athletes to improve their performance; more specifically, to identify the nutritional habits of a group of middle-distance runners in terms of EVOO consumption; to observe the performance of middle-distance runners with an EVOO-based diet; and to establish dietary guidelines with increased EVOO consumption to improve performance in a group of runners. Consequently, some of the questions we ask ourselves are:

- How can we use EVOO as a factor for an athlete's performance?
- What benefits does its consumption bring to the athlete in terms of physical condition?
- What dose of EVOO is needed to improve performance and health in athletes?
- How can we promote its consumption in athletes?

It should be added that EVOO has been proven to have multiple benefits, not only as a nutritional supplement, but as a factor which can enhance an athlete's performance. Therefore, this study wishes to promote its consumption as an ergogenic aid for middle-distance runners and demonstrate that it helps performance. EVOO is very healthy and beneficial for endurance athletes and should, therefore, be an essential part of their diets.

Material and method

First, a bibliographic search was carried out using information from books, databases, websites and current papers which included data on olive oil consumption and its relationship with athlete performance.

The databases used were:

- Cuiden Plus. This is a bibliographic database with documents on health care of Ibero-American origin. Access is exclusive to subscribers.
- Pubmed. Database containing biomedical literature from Medline, scientific journals and online books.
- Researchgate. Online social network for users of any science discipline. It has a large database and offers a search function for papers from scientific journals, among other functions.
- MedlinePlus. Database produced by the United States National Library of Medicine. Its information comes from the National Institutes of Health, with journal citations and abstracts of biomedical literature from around the world.
- In addition to these databases, the Google Academic search engine was also used.

A search was carried out in Spanish and English using 3 key terms: *aceite de oliva virgen extra y rendimiento*/Extra virgin olive oil performance; *AOVE y beneficios*/EVOO and benefits; and *aceite de oliva ergogénica*/ Olive Oil ergogenic. *AOVE*/EVOO was also combined with *Polifenoles* (polyphenols), *Oleocantal* (Oleocanthal), *Antioxidante* (Antioxidant), *Anti Inflamatorio* (anti-inflammatory), *Deporte y aceite de oliva* (Sport olive oil) and *efectos del aceite de oliva* (effect of olive oil). 135 papers were found. These were systematically reviewed to gather and condense scientific evidence on the consumption of EVOO and its relationship with performance, summarising and evaluating the studies available.

The papers were selected taking into account:

- Search criteria: Evidence on EVOO consumption and performance; Benefits of EVOO consumption in athletes.
- Papers sufficiently homogenous as to be able to perform a quantitative meta-analysis and see and interpret the results obtained in order to arrive at conclusions.
- The inclusion criteria used for the review:
  - Date: from 2015 to the present.
  - Papers which refer to the consumption of EVOO as an ergogenic aid.
  - An intervention group with EVOO and a control group.
  - The subjects should do sport on a regular basis.

The study variables aim to see if there is a relationship between EVOO and performance, and to consider its consumption as an ergogenic aid for athletes. Therefore, this work seeks to demonstrate the relationship between EVOO consumption and performance in order to define adequate consumption to serve as an ergogenic aid for athletes.

Programme or intervention design

This is a cross-sectional, quasi-experimental study. The variables to measure are:

- EVOO consumption.
- Sports performance.

Measuring tools

First, a nutritional survey was conducted on 30 amateur endurance athletes (women and men) of a medium-high level with a weekly diet of their own design to find out their eating habits and see how often they consume fats, olive oil or other types of oils.

When the surveys had been carried out and the information collected, the results were analysed and guidelines were set for the athletes surveyed to change their eating habits and eliminate all type of non-beneficial fats from their diets and change them for extra virgin olive oil as main beneficial, nutritious fat.

With this study, we will help to ensure that the overriding objective of the study can be achieved and that EVOO becomes a very important ergogenic aid to consider in athletes' diets.

Target population

The sample consists of 30 middle-distance runners and trail runners (10 - 21 km) (women and men) and a control group (30 runners).

Inclusion and exclusion criteria

- The inclusion criteria are:
  - Age between 25 and 45 years old.
  - Sports: middle-distance and trail running.
  - Training at least 3 to 4 days a week at advanced amateur level.
  - Having an injury or illness which may interfere with the results.
- The exclusion criteria are:
  - Not old enough.
  - Sport not running or trail running.
  - Not training at least three days a week.
  - Not wanting to participate in the study.
  - Having an injury or illness which may interfere with the results.

The recruitment protocol for the participants will be carried out through a pre-questionnaire where information will be collected on eating habits, training, intensity and EVOO consumption habits with informed consent regarding data protection and collection.

Activities to perform

- The intervention will take place during the month of January 2021.
- The following variables will be measured through the study's own online pre-post intervention questionnaire:
  - Sociodemographic data.
  - Eating habits.
  - Level of physical activity or sport.
- EVOO consumption habits.

– When the results are obtained, an infographic will be designed with information on the benefits of EVOO consumption which will then be given to the athletes in question so that they know about its benefits and how their performance could change if they increase their consumption.
– According to data from the Predimed study, about 40 ml of EVOO (about 37 grams) per day are sufficient in order to obtain benefits from it and balance the amount consumed with the Mediterranean diet. However, we will increase this consumption because this data is for the general population and the energy requirements of runners are higher and all their intake needs are higher in consonance.
– The recommended consumption to see a significant change is 40-50 ml of EVOO a day and they will be required to ingest this amount for 20 days to confirm the short-term effect and be able to observe that its consumption is beneficial and aids athletic performance. The study *Olive Oil Consumption and Cardiovascular Risk in U.S. Adults* by Dr Miguel Angel Martínez (Co-author of the Predimed study) published in the *Journal of the American College of Cardiology* confirms the amount of this product to consume and sets guidelines for its intake as a healthy main addictive fat.
– The EVOO-based diet set for the intervention group will consist of a weekly diet based on the consumption of EVOO as the only main fat.
– This diet will be adapted to the energy and nutritional needs of the runners and, therefore, will also be used as a source of energy. The control group will continue with their usual diet without adding any food that they do not normally consume. Thanks to the dietary instructions, the consumption of EVOO will be increased and, consequently, it will become the main addictive fat and so the subjects' dietary habits will be modified in terms of fat consumption, with EVOO being the only fat they use.
– Subsequently, a post-test of EVOO consumption with new items will be carried out to collect information again in order to analyse and assess the results of the period of recommendations and intake of EVOO as main fat.
– Finally, the runners' results in terms of perception of EVOO intake and its relationship with performance, measured through stress tests with the Cooper test and/or other tools we need to use to evaluate the impact of the intervention and EVOO intake on the athletes' performance, will be assessed.

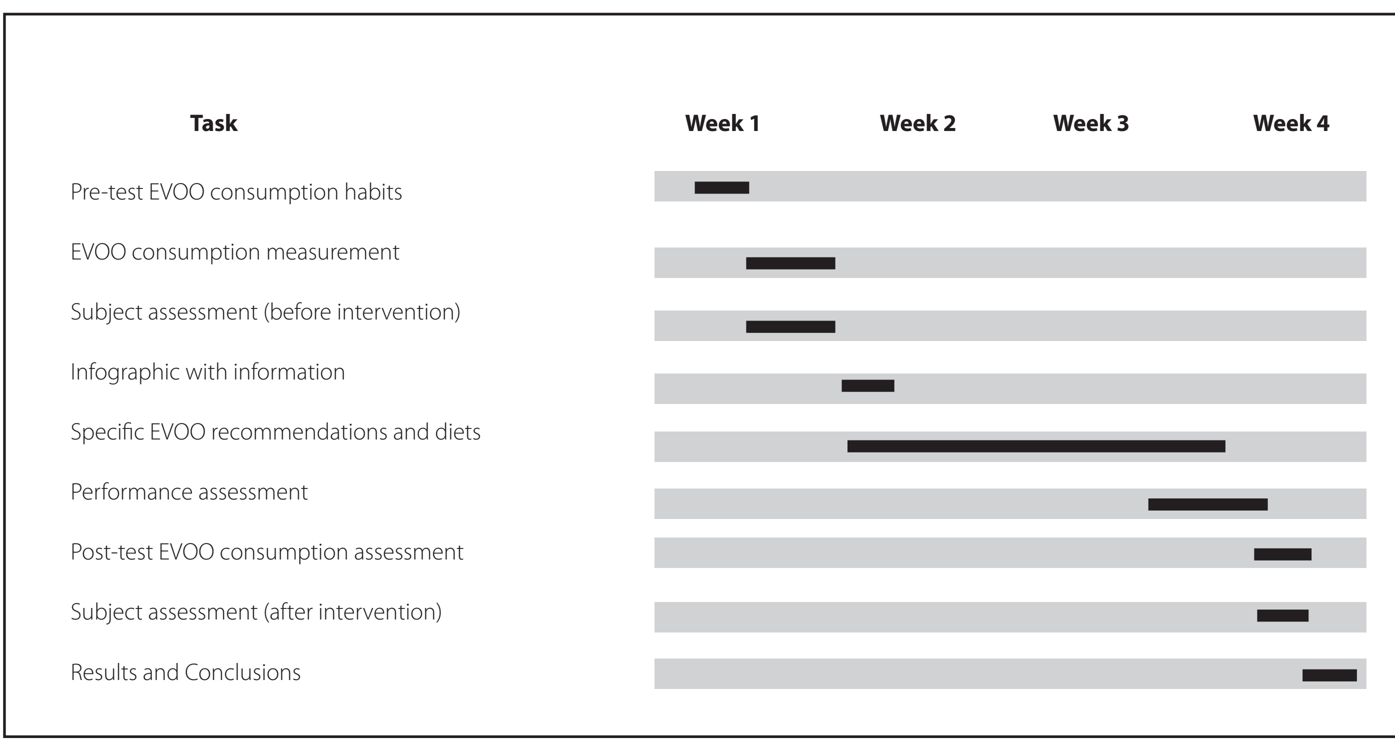
Required resources and budget

The resources necessary to carry out this intervention are:

– Human resources: The researcher/ student writing the dissertation and the sample group are from the Vega Baja region (Alicante) and mostly from C.A. Vega Fibra athletics club (Orihuela – Alicante).
– Material resources:
  - Consumables: pens, paper, pencils.
  - Non-expendables: computer, phone, tablet.
  - Other resources: literature review.

Budget: the cost of resources is zero, everything is done online and at no cost. Digital resources are used for the promotion of EVOO. All the

Figure 2. Timeline. January, 2021.



information and feedback is collected and generated through digital applications and/or email. Therefore, this promotional campaign will not involve any expenses.

Ethical considerations

This study respects the freedom of participation and so it will be necessary for everybody to give their informed consent for the test and check the authorisation for their personal data to be processed for the purpose described.

"Data Protection Law. In accordance with the provisions of Regulation (EU) 2016/679 of the European Parliament and of the Council of April 27, 2016, on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and with Organic Law 3/2018 of December 5 on the protection of personal data and guarantee of digital rights, we inform you that the data you provide in this form will be included in a computer file belonging to the researcher Laura Gil Caselles. The data will be processed for use in research work on EVOO and sports performance. The data will be kept for the time necessary to carry out the activity described and may only be transferred to third parties when so required in order to comply with legally established obligations. We inform you that at any time you may exercise your rights of access, rectification, erasure and objection, and the rights explained in the additional information. CHECK I expressly AUTHORISE Laura Gil Caselles, to process my personal data included in this questionnaire for the purpose described."

Also, the confidentiality of the participants' information and custody of the data collected in accordance with the provisions of: a. Organic Law 15/1999 of 13 December, regulating the automated processing of personal data. http://www.boe.es/boe/dias/1999/12/14/pdfs/A43088-43099.pdf b. Royal Decree 994/1999 of 11 June, passing the Regulations on security measures for computer files containing personal data.

Intervention evaluation plan

This project will be assessed by collecting information on extra virgin olive oil consumption from a group of amateur runners and trail runners.

First, an initial evaluation or pre-test will be carried out with 21 questions designed for this study based on the validated Predimed[28] questionnaire on consumption of and adherence to the Mediterranean diet, which will serve to find out the athletes' EVOO consumption and intake, and provide an initial basis on which to evaluate EVOO habits in the study group.

When the questionnaire has been completed and after verifying compliance with the inclusion criteria, the subject will be provided with information on the benefits of EVOO consumption for performance and the relationship between consumption and performance, and the research and promotion of EVOO as an ergogenic aid in sports performance will continue.

Subsequently, when the subjects' consumption habits are known, a promotion campaign will be designed with the material and information needed to promote EVOO consumption and publicise its benefits as an ergogenic aid for sports performance.

The assessment will need to take into account certain variables which may arise and affect performance. Some of these factors are sleep, physical activity level, the consumption of toxic substances, environmental factors (air, wind, humidity, temperature, etc.), psychological factors and so on. Consequently, we must establish a recommendation protocol to apply during the EVOO intervention:

- Sleep 8-10 hours a day.
- Establish an appropriate physical activity level for the subject; train 3- 4 days a week at moderate intensity, not adding extra loads or increasing the average intensity during the study.
- Avoid the consumption of alcohol, tobacco and other elements harmful to the athletes which may minimise their performance and affect assessment.
- Monitor and know if any psychological factor may be limiting the athletes' performance and, consequently, the study.
- Assess environmental factors if they occur abruptly or the subjects are training in different conditions and environments.

A control group of study participants will be established to compare the two. Both groups (experimental group and control group) will be evaluated because it is necessary to compare the performance of the group that is consuming EVOO to increase their performance and another group (control group, which we will use for the purpose of comparison and which will perform the same activity but without the EVOO consumption). In this way, we can establish if there are significant considerations and changes thanks to EVOO consumption.

To measure sports performance, we will use a stress test, in this case the Cooper test[10] to measure the athletes' VO_{2max} and see how much oxygen they consume and transport to their muscles.

The Cooper test involves running on flat ground for 12 minutes at maximum effort. The following equation is used to arrive at the results: VO_{2max} (ml/kg/min) = (22,351 x distance travelled (km)) – 11,288.

The beneficial effects of olive oil are observed at systemic level. Its benefits cannot be measured accurately with the maximum values and thresholds of physiological parameters.

Therefore, we can determine them through variables which indicate changes in the physiological system or monitor specific aerobic physiological markers such as maximum oxygen absorption (VO_{2max}) to obtain significant changes.

To evaluate our intervention and see if there are significant changes, we need to set up a control group. We will also use tools to measure performance (Cooper test) in which we will monitor heart rate (HR) and maximum heart rate (MHR) to find out the intensity and effort of the athletes. We need to be aware that the parameters of improvement with EVOO consumption will be obtained through the athletes' physiological variables. EVOO will be introduced into the diet as a supplement that helps the athletes due to its antioxidant effect, which aids in the oxidation of the free radicals produced by exercise, and minimises muscle damage through its anti-inflammatory effect, and this will be reflected in the athletes' performance.

Another evaluable point of the intervention design will consist of making a series of recommendations to the athletes in which a personalised diet model based on EVOO consumption will be established and will be assessed in the post-intervention because it will serve to improve their habits and effectively and efficiently increase their performance by demonstrating the ergogenic aid that is EVOO for sports activity. And lastly, there will be a final evaluation to analyse the results. Through a questionnaire (post-test), we will discover the perception of the respondents regarding EVOO consumption, but this evaluation is much more complex because we need to analyse all the information collected throughout the pre-post intervention process, produce parametric statistics comparing both groups (consumption group and control group) and also arrive at the relevant conclusions and/or benefits, including possible alternatives and future lines of research.

Applicability of the intervention

Although the multiple benefits of EVOO for the health of the general population, such as prevention of cardiovascular diseases, improvements delaying diseases, prevention of diabetes and some types of cancer, reduction of bad cholesterol and so on, are already known, this project aims to publicise the benefits of EVOO consumption in athletes. Therefore, given its beneficial effects in general, we have investigated how its consumption can also be beneficial in athletes and how it can be considered an ergogenic aid.

Ergogenic aids are defined as any strategy or method (nutritional, physical, psychological, etc.) given and/or applied to athletes with the aim of improving sports performance. In our case, we intend to highlight the benefits of EVOO consumption because it provides sufficient benefits to enhance athletes' performance and their performance will be affected differently as a result of its consumption because it has been observed that there is an improvement particularly as an ergogenic aid.

On the other hand, EVOO consumption is not a direct indicator of lowering running time, but it will because it helps at a physiological level and, therefore, we can see how its effect on the body benefits the athlete when he/she performs physical activity in his/her VO2. We will therefore see how it improves the athletes' times thanks to its anti-inflammatory effect, which repairs muscle damage, and helps reduce the free radicals caused by exercise that limit performance. Consuming EVOO contributes and fights this thanks to its antioxidant effect, which, in general, will protect and look after the lives of athletes both when doing sports and in normal life.

The proposed future actions are as follows:

- To increase the promotion of EVOO consumption as addictive fat for endurance athletes.
- To demonstrate clinically and scientifically how its consumption directly affects performance through the physiological processes that occur when doing physical activity.
- To provide EVOO as a dietary supplement and/or ergogenic aid.
- To prescribe the recommended doses for different sports which may require more or less fat intake.
- Also, to use EVOO as an energy source, especially in food strategies such as hypoglycaemia dieting and fasted training.

Conclusiones

EVOO is a very important part of our diet. It is a very healthy vegetable fat with a multitude of health benefits: It supplies 822 kcal (per 100 ml), providing lots of energy, especially for athletes. If we combine EVOO with sport, we can see that its intake is beneficial for athletes for the following reasons:

- Oleic acid helps lower blood cholesterol levels.
- Its antioxidant effect helps athletes fight the free radicals produced by exercise and increases the creation of mitochondria, thereby augmenting their energy. It also reduces and prevents a multitude of diseases thanks to this component.
- Vitamin E decreases muscle damage from exercise and protects muscles. It is an indirect sports performance factor. A lack of this vitamin can limit performance, generating muscular dystrophy, anaemia, etc.
- Omega 3. Its Omega 3 content helps in muscle gain.
- Phenolic compounds: such as oleocanthal, a natural non-steroidal anti-inflammatory which is highly beneficial for athletes. 40 ml of EVOO is equivalent to 250 mg of Ibuprofen. As a consequence, the athlete will experience reduced muscle pain after exercise and enjoy a greater and faster recovery.

For all these reasons, EVOO is seen as an essential part of athletes' diets and, thanks to its benefits, it is considered an ergogenic aid because by consuming it, athletes are able to increase their performance and help their metabolism at a physiological level.

Conflict of interest

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

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Original article

Blood flow restriction plyometric training and muscle power in untrained adults

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doi: 10.18176/archmeddeporte.00168

Received: 26/06/2023
Accepted: 21/03/2024

Summary

Introduction: Anaerobic training with blood flow restriction stimulates the gain of strength and muscle mass. It is efficient in low weekly training load modalities. It has not been elucidated whether flow-restricted training modalities can influence muscle power, nor their usefulness in plyometric training. Power development is a key indicator of human health and functional integrity.
Objective: To test the effect of low-load plyometric training with or without blood flow restriction on muscle power gains measured by vertical jumps in healthy, untrained male individuals.
Material and method: A quasi-experimental study was carried out in 18 healthy adult men with no previous strength training. They were divided into two groups, one group performed two weekly sessions for four weeks of plyometric exercises with partial blood flow restriction, ERF group (n = 9; 22.77 ± 5.11 years) and another with conventional plyometric exercises, EC group (n = 9; 21.66 ± 4.21 years). Prior to group distribution, an anthropometric characterization was performed. Before and after the training protocol, maximum strength (leg press 1RM), muscle power (Squat Jump and Counter Movement Jump) of the lower limbs, thigh circumference and thigh crease were measured.
Results: The comparison of means of previous anthropometric characteristics showed no differences between the groups. On average, power and relative power increased significantly in both groups (*P*-value <0.05). Compared to the EC group, the mean of the ERF group was significantly higher in the indicators of the jump test without counter movement (*P*-value <0.05). Strength and thigh circumference only increased significantly in the ERF group.
Conclusion: The plyometric training program with flow restriction showed greater adaptations in power, strength, and muscle growth than the conventional plyometric training.

Key words:
Plyometric exercise. Strength training. Blood flow restriction training. Physical training. Sports medicine.

Entrenamiento pliométrico con restricción del flujo sanguíneo y potencia muscular de adultos no entrenados

Resumen

Introducción: El entrenamiento con restricción del flujo sanguíneo (ERF) estimula la ganancia de fuerza y masa muscular. Es eficiente en modalidades de baja carga semanal de entrenamiento. No se ha dilucidado el entrenamiento con restricción de flujo puedan tener influencia en la potencia muscular, tampoco su utilidad en el entrenamiento pliométrico. El desarrollo de la potencia es un indicador clave de salud y funcionalidad del ser humano.
Objetivo: Comprobar el efecto del entrenamiento pliométrico de baja carga con o sin restricción del flujo sanguíneo en la ganancia de potencia muscular medida a través de saltos verticales de individuos varones, sanos y no entrenados.
Material y método: Se plantea un estudio cuasiexperimental, en 18 hombres adultos sanos sin entrenamiento de la fuerza previo. Fueron divididos en dos grupos, un grupo realizó dos sesiones semanales por cuatro semanas de ejercicios pliométricos con restricción de flujo, grupo ERF (n = 9; 22,77 ± 5,11 años) y otro con ejercicios pliométricos convencionales, grupo EC (n = 9; 21,66 ± 4,21 años). Previa a la distribución en grupos se realizó una caracterización antropométrica. Antes y después de protocolo de entrenamiento fueron medidas la fuerza máxima (*leg press* – 1 repetición máxima), la potencia muscular (*Squat Jump* y *Counter Movement Jump*), el perímetro y pliegue del muslo.
Resultados: La comparación de medias de características antropométricas previa no mostró diferencias entre los grupos. En promedio, la potencia y potencia relativa aumentó de forma significativa en ambos grupos (P-valor <0,05). En comparación al grupo EC, la media del grupo ERF fue significativamente mayor en los indicadores la prueba de salto sin contra movimiento (P-valor <0,05). La fuerza y el perímetro del muslo solo aumentó de forma significativa en el grupo ERF.
Conclusión: El programa de entrenamiento pliométrico con restricción parcial de flujo mostró mayores adaptaciones en la potencia, fuerza y crecimiento muscular que el grupo sin restricción.

Palabras clave:
Ejercicios pliométricos. Entrenamiento de la fuerza. Entrenamiento con restricción del flujo sanguíneo. Entrenamiento físico. Medicina del deporte.

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Introduction

Current scientific evidence has shown that blood flow restriction training stimulates strength gain, hypertrophy and muscle activation, and that is has even been effective when used with low load training[1]. In healthy populations, resistance training at controlled speed and with restricted blood flow rapidly increases muscle mass and strength gain[1,2]. These phenomena are considered to be related to higher metabolite concentrations, increased growth hormone release, enhanced activation of mTOR cell signalling, greater neuromuscular recruitment and reduced myostatin mRNA expression[3]. However, it is not yet clear whether forms of blood flow restriction training can influence another indicator of muscle integrity and function, power.

Muscle power is the result of the relationship between strength and movement execution speed, which is highly important for health, functional capacity[4] and athletic performance[5]. In this context, plyometric training has been widely used as the most versatile and practical strategy to develop this aspect of the musculoskeletal system[6]. In addition to being inherently related to strength gain, muscle power affects adaptations in the elastic elements of the musculoskeletal system, such as tendons, fascia and connective tissue, and the subsequent relationship with the stretch-shortening cycle (SSC). Insufficient evidence linking blood flow restriction training combined with specific types of plyometric training has hindered adaptations in muscle power[7].

The literature shows that low speed, high load training is recommended for muscle hypertrophy while high speed, low load training is indicated to increase muscle power[8,9]. Some authors have questioned these recommendations due to ambiguous results in relation to performance increases after short-term strength and power protocols, finding similar results in both. Some studies have also described increases in the rate of force development and improvements in jump height with both training regimes[10,11].

Previous studies support the thesis of greater muscle hypertrophy after strength training. In power training, however, increases in the motor unit discharge rate and improvements in SSC are found, chiefly when body position specificity, as there is in jumping, is involved[12,13]. Accordingly, it seems that both factors are important to increase muscle power.

Considering that blood flow restriction can lead to functional and morphological adaptations even with low training loads, and contextualising plyometric training as an effective strategy for developing muscle power, the main objective of this study is to verify the effect of plyometric training models with and without blood flow restriction on muscle power gain measured through vertical jumps performed by healthy, untrained male individuals.

Materials and method

A quasi-experimental study was proposed because the groups were not organised at random. The aim was to analyse the adaptations and functional responses caused by a plyometric training regime prescribed in 8 sessions over four weeks in two groups of healthy young adult men, one of which completed the sessions with cuffs partially restricting blood flow to the lower limbs.

Subjects

As a result of exposure and public invitation on social networks, 23 young men presented themselves as volunteers at the bodybuilding laboratory of *Universidade Regional Integrada do Alto Uruguay y das Missões* (Brazil), where the procedures involved in this study were carried out[5]. were excluded because they had painful symptoms and musculoskeletal disorders in the lower limbs. The remaining 18 subjects met the inclusion criteria, which included having a low level of physical activity, not having participated in training programmes for at least 3 months and having no significant systemic diseases.

Procedures

The participants were first subjected to an anthropometric assessment and performed a one-repetition maximum (1RM) test to assess maximum dynamic force, and two vertical jump tests on a contact mat to measure jump height. They were then divided into two groups: a blood flow restriction plyometric training group (BFRT n = 9) and a conventional plyometric training group (CT n = 9). After the draw, the participants started the training protocol with two sessions per week for 4 weeks. After competing the training protocols, the participants returned to the laboratory to repeat the tests. All the tests were conducted by the same tester, who was unaware of the purpose and distribution of the groups, and used the same procedures before the training protocols and after 4 weeks of training.

Anthropometric measurements: the measurements were taken using a calliper (Mitutoyo 0.1 mm precision - Cescorf), scales with coupled stadiometer (Welmy, 200 kg capacity, 0.1 kg and 0.005 m precision) and, for circumferences, a tape measure (Cescorf- Porto Alegre Brazil). The marks and measuring techniques followed the standards of *The International Society for the Advancement of Kinanthropometry* (ISAK). The measurements of body mass (kg), height (cm), front thigh skinfold (mm), and mean thigh circumference (cm) were verified.

Power tests: the participants became familiar with the movement required by warming up with 8 vertical jumps of variable heights, with a rest of two minutes before the tests started. The protocol first consisted of *Counter Movement Jumps* (CMJ), jumps without the aid of the upper limbs, the participants keeping their hands on their hips and their trunks upright. They did three maximum vertical jumps with a 10-second interval between attempts and following the verbal orders given. After 2 minutes of recovery and the same number of attempts, the participants did a *Squat Jump* (SJ), which consisted of a maximum vertical jump starting with their knees bent to a right angle, without any counter movement in the lower limbs and without the help of the upper limbs, keeping their hands on their hips from the starting position until completion of the jump[14]. The jumps were performed on a contact mat (Jump System 1.0®, CEFISE, SP/Brazil).

1RM test: a 1RM leg press test was performed bilaterally on a variable loading leg press (Taurus, Brazil). Prior to the test, the participants completed a five-minute general warm-up at 5 km/h on an ergometer. After the general warm-up, they took up position on the leg press (Taurus, Brazil). Each participant then completed a specific warm-up consisting of two sets of eight repetitions with loads which the participants estimated required moderate effort. During the warm-up, the participants had to fully extend their knees and repetition was only assessed when the participants were able to reach the range limiter when in front of the equipment. After the specific warm-up, the participants had a 3-minute break before starting the maximum test.

The maximum test consisted of obtaining the greatest load it was possible to lift in a complete cycle (flexion and extension of the knees). When the participant was able to do more than one repetition, the load was readjusted based on Lombard correction coefficients[15]. The participants had a 5-minute break between attempts. If more than four attempts were needed to determine the 1-RM value, the test was interrupted and performed 48 hours later. Each participant was familiarised with the test before the maximum test. The execution speed of each repetition was guided by a metronome.

Training protocol

The training sessions were identical for both groups in terms of structure and content. The participants initially did a 5-minute warm-up on a treadmill and then completed the main phase, which involved plyometric exercises with 30 seconds of rest between sets and 2 minutes between exercises. Finally, the subjects performed low intensity activities which included walking and breathing exercises for a further 5 minutes to warm down. A weekly progression was proposed based on an increase in the difficulty and volume of plyometric exercises in the main phase. Table 1 shows the structure of the sessions and the progression strategy. The approximate duration of the sessions was 30 minutes in weeks 1 and 2, and 35 minutes in weeks 3 and 4. A 45-cm plyo box was used for those exercises for which one was necessary.

Vascular restriction protocol

To determine partial vascular occlusion or restriction in the lower limbs, the participants in the BFRT group adopted the supine position and remained at absolute rest for 20 minutes prior to each session. Their resting blood pressure was then measured and used to calculate cuff fixation for partial limb occlusion (Scientific Pro -WCS 2020). The pressure used was 20 mmHg above resting systolic blood pressure, thereby ensuring that limb occlusion was partial, particularly impeding venous return. The exercises were carried out with the lower limbs occluded, even during recovery intervals. The methodology used included constant inspection of the limbs and monitoring of the subjects' degree of comfort[16].

Table 1. General structure of the main phase of the training programme sessions for the groups studied in the 4 weeks of training.

Week/Sessions (intensity)	Exercise	Sets	Repetitions
Week 1 / Sessions 1-2 (Low)	*Squat jump* *Split squat jump* *Cycled split squat jump*	2	10
Week 2 / Sessions 3-4 (Low to moderate)	*Split squat jump* *Pike jump* *Double leg tuck jump*	2	10
Week 3 / Sessions 5-6 (Moderate)	*Pike jump* *Double leg tuck jump* *Double leg zigzag hop* *Double leg hop*	3	10
Week 4 / Sessions 7-8 (High)	*Double leg zigzag hop* *Double leg hop* *In-depth jump* (45 cm) *Box jump* (45 cm)	3	10

Statistics

The data were presented as means with their corresponding standard deviation. The Shapiro Wilk test was used to verify the normality of the data. A paired Student's t-test was used for the comparisons of the variables at the pre- and post-training moments The independent Student's t-test was used to compare these variables between groups. The computer program used was IBM SPSS 20.0.

Ethical considerations

This study was approved by the Research Ethics Committee of Centro Universitario Metodista IPA, under decision number 1,475,648 and followed all the recommendations of decision 466/12 of the National Health Council of Brazil. The Helsinki Declaration regulating ethical principles for research studies involving human subjects with prior informed consent was also taken into account.

Results

The data of all the variables are presented as means and standard deviation. The initial characterisation of the population studied showed that the mean age of the subjects was 22.22 ± 4.58 years and their BMI was 23.92 ± 3.40. The random distribution of subjects in two study groups showed no differences in any of the characteristics shown in Table 2.

According to the results of the SJ test shown in Figure 1, significant differences were found in the mean values of pre- and post-training power both in the BFRT group (1,610.7 ± 407.3 *vs.* 3,590 ± 553.1 W, Δ138.55%; *P* <0.001) and in the CT group (1,803.6 ± 371.2 *vs.* 2,942.2 ± 335.1 W, Δ68.51%; *P* <0.001). The mean values before and after the relative power training programme for both groups (BFRT: 22.6 ± 2.9 *vs.*48.7 ± 4.9 W/kg, Δ118.67%; CT: 24.6 ± 3.7 *vs.* 42.7 ± 1.2 W/kg Δ76.86%) and jump height (BFRT: 26.1 ± 6.9 *vs.* 34.3 ± 2.3 cm, Δ41.49%; CT: 26.2 ± 2.5 *vs.* 30.5 ± 1.3 cm, Δ17.20%) were statistically different (*P*-value <0.01). Regarding the comparison between groups, a statistical difference (*P*-value <0.01) was found after the training programme in favour of the BFRT group, the mean observed in this group being higher in power, relative power and jump height.

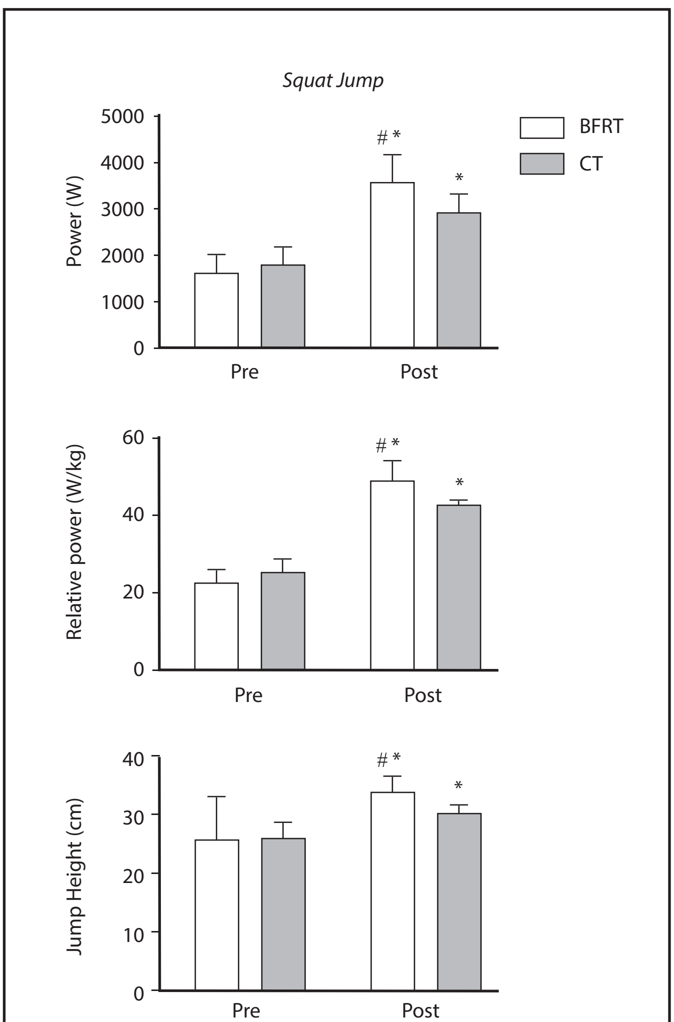
Table 2. Comparison of means of the general characteristics of the population according to the groups formed and studied.

Characteristic	BFRT	CT	*P*-value
Age (years)	22.77 ± 5.11	21.66 ± 4.21	0.621
Weight (kg)	72.77 ± 10.52	74.00 ± 13.20	0.830
Height (m)	1.72 ± 0.06	1.77 ± 0.07	0.165
BMI (kg/m²)	24.34 ± 2.99	23.511 ± 3.90	0.620

BMI: body mass index.

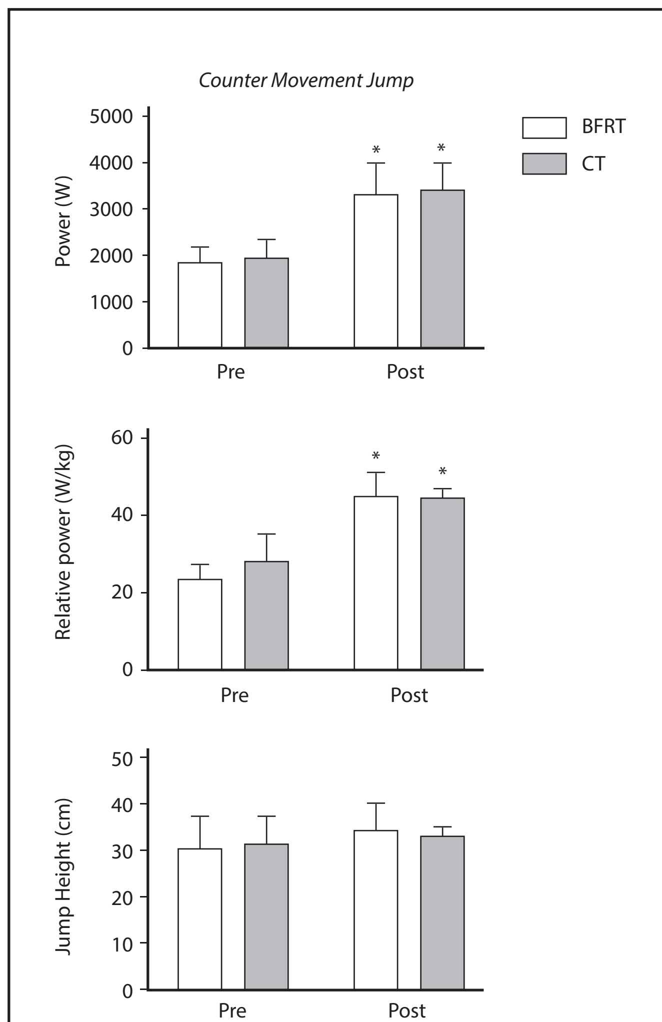
As Figure 2 shows, significant differences (*P*-value <0.001) were found in the CMJ test results between the pre- and post-training moments of both groups, both in power (BFRT: 1,830,6 ± 391.6 *vs.* 3,355.6

Figure 1. Pre- and post-training comparison of mean values of power, relative power and jump height according to the results of the SJ test in the groups studied.



*P-value <0.05 between pre- and post-training; #P-value <0.05 between groups.

Figure 2. Pre- and post-training comparison of mean values of power, relative power and jump height according to the results of the CMJ test in the groups studied.



*P-value <0.05 between pre- and post-training; #P-value <0.05 between groups.

Table 3. Comparison of intra- and inter-group means of anthropometric and lower limb strength measurements before and after the training programme.

Measurement	Pre	Post	Δ%	Intra-group *P*-value	Inter-group *P*-value	
					Pre	Post
1RM leg press (kg)						
BFRT	259.66 ± 86.38	381.33 ± 62.02	54.72	0.003	0.887	0.007
CT	254.11 ± 76.63	300.33 ± 50.46	26.40	0.150		
Thigh circumference (cm)						
BFRT	52.77 ± 4.60	57.88 ± 4.13	9.83	0.024	0.465	0.009
CT	51.00 ± 5.45	51.22 ± 5.35	0.46	0.931		
Thigh skinfold (mm)						
BFRT	9.69 ± 1.40	7.55 ± 1.42	-22.22	0.005	0.112	0.005
CT	11.88 ± 3.65	11.44 ± 3.39	-3.37	0.792		

RM: repetition maximum.

± 672.2 W, Δ86.47%; CT: 1,973 ± 347 *vs.* 3,414.4 ± 651.2 W, Δ75.00%) and relative power (BFRT: 24.8 ± 2.5 *vs.* 45.9 ± 4.2 W/kg, Δ86.21%; CT: 28.8 ± 6.9 *vs.* 45.1 ± 1.2 W/kg). Although there was an increase, the jump height did not show statistical differences in the mean variations before and after the training programme in the groups (BFRT: 31.02 ± 6.7 *vs.* 34.90 ± 5.1 cm, Δ14.80%; CT: 31.74 ± 6.1 *vs.* 33.70 ± 1.56, Δ9.80%). No significant differences were found when comparing the groups.

The results of the strength assessment and the specific anthropometric characteristics considered in the study are shown in Table 3. The 1RM leg press test showed significant differences between the pre- and post-training moments in the BFRT group and differences with the CT group in the final results (*P*-value <0.01). Finally, only the BFRT group showed statistically significant variations in thigh circumference and skinfold, differing from the results of the CT group in the post-training measurements (*P*-value <0.01).

Discussion

The results of this study show that, compared to the subjects who followed a conventional low load plyometric training programme, the previously untrained individuals who did the training sessions with partial blood flow restriction showed greater adaptations in power, strength and muscle mass. Although scientific evidence has previously supported the beneficial effects of blood flow restriction resistance training with increased peaks in strength and muscle mass at low loads[1,3,8,10], evidence supporting adaptations in power and functional indicators such as jump height is limited.

Previous findings with similar methodological approaches have shown, in general, results which contradict those of this study. In this vein, Horiuchi *et al.* reported in their study that subjects who did four weeks of training with traditional jumps improved jump performance and muscle power to a greater extent than those who trained with flow restriction[17]. However, although they analysed the responses in untrained subjects, it should be noted that their methodology involved high occlusion pressures for the training (200 mmHg), inducing total flow restriction. At present, high levels of vascular occlusion for strength training are not usually associated with adaptive advantages and, consequently, limited gains in power and jump height[18].

Our study shows that the BFRT group registered greater gain in relative power and that their jump height improved to a greater extent in the SJ test. This finding is interesting because, although all the indicators of the stretch-shortening cycle test, CMJ, improved, no differences with the results of the group without flow restriction, including jump height, were observed. Previous reports have shown that blood flow restriction training can lead to significant improvements in the functional and elastic properties of the musculoskeletal system, optimising the stretch-shortening cycle, which, in turn, leads to greater acute responses in power and vertical counter movement jump height[19].

In individuals with prior training, evidence supports blood flow restriction methods with significant adaptations in muscle power. Recently, Sun *et al.* showed that, in 4 weeks, a low load, squat-based exercise programme with varying levels of vascular restriction improved vertical jump performance in female football players[20]. Along the same lines, Yang *et al.* described the effectiveness of low load blood flow restriction training in gymnasts. They compared a ten-week training programme based on low intensity resistance exercises with blood flow restriction to conventional high intensity resistance training without flow restriction, the two groups displaying similar adaptations in strength, power and jump height at the end of the study[21]. Although they did not apply specifically plyometric or jump-based exercise protocols, these studies concluded that the effects of blood flow resistance training were potentially safe in improving muscle power as a result of neuromuscular and morphological plasticity.

The improved strength of the BFRT group observed in the present study is not a new finding. However, it should be noted that the plyometric training programme involving vascular occlusion was, in proportion, more effective than conventional training. There is a strong relationship between strength, muscle power and jump performance. Previous studies have reported that improved jump performance is proportional to the contractile capabilities of muscle tissue and the rate of force development in the lower limbs[22]. In parallel, morphological adaptations lead to improvements in the elastic properties of the tissue which benefit jump execution and, consequently, improvements in power[23]. As this study has found, therefore, the physiological conditions stimulated by blood flow restriction methods act as a catalyst in such a way that, with a low weekly training load, there is a greater potential for morphological adaptation, which is consistent with the development of maximum strength.

The strength gain measured by 1RM leg press tests is not necessarily a factor which ensures adaptations in power and jump height[24,25], which is why the authors recommend that, as is well known in sports science, training must be specifically managed in order to improve the required performance indicators, such as jump height, maximum strength or muscle mass.

Finally, the authors regard the simple methodological design of this study as a strength beyond the barriers of quasi-experimental or pre-experimental studies, especially those related to controlling all the factors which could influence the subjects' adaptive potential at a physiological level over the limited training period or could also directly affect the collection of information when applying the tests. The limited number of subjects involved in the groups could also be considered a limitation. However, the authors were as methodologically rigorous as possible when executing the different procedures, calling on assistance from first-rate academics and experts to ensure the quality of the data obtained.

In conclusion, the results of this research suggest that both weekly low load blood flow restriction plyometric training and conventional training can prove effective when it comes to improving power, jumping capability and muscle strength in untrained healthy men, although the effect on subjects who trained with blood flow restriction was statistically greater. These findings are consistent with approaches which make use of partial flow restriction to obtain great benefits with low training loads in short training periods.

Support: this study received funding from FAPEMIg (Minas Gerais State Agency for Research and Development) – Brazil. The Research Productivity Grants Programme (PQ/UEMG) – Brazil; and the Research Fund of Universidad Metropolitana de Barranquilla, Colombia.

Conflict of interest

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

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Original article

Assessment of salivary parameters and oral microbiota in amateur swimmers

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doi: 10.18176/archmeddeporte.00169

Received: 25/05/2023
Accepted: 21/03/2024

Summary

Objectives: The growing diffusion of sports activities is centering attention on the development of diseases correlated with sports performance. The most common diseases reported by sswimmers are dental stains. They are also exposed to the onset of erosive tooth wear and harbor cariogenic bacteria. Considering that the oral cavity of swimmers is in close contact with the swimming pool water in their daily training environment, this study aimed to evaluate whether swimming can change salivary parameters and oral microbiota of amateur athletes.
Material and method: This before-after study included 18 amateur athletes between 10 to 18 years old from a Swimming Team who practiced the sport at least three times a week. The swimmers were interviewed by a questionnaire and clinically evaluated. Unstimulated saliva was collected before and immediately after swimming. The salivary flow, pH, and buffer capacity were evaluated. The microbiological analysis included: total microorganisms, mutans *streptococci* group, *Lactobacillus* spp., and *Candida* spp. Wilcoxon test was applied before and after swimming with 5% level of significance.
Results: A total of 18 subjects participated in this study. All of the pool parameters were under acceptable limit. There was no statistical difference in the salivary parameters: salivary flow ($P = 0.264$), pH ($P = 0.132$); buffer capacity ($P = 0.067$). Regarding the oral microbiota, no significant differences were found before and after swimming for mutans *streptococci* group ($P = 0.950$), *Lactobacillus* spp. ($P = 0.432$), *Candida* spp. ($P = 0.386$), and total microorganisms ($P = 0.332$).
Conclusion: No change was observed in the salivary parameters and the oral microbiota before and after swimming in the evaluated group.

Key words:
Swimmer. Saliva. Swimming. Microbiota.

Evaluación de los parámetros salivales y de la microbiota oral de nadadores aficionados

Resumen

Objetivos: La creciente difusión de las actividades deportivas está centrando la atención en el desarrollo de enfermedades relacionadas con el rendimiento deportivo. Las enfermedades más comunes reportadas por los nadadores son las manchas dentales. También están expuestos a la aparición de desgaste dental erosivo y albergan bacterias cariogénicas. Teniendo en cuenta que la cavidad bucal de los nadadores está en estrecho contacto con el agua de la piscina en su entorno de entrenamiento diario, este estudio tuvo como objetivo evaluar si la natación puede cambiar los parámetros salivales y la microbiota oral de los atletas aficionados.
Material y método: Este estudio antes-después incluyó 18 deportistas aficionados de entre 10 y 18 años de un Equipo de Natación que practicaban este deporte al menos tres veces por semana. Los nadadores fueron entrevistados mediante un cuestionario y evaluados clínicamente. La saliva no estimulada se recogió antes e inmediatamente después de nadar. Se evaluó el flujo salival, el pH y la capacidad amortiguadora. El análisis microbiológico incluyó: microorganismos totales, grupo *Streptococcus mutans, Lactobacillus* spp. y *Candida* spp. Se aplicó la prueba de Wilcoxon antes y después de nadar con un nivel de significancia del 5%.
Resultados: Un total de 18 sujetos participaron en este estudio. Todos los parámetros del pool estuvieron por debajo del límite aceptable. No hubo diferencia estadística en los parámetros salivales: flujo salival ($p = 0{,}264$), pH ($p = 0{,}132$); capacidad amortiguadora ($p = 0{,}067$). En cuanto a la microbiota oral, no se encontraron diferencias significativas antes y después de nadar para el grupo *Streptococcus mutans* ($p = 0{,}950$), *Lactobacillus* spp. ($p = 0{,}432$), *Candida* spp. ($p = 0{,}386$), y microorganismos totales ($p = 0{,}332$).
Conclusión: No se observó cambio en los parámetros salivales y en la microbiota oral antes y después de nadar en el grupo evaluado.

Palabras clave:
Nadadores. Saliva. Natación. Microbiota.

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Introduction

Sport is a double-edged sword with positive and negative effects on health[1]. On the one hand, sports and physical activity can improve the quality of life through the prevention of diseases and the maintenance and recovery of the individual's health[2-4]. On the other hand, negative effects include the risk of failure leading to poor mental health[5,6], risk of injuries[7,8], eating disorders[9], burnout[10], oral cavity alterations[11-14], and exercise-induced gastrointestinal tract discomfort[15].

The growing diffusion of sports activities is centering attention on the development of diseases correlated with sports performance[16]. The main disorders of the athletes' oral cavity are dentofacial trauma, caries, erosions, and periodontal disease[11-14]. Such oral diseases harm quality of life and have a negative impact on self-esteem, eating ability, and health, causing pain, anxiety, and impaired social functioning[17,18].

Regarding the swimmers, the most common diseases reported are dental stains. In addition, they are exposed to the onset of erosive tooth wear (ETW), a chemical-mechanical process characterized by a painful and irreversible cumulative loss of the enamel of a non-bacterial nature[18,19]. Swimmers can also harbor cariogenic bacteria, such as *Streptococcus mutans, Streptococcus sobrinus,* and *Lactobacillus* spp. and favor their growth[11]. There is little information available about the correlation between the performance of swimming and tooth decay occurrence[20]. Dental caries is a lifetime disease that depends on biological factors present within the saliva and dental plaque. Dental plaque favors the emergence of *Streptococcus mutans* and *Lactobacillus* spp., which are capable of rapidly fermenting dietary carbohydrates and lowering the pH causing tooth demineralization[21,22]. The concentration of cariogenic bacteria levels within saliva and plaque will be determinant for the occurrence of caries[23].

Saliva is a biological oral fluid, involved in several functions of oral health and homeostasis, and plays an active role in maintaining oral health itself[24,25]. The saliva components have several vital roles in the oral mucosa immunity (immunoglobulin A [IgA], mucins and cystatins), in the protection of teeth against the action of microorganisms (lysozyme, lactoferrin, histamine)[26], in food digestion (alpha-amylase and protease)[27], and in the buffering of acidic substances (bicarbonate, phosphate and proteins)[28,29]. The performance of sports activities influences the main characteristics of saliva, such as consistency, flow, pH, and buffer capacity[25]. Exercising may also alter saliva protein content. Physical activity activates the autonomic nervous system which impacts the secretion and content of saliva[30]. The stimulation of the sympathetic system results in the secretion of low volumes of saliva which is high in protein, whereas the stimulation of the parasympathetic system causes increased secretion of water and mucin[31]. The stimulation of the sympathetic system may result in changes in the salivary flow, reabsorption and the secretion of electrolytes in the secretory cells by modifying the ion concentration of the saliva[32].

Among the most abundant salivary proteins in the sports area are the salivary α-amylase and IgA, which play a key role in oral mucosa immunity[27,33]. Some factors are responsible to regulate the oral ecology, such as salivary pH, flow rate, buffering capability, total bacterial count, cariogenic bacterial load, and IgA levels[34,35]. Considering that swimmers are in close contact with the swimming pool water on their daily basis, this study aimed to evaluate whether swimming can change salivary parameters and oral microbiota of amateur athletes. The hypothesis is that the exposure to pool water changes the salivary parameters and the oral microbiota.

Material and method

Ethical approval

The study was approved by the local Ethics and Research Committee (#830.318). Appropriate written informed consent was obtained from all participants and legal guardians in case of underage athletes.

Study design

This before and after study consisted of 18 amateur swimmers, aged between 10 and 18 years, from a swimming team in the city of Nova Friburgo, Rio de Janeiro state, Brazil.

Subjects were invited and participated voluntarily in the study. The following inclusion criteria were considered: amateurs athletes practicing swimming at least three times a week for at least one year and that participate in competitions. Exclusion criteria were: swimmers who were not willing to participate in all parts of the survey; syndromes or chronic systemic diseases; systemic antibiotics, or local antimicrobials within the previous 3 months; patients under medication affecting the saliva flow rate; partial or total removal prosthesis or orthodontic appliances.

A self-administered questionnaire was used to obtain data concerning hours and frequency of weekly training, complete pathological history, history of hard and soft tissues of the oral cavity, family history, oral hygiene practices, and eating habits (supplements consumed and dietary information such as intake of drinks, fruit juices, and soda)[11].

The selection of the participants was done through convenience sampling.

Clinical monitoring and saliva collection

Each patient was clinically evaluated and intraoral examination was performed and the presence/absence of bad habits and/or parafunctional habits, and dental erosions were assessed.

The unstimulated saliva from each swimmer was collected before and immediately after the training, which averaged two hours (13:00-15:00). The volunteers were instructed to not brush their teeth, eat or drink excepting for water, at least 1 hour prior to the saliva collection. During the sample collection, the subjects were comfortably seated in a ventilated and lighted environment with head slightly down. They were instructed not to swallow or move their tongue or lips during the collection process. With the use of a chronometer, over a period of 6 minutes, the swimmers were asked to spit the accumulated saliva on a tube type Falcon calibrated. Abnormal values were less than 0.1 mL/min without stimulation.

The saliva samples were immediately placed on ice and transferred to the laboratories for processing. The pH, buffer capacity, salivary flow at rest, and counts of mutans *streptococci* group, *Lactobacillus* spp., and *Candida* spp., expressed in Colony Forming Unit (CFU)/mL were analyzed.

The saliva pH was measured using a pH indicator strip (0 to 14) (Macherey-Nagel GmbH & Co, Düren, Nordrhein-Westfalen, Germany) according to the manufacturer.

For buffer capacity analysis, 500 µL of saliva samples were mixed with 1.5 mL of 5 mM HCl (hydrochloric acid) in a sterile microtube. Then, the microtubes were agitated for 1 min and opened for 5 min to allow the CO2 to escape. After that, 10 µL of the solution was pipetted onto pH indicator strip (0 to 14) (Macherey-Nagel GmbH & Co).

Microbiological evaluation

For counting total microorganisms, mutans *streptococci* group, *Lactobacillus* spp., and *Candida* spp., the saliva was vortexed for 1 min. Afterwards, an aliquot of 100 µL of each sample was transferred to sterile microtube containing 900 µL of sterile saline (0.9% NaCl). Serial decimal dilutions were made up to 10-8 and 50 µL of each dilution were inoculated into Petri dishes containing the culture media to be tested. The medium used for counting the mutans *streptococci* group was the commercial *Mitis Salivarius agar* (HiMedia Laboratories, LLC, Mumbai, India). The culture medium used for counting *Lactobacillus* was *Rogosa agar* (HiMedia Laboratories, LLC, Mumbai, India). The culture medium used for counting *Candida* spp. was the Sabouraud dextrose agar (Becton, Dickinson and Company, Sparks, USA). The Mitis Salivarius and Rogosa plates were incubated in a candle jar, while Sabouraud dextrose plates were aerobically incubated, for 48 h at 36 °C. The colonies with morphological characteristics of the respective microorganism were considered for counting. The results were expressed in CFU/mL of saliva.

Swimming pool water collection

Samples of the swimming pool water (10 mL) were also collected in test tubes at regular intervals throughout the day and sent to the laboratory for evaluation.

Free Residual Chlorine, pH, Bicarbonate Alkalinity, Calcium Severity and salinity were evaluated by the LabAgua Environmental Laboratory, Niterói, RJ, Brazil.

Statistical Analysis

Data were analyzed through the Statistical Package for the Social Science program (SPSS® for Windows; version 16.0; Chicago, IL, USA). The Shapiro-Wilk test was used to verify the normal distribution of the microbiological results. The principle of normality of the sample was not confirmed. The Wilcoxon test was applied to establish a comparison between variables of interest (P <0.05).

Results

A total of 18 subjects participated in this study (11 females and 7 males). The mean age was 13.44 ± 2.14 years. The athletes practice swimming at least 3 times a week and two hours a day. The demographic and clinical characteristics of the studied population are presented in Table 1.

Table 1. Questionnaire with the prevalence (%) of clinical characteristics and habits.

Questions	Non-competitive swimmers (n=19)	%
Gender		
Male	7	39
Female	11	61
How many times per week do you swim?		
3	1	5
4	1	5
5 or more	16	88
Dental erosion		
Have you observed erosive effects on your teeth after drinking isotonic or energy drinks?		
Yes	1	6
No	17	94
"Yellow teeth"		
What color do you think your teeth are?		
Yellow	12	67
White	6	33
Oral habits		
Bruxism (Clench or grind your teeth?)		
Yes	4	22
No	14	78
Mouth or nose breathing?		
Mouth	8	44
Nose	10	56
Hygine habits		
Do you brush your teeth after meals?		
Yes	12	67
No	6	33
How many times a day do you use dental floss?		
Never	5	28
Once a day	8	44
2 or more times a day	5	28
Does your gum usually bleed when brushing your teeth or flossing?		
Yes	6	33
No	12	67
What is the best way for you to hydrate yourself? (Water, Isotonic, Energetic, natural juice?)		
Water	18	100
Isotonic drinks intake?		
Yes	10	56
No	8	44
Energetic drinks intake?		
Yes	3	17
No	15	83
Acid drinks intake?		
Soda		
Yes	1	6
No	17	94
Juice fruit		
Yes	5	28
No	13	72

Pool parameters at the time of swimming and saliva collection are shown in Table 2. All of the parameters were under acceptable limit.

There was no statistical difference between salivary parameters, such as sialometry, pH and buffer capacity before and after swimming (P >0.05). The salivary parameters before and after swimming are shown in Table 3.

Regarding the oral microbiota, no significant differences were found before and after swimming for mutans *streptococci* group (P = 0.950), *Lactobacillus* spp. (P = 0.432), and *Candida* spp. (P = 0.386) (Table 4).

Discussion

Swimming is often a recommended sport due to its benefits on the whole body. With the increasing number of amateurs swimmers regularly attending swimming pools, this study aimed to evaluate whether exposure to chlorine derivatives may change salivary parameters and oral microbiota of amateur swimmers. The authors hypothesized that the exposure to pool water could influence the salivary parameters and the oral microbiota of amateur swimmers. This hypothesis was rejected.

Table 2. Pool parameters at the time of swimming.

Test	Result	Unit	Acceptable limit
pH	7.92	-	7.0 – 7.6
Free Residual Chlorine	1.53	mg/L	1.0 – 3.0
Bicarbonate Alkalinity	89	mg/L CaCO3	120
Calcium Severity	126	mg/L CaCO3	200 – 400
Salinity	10.5	%	---

The results of this study showed that all amateur swimmers did not experience a significant alteration of their salivary parameters and oral microbiota. Contrastingly, Bretz *et al.*[36] found that competitor athletes who had swum at a gas-chlorinated swimming pool experienced a significant alteration in their salivary parameters. This difference between amateur and competitor swimmers may be explained by the time spent inside the swimming pools and performing a more vigorous physical exercise. Consequently, having more contact between water and oral cavity. In this sense, amateur swimmers seem to be much less exposed than competitive swimmers[18]. Chlorine-based disinfectants are used for microbial disinfection of the swimming pools[37,38]. They provide rapid and long-lasting disinfection effects in the water[39]. The use of ozone and ultraviolet disinfectants has been adopted in some cases, although generally they are used together with either chlorine or bromine for the provision of a residual disinfectant[37]. However, chlorination has the potential to produce a wide range of disinfection by-products (DBPs)[40]. The American Public Health Association recommends that proper pool maintenance records be kept, including thrice-daily chlorine level measurements and pH readings as well as the daily consumption of chlorine gas and soda ash[41].

Swimmers in improperly maintained swimming pools may be susceptible to acid erosion of the enamel[42]. Some authors believe that if the pH of the pool water decreases below that of saliva, erosions on dental hard tissue may occur[36,43]. In this study, the pool water showed a daily pH of 7.9, thereby meeting the required pH values (from 7.20 to 9.0) and having no effect on swimmers in relation to the development of erosions, which is in accordance with other studies[11,43]. A tendency for a decrease in average salivary pH after the swimming session has also been reported[36]. However, other data pointed to an opposite trend with no significant alteration in pH, before and after training sessions[25,44]. Similar results were observed in this study.

Table 3. Salivary parameters before and after swimming.

	Sialometry		pH		Buffer capacity	
	Before	After	Before	After	Before	After
Mean	3.05	2.80	6.86	7.00	4.25	3.73
(SD)	(2.30)	(2.28)	(0.59)	(0.51)	(0.84)	(0.81)
Median	2.10	1.70	7.00	7.00	4.00	3.50
(Q1-Q3)	(1.25- 4.35)	(1.18-4.50)	(6.37-7.12)	(6.87-7.50)	(3.50-5.00)	(3.00-4.50)
Significance	P = 0.264		P = 0.132		P = 0.067	

Wilcoxon test; P <0.05 indicates statistical significance; Q1-Q3: 1st and 3rd quartiles (25%, 75%, respectively).

Table 4. Oral microbiota before and after swimming.

Microorganism	Total microorganisms		*Streptococcus* spp.		*Lactobacillus* spp.		*Candida* spp.	
log10 CFU/mL)	Before	After	Before	After	Before	After	Before	After
Mean	7.236	7.120	2.731	2.443	2.637	2.307	2.248	2.103
Standard deviation	1.017	0.920	0.842	1.089	0.496	0.893	0.990	1.026
Median	7.477	7.031	2.929	2.812	2.656	2.477	2.964	2.280
Quartiles (Q3-Q1)	6.577-7.700	6.705-7.594	2.508-3.000	2.088-3.000	2.306-3.000	2.299-2.930	1.434-3000	1.516-3.000
Significance	P = 0.332		P = 0.950		P = 0.432		P = 0.386	

Wilcoxon test; P <0.05 indicates statistical significance; Q1-Q3: 1st and 3rd quartiles (25%, 75%, respectively).

During swimming, energy consumption is high and prolonged. This condition may alter the salivary flow rate[24]. The loss of electrolytes and water through sweat may contribute to decrease the salivary flow rate[45]. In this study, it was observed a decrease in salivary flow rate and buffer capacity before and after training session, but this decrease was not statistically significant ($P > 0.05$). Previous studies also found a decrease in the salivary flow rate[36,46], which has been explained by an increase in sympathetic activity during intense exercise, since sympathetic innervations cause a marked vasoconstriction, resulting in reduced salivary volume[29]. Another explanation is the loss of electrolytes and water through sweat and restricted fluid intake during exercise that may contribute to decrease the salivary flow rate[32].

Athletes require high performance standards, especially swimmers, who must be totally healthy. Thereby, it is of paramount importance to evaluate the oral health of hard and soft tissues and the prevalence of caries in swimmers by assessing salivary cariogenic bacteria. *Streptococcus* spp. are related to dental caries[47]. *S. mutans* and *S. sobrinus* have greater cariogenic potential in humans[48,49]. *Lactobacillus* spp. are also secondary pathogens[50]. Besides these traditional culprits for dental caries, it has been discovered that *Candida albicans* has a synergistic interaction with *S. mutans* which may influence early childhood caries (ECC), since children with *C. albicans* present five times greater odds of experience ECC[51]. Therefore, this study also assessed salivary cariogenic bacteria (*Streptococcus* spp., *Lactobacillus* spp.), and *C. albicans* before and after swimming and found no statistical difference in the athletes' oral microbiota. Contrastingly, D'Ercole *et al*.[25] found that the swimmers total bacterial count and the load of *S. mutans, S. sanguis, L. fermentum* and *A. gerencseriae* underwent a statistically significant increase after swimming. *S. mutans, S. mitis* and *L. acidophilus* mean values were significantly higher in swimmers than in controls. A possible explanation is that the frequency and duration of swimming may increase the risk, since athletes are exposed to adverse conditions, such as pH and salivary flow changes during sports practice.

Despite not being the focus of this study, the eating habits and the use of isotonic and/or supplements need some attention since there are evidences, they can be responsible for alteration of the salivary pH[52,53]. In vitro studies have shown that acidic beverages cause dental erosion, for example cola drinks, energy drinks, sports drink and acidic juices[54,55]. Regarding isotonic drinks, marketing strategies emphasize performance improvement, and replacement of fluids and electrolytes lost in sweat during and after exercise[56]. Many athletes regularly consume these beverages[57,58]. This is in accordance with the present study, where 56% of swimmers informed the habit of isotonic drinks intake. Water was the most frequently consumed liquid (100%), and in most cases, it is the appropriate choice to maintain hydration before, during, and after physical exercise[56]. There was no association between consumption of isotonic drinks and dental erosion in the present study, and the number of athletes presenting dental erosion was very low (6%). A systematic review[59] also reported no association between isotonic drink consumption and the prevalence of dental erosion. This lack of association may be due to the fact that isotonic drinks have varied concentrations of calcium and phosphate in their formulations which keep high concentrations of these salts in salivary fluids, thereby inhibiting tooth demineralization[60,61].

This study has some limitations. First, it included only amateur swimmers. Second, the athletes were asked to self-report their training habits, and it is thus possible that some athletes had under- or over-reported their weekly training habits. Even so, our findings contribute to provide new information about the influence of swimming on salivary and microbiological parameters of athletes. This study also highlights the importance of studying salivary flow and composition since these parameters are useful tools in prevention programs or individualized treatment in several clinical situations.

Conclusion

Under the limitations of this study, it can be concluded that the salivary parameters and oral microbiota of amateur athletes had no significant differences before and after swimming. Additional studies are needed to observe and compare these parameters between amateurs and competitive swimmers.

Acknowledgements

We are indebted to the study participants. This work was supported by individual scholarships (FAPERJ – Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (#E-26/010.100995/2018; #E-26/202.805/2019; #E-26/010.002195/2019), CAPES – Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

Author's contribution statement

All authors equally contributed to this research.

Conflict of interest

The authors declare no conflict of interest.

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Lactate responses in high-intensity interval training sessions and their metabolic implications in different protocols: an integrative review

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doi: 10.18176/archmeddeporte.00170

Received: 15/04/2023
Accepted: 16/03/2024

Summary

Objective: To verify, through an integrative review, the behavior of lactate in the face of High-Intensity Interval Training (HIIT).
Material and method: Specific recommendations for the type of work were followed. Original studies that used HIIT in different populations were used. In order for the discussions to be broader, publication periods were not determined. The studies included in this review were carried out with healthy, trained individuals.
Results: Both types of protocol (short and long) result in a significant increase in lactate due to the high metabolic demand. Lactate can provide parameters for the aerobic and anaerobic contribution, as a more significant accumulation of this metabolite can lead to a greater anaerobic contribution. However, in HIIT, recovery time can interfere with lactate accumulation, which predicts the magnitude of the aerobic and/or anaerobic contribution. Shorter recovery times may require greater aerobic contributions, due to insufficient resynthesis of energy (ATP) via the glycolytic pathways. There is a tendency for lactate to accumulate more due to the high anaerobic effect (even with aerobic participation) and the lower removal capacity of this metabolite. On the other hand, a longer recovery time is more conducive to optimizing energy resynthesis via the glycolytic pathway, as there will be more time for this system to re-establish itself (totally or partially) in order to perform a high-intensity stimulus. With regard to lactate, the longer the recovery time, the lower the accumulation, as there is greater removal capacity and less intramuscular imbalance responsible for acidosis.
Conclusion: Despite some limitations, this review shows that we can use lactate to determine energy demand. However, it seems that the recovery time between stimuli is a determining factor in energy intake and, consequently, lactate accumulation. In this way, this metabolite can help us understand different HIIT protocols and, therefore, prescribe them for different objectives.

Key words:
Interval training. Lactate. Aerobic system. Anaerobic system. Training physiology.

Respuestas del lactato en sesiones de entrenamiento interválico de alta intensidad y sus implicaciones metabólicas en diferentes protocolos: una revisión integradora

Resumen

Objetivo: Verificar, a través de una revisión integradora, el comportamiento del lactato frente al Entrenamiento Interválico de Alta Intensidad *(HIIT)*.
Material y método: Se siguieron recomendaciones específicas para el tipo de trabajo. Se utilizaron estudios originales que utilizaron *HIIT* en diferentes poblaciones y no se determinaron los periodos de publicación. Los estudios incluidos en esta revisión se realizaron con individuos sanos y entrenados.
Resultados: Los protocolos cortos y largos dan lugar a un aumento significativo del lactato debido a la elevada demanda metabólica. El lactato puede proporcionar parámetros para la contribución aeróbica y anaeróbica, ya que una acumulación más significativa de este metabolito puede conducir a una mayor contribución anaeróbica. Sin embargo, en el *HIIT*, el tiempo de recuperación puede interferir con la acumulación de lactato, lo que predice la magnitud de la contribución aeróbica y/o anaeróbica. Los tiempos de recuperación más cortos pueden requerir mayores contribuciones aeróbicas, debido a la insuficiente resíntesis de energía a través de las vías glucolíticas. Existe una tendencia a una mayor acumulación de lactato debido al elevado efecto anaeróbico y a la menor capacidad de eliminación de este metabolito. Por otro lado, un mayor tiempo de recuperación es más propicio para optimizar la resíntesis energética a través de la vía glucolítica, ya que habrá más tiempo para que este sistema se restablezca para realizar un estímulo de alta intensidad. Al lactato, cuanto mayor sea el tiempo de recuperación, menor será la acumulación, ya que existe una mayor capacidad de eliminación y un menor desequilibrio intramuscular responsable de la acidosis.
Conclusiones: Esta revisión muestra que podemos utilizar el lactato para determinar la demanda energética. Parece que el tiempo de recuperación entre estímulos es un factor determinante en el consumo energético y, en consecuencia, en la acumulación de lactato. Este metabolito puede ayudarnos a comprender diferentes protocolos *HIIT*.

Palabras clave:
Entrenamiento por intervalos. Lactato. Sistema aeróbico. Sistema anaeróbico. Fisiología del entrenamiento.

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Introduction

High-Intensity Interval Training (HIIT) has become popular in the fitness and training market and is among the latest trends in activities to be practiced worldwide[1]. Regarding scientific research, studies related to HIIT have shown constant growth[2]. HIIT, first and foremost, is not a method but a variation of interval training (which is the method)[3]. Physiologically, HIIT causes necessary adaptations, central (e.g., maximum oxygen consumption, cardiac efficiency, etc.) and peripheral (e.g., molecular responses, mitochondrial density, etc.)[4] and metabolic (e.g., muscle glycolytic and oxidative capacity)[5].

These adaptations are relevant to the functional improvement of essential variables for increasing health levels[6–8]. These components are significantly altered because, in HIIT, high-intensity stimuli provide a high and rapid physiological demand[4], which can consequently interfere with chronic conditional responses. On the metabolism behavior, in HIIT, independent of the level of contribution of the energy pathway[9,10], there is a high lactate production. This is because there is a high metabolic demand due to the high intensity of the stimuli[11].

In general, one of the reactions to physical exercise is the behavior of lactate, a component resulting from glycolytic metabolism, independent of its magnitude of contribution to the exercise performed[12], widely used to delineate intensities starting from the anaerobic threshold[13,14] and is also considered one of the primary markers of fatigue and physiological stress[15,16]. In HIIT, we can better understand the stimuli applied through the accumulation of lactate, which is an important parameter for metabolic analysis[17] and, therefore, performance[18].

HIIT has been widely used in different training fields with different objectives. However, there is a gap in knowing more about its repercussions on the behavior of lactate, one of the components responsive to high-intensity effort. In this way, it will be even more possible to have a more significant interpretation of the metabolic reactions in different protocols of this training variation, thus making it possible to apply it with greater precision to different physiological objectives. In addition, despite knowing about the participation of lactate during a physiological integration in different organic metabolisms[19], we don't know for sure about the possible positive response of HIIT against lactate.

Another issue is that we know that lactate will be produced significantly as a result of high-intensity stimuli. In HIIT, little is known about lactate production and its significance in metabolism in different protocols. Could it be that the level of production can direct energy behavior in HIIT? Therefore, through an integrative review, this study aimed to describe lactate responses in HIIT sessions and their interpretations of metabolic behavior in different protocols.

Material and method

This integrative review was developed following specific scientific recommendations for this type of research[20,21]. Therefore, this research was conducted after determining some didactic parameters, such as problem formulation, bibliographic research, data evaluation and analysis (of the selected studies), and finally, data interpretation and presentation[22,23]. As this is an integrative review, it was not necessary to determine a minimum or maximum publication period for the articles selected for this discussion. However, only studies directly related to this research's subject were used. The studies selected for this integrative review were found in Pubmed and Web of Science scientific databases. For this search, strategies using combinations of keywords related to the theme of the work were used[24]. Moreover, the personal archives of the researchers involved in the work were consulted to identify possible studies to be included in this work.

A brief explanation of HIIT: Types of protocols, terminology, and methodological aspects

HIIT can be applied in different types of protocols characterized by the stimulus time, which is more directly short (<60 s) and long (≥60 s)[25]. HIIT with short stimuli is generally conducted in sprints, called Repeated Sprint Training (RST) or Sprint Interval Training (SIT). But, even more categorically, in HIIT, stimuli of less than or equal to 10 seconds (RST) and 10-30 seconds (SIT) were considered to be short, 30 to 2 minutes as medium, and greater than or equal to 2 minutes as long[6].

In methodological terms, the literature on HIIT is based on physiological (e.g., maximum oxygen consumption and heart rate) and mechanical (e.g., maximum aerobic speed) thresholds to define this variation of IT application[26,27]. In general, HIIT is applied at submaximal (close to the determined threshold: 90-95%), maximal (at the determined threshold: 100%), and supramaximal (above the determined threshold: greater than 100%) stimulus intensities related to some physiological or mechanical parameter[25,28]. However, due to its different methodological variations, HIIT can interfere with understanding its applicability[25,28] for different objectives and sampling characteristics.

A brief explanation of lactate in response to exercise

The lactate is well known for its role in protecting and preserving the cellular environment (though for a limited time) in a situation of acidosis being established due to heavy exertion[15]. However, this component also participates in critical metabolic functions in different systems of the human organism. In addition, lactate is an essential component (despite some misinterpretations) in cellular metabolism, through oxidation not only by the well-known Cori cycle but also by mitochondria[29]. Another important role of lactate is in the heart, where this organ participates directly in the transport function of the metabolite[30] and also has a demand for consumption of this chemical component through myocardial metabolism[31].

Still on the importance of lactate in physiological behavior, this component is also a direct agent in the efficiency of brain function in terms of the energy process[32] and the performance of executive functions, which are essential and necessary for human beings[33]. Finally, mediated by the anaerobic threshold, lactate is also present in a broad physiological integration, which allows for better responses in different states (rest and/or exertion)[19]. All this behavior in different systems will be decisive in times of effort, especially at high intensity.

HIIT, its repercussions on lactate, and interpretations of energy metabolism

In HIIT, high-intensity stimuli cause a significant increase in lactate in response to the high metabolic demand[34]. This is due to the demand for anaerobic metabolism during stimuli[9,28], but it's important to note that even with this anaerobic demand, HIIT is predominantly aerobic[10,25], including critical intramuscular responses to increased oxidative metabolism through mitochondrial density (greater efficiency) and biogenesis (reproduction)[35].

Considering that lactate is an essential component in the intramuscular energy process[12,15], as well as in other important organs (e.g. heart and brain)[31,32], HIIT can be a positive intervention in the sense of enabling production/removal (by different pathways, e.g. liver and heart) and thus promoting more significant interaction of this metabolite with the physiological environment.

HIIT and lactate responses in some studies with short model protocols

In general, HIIT with short stimuli is methodologically conducted at maximum or supramaximum intensities[25,28], and therefore, there is a high lactate response[36] due to its high metabolic demand. For example, some studies have shown the repercussions of protocols with the same (short) characteristics on this important metabolite. Bogdanis *et al.*[37] used a protocol with only two stimuli, 30 seconds (75g.Kg^{-1}), plus a third 6-second stimulus (11 minutes after the second 30-second sprint). A 4-minute recovery period (active and passive) was used. Between the conditions (type of recovery), they observed no differences in lactate responses, but there was an approximate increase of 1.0 mmol. l^{-1} to 12.0 mmol. l^{-1}.

Among the control variables of HIIT, it is discussed that the type of recovery (active or passive) can influence the accumulation of lactate[38]. But, controversially, protocols with six 15-second stimuli (all out) with 3-minute active (80 rpm - 1kg) and passive recovery showed no difference in lactate (active rec: 9.09 ± 2.37 mmol. l^{-1}; passive rec: 10.05 ± 2.84 mmol. l^{-1}) after the protocol[39]. Furthermore, both active and passive recovery showed no differences in lactate (P >.05) after a short protocol containing two 15-second stimuli (120% maximum aerobic speed: MAS) with 15 seconds of recovery (the active one with 50% MAS), with values of 10.7 ± 2.0 mmol. l^{-1} for active recovery and 11.7 ± 2.1 mmol. l^{-1} for passive recovery[40]. In addition, 2 stimuli of 15 or 30 seconds (conditions carried out on different days) with three types of recovery (also carried out on different days) with 15 seconds, being active (20 and 40% maximum aerobic power) and passively generated a peak in lactate accumulation of 14.5 ± 2.8 mmol. l^{-1}, with all conditions having values close without significant differences (P >.05)[41].

Protocols with a progressive stimulus volume (every 2 weeks), starting with 6 (1st and 2nd week) and ending with 8 (5th and 6th week) of 30 seconds (120% MAS) with 3 to 5 minutes of active recovery (50w), did not alter the average lactate results (post-effort) in groups that performed 1 HIIT session per week (9.5 ±1.7 mmol. l^{-1}) to those that performed 2 weekly sessions (9.8 ± 2.9 mmol. l^{-1})[34].

HIIT and lactate responses in some studies with long-model protocols

Long protocols usually work with submaximal stimuli (close to thresholds)[9,10]. However, they also cause high responses in lactate production. Acala *et al.* (2020), using a protocol with 4 stimuli of 4 minutes (85-95% HR_{max}) with 3 minutes of active recovery (25% peak power output - PPO), showed discreet results in intra (9.3 ± 2.4 mmol. l^{-1}) and post (8.1 ± 2.2 mmol. l^{-1}) lactate. In another study with progressive stimulus volume (3 sessions per week), from 8 (1st week) to 10 (3rd week) of 1 minute (130% of ventilatory threshold = 70% PPO) with only 15 seconds of active recovery (10% PPO) they observed no differences (P >.05) in lactate between the first (10.5 ±2.2 mmol. l-^{1}) and ninth session (10.3 ± 2.2 mmol. l^{-1})[43].

Agnol *et al.* (2021) used four protocols with stimuli conducted at self-selected intensities (maximum possible levels): 1) 4 stimuli of 4 minutes for 1 minute of recovery, 2) 4 stimuli of 4 minutes for 2 minutes of recovery, 3) 4 stimuli of 8 minutes for 2 minutes of recovery and, 4) 4 stimuli of 8 minutes for 4 minutes of recovery. All protocols had active recovery at an intensity of between 80 and 100 w. Lactate was measured before and after the session (1, 3, 5, and 9 minutes). No differences (P >.05) were found between the mean and peak values, respectively, for protocols 1 (8.8 ± 4.1 mmol. l^{-1} and 11.3 ± 5.0 mmol. l^{-1}), 2 (9.0 ± 2.8 mmol. l^{-1} and 11.9 ± 3.4 mmol. l^{-1}), 3 (7.0 ± 2.8 mmol. l^{-1} and 8.6 ± 3.3 mmol. l^{-1}) and 4 (8.1 ± 3.4 mmol. l^{-1} and 9.6 ± 4.3 mmol. l^{-1}).

Another study carried out the interventions on a natural road (outdoors) with an equalized volume of 4800 meters: 1) 12 stimuli of 400 meters (with 15 seconds of passive recovery), 2) 6 stimuli of 800 meters (with 30 seconds of passive recovery) and 3) 3 stimuli of 1600 meters (with 60 seconds of passive recovery). This study was conducted with two groups: runners (R) and multi-sport athletes (MT: triathletes, mountain bikers, and skiers). After the sessions, the lactate values did not differ (P >.05) between the groups for protocols 1 (R: 16.7 mmol. l^{-1} and MT: 15.3 mmol. l^{-1}), 2 (R: 15.1 mmol. l^{-1} and MT: 14.6 mmol. l^{-1}) and 3 (R: 15.9 mmol. l^{-1} and MT: 16.5 mmol. l^{-1})[45]. Billat *et al*. (1999) observed a maximum lactate value of 8.4 ± 2.3 mmol with a training program with different stimuli. l^{-1}. The intensities of the programmed stimuli were related to speed related to VO_{2max} (vVO_{2max}) and speed related to the onset of blood lactate accumulation (vOBLA) and with active recovery at 60% vVO_{2max}.

Metabolic implications and interpretations of lactate behavior in different HIIT protocols

Despite some confusion, it is now well established that HIIT (and its sub-variations: SIT and RST) is aerobic[9,10,25]. Perhaps the reason for some confusion is that the stimulus is considered in isolation (which can have an anaerobic characteristic), whereas, when it comes to HIIT, the session as a whole is considered in terms of its metabolic power[36,46].

However, lactate can provide parameters for aerobic and anaerobic contribution[47,48]. However, in terms of types of protocols, in HIIT, one of the variables that can significantly define the energy contribution is the length of the recovery period[49], not being so restricted to its type, active or passive[38–40]. To this end, shorter recoveries increase the demand for aerobic input[9]. This is because the recovery time is insufficient to promote the resynthesis of energy (ATP) via glycolytic pathways, leading to a greater aerobic contribution[36,46,49]. These protocols tend to have a greater lactate accumulation because they promote a greater reduction in blood pH and H^+ ions[50]. Lactate, to a certain extent, tries to contain intramuscular acidosis using a mechanism called buffering, and also that in short recovery times, the ability to remove this lactate becomes more complex through different physiological pathways[12,15,16].

On the other hand, in HIIT, stimuli with a longer recovery time are more likely to optimize energy resynthesis via the glycolytic pathway, as there will be more time for this system to re-establish itself (wholly or partially) to perform high-intensity stimuli (mainly short stimuli: short HIIT)[9]. In this case, regarding the behavior of lactate, it tends to be the case that the longer the recovery time, the lower the accumulation of lactate[44]. Another issue is that HIIT can also promote greater anaerobic capacity, and this makes the system more efficient, providing more work for less energy expenditure, resulting in less lactate accumulation[47] and consequently improving the lactate threshold[34].

Finally, HIIT also improves intramuscular oxidative capacity[48,51], making the aerobic contribution efficient (in this case, regardless of the type of protocol) through cellular mechanisms, such as improved mitochondrial density[4,5,52], so less lactate will also be accumulated. However, a significant increase in lactate during maximal/supra-maximal stimuli can also occur because the lactate produced is being reused for intramuscular energy resynthesis, but this is a particular case in severe exercise in terms of intensity[36,46].

Study limitations

This study has some limitations, and perhaps the main one, even knowing that HIIT is predominantly aerobic[46], is the fact that there are no studies that have evaluated the energy contribution (aerobic and anaerobic) of high-intensity interval training sessions. Studies on this topic are scarce. Studies on this subject are scarce[47,48], making it more challenging to discuss and even assume specific explanations related to the metabolic mechanism of lactate responses in HIIT. Therefore, we believe that, even without being able to extrapolate or even expose more information, this review is composed of the necessary information for the understanding of this physiological phenomenon between HIIT and lactate to be absorbed. However, further studies on this subject are of the utmost importance to make the whole context of this essential mechanism even more solid, and it deserves attention at the time of prescription (coach) and training (coach and/or practitioner/athlete).

Conclusion

Based on an integrative review, this study aimed to discuss the behavior of lactate in different HIIT protocols and the state of energy metabolism. However, even though it is constrained (as not all studies have assessed levels of aerobic or anaerobic contribution), we can use lactate to guide energy demand as long as this interpretation is coherent and without extrapolation. In this way, this metabolite can help understand different HIIT protocols and thus help prescribe this type of training to achieve different objectives. Similarly, using lactate (for the same HIIT intervention), we can suggest an improvement in metabolic performance, for example, a lower accumulation of post-exercise lactate compared to previous interventions. This parameter is fundamental for assessing physiological and mechanical performance.

Acknowledgments

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Conflict of interest

The authors declare that they have no conflict of interest with this research.

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