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Shoulder pain and disability predict clinical outcomes better than biomechanical and functional measures in young swimmers: a prospective cohort study

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ABSTRACT

Objective: This study investigated the association between shoulder pain, disability and functional measures in young competitive swimmers to identify risk factors for pain occurrence. **Methods:** In this prospective study, 32 swimmers (13–16 years) underwent clinical and functional assessments, including the Western Ontario Shoulder Instability Index (WOSI) and Upper Quarter Y Balance Test (UQ-YBT) performed on a force platform, with postural displacements quantified as resultant distance path length. Shoulder pain was self-reported after six months via telephone follow-up. **Results:** After six months, 9 (28%) swimmers reported shoulder pain within 6 months. Swimmers with shoulder pain showed higher WOSI scores (physical symptoms, sports/recreation, emotional domains, and total score), indicating greater dysfunction. UQ-YBT performance and balance measures showed no significant group differences. Logistic regression identified WOSI subscales as significant predictors of shoulder pain, with higher scores increasing the odds of pain occurrence. Age was also a predictor, with younger athletes at slightly higher risk. **Conclusion:** Clinical assessments like WOSI are better than functional tests in predicting shoulder pain risk in young swimmers, underscoring the importance of monitoring symptom-related disability for early prevention.

Keywords: pain perception; physical functional performance; sports medicine; health risk; postural control; youth sports.

El dolor y la discapacidad del hombro predicen mejor los resultados clínicos que las medidas biomecánicas y funcionales en nadadores jóvenes: estudio de cohorte prospectivo

RESUMEN

Objetivo: Este estudio investigó la asociación entre dolor de hombro, discapacidad y medidas funcionales en jóvenes nadadores competitivos para identificar factores de riesgo para la aparición del dolor. **Métodos:** En este estudio prospectivo, 32 nadadores (13–16 años) se sometieron a evaluaciones clínicas y funcionales, incluidos el Índice de Inestabilidad del Hombro de Western Ontario (WOSI) y la Prueba de Equilibrio Y de Cuadrante Superior (UQ-YBT), realizada en una plataforma de fuerza, con los desplazamientos posturales cuantificados como longitud de la trayectoria resultante. El dolor de hombro fue autoinformado después de seis meses mediante seguimiento telefónico. **Resultados:** A los seis meses, 9 (28%) nadadores reportaron dolor de hombro. Los nadadores con dolor de hombro mostraron puntuaciones más altas en el WOSI (síntomas físicos, deporte/recreación, dominios emocionales y puntuación total), lo que indica una mayor disfunción. El rendimiento en el UQ-YBT y las medidas de equilibrio no mostraron diferencias significativas entre los grupos. La regresión logística identificó las subescalas del WOSI como predictoras significativas del dolor de hombro, con puntuaciones más altas que aumentaban las probabilidades de aparición del dolor. La edad también fue un predictor, con los atletas más jóvenes presentando un riesgo ligeramente mayor. **Conclusión:** Las evaluaciones clínicas como el WOSI son mejores que las pruebas funcionales para predecir el riesgo de dolor de hombro en jóvenes nadadores, lo que subraya la importancia del monitoreo de la discapacidad relacionada con los síntomas para la prevención temprana.

Palabras clave: percepción del dolor; rendimiento funcional físico; medicina deportiva; riesgo para la salud; control postural; deportes juveniles.

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A dor e a incapacidade do ombro predizem melhor os resultados clínicos do que as medidas biomecânicas e funcionais em nadadores jovens: estudo de coorte prospetivo

RESUMO

Objetivo: Este estudo investigou a associação entre dor no ombro, incapacidade e medidas funcionais em jovens nadadores competitivos, a fim de identificar fatores de risco para a ocorrência de dor. **Métodos:** Neste estudo prospectivo, 32 nadadores (13–16 anos) foram submetidos a avaliações clínicas e funcionais, incluindo o Índice de Instabilidade do Ombro de Western Ontario (WOSI) e o Teste de Equilíbrio Y de Quadrante Superior (UQ-YBT), realizado em uma plataforma de força, com os deslocamentos posturais quantificados como comprimento da trajetória resultante. A dor no ombro autorrelatada foi registrada após seis meses, por meio de acompanhamento telefônico. **Resultados:** Após seis meses, 9 (28%) nadadores relataram dor no ombro. Nadadores com dor no ombro apresentaram escores mais altos no WOSI (sintomas físicos, esporte/lazer, domínios emocionais e escore total), indicando maior disfunção. O desempenho no UQ-YBT e as medidas de equilíbrio não apresentaram diferenças significativas entre os grupos. A regressão logística identificou as subescalas do WOSI como preditoras significativas da dor no ombro, com escores mais elevados aumentando as chances de ocorrência de dor. A idade também foi um preditor, com atletas mais jovens apresentando risco ligeiramente maior. **Conclusão:** Avaliações clínicas como o WOSI são mais eficazes do que testes funcionais para predizer o risco de dor no ombro em jovens nadadores, destacando a importância do monitoramento da incapacidade relacionada aos sintomas para a prevenção precoce.

Palavras-chave: percepção da dor; desempenho funcional físico; medicina esportiva; risco à saúde; controle postural; esportes juvenis.

Introduction

Swimming demands repetitive and intense shoulder rotation movements. Elite swimmers may cover up to 14,000 meters/week, performing around 16,000 rotations weekly, placing significant strain on joint structures.[1] The shoulder complex consists of four joints and several muscles, and its integrity ensures stability and movement precision. Pain or injury-related changes can compromise motor control and the kinematics of this joint complex, predisposing it to dysfunction.[2] Consequently, pain (defined as an "unpleasant sensory and emotional experience"[3]) in shoulder complex is reported by 40-91% of athletes, and it is an early sign of overload or incipient injury.[4] This high incidence underscores the need for specific preventive strategies for this population.

Early and multidimensional assessments are essential to detect shoulder dysfunction and guide effective prevention and rehabilitation strategies. In this context, Feijen et al.[5] developed a prognostic model for shoulder pain in young swimmers, identifying the acute-chronic workload ratio as the strongest predictor (4.3 times higher risk). Souza et al.[6] had already associated competitive swimming with shoulder pain and signs of impingement and rotator cuff injuries, while Kennedy et al.[7] linked range of motion, laxity, and muscle imbalances to pain, emphasizing age- and level-specific assessments. Finally, Porter and collegues[8] showed that an acute increase in supraspinatus tendon thickness after training predicts pain at 3 and 6 months, reinforcing the importance of individualized monitoring. However, these studies did not investigate measures of shoulder sensorimotor control.

The stability of this joint depends on the interaction between static and dynamic components, mediated by the sensorimotor system,[9,10] and dysfunction in this joint is associated with proprioceptive and neuromuscular control alterations.[2,9] For assessing shoulder sensorimotor control in competitive swimmers, the Upper Quarter Y Balance Test (UQ-YBT) is a valid and reliable tool,[11] encompassing strength, stability, and mobility.[12] Its results are influenced by factors such as maturation and competitive level.[12,13] Recently, Albuquerque et al.[14] integrated a force platform assessment into the UQ-YBT, previously used in static conditions.[15,16] In young swimmers, performance was minimally affected by laterality, while center of pressure displacements was influenced by task demands. Importantly, performance and sensorimotor control on the UQ-YBT were not affected by sex or the presence of shoulder pain at the time of assessment.

The present study aimed to expand on previous findings by prospectively investigating the association between shoulder sensorimotor measures, clinical scores, and functional scores, and the subsequent occurrence of pain in youth swimmers. Considering the multifactorial nature of pain, we sought to identify, among the applied clinical and functional tests, a set of factors that could provide insights into the early identification of shoulder injury risk.

Methods

Ethical considerations

The study was approved by the Institutional Research Ethics Committee prior to its execution (process no. 4.000.902 on April 30, 2020). All parents or guardians of the participants signed an informed consent form after receiving an explanation of the study, and before any procedures were performed.

Study Design

This prospective cohort study was conducted from March to October 2023. The flowchart shown in Figure 1 describes the research protocol. First, athletes were asked to complete an anamnesis and two questionnaires. Subsequently, the Upper Quarter Y Balance Test (UQ-YBT) was performed over a force platform, where participants had to reach in three directions (medial, inferolateral, and superolateral) with each upper limb. Finally, six months later, a follow-up questionnaire was administered to assess shoulder symptoms.

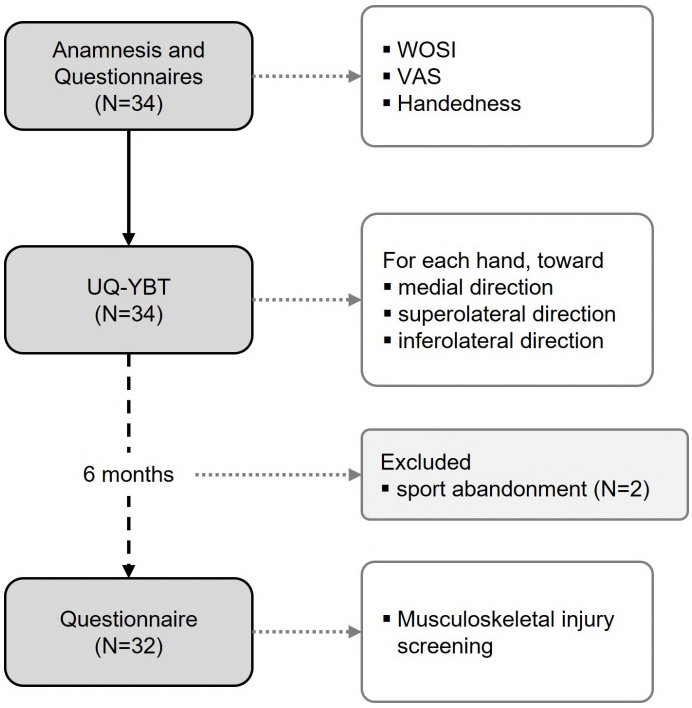

Fig. 1 Flowchart describing the research protocol.

Setting and Participants

The study sample comprises swimming athletes from a local elite sports club, aged 13 to 17 years, who train 5 to 7 times weekly and swim between 3000m and 8000m daily. Exclusion criteria include a history of incapacitating musculoskeletal disorders, neurological conditions, major trauma, or prior surgery on the upper limbs, trunk, or lumbar spine, as well as the current use of anti-inflammatory medication.

Baseline assessment of clinical and functional measures

An interview was taken to collect athletes' sociodemographic, anthropometric, and sports-related information.

Shoulder instability symptoms were assessed using the Brazilian Portuguese version of the Western Ontario Shoulder Instability Index (WOSI),[17,18] which consists of four domains related to: physical symptoms; sports, recreation, and work; lifestyle; and emotional factors. The WOSI contains 21 items, with responses given on a 100-mm visual analogue scale, ranging from "no complaints" (0) to "severe complaints" (100). The items are summed into four scores, with a total score ranging from 0 to 2100, where 0 indicates no limitations and 2100 corresponds to extreme limitations.

To determine the participant's preferred upper limb, we used the Edinburgh Handedness Inventory.[19] This questionnaire was administered in an interview format, where each subject indicates their preferred hand for each of the listed manual activities by selecting the right or left column for their response.

Baseline assessment of Upper Quarter Y Balance Test

First, the upper limb length was measured with a tape measure (precision of 0.5 cm), with participants standing, arms abducted to 90°, elbows extended, forearms in neutral position, and thumbs pointing upward. The measurement was taken from the spinous process of the 7th cervical vertebra to the tip of the middle finger.[13]

Next, the athletes were positioned on a force platform in a push-up posture, with the shoulders and wrists at 90 degrees of flexion, elbows and knees extended, trunk straight, and feet hip-width apart. The head remained in a neutral position, in line with the trunk. In this position, body weight is distributed between the athlete's feet and the supporting hands (randomly assigned as the reaching or supporting limb), which stay in contact with the platform.

After a familiarization period with the procedure, athletes performed the UQ-YBT adapted for the force platform, using a wooden ruler (5 cm in height) positioned in each of the three directions. This test challenges shoulder mobility and stability, requiring the participant to bear weight on the supporting limb on the platform, while reaching with the contralateral limb in the medial, inferolateral, and superolateral directions.[11] Each direction was tested three times in random order, with reach distance and posturographic data recorded. UQ-YBT reach distances were averaged and normalized by upper limb length.

Baseline assessment of postural sway

Center of pressure (COP) coordinates were acquired at 30 Hz using a force platform (Wii Balance Board, Nintendo Co Ltd, Japan). Data was transmitted via Bluetooth to a laptop running a custom LabVIEW program (National Instruments, USA). The platform was calibrated according to the manufacturer's guidelines. The COP signal was resampled to 100 Hz using the SWARII algorithm,[20] converted into resultant distance (square root of the sum of the squared displacements in the lateral and anteroposterior directions), and expressed as path length (summed distances between consecutive points) for each direction.[21] Data processing was performed offline in the Python 0.5.4 environment.

Outcome assessment

After six months, a follow-up phone call was made to assess sports-related shoulder symptoms. The questionnaire evaluated the occurrence of pain in the previous six months, including: specific conditions or activities associated with it; affected body parts; duration of activity suspension; whether treatment was sought; and whether the athlete resumed their usual activities. Athletes were classified as positive (=1) or negative (=0) for pain based solely on reported shoulder symptoms (with/without pain symptoms, respectively).

Statistical analysis

Missing data (approximately 6% of total) from functional assessments (UQ-YBT performance and force platform variables) were addressed using Multiple Imputation by Chained Equations (MICE). Normality assessment indicated that 60% of the variables showed Gaussian distribution (Shapiro-Wilk test, $P>0.062$).

Group comparisons (positive vs. negative shoulder pain symptoms) used Welch's t-tests for unequal sample sizes, with Cohen's d effect sizes being computed (trivial: <0.2; small: 0.2–0.5; moderate: 0.5–0.8; large: >0.8). False Discovery Rate (FDR) correction maintained false positives below 5%.

Variables with large effect sizes ($d>0.8$) entered univariate logistic regression to assess predictive value for pain status. Predictors included age, WOSI subscores (physical symptoms, sports/recreation/work, emotion, and total score), with previous shoulder injury/pain as covariate. Continuous predictors were Z-score normalized (mean=0; SD=1) to allow for direct comparison of effect sizes across different measurement scales. All logistic regression models were fitted using maximum likelihood estimation, with results expressed as odds ratios (OR) with corresponding 95% confidence intervals.

Table 1. Sample characteristics, functional performance and postural displacement during UQ-YBT, by groups (post-6-mo pain report).

	Groups			
	Neg. (N=23)	Pos. (N=9)	P-value*	Cohen-d
Demographics				
Age (years)	14.7 (0.8)	13.8 (0.7)	0.024	1.240
Height (cm)	170.2 (7.3)	166.8 (6.5)	0.251	0.487
Weight (kg)	60.8 (8.7)	55.2 (5.4)	0.104	0.699
BMI (kg/m^2)	20.9 (1.8)	19.8 (1.1)	0.104	0.638
Time of practice (years)	7.0 (1.7)	7.4 (2.4)	0.590	0.251
Training volume (km/week)	7.2 (0.9)	6.7 (0.8)	0.251	0.525
Functional performance				
UQ-YBT-comp., right	94.2 (7.1)	92.6 (9.2)	0.962	0.211
UQ-YBT-comp., left	93.9 (7.7)	91.8 (8.8)	0.962	0.268
UQ-YBT-IL, right	87.1 (7.9)	84.0 (9.3)	0.962	0.373
UQ-YBT-IL, left	85.4 (8.2)	81.1 (10.5)	0.962	0.482
UQ-YBT-ME, right	90.3 (7.3)	89.4 (5.6)	0.962	0.125
UQ-YBT-ME, left	92.6 (8.3)	89.8 (6.8)	0.962	0.359
UQ-YBT-SL, right	81.7 (10.9)	81.4 (13.1)	0.962	0.021
UQ-YBT-SL, left	81.3 (10.0)	81.7 (10.5)	0.962	0.045
Postural displacement				
PL-IL, right	429.7 (162.8)	426.7 (191.3)	0.967	0.018
PL-IL, left	363.4 (89.0)	371.4 (112.0)	0.967	0.084
PL-ME, right	490.0 (229.8)	453.4 (289.5)	0.967	0.148
PL-ME, left	402.7 (133.1)	333.8 (76.0)	0.348	0.571
PL-SL, right	717.2 (228.6)	590.7 (180.8)	0.348	0.583
PL-SL, left	720.6 (270.0)	669.7 (178.9)	0.967	0.204

Data are presented as mean (SD). Neg./Pos., negative/positive shoulder symptoms. *FDR corrected. Right/left, hand on which the test was performed; UQ-YBT, Upper Quarter Y-Balance Test; comp., composite score; IL, inferolateral; ME, medial; SL, superolateral; PL, path length.

All analyses were performed in Python 3.11.7, using the pingouin (version 0.5.5) and statsmodels (version 0.14.0) packages. Statistical significance was set at 5%.

Results

Participants

Thirty-four young athletes were originally enrolled, but two dropped out before the study's completion due to leaving the sport. The study included 32 competitive swimmers (18 female, 14 male) aged (mean and range) 14 (13-16) years, with a body mass of 59.2 (44.0-80.0) kg, height of 169 (158-187) cm, and BMI of 20.6 (15. 8-23.8) kg/m^2. Participants had been swimming for 7 (3-13) years and reported an average training volume of 7.1 (6.0-9.5) km/week. The sample was predominantly right-handed (N=30, 93.8%), with an equal distribution of swimmers with and without a history of previous shoulder injury/pain (N=16 in both groups). Regarding swimming specialization, the cohort consisted of 17 sprinters, 14 long-distance swimmers, and 1 middle-distance swimmer. The most common stroke was freestyle (N=14), followed by butterfly (N=8), breaststroke (N=5), backstroke (N=4), and individual medley (N=1).

Shoulder pain symptoms after 6 months

Of the total participants, 9 (28%) experienced shoulder pain in the last six months, while 23 (72%) reported no shoulder pain. All affected athletes reported pain during training, with the following distribution: bilateral shoulder pain (N=6), right shoulder pain (N=2), and left shoulder pain (N=1). Regarding physical therapy, seven sought treatments, while two did not. All athletes with shoulder pain symptoms returned to or maintained their regular sports activities without prolonged interruption (at least one day off due to pain was taken). Of the 9 athletes with positive pain symptoms, 6 (67%) had already reported shoulder injury/pain in the previous 6 months; these overlapping was accounted in logistic modeling.

Group comparisons

Welch's independent sample t-test revealed no significant differences between groups regarding height, weight, BMI, practice time, or swimming volume (P>0.104; Table 1). The only exception was the age, where the no pain symptoms group was older than the positive group. In addition, age showed large effect size, warranting its inclusion in the subsequent regression model.

After FDR correction, close-to-threshold P-values and large effect sizes were found for several WOSI's subscales (all P=0.061;Fig. 2): physical symptoms domain (d=0.936;Fig. 2A); the sports/recreation/work domain (d=1.017;Fig. 2B); the emotion domain (d=1.026;Fig. 2C); and the total WOSI score (d=0.959;Fig. 2D). All showed a tendency for higher scores for those with positive pain symptoms.

Table 2. Results from the univarate logistic regression analysis for factors associated with shoulder pain symptoms.

			Odds ratio		
Predictor variable	Beta	P-value*	OR	CI95%, lower	CI95%, upper
Age	-1.672	0.012	0.188	0.051	0.698
WOSI, physical	0.893	0.061	2.444	0.960	6.220
WOSI, sports	0.943	0.030	2.569	1.095	6.027
WOSI, emotion	0.901	0.044	2.461	1.025	5.912
WOSI, total	0.892	0.050	2.441	0.999	5.968

The dependent variable was the presence of shoulder pain (coded as 1 if positive, 0 if negative). OR, odds ratio; CI, confidence interval; "physical", WOSI's physical symptoms; "sports", WOSI's sports, recreation and work.

* Non-corrected P-values; FDR corrected P-values were all 0.061.

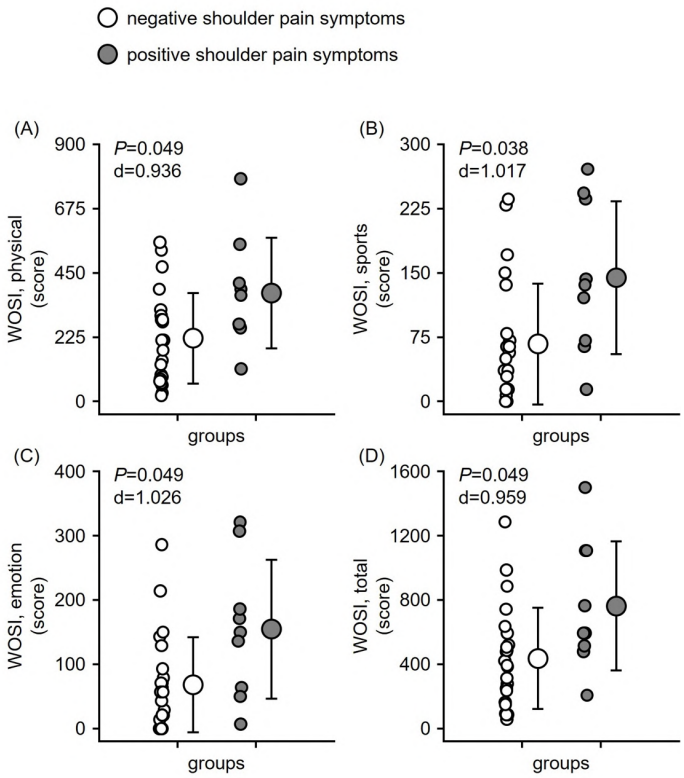

Fig 2. WOSI group analysis. Data are presented as mean (SD) and individual values (small circles) for those with negative (white markers) and positive (gray markers) shoulder pain symptoms. Non-corrected P-value and Cohen's d are shown.

For the UQ-YBT, no significant differences were observed in composite scores or normalized reach distances (P>0.962; Table 1). Similarly, path length measurements showed no significant differences between groups (P>0.348; Table 1). The computed effect sizes were all below d=0.583.

In general, the most pronounced differences between groups were in age and shoulder function (WOSI), while dynamic balance and functional measures were largely similar between groups.

Predictive regression modeling

Logistic regression analysis (Table 2), considering previous shoulder pain as covariate, revealed significant associations between shoulder-related outcomes and demographic and clinical measures. Along with age, the WOSI sports and emotion subscale, together with close-to-threshold effect for WOSI physical function and total score, emerge as significant predictors. Overall, higher disability scores increased the odds of the outcome (shoulder pain symptoms) while increased age reduces its odds.

Discussion

In this prospective study of 32 young swimmers, we investigated clinical and functional factors associated with shoulder pain development. Results showed that athletes reporting shoulder pain after six months already exhibited higher baseline WOSI scores, indicating greater dysfunction and pain perception, while functional measures (UQ-YBT and postural displacements) did not differ significantly between groups. Regression analysis revealed that higher WOSI sub-scores, along with younger age, increased pain risk, suggesting clinical assessments have greater predictive value than functional tests for this outcome in young competitive swimmers.

Our findings align with previous research. Freijen et al.[5] identified five significant predictors of shoulder pain in swimmers: acute-to-chronic workload ratio, competitive level, posterior shoulder muscle endurance, flexion range of motion, and hand entry error. Souza et al.[6] demonstrated that competitive swimming is associated with higher frequency of shoulder pain and rotator cuff injuries, suggesting excessive training load without adequate control contributes to chronic pain development. Finally, Kennedy et al.[7] and Porter et al.[8] highlighted that anatomical and kinesiological variables – such as range of motion, joint laxity, and supraspinatus tendon thickness – are associated with shoulder pain risk.

Our results corroborate previous findings showing that the WOSI is a robust predictor of subjective disability perception,[22,23] with elevated scores correlating with pain presence. Conversely, the UQ-YBT performance was insufficiently sensitive to detect functional deficits related to subclinical pain stages, consistent with studies finding no significant correlation between this test and shoulder injury.[24]

Pain alone does not confirm injury presence. However, its persistence, particularly when accompanied by positive clinical tests, significantly increases musculoskeletal injury risk. According to Hoegh et al.,[25] distinguishing between sport-related pain (absence of measurable tissue damage, typically associated with training adaptations) and sport-related injury (objective clinical signs or imaging findings compatible with structural impairment) is essential. In this context, disabling pain measured by WOSI represents a more advanced stage in the pain-injury continuum,[18] associated with greater dysfunction risk and higher structural injury probability. This distinction, evidenced by higher scores across all WOSI domains (physical symptoms, sports/recreation/work, emotional, and total score) in positive shoulder pain athletes, captures aspects functional tests cannot detect, such as perceived instability, shoulder insecurity, and emotional impact.

Corroborating this view, body height, weight, and swimming volume were not significant predictors of pain presence in the studied sample. This suggests that, in homogeneous groups regarding activity level, anthropometric and load factors alone may not explain pain onset in athletes with a history of instability. It is important to note,

however, that these variables may act as adjusting predictors or even as confounding factors in more complex models and should therefore be considered in the design of future studies.

Limitations

Study limitations include sample size and assessment interval. A larger sample could reveal differences between symptomatic and asymptomatic groups not observed here. Additionally, longer follow-up would increase shoulder the probability of pain occurrence, making group comparisons more equivalent. However, observed differences, even after multiple comparison correction, showed strong effect sizes, indicating relevant pain and functionality alterations despite sample size asymmetry. Conversely, longer intervals could increase sample loss due to sport dropout (as occurred with two athletes) or contact loss. Despite limitations, results provide important insights into clinical decision-making and future investigations.

Conclusion

WOSI are useful instruments for identifying athletes at higher risk of developing or exacerbating shoulder complex dysfunction. Elevated scores on these scales are associated with subsequent pain development, even when objective functional tests (UQ-YBT and hand-support postural displacement measures) detect no significant alterations. Our findings corroborate current models positioning perceived disability as a more sensitive risk marker in the pain-injury continuum. Future studies should validate these scales' predictive power and establish clinical cut-off points in sports contexts.

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Conflicts of Interest

The authors report no conflict of interest.

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Originales

Efecto del uso del foam roller seguido de estiramientos sobre la tendinopatía del hombro

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RESUMEN

Introducción: La articulación del hombro puede ser sensible a trastornos como las tendinopatías y la rotura de los tendones del manguito rotador representando más de la mitad de las afecciones del hombro. El rodillo de espuma de liberación miofascial (foam roller - FM) consiste en realizar movimientos de balanceo aplicados en zonas específicas del cuerpo mejorando el rango de movimiento y el dolor. **Objetivo:** Analizar el efecto del uso del FR seguido de estiramientos en 14 individuos con tendinopatía del manguito rotador. **Métodos:** Se realizaron las maniobras ortopédicas de Napoleón. Gerber y Hawkins. el cuestionario DASH y la medición del rango de movilidad del hombro mediante goniómetro. comparando el hombro afectado con el sano. En bipedestación se presionó sobre el rodillo (ubicado contra la pared) con el músculo infraespinoso durante tres segundos para cada lado repitiendo cinco veces. realizándose después estiramientos y repitiendo dos veces más. posteriormente se hizo de manera igual. pero ejerciendo presión con el músculo pectoral mayor. **Resultados:** Las maniobras ortopédicas resultaron negativas. el dolor y la dificultad funcional disminuyeron (pre: 86.6 vs post: 50.2) evidenciándose un mayor grado de movimiento sobre todo en la flexión y rotación externa del miembro tratado (pre: 148.4° vs post: 174.6° y 179.2° vs 183.7° respectivamente). **Conclusión:** El uso del FR podría ser beneficioso para aquellas personas con tendinopatía del manguito rotador.

Palabras clave: Tendinopatía; Lesión del manguito rotador; Dolor de hombro.

Effect of foam roller use followed by stretching on shoulder tendinopathy

ABSTRACT

Introduction: The shoulder joint can be sensitive to disorders such as tendinopathies and rotator cuff tendon rupture. accounting for more than half of shoulder conditions. The myofascial release foam roller (FM) consists of performing rocking movements applied to specific areas of the body. improving range of motion and pain. **Objective:** To analyze the effect of using RF followed by stretching in 14 individuals with rotator cuff tendinopathy. **Methods:** The orthopedic maneuvers of Napoleon. Gerber and Hawkins. the DASH questionnaire and the measurement of the range of motion of the shoulder by goniometer were performed. comparing the affected shoulder with the healthy one. In standing position. the roller (located against the wall) was pressed with the infraspinatus muscle for three seconds on each side. repeating five times. then stretching and repeating two more times. then it was done in the same way. but exerting pressure with the pectoralis major muscle. **Results:** Orthopedic maneuvers were negative. pain and functional difficulty decreased (pre: 86.6 vs post: 50.2) showing a greater degree of movement especially in flexion and external rotation of the treated limb (pre: 148.4° vs post: 174.6° and 179.2° vs 183.7° respectively). **Conclusion:** The use of RF could be beneficial for those with rotator cuff tendinopathy.

Keywords: Tendinopathy; Rotator cuff injury; Shoulder pain.

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Efeito do uso de rolo de espuma seguido de alongamentos na tendinopatia do ombro

RESUMO

Introdução: A articulação do ombro pode ser sensível a doenças como tendinopatias e rutura do tendão do manguito rotador. representando mais de metade das condições do ombro. O rolo de espuma de libertação miofascial (FM) consiste em realizar movimentos de balanço aplicados em áreas específicas do corpo. melhorando a amplitude de movimento e a dor. **Objetivo:** Analisar o efeito do uso de RF seguido de alongamentos em 14 indivíduos com tendinopatia do manguito rotador. **Métodos:** Foram realizadas as manobras ortopédicas de Napoleon. Gerber e Hawkins. o questionário DASH e a medição da amplitude de movimento do ombro por goniómetro. comparando o ombro afetado com o saudável. Em posição de pé. o rolo (encostado à parede) era pressionado com o músculo infraespinoso durante três segundos de cada lado. repetindo cinco vezes. depois alongando e repetindo mais duas vezes. e depois era feito da mesma forma. mas exercendo pressão com o músculo peitoral maior. **Resultados:** As manobras ortopédicas foram negativas. a dor e a dificuldade funcional diminuíram (pré: 86.6 vs post: 50.2) mostrando um maior grau de movimento. especialmente na flexão e rotação externa do membro tratado (pré: 148.4° vs poste: 174.6° e 179.2° vs 183.7°. respetivamente). **Conclusão:** O uso da RF pode ser benéfico para quem sofre de tendinopatia do manguito rotador.

Palavras-chave: Tendinopatia; Lesão no manguito rotador; Dor no ombro.

INTRODUCCIÓN

El manguito rotador lo componen cuatro músculos que tienen su origen en la escápula y convergen en la cabeza del húmero, teniendo relación entre ellos. Estos músculos son el supraespinoso, el infraespinoso, el subescapular y el redondo menor, que participan en la movilidad del hombro en distintas direcciones, ejerciendo al mismo tiempo la estabilización, contribuyendo a que la cabeza del húmero esté centrada en la cavidad glenoidea de la escápula[1]. A su vez, la articulación del hombro puede ser sensible a algunos trastornos como los problemas musculoesqueléticos que causan dolor, repercutiendo así sobre la capacidad funcional de este[2].

Siguiendo la idea anterior, los trastornos de los músculos del manguito rotador representan más de la mitad de las afecciones del hombro[1] siendo las tendinopatías y la rotura de los tendones del manguito rotador el grupo de trastornos más comunes que lo afectan, estando más relacionados con el sobreuso[3], y causas de origen multifactorial, como por ejemplo los lanzamientos repetidos o la sobrecarga de deportes como el béisbol, la natación, el levantamiento de pesas olímpico[4] un estrechamiento del espacio entre el acromion y la cabeza humeral, traumatismos como caídas en un brazo, especialmente en personas mayores, o desgaste relacionado con la edad de los tendones que componen el manguito rotador, que son más susceptibles a lesiones debido a la disminución del flujo sanguíneo[5] y caracterizando las tendinopatías por la aparición de dolor en el tendón y pérdida de la funcionalidad cuando el hombro se somete a un esfuerzo o carga mecánica[3].

Por otro lado, el uso del rodillo de espuma de liberación miofascial (FR) se utiliza cada vez más en el campo de la fuerza y el acondicionamiento físico[6]. Esta técnica consiste en movimientos de balanceo hacia adelante y hacia atrás que se aplican a áreas específicas del cuerpo[7], usando el propio peso corporal en donde los tejidos musculares y otros tejidos blandos son sometidos a presión[8,9] y cuyo beneficio puede asociarse con una mejora de la flexibilidad, la amplitud de movimiento y la reducción del dolor[6].

En la misma línea, se ha sugerido que el aporte de energía a las fascias musculares por medio de presión mecánica puede provocar un mayor retorno de las propiedades viscoelásticas y tixotrópicas[8], así como la alteración de la rigidez de los tejidos y la descomposición de los puntos gatillo musculares[10]. De acuerdo con lo anterior, el objetivo de este estudio se centra en evaluar el efecto del FR y estiramientos en un grupo de adultos jóvenes con tendinopatía del manguito rotador.

MÉTODOS

Población de estudio y pruebas

15 individuos (8 mujeres y 7 hombres) con edades comprendidas entre los 22 y los 48 años, una vez han aceptado su participación voluntaria por medio del consentimiento informado, fueron elegidos por tener tendinopatía del manguito rotador, en donde, presentaron un hallazgo positivo en las siguientes maniobras exploratorias para el hombro doloroso: *Prueba de Napoleón:* En esta maniobra se evalúa la facultad del individuo de mantener la palma de la mano pegada al abdomen ejerciendo presión contra este. La prueba será positiva si el individuo es incapaz de mantener la presión contra el abdomen, percibe debilidad, siente dolor o lleva el codo hacia atrás para compensar[11], así como extender el hombro y flexionar la muñeca[12], pudiendo indicar debilidad o rotura del tendón del músculo subescapular[11].

Prueba de Gerber: El individuo realiza una rotación interna llevando el dorso de la mano sobre la espalda, en donde el evaluador solicita que se separe la mano de la espalda. El resultado será positivo si el individuo no puede separar la mano desde esa posición, pudiendo evidenciar una potencial rotura del tendón del subescapular[12].

Prueba de Hawkins: En esta prueba, el individuo flexiona el hombro (eleva anteriormente) a 90° con el codo flexionado también a 90° y simulando la forma de "L" frente al cuerpo. El evaluador estabiliza la escápula con una mano mientras aplica fuerza hacia abajo en el antebrazo distal para crear la máxima rotación interna, en donde el test será positivo si existe dolor[13] indicando posible bursitis subacromial, ya que pone en compromiso el espacio subacromial.

Cuestionario DASH: El DASH es un cuestionario autoadministrado que consta de 30 ítems que evalúan diversas síntomas y funciones relacionadas con el brazo, el hombro y la mano. Cada ítem ofrece cinco opciones de respuesta (puntuación del 1-5), lo que permite a los pacientes calificar su nivel de dificultad[14], en donde 1 significa ninguna dificultad y 5 que es imposible de realizar la actividad. Esta herramienta posee consistencia interna de acuerdo al alfa de Cronbach de 0.96 y una sensibilidad al cambio superior de 0.8020[15].

Por último, se midió el grado de movilidad del hombro con tendinopatía y sin tendinopatía mediante un goniómetro. Seguidamente, se excluyó a todo individuo que presentara: (1) herida abierta que complicaría la aplicación del FR; (2) individuos que hayan tenido previamente una cirugía de hombro; (3) alergia o intolerancia a la aplicación del FR; (4) antecedentes de luxación en la articulación del hombro en los últimos 12 meses o cualquier fractura en la cintura escapular; (5) algún síntoma o señal clínica de desgarros del espesor completo de cualquier músculo del manguito rotador. Al final, quedaron seleccionados para el análisis 8 mujeres y 6 hombres, ya

que un participante abandonó el estudio por razones personales. El estudio se envió y revisó de acuerdo a la normativa uruguaya que regula la investigación en/con seres humanos con decreto nº 158/019 de la Universidad de la República, Uruguay.

Intervención

El proceso de intervención del sujeto se basó en el uso de FR y estiramientos, cuya frecuencia fue de cuatro veces por semana durante seis semanas. Solo se realizaron dos movimientos (**figura 1A**y**1B**, en el primero el sujeto se colocó en posición de pie con la espalda apoyada en una pared, el rodillo de espuma se colocó verticalmente entre la pared y la región posterior y superior del tronco, con el rodillo sobre el músculo infraespinoso (**figura 1A**y**1C**), el sujeto realizó movimientos de un lado a otro ejerciendo presión sobre el rodillo con el peso corporal durante tres segundos para el izquierdo y tres segundos para el derecho y repitiendo para cada lado cinco veces, luego se realizó el estiramiento (**figura 2A**) durante 30 segundos y se repitió con el rodillo dos veces más alternas.

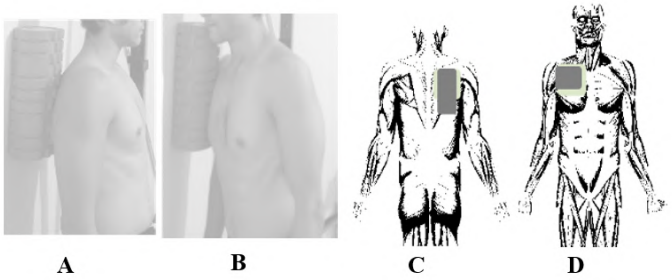

Figura 1. Auto masaje con el foam roller sobre los músculos infraespinoso (A) y pectoral (B), y sobre las áreas específicas en gris (C y D).

El segundo movimiento se realizó de manera similar al anterior, pero esta vez con el sujeto en posición de pie frente a la pared y el rodillo presionado desde las áreas del borde anterior de la clavícula derecha y la cuarta costilla, y desde el tubérculo menor y el tronco anterior y superior derecho (**figura 1B**y**1D**) y posteriormente el estiramiento respectivo (**figura 2B**).

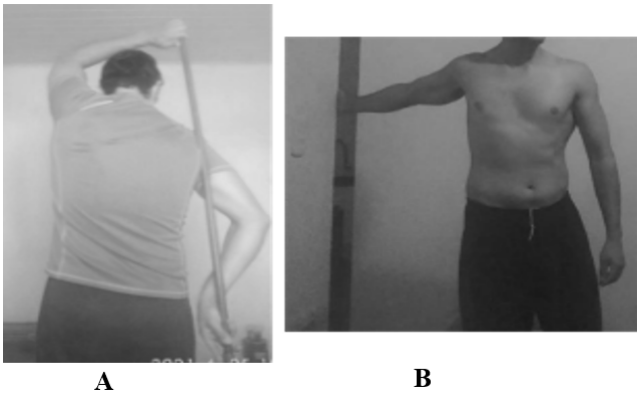

Figura 2. Estiramiento del músculo infraespinoso (A), pectoral y subescapular (B).

Análisis estadístico

Los datos fueron recolectados en el programa Microsoft® Excel y posteriormente se analizaron con el programa estadístico Jamovi, versión 2.3, considerándose significativo un nivel α de 0.05. Posterior al análisis de normalidad, los datos se informan como medias y desviaciones estándar. Las diferencias entre el pre test y el pos test se evaluaron mediante pruebas *t* pareadas. De la misma manera, se calculó el tamaño del efecto (TE), considerando valores entre 0 y 0.19, como no efecto o que el efecto es intrascendente; de 0.2 a 0.49, un efecto pequeño; de 0.5 a .79, como efecto moderado; de 0.8 a 1.29 efecto grande; y ≥ 1.3, efecto muy grande[16].

RESULTADOS

El cuestionario DASH fue autoadministrado, sumándose los valores asignados a cada una de las respuestas completadas hallándose el promedio, obteniendo así una puntuación del uno al cinco. Para expresar esta puntuación en por cientos, se le restó 1 y se multiplicó por 25, así, un puntaje cercano a 0 representa menor dificultad y cercano a 100 se refiere a mayor dificultad, donde se evidenció una mejoría importante a nivel estadístico con un efecto moderado, más, en la intensidad del dolor se obtuvo una mejora importante con un efecto grande y diferencia significativa (tabla 1).

Del mismo modo, se han observado cambios en varias variables tras seis semanas de uso del FR, donde para las maniobras ortopédicas el resultado fue negativo, seguido de una mejora sustancial en la movilidad del hombro, específicamente en flexión y rotación externa, en donde además de lograr diferencias significativas, tuvieron un efecto muy grande y grande respectivamente. En cuanto a la abducción y rotación interna, a pesar de haber logrado diferencias significativas, el efecto fue pequeño. En el movimiento de extensión, no se evidenció prácticamente ningún cambio al igual que en el hombro sin tendinopatía.

DISCUSIÓN

El uso de FR puede ser beneficioso para tratar la tendinopatía en los músculos del manguito rotador, en este sentido, algunos datos disponibles indican que el uso de esta técnica durante 90 segundos puede ser la duración mínima para lograr una reducción del dolor a corto plazo, así como en la mejora del rango de movimiento e incluso de la funcionalidad en los individuos tratados[17,18], así como una mejora en el rango de movimiento siguiendo un protocolo de fatiga inducida[19]. A su vez, y contrariamente a nuestro estudio y a las propuestas anteriores,Hughes & Ramer, (2019), no observaron ningún efecto en el rango de movimiento o el rendimiento[20].

Por otro lado, estudios como el deBehm et al. (2020). donde se emplearon fórmulas de regresión, predijeron prescripciones de swing que involucraban de una a tres series con una duración de dos a cuatro segundos por repetición y una duración total de 30 a 120 segundos por serie, lo que sugiere que volúmenes relativamente pequeños pueden mejorar el rango de movimiento con efectos generalmente leves en la fuerza y el rendimiento de salto[21], coincidiendo con nuestro trabajo en relación con el rango de movimiento. Además, se han visto efectos favorablemente superiores cuando el estiramiento está precedido por FR, pero no al revés[22], sin embargo, se ha encontrado que el FR o estiramiento es igualmente similar y se puede aplicar de forma independiente[17], en definitiva, son varios los hallazgos que avalan los efectos inmediatos con un impacto positivo del tratamiento con el FR en el rango de movimiento y la flexibilidad muscular[23].

Ahora bien, el FR puede tener un efecto distinto al de solo realizar estiramientos, por cuanto se ha sugerido la posibilidad de un efecto sobre el sistema nervioso central (SNC) por el que la fuerza mecánica aplicada al tejido estimula los mecanorreceptores intrafasciales, lo que afecta a la entrada propioceptiva enviada al SNC, alterando la regulación del tono de las unidades motoras asociadas dentro de la fascia[24], a lo queShah y Bhalara (2012) han resumido este efecto con la frase: "la estimulación aferente suele provocar una inhibición eferente"[25]. De este modo, la presión mecánica aplicada a la fascia envía una señal neural al SNC, que a su vez envía una señal neural para reducir el tono en los músculos asociados, entonces, el FR no sólo afecta al tono, sino que puede mejorar la producción de potencia al estimular el sistema neural para aumentar

Tabla 1. Variables consideradas durante la intervención.

Variable	Evaluación 1 (semana 1)	Evaluación 2 (semana 6)	*P* valor	TE
Intensidad del dolor VAS /10	9.4	2.7	.016	.945
Cuestionario DASH	86.6	48.2	.022	.788
Maniobras ortopédicas				
Napoleón	+	-		
Gerber	+	-		
Hawkins	+	-		
Movilidad hct (grados)				
Flexión	144.4	175.6	.000	1.421
Extensión	60.2	60.2	.718	.120
Abducción	178.2	183.7	.044	.341
Rotación externa	65.4	74.9	.025	.875
Rotación interna	88.4°	93.9°	.031	.282
Movilidad hst (grados)				
Flexión	172.2	172.8	.736	.013
Extensión	60.1	60.4	.521	.088
Abducción	182.1	183.7	.840	.027
Rotación externa	77.1	77.6	.622	.055
Rotación interna	96.5	96.3	.601	.012

VAS: escala analógica visual; **hct:** hombro con tendinopatía; **hst:** hombro sin tendinopatía; **TE:** Tamaño del efecto.

su ritmo de disparo y el patrón de reclutamiento[26]. Este puede ser el mecanismo por el que el FR influye en el rendimiento muscular. No obstante, estos resultados hablan de la comunicación entre los sistemas muscular y neural para optimizar solamente la función neuromuscular[27].

CONCLUSIONES

De acuerdo con nuestros resultados, el tratamiento con FR en donde cada repetición tenga una duración de al menos tres segundos, combinado con estiramientos específicos con una duración de 30 segundos, puede considerarse efectivo, ya que se han observado mejoras en las variables estudiadas. Se necesitan investigaciones futuras para validar completamente estos hallazgos. El uso del FR se hace cada vez más notorio en distintos ámbitos, tanto del acondicionamiento físico o fitness, como en el clínico o de rehabilitación, por tanto, creemos necesario más estudio para desarrollarse un consenso entre investigadores y clínicos y diferenciar el protocolo para cada situación particular, sin que un protocolo beneficie alguna capacidad en detrimento de otra.

LIMITACIONES

Existen algunas limitantes específicas a la investigación, una de ellas, es el reducido tamaño de la muestra, otra es que la intervención fue realizada a sujetos con tendinopatía del hombro y específicamente a las maniobras realizadas en este estudio, por lo que se limita la generalización de los resultados a población con estas características. Se ha empleado una técnica de FM en zonas específicas comunes a músculos del manguito rotador y un tiempo específico, por lo que otras técnicas pueden conllevar a resultados diferentes, así como su aplicación en otros grupos musculares.

Aplicaciones prácticas

La aplicación de este protocolo pudiera ser beneficioso tanto en el campo de la rehabilitación como en el acondicionamiento físico, pudiendo ser usado durante la fase inicial de una sesión de rehabilitación o para complementar un programa de ejercicio terapéutico, favoreciendo la preparación del tejido antes de realizar ejercicios de fortalecimiento o movilidad más complejos y que empleen una intensidad importante.

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Originales

Impacto del formato de visualización convencional 2D versus realidad virtual 3D sobre la superficie ocular en universitarios de deporte electrónico

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RESUMEN

Objetivo: Determinar el efecto de la exposición a videojuegos en formato de visualización convencional (2D) versus estereoscópico (3D/VR) sobre la superficie ocular en estudiantes universitarios. **Método:** Estudio cuasiexperimental con 49 estudiantes asignados a formatos 2D o 3D. Se evaluaron pre y post exposición: prueba de Schirmer I, menisco lagrimal, hiperemia conjuntival, TBUT y OSDI. El análisis empleó modelos mixtos para medidas repetidas (GLMM Gamma-log) y pruebas no paramétricas para el OSDI. **Resultados:** El grupo 3D presentó reducción significativa del menisco lagrimal en el ojo izquierdo (0.229 a 0.194 mm; p=.002) y misma tendencia en el derecho. La hiperemia aumentó significativamente en ambos ojos (χ^2=50.08; p<.001) y la prueba de Schirmer disminuyó en ambos grupos. El TBUT mostró tendencia a la baja sin alcanzar significancia (p>0.220); el OSDI fue similar entre grupos y momentos. **Conclusiones:** La exposición de una hora a videojuegos en los formatos 2D y 3D no produjo cambios significativos en la función lagrimal, excepto por un aumento en la hiperemia conjuntival

Palabras clave: Juegos de Video; Salud ocular; Realidad virtual; Síndrome de ojo seco; Competencia Profesional.

Impact of Conventional 2D Display Versus 3D Virtual Reality on the Ocular Surface in Esports University Students

ABSTRACT

Objective: To determine the effect of exposure to video games in conventional (2D) versus stereoscopic (3D/VR) viewing formats on the ocular surface in university students. **Methods:** A quasi-experimental study was conducted in 49 students assigned to 2D or 3D formats. Pre- and post-exposure assessments included the Schirmer I test, tear meniscus height, conjunctival hyperemia, tear break-up time (TBUT), and the Ocular Surface Disease Index (OSDI). Data were analyzed using mixed-effects models for repeated measures (Gamma-log GLMM) and nonparametric tests for OSDI. **Results:** The 3D group showed a significant reduction in tear meniscus height in the left eye (0.229 to 0.194 mm; p = .002), with a similar trend in the right eye. Conjunctival hyperemia increased significantly in both eyes (χ^2 = 50.08; p < .001), and

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Schirmer I values decreased in both groups. TBUT showed a decreasing trend without reaching statistical significance (p > .220), while OSDI scores were similar across groups and time points. **Conclusions:** One hour of exposure to video games in 2D and 3D formats did not produce significant changes in tear function, except for an increase in conjunctival hyperemia.

Keywords: Video games; Ocular surface; Virtual reality; Dry eye syndrome; professional competence.

Impacto do formato de visualização convencional 2D versus realidade virtual 3D na superfície ocular em universitários praticantes de esportes eletrônicos

RESUMO

Objetivo: Determinar o efeito da exposição a videogames em formatos de visualização convencional (2D) versus estereoscópico (3D/VR) sobre a superfície ocular em estudantes universitários. **Métodos:** Estudo quase-experimental realizado com 49 estudantes, alocados em formatos 2D ou 3D. Foram realizadas avaliações pré e pós-exposição: teste de Schirmer I, altura do menisco lacrimal, hiperemia conjuntival, tempo de ruptura do filme lacrimal (TBUT) e Ocular Surface Disease Index (OSDI). A análise utilizou modelos mistos para medidas repetidas (GLMM Gamma-log) e testes não paramétricos para o OSDI. **Resultados:** O grupo 3D apresentou redução significativa da altura do menisco lacrimal no olho esquerdo (0,229 para 0,194 mm; p = 0,002), com tendência semelhante no olho direito. A hiperemia conjuntival aumentou significativamente em ambos os olhos (χ^2 = 50,08; p < 0,001), e os valores do teste de Schirmer I diminuíram em ambos os grupos. O TBUT apresentou tendência de redução sem alcançar significância estatística (p > 0,220), enquanto os escores do OSDI foram semelhantes entre grupos e momentos. **Conclusões:** A exposição de uma hora a videogames nos formatos 2D e 3D não produziu alterações significativas na função lacrimal, exceto por um aumento na hiperemia conjuntival.

Palavras-chave: Videogames; Superfície ocular; Realidade Virtual; Síndrome do olho seco; competência profissional.

Introducción

En la última década, los esports han redefinido el consumo digital entre los jóvenes, imponiendo exigencias oculomotoras variables según el género: los títulos de disparos demandan sacadas rápidas, los estratégicos combinan fijación sostenida con exploración periférica, los de lucha exigen discriminación visual central y los simuladores requieren seguimiento ocular continuo (1). Cada género representa un reto visual único.

El formato de visualización determina demandas fisiológicas diferenciadas. Mientras el formato 2D opera con señales de profundidad monoculares, la realidad virtual introduce disparidad retinal binocular que activa el conflicto vergencia-acomodación, incrementando la carga oculomotora (2). Ambos escenarios se enmarcan en el síndrome visual informático, caracterizado por: ojo rojo, visión borrosa y fatiga visual, asociados a la reducción del parpadeo en visión próxima (3).

En poblaciones de alta exposición, como estudiantes universitarios y gamers, se ha documentado mayor prevalencia de alteraciones de la superficie ocular, incluyendo síndrome de ojo seco (4). Ante esta evidencia, el presente estudio determinó el efecto de la exposición a videojuegos en formato de visualización convencional (2D) versus estereoscópico (3D/VR) sobre la superficie ocular en estudiantes universitarios, con el propósito de generar evidencia fisiológica que oriente estrategias de prevención y ergonomía visual adaptadas a cada formato para la práctica segura de los deportes electrónicos.

Metodología

Estudio cuasiexperimental en 49 estudiantes universitarios (18–25 años), asignados aleatoriamente a grupos 2D (n=25) y 3D (n=24). La muestra por conveniencia incluyó participantes con corrección refractiva, agudeza visual 0.0–0.1 y binocularidad estable. Se excluyeron alteraciones oculares, binoculares y neuromotoras. El tamaño muestral se consideró adecuado para un diseño exploratorio con medidas repetidas y modelos mixtos. El estudio contó con consentimiento informado y aprobación ética (CV2025-SPE-BOG-13340).

La evaluación de la superficie ocular siguió un orden estandarizado: OSDI, valoración de la hiperemia conjuntival (escala de Efron), altura del menisco lagrimal, prueba de Schirmer I sin anestesia y tiempo de ruptura lagrimal (BUT).

La condición 2D se implementó con Valorant en computador portátil de 16 pulgadas (50–60 cm, posición sedente), y la condición de visualización estereoscópica por realidad virtual (VR) con Astro Bot mediante PlayStation VR (PSVR, ~5 cm ojo-pantalla, posición en bipedestación). La distinción entre formatos no refiere al motor gráfico, ambos juegos son tridimensionales en su renderizado, sino al mecanismo de procesamiento visual de la profundidad: el formato 2D emplea señales monoculares, mientras que el formato VR introduce disparidad retinal binocular real, activando el conflicto vergencia-acomodación propio de la visualización estereoscópica. La iluminación fue mixta y constante durante toda la sesión.

Se calcularon estadísticos descriptivos por ojo, grupo y momento. Dado el tipo de distribución de los datos, se aplicaron modelos mixtos para medidas repetidas con efectos fijos de grupo, momento e interacción, e intercepto aleatorio por participante: GLMM Gamma-log para menisco lagrimal y Schirmer; LMM sobre escala logarítmica para BUT y OPI; y GLMM ordinal para hiperemia conjuntival. Se obtuvieron medias marginales estimadas con IC95% y contrastes simples desde el modelo. El OSDI se evaluó complementariamente mediante pruebas no paramétricas bivariadas. Todos los análisis se realizaron en Jamovi v2.5.5 (GAMLj 4.0.3), con nivel de significancia p<.05.

Resultados

Se analizaron 49 estudiantes asignados a videojuegos en formato convencional 2D (n=25) o estereoscópico VR (n=24). Una hora de exposición aguda no produjo cambios consistentes en la mayoría de los indicadores de superficie ocular, con excepción de una interacción significativa Grupo × Momento en el menisco lagrimal del ojo izquierdo y un efecto principal del momento en la hiperemia conjuntival bilateral (Tablas 1 y 2).

Tabla 1. Medias marginales estimadas (IC 95%) para altura del menisco lagrimal y tiempo de ruptura lagrimal según grupo y momento.

Variable	Ojo	2D pre	2D pos	3D pre	3D pos
Menisco lagrimal (mm)	Derecho	0.216 (0.179–0.261)	0.215 (0.178–0.260)	0.268 (0.221–0.325)	0.231 (0.191–0.280)
Menisco lagrimal (mm)	Izquierdo	0.195 (0.159–0.239)	0.211 (0.172–0.259)	0.229 (0.186–0.282)	0.194 (0.157–0.238)
Tiempo de ruptura lagrimal (s)	Derecho	1.45 (1.04–2.01)	1.37 (0.98–1.90)	1.50 (1.07–2.09)	1.27 (0.91–1.78)
Tiempo de ruptura lagrimal (s)	Izquierdo	1.77 (1.20–2.60)	1.48 (1.00–2.18)	1.61 (1.09–2.37)	1.34 (0.91–1.98)

Nota Los valores corresponden a medias marginales estimadas (IC 95%). El menisco lagrimal se analizó mediante GLMM con distribución Gamma y enlace log, y el BUT mediante LMM sobre ln(BUT), reexpresado en la escala original. La inferencia estadística se presenta en el texto.

Tabla 2. Medias marginales estimadas (IC 95%) para test de Schirmer, índice de protección ocular e hiperemia conjuntival, y descriptivos del puntaje total del OSDI.

Variable	Ojo / Formato visualización	2D pre	2D pos	3D pre	3D pos
Schirmer (mm)	Derecho	12.5 (9.08–17.2)	11.4 (8.26–15.7)	16.6 (11.94–23.0)	16.1 (11.63–22.3)
Schirmer (mm)	Izquierdo	11.3 (8.38–15.4)	11.1 (8.11–15.2)	14.7 (10.9–19.8)	14.6 (10.7–19.8)
Índice de protección ocular	Derecho	0.194 (0.163–0.231)	0.169 (0.142–0.200)	0.184 (0.154–0.220)	0.155 (0.128–0.187)
Índice de protección ocular	Izquierdo	0.215 (0.164–0.284)	0.167 (0.137–0.203)	0.230 (0.185–0.307)	0.169 (0.135–0.212)
Hiperemia conjuntival	Derecho	2.00 (2.00–2.00)	2.00 (2.00–2.00)	2.00 (2.00–2.00)	2.00 (2.00–2.00)
Hiperemia conjuntival	Izquierdo	1.96 (1.80–2.12)	2.37 (1.98–2.76)	1.87 (1.63–2.11)	2.22 (1.90–2.54)

Nota Los valores de Schirmer, OPI e hiperemia corresponden a medias marginales estimadas (IC 95%). Schirmer se analizó mediante GLMM con distribución Gamma y enlace log; el OPI, mediante LMM sobre ln(OPI), retransformado a la escala original; y la hiperemia conjuntival, mediante GLMM ordinal con enlace logit acumulativo.

El grupo VR presentó una reducción significativa del menisco lagrimal en el ojo izquierdo (0.229 a 0.194 mm; χ^2=10.02, p=.002; −15.3%), mientras que el grupo 2D no mostró cambios significativos (0.195 a 0.211 mm; p=.127). En el ojo derecho, el grupo VR evidenció una tendencia a la disminución (0.268 a 0.231 mm; p=.052) sin alcanzar significancia estadística (Figura 1).

El BUT no mostró efectos significativos en ningún ojo; no obstante, se observó una tendencia descriptiva a la reducción posexposición en ambos grupos, más marcada en el grupo VR (OD: 1.50 a 1.27 s; OI 2D: 1.77 a 1.48 s; OI VR: 1.61 a 1.34 s). El Schirmer no evidenció efectos significativos de grupo, momento ni interacción. El OPI mostró una tendencia al efecto del momento en el ojo izquierdo (F(1,47)=4.03, p=.050) y una disminución descriptiva posexposición en ambos grupos, sin alcanzar significancia.

La hiperemia conjuntival aumentó significativamente tras la exposición en ambos ojos, independientemente del formato: OD (χ^2(1)=50.08, p<.001) y OI (χ^2(1)=9.01, p=.003), sin efecto de grupo ni interacción. El OSDI no mostró diferencias entre grupos en síntomas oculares (p=.786), limitación funcional (p=.533), desencadenantes ambientales (p=.752) ni en la puntuación total (U=273.5, z=−0.53, p=.595), con medianas de 29.2 (RIC=16.7) para 2D y 30.2 (RIC=22.9) para VR.

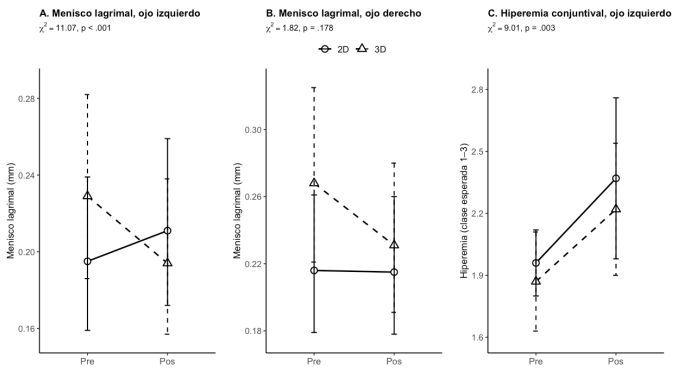

Figura 1. Cambios pre–pos en la altura del menisco lagrimal e hiperemia conjuntival según grupo de exposición (2D: círculos; 3D: triángulos). A) menisco lagrimal izquierdo: interacción Grupo × Momento, χ^2(1)=11.07, p<.001; B) menisco lagrimal derecho: interacción Grupo × Momento, χ^2(1)=1.82, p=.178; C) hiperemia conjuntival izquierda: efecto principal del momento, χ^2(1)=9.01, p=.003. Las barras de error representan IC 95% de las medias marginales estimadas.

Discusión

El presente estudio evaluó la superficie ocular pre y post exposición a videojuegos en formato convencional (2D) y estereoscópico por realidad virtual (VR). La mayoría de los parámetros no mostró cambios significativos; no obstante, se observó una interacción Grupo × Momento en el menisco lagrimal del ojo izquierdo y un efecto significativo del momento en la hiperemia conjuntival bilateral.

Los valores basales sugieren una superficie ocular previamente comprometida, atribuible a la exposición crónica a dispositivos electrónicos en esta población. Tras una hora de exposición, no se registraron cambios significativos en la película lagrimal, hallazgo coherente con la literatura, que indica que las alteraciones clínicamente relevantes emergen con exposiciones más prolongadas, asociadas a reducción del parpadeo, mayor evaporación lagrimal y disminución de la producción acuosa.(5)(6)(7)

La ausencia de cambios significativos en BUT, Schirmer y OPI tras una hora de exposición podría explicarse por mecanismos compensatorios lagrimales propios de usuarios habituados, en quienes la producción lagrimal basal se preserva a pesar de la exposición acumulada (7). No obstante, los valores basales reducidos de estabilidad lagrimal previos a la exposición sugieren una adaptación crónica subyacente (6), en la que la hipoestesia corneal podría enmascarar la sintomatología subjetiva aguda al disociar los signos clínicos de los síntomas percibidos (8).

Exposiciones menores a dos horas no siempre evidencian diferencias objetivas en BUT o Schirmer, incluso en poblaciones pediátricas, lo que sugiere un daño acumulativo sin expresión clínica en exposiciones cortas (9). El aumento significativo de hiperemia conjuntival observado en el presente estudio indica que el estrés vascular precede a la alteración lagrimal, confirmando que el daño inducido por pantallas es multifactorial y puede manifestarse de forma selectiva (10). Estos hallazgos respaldan la recomendación de pausas activas antes de superar una hora de exposición para prevenir la progresión hacia alteraciones crónicas.

La reducción significativa del menisco lagrimal tras exposición a formato estereoscópico, particularmente en el ojo izquierdo con

tendencia no significativa en el derecho (p=.052), sugiere una respuesta asimétrica posiblemente relacionada con parpadeo asimétrico durante la fusión estereoscópica o variaciones en la apertura palpebral. Dado que la dominancia ocular no fue evaluada, no puede descartarse variabilidad de medición. Esta reducción del volumen de reserva lagrimal, sin afectación del BUT, podría constituir un marcador temprano de estrés ocular previo a la inestabilidad lagrimal (11), resaltando la importancia de incorporar la lateralidad ocular en futuros estudios de fatiga visual digital.

Aunque el formato de visualización no generó diferencias significativas en la mayoría de los parámetros, el formato VR mostró una tendencia hacia mayor inestabilidad de la película lagrimal, consistente con el conflicto vergencia-acomodación propio de la visualización estereoscópica, que genera un esfuerzo visual sostenido asociado a fatiga ocular y deterioro lagrimal (12).

Estos hallazgos son coherentes con la literatura en dispositivos de visualización montados en la cabeza (HMD), donde se ha documentado mayor carga oculomotora respecto a monitores convencionales, reducción de la tasa de parpadeo, inestabilidad lagrimal y disconfort visual tras exposiciones de 30 a 60 minutos. Las características propias de los HMD, distancia fija ojo-pantalla, ausencia de señales ambientales de profundidad y restricción de la movilidad ocular natural, podrían explicar la tendencia consistente hacia mayor estrés ocular observada en el grupo VR, aun sin alcanzar significancia estadística en la mayoría de los parámetros.

Aunque el OPI no mostró cambios significativos, la mayor reducción observada en el formato VR sugiere que el esfuerzo visual estereoscópico podría alterar los patrones de parpadeo de forma más marcada. En conjunto, estos hallazgos indican que el esfuerzo visual sostenido induce cambios sutiles que, aunque no significativos tras una hora, podrían adquirir relevancia clínica con exposiciones prolongadas, resaltando la necesidad de estudios longitudinales.

Respecto a los síntomas subjetivos, el OSDI no evidenció diferencias significativas entre grupos, aunque el formato VR presentó valores ligeramente superiores, cuya confirmación requiere mayor tamaño muestral o exposiciones más prolongadas. El diseño de sesión única limita la extrapolación a exposiciones crónicas, por lo que se recomiendan estudios longitudinales que incorporen variables como tiempo acumulado, distancia de visualización e iluminación. Los valores basales alterados sugieren una afectación crónica asociada al uso continuo de pantallas, subrayando la necesidad de monitoreo en esta población y de estrategias preventivas como pausas visuales, lubricación ocular y educación en higiene visual.

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Responsabilidades éticas

Protección de personas y animales. Los autores declaran que los procedimientos seguidos se conformaron a las normas éticas del comité de experimentación humana responsable y de acuerdo con la Asociación Médica Mundial y la Declaración de Helsinki

Confidencialidad de los datos

Los autores siguieron los protocolos institucionales, garantizando la confidencialidad, anonimización de los datos y la no identificación de los participantes.

Derecho a la privacidad y consentimiento informado

Los autores han obtenido el consentimiento informado de los participantes. Este documento obra en poder del autor de correspondencia

Conflicto de intereses

Los autores declaran no tener ningún conflicto de intereses

Consideraciones adicionales

Durante la preparación de este manuscrito, los autores utilizaron herramientas de inteligencia artificial exclusivamente como apoyo en la corrección gramatical y traducción del texto. Los autores revisaron y editaron el contenido final y asumen plena responsabilidad sobre la versión publicada.

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Originals

Crossed laterality and performance in fencing: an analysis of ocular dominance, handedness, and reaction times in fencers

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Introduction: Fencing is a sport that demands precise visuomotor coordination, rapid reaction times, and a high level of perceptual-cognitive ability. In this context, laterality—understood as the functional preference for one side of the body—may play a critical role in athletic performance. While the influence of handedness has been widely studied, the contribution of ocular dominance, and particularly its interaction with handedness (i.e., crossed or uncrossed laterality), has received limited attention in this sport.
Objective: to examine the relationship between their laterality profiles (dominant eye and hand) and reaction times in tasks of increasing complexity.
Methods: This study evaluated 97 fencers of varying competitive levels and weapon types (épée, foil, and sabre). Tests included simple reaction, choice reaction, Go/No-Go, and decision-making tasks, with response times measured precisely in milliseconds. Additionally, the analysis examined the distribution of laterality profiles across competition levels and weapon specializations.
Results: Findings indicated that fencers with crossed laterality (dominant eye and hand on opposite sides) exhibited significantly faster reaction times in complex tasks, particularly those involving decision- making and motor execution. Furthermore, this profile was more prevalent among national and international-level athletes, especially in foil and sabre disciplines. In contrast, uncrossed laterality was more common among épée fencers and those at regional or amateur levels.
Conclusion: These findings suggest that crossed laterality may represent an optimal perceptual-motor profile in fencing, potentially enhancing sensorimotor integration and reducing cerebral processing time. This knowledge may be crucial for optimizing training programs, enhancing talent identification, and developing personalized strategies for achieving high performance.

Keywords: Visuomotor Coordination; Sensorimotor Integration; Talent Identification; Cognitive Load; Fencing.

Palabras clave: coordinación visuomotora; integración sensoriomotora; identificación de talentos; carga cognitiva; esgrima.

Palavras-chave: coordenação visuomotora; integração sensoriomotora; identificação de talentos; carga cognitiva; esgrima.

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Lateralidad cruzada y rendimiento en esgrima: análisis de la dominancia ocular, la lateralidad manual y los tiempos de reacción en esgrimistas

RESUMEN

Introducción: La esgrima es un deporte que exige una coordinación visuomotora precisa, tiempos de reacción rápidos y un alto nivel de capacidad perceptivo-cognitiva. En este contexto, la lateralidad —entendida como la preferencia funcional por un lado del cuerpo— puede desempeñar un papel crítico en el rendimiento deportivo. Aunque la influencia de la lateralidad manual ha sido ampliamente estudiada, la

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contribución de la dominancia ocular, y especialmente su interacción con la lateralidad manual, es decir, la lateralidad cruzada o no cruzada, ha recibido una atención limitada en este deporte.

Objetivo: Examinar la relación entre los perfiles de lateralidad de los esgrimistas, ojo y mano dominantes, y los tiempos de reacción en tareas de complejidad creciente.

Métodos: Este estudio evaluó a 97 esgrimistas de diferentes niveles competitivos y modalidades de arma, espada, florete y sable. Las pruebas incluyeron tareas de reacción simple, reacción de elección, Go/No-Go y toma de decisiones, con tiempos de respuesta medidos con precisión en milisegundos. Además, el análisis examinó la distribución de los perfiles de lateralidad según el nivel competitivo y la especialidad de arma.

Resultados: Los hallazgos indicaron que los esgrimistas con lateralidad cruzada, ojo y mano dominantes en lados opuestos, mostraron tiempos de reacción significativamente más rápidos en tareas complejas, especialmente aquellas que implicaban toma de decisiones y ejecución motora. Además, este perfil fue más frecuente entre deportistas de nivel nacional e internacional, especialmente en las disciplinas de florete y sable. En cambio, la lateralidad no cruzada fue más común entre esgrimistas de espada y en aquellos de nivel regional o amateur.

Conclusión: Estos hallazgos sugieren que la lateralidad cruzada puede representar un perfil perceptivo-motor óptimo en esgrima, al favorecer potencialmente la integración sensoriomotora y reducir el tiempo de procesamiento cerebral. Este conocimiento puede ser clave para optimizar los programas de entrenamiento, mejorar la identificación de talentos y desarrollar estrategias personalizadas orientadas al alto rendimiento.

Palabras clave: coordinación visuomotora; integración sensoriomotora; identificación de talentos; carga cognitiva; esgrima.

Lateralidade cruzada e desempenho na esgrima: uma análise da dominância ocular, da lateralidade manual e dos tempos de reação em esgrimistas

RESUMO

Introdução: A esgrima é um desporto que exige coordenação visuomotora precisa, tempos de reação rápidos e um elevado nível de capacidade percetivo-cognitiva. Neste contexto, a lateralidade —entendida como a preferência funcional por um dos lados do corpo— pode desempenhar um papel crítico no desempenho desportivo. Embora a influência da lateralidade manual tenha sido amplamente estudada, a contribuição da dominância ocular, e particularmente a sua interação com a lateralidade manual, isto é, a lateralidade cruzada ou não cruzada, tem recebido atenção limitada neste desporto.

Objetivo: Examinar a relação entre os perfis de lateralidade dos esgrimistas, olho e mão dominantes, e os tempos de reação em tarefas de complexidade crescente.

Métodos: Este estudo avaliou 97 esgrimistas de diferentes níveis competitivos e modalidades de arma, espada, florete e sabre. Os testes incluíram tarefas de reação simples, reação de escolha, Go/No-Go e tomada de decisão, com os tempos de resposta medidos com precisão em milissegundos. Além disso, a análise examinou a distribuição dos perfis de lateralidade de acordo com o nível competitivo e a especialização da arma.

Resultados: Os resultados indicaram que os esgrimistas com lateralidade cruzada, olho e mão dominantes em lados opostos, apresentaram tempos de reação significativamente mais rápidos em tarefas complexas, especialmente aquelas que envolviam tomada de decisão e execução motora. Além disso, este perfil foi mais prevalente entre atletas de nível nacional e internacional, especialmente nas disciplinas de florete e sabre. Em contraste, a lateralidade não cruzada foi mais comum entre esgrimistas de espada e entre aqueles de nível regional ou amador.

Conclusão: Estes resultados sugerem que a lateralidade cruzada pode representar um perfil percetivo-motor ótimo na esgrima, podendo favorecer a integração sensoriomotora e reduzir o tempo de processamento cerebral. Este conhecimento pode ser crucial para otimizar programas de treino, melhorar a identificação de talentos e desenvolver estratégias personalizadas para alcançar elevado desempenho.

Palavras-chave: coordenação visuomotora; integração sensoriomotora; identificação de talentos; carga cognitiva; esgrima.

INTRODUCTION

Fencing, as a high-speed combat sport, demands exceptional visuomotor coordination, ultra-fast reaction times, and superior perceptual-cognitive abilities to anticipate and execute precise actions [1, 2]. In such a dynamic context, laterality—understood as the functional preference for one side of the body over the other [3, 4]—emerges as a potentially critical factor in shaping athletic performance [5].

While handedness (right- or left-handedness) has traditionally been recognized for its tactical impact in fencing [6], influencing fighting style and both offensive and defensive strategies, the influence of ocular dominance and its interaction with handedness remains underexplored in this elite sport.

Research on ocular dominance suggests that this preference is not merely an anatomical curiosity but may have significant implications for tasks requiring visual precision and hand-eye coordination [7, 8].

Understanding and leveraging the preference for one eye over the other is essential for achieving optimal positioning in sport in general, and in fencing in particular. Given that fencing requires precise coordination and rapid decision-making, identifying laterality profiles may be key to optimizing training and performance.

Studies in this area have shown a notable prevalence of left-handed fencers at the highest levels of international rankings, with most of them exhibiting right-eye dominance. Similarly, researchers have observed a relatively high proportion of right-handed athletes who are left-eye dominant.

Experiments involving tasks with spatiotemporal uncertainty have confirmed a visuomotor advantage in response time among individuals with crossed eye-hand laterality. It appears that the dominant eye operates the geniculostriate pathway — in which temporal retinal fibers project ipsilaterally and nasal retinal fibers project contralaterally, resulting in each hemisphere processing

the contralateral visual field. Moreover, studies have shown that the specific effects of ocular dominance on hand–eye coordination emerge only when spatial uncertainty exceeds a certain threshold [9].

There are two primary laterality profiles: ipsilateral or uncrossed (where the dominant eye and dominant hand are on the same side), and crossed or contralateral (where the dominant eye and dominant hand are on opposite sides). In the general population, between 10% and 30% exhibit a crossed laterality profile, while 70% to 90% display an uncrossed profile. However, in certain sports, the proportion of athletes with crossed laterality is higher than in the general population, suggesting a potential advantage in specific performance contexts [8].

In sports that require rapid processing of visual information to guide motor responses—such as baseball, cricket, or shooting—a correlation has been identified between eye dominance and performance [10-13]. Within this framework, clarifying the precise effects of these laterality conditions is a critical research priority. Specifically, the question remains whether crossed laterality (e.g., left-eye dominance with right-hand dominance) or uncrossed laterality (dominant eye and hand on the same side) provides an advantage or disadvantage in fencing—a sport defined by lateral movements and complex feints [14, 15]. To date, this issue remains largely unanswered in the current literature.

Crossed laterality is present in a considerable proportion of athletes and may influence performance in fencing and other sports. Identifying whether a fencer exhibits a crossed or uncrossed profile could assist coaches in tailoring physical, technical, tactical, and psychological training to the athlete's strengths and limitations. Furthermore, it could support the development of training programs that promote more effective athletic development and facilitate talent identification by aligning training strategies with individual motor preferences [16].

This study aims to investigate the distribution of ocular and manual dominance among fencers, examining how these lateral preferences relate to athletes' performance levels and reaction times. Specifically, it compares the reaction times of fencers grouped according to hand and/or eye dominance (right- or left-dominant), as well as into two broad categories: ipsilateral and crossed laterality. The goal is to establish direct links between laterality profiles, reaction time results, and fencing performance.

Such findings will offer valuable insights into elite fencers, helping determine whether an optimal laterality profile exists that contributes to faster and more effective decision-making during bouts. Understanding these relationships will not only enrich knowledge of the perceptual-motor foundations of fencing performance but also inform more personalized and efficient training.

MATERIALS AND METHODS

Data Assessed

The study included 97 fencers (53 males, 44 females; mean age 24.53 ± 12.54 years) from various competitive levels (12 international, 25 national, 42 regional, and 18 amateur) and disciplines (48 épée, 28 foil, and 27 sabre). All participants, or their legal guardians when applicable, provided written informed consent in accordance with the Declaration of Helsinki [17].

Fencers were classified based on their dominant hand (used to hold the weapon—73 right-handed and 24 left-handed), as well as their motor and sensory dominant eyes.

Motor eye dominance was determined using the Miles test, in which the participants extended both arms and forms a small triangle with the hands. The participants were instructed to focus on a distant object through the triangle with both eyes open. Then, each eye is closed alternately. The object remains centered when viewed through the dominant eye (Ojo et al., 2017).

Sensory eye dominance was assessed using the +2.00 lens test (also known as the binocular rivalry or blur sensitivity test), in which a +2.00 dioptre lens was alternately placed in front of each eye [18]. The dominant eye is the one for which the induced blur most strongly affects visual perception. Each measurement was repeated three times, and participants without a clearly defined ocular dominance were excluded from the study.

Once participants were classified, the evaluation proceeded with reactive tasks. Four Queling Sport (Queling, China) reaction-time light devices were used, synchronized via Bluetooth 5.0 with the ReactionX app on an Android tablet, which also recorded the reaction times. Each device, measuring 9 cm in diameter, was mounted vertically using Velcro, and participants used their own fencing weapons during testing. Four exercises were specifically designed to assess reaction time and decision-making under fencing-specific conditions [19].

For the evaluation, several types of reaction times were measured: Simple Reaction Time (SRT), defined as the time to react to a known and predictable stimulus; Election Reaction Time (ERT), the time to respond to a randomly activated device; Go/No-Go Reaction Time (G/NG), requiring a response only to specific light colors; and Decision-Making Time (DM), which involved performing different fencing movements (lunge, advance, retreat) depending on the color of the light.

Each exercise consisted of two repetitions, with a 30-second rest between them, and the total duration for each participant was approximately 14 minutes. Anticipated responses (<100 ms) and excessively delayed responses (>1000 ms relative to the participant's best time) were excluded from the analysis. All participants completed a familiarization session in the days before data collection.

Statistical Analysis

This study aimed to examine the distribution of different laterality profiles (crossed or ipsilateral) within a sample of fencers across various competitive levels and to investigate how these configurations relate to variables such as dominant hand, weapon type, and performance in reaction time tasks.

Through various statistical tests, both distribution patterns and differences in motor and cognitive performance were analyzed, with particular focus on tasks simulating the perceptual demands and decision-making processes typical of fencing combat.

To analyze contingency tables, the chi-square test was employed, which is appropriate for comparing non-continuous categorical variables, such as ipsilateral versus crossed laterality in relation to dominant hand or dominant eye. A p-value less than 0.05 was interpreted as evidence of a statistically significant association between variables, indicating they were not independent.

To assess mean reaction times, the Shapiro–Wilk test for normality was applied to determine whether the data followed a normal distribution. In all analyzed groups, p-values were below 0.05, leading to the rejection of the normality hypothesis. Consequently, the non-parametric Kruskal–Wallis test was used to compare mean reaction times across the different groups of the studied variables. The tasks assessed reaction time under increasing levels of complexity, ranging from simple responses to those involving decision-making and movement execution.

RESULTS

The results of the chi-square tests, as shown in Table 1, indicate a significant association between laterality and all the studied variables.

Particularly, the results regarding the relationship between crossed laterality and higher competitive level, specific weapon type,

Table 1. Chi-Square Test Results for the Association Between Laterality and Other Variables.

Variable Association	N	df	χ^2	p
Laterality and Eye	97	1	26.48	< .001
Laterality and Hand	97	1	7.65	.006
Laterality and Competition Level	97	3	19.83	< .001
Laterality and Weapon	97	2	10.46	.005

Table 2. Relationship between dominant eye and type of laterality in fencers.

Dominant Eye	Contralateral	Ipsilateral	Total
Right-eyed	18	42	60
Left-eyed	31	6	37
Total	**49**	**48**	**97**

Table 3. Relationship between dominant hand and type of laterality in fencers.

Dominant Hand	Contralateral	Ipsilateral	Total
Right-handed	31	42	73
Left-handed	18	6	24
Total	49	48	97

Table 4. Relationship between laterality type (crossed or ipsilateral) and highest competitive level achieved by fencers in the study.

Competition Level	Contralateral	Ipsilateral	Total
International	9	3	12
National	18	7	25
Regional	17	25	42
Amateu	5	13	18
Total	49	48	97

Table 5. Relationship between weapon type (épée, foil, or sabre) and laterality (contralateral or ipsilateral) in fencers.

Weapon	Contralateral	Ipsilateral
Épée	15	27
Foil	21	7
Sabre	13	14

Table 6. Reaction time test results for ipsilateral and contralateral laterality groups.

Task	Ipsilateral (n = 48)	Contralateral (n = 49)	p-value	η^2
*SRT**	*417 ± 143*	*333 ± 109*	*< .001*	*0.106*
ERT	543 ± 114	504 ± 92	0.136	0.013
G/NG	555 ± 98	543 ± 80	0.466	0.000
*DM (overall)**	*1356 ± 336*	*1190 ± 264*	*< .001*	*0.061*
*DML (lunge)**	*1118 ± 179*	*1013 ± 197*	*< .001*	*0.101*
*DMM (advance)**	*1250 ± 251*	*1112 ± 187*	*0.005*	*0.072*
*DMR (retreat)**	*1700 ± 242*	*1444 ± 189*	*< .001*	*0.259*

Note Exercises that were statistically significant (p<0.05) were marked with "*".

Overall, 49 had contralateral laterality and 48 had ipsilateral laterality (Table 4). At higher levels of competition (national and international), a greater proportion of fencers displayed contralateral laterality: among international-level athletes, 9 were contralateral and 3 ipsilateral; among national-level athletes, 18 were contralateral and 7 ipsilateral. In contrast, at lower competitive levels (regional and amateur), ipsilateral laterality was more common. At the amateur level, 5 fencers were contralateral and 13 ipsilateral; at the regional level, 17 were contralateral compared to 25 ipsilateral.

In foil, a high proportion of fencers exhibited contralateral laterality (21 out of 28), suggesting that this configuration may either be advantageous or more prevalent in this discipline. In contrast, in épée, ipsilateral laterality was clearly dominant (27 out of 42), which may be related to the technical or tactical demands of the weapon. Sabre showed a relatively balanced distribution between the two profiles (13 vs. 14), indicating no clear preference in this weapon category.

A chi-square test was conducted to examine whether there was a significant association between weapon type and laterality. The p-value (0.005) was below the conventional significance threshold ($\alpha = 0.05$), indicating a statistically significant association between weapon type and laterality.

The table 6 show the P-values from Kruskal–Wallis test and η^2 effect size estimates are included. Mean values and standard deviations are in milliseconds. In this sense, the fencers with contralateral laterality demonstrated significantly faster reaction times than those with ipsilateral profiles in several tasks. In the Simple Reaction Time (SRT) test, the contralateral group averaged 333 ± 109 ms, compared to 417 ± 143 ms in the ipsilateral group, with a statistically significant difference and a medium effect size.

In the Election Reaction Time (ERT) and Go/No-Go (G/NG) tasks, no statistically significant differences were found between the groups. However, contralateral fencers still showed numerically faster response times (ERT: 504 ± 92 ms vs. 543 ± 114 ms; G/NG: 543 ± 80 ms vs. 555 ± 98 ms), suggesting that the contralateral advantage may emerge more clearly under conditions of higher cognitive or motor demand.

In tasks requiring higher cognitive and motor complexity—such as decision-making reaction time—the differences between fencers were even more pronounced, favoring significantly shorter times for those with contralateral laterality (DM: 1190 ± 264 ms vs. 1356 ± 336 ms; $\boldsymbol{p} < 0.001$).

In dynamic variants of the task, such as the retreat decision-making task (DMR), contralateral fencers recorded an average of 1444 ± 189 ms, compared to 1700 ± 242 ms in the ipsilateral group ($p < 0.001$), with a large effect size, the largest difference observed in the entire study.

Other decision-making subtests also revealed a consistent advantage for contralateral fencers. In the left-lateralized movement (DML), the contralateral group scored 1013 ± 197 ms versus 1118 ± 179

or more effective reactions under increasing motor and cognitive complexity are presented below (Table 2).

Among right-eye dominant fencers, most displayed ipsilateral laterality (42 out of 60), meaning their dominant hand was also the right. Conversely, among left-eye dominant fencers, the majority showed contralateral laterality (31 out of 37), meaning their dominant hand was the right. A chi-square analysis revealed a statistically significant difference between right- and left-eye dominant fencers regarding laterality type ($p < 0.001$). Specifically, left-eye dominant individuals had a significantly higher proportion of crossed laterality, whereas right-eye dominant fencers tended to have uncrossed (ipsilateral) laterality.

The table 3 show that with (75.26%) the dominant hand was right-handed. Of these, the majority (42 of 73, or 57.54%) had ipsilateral laterality, with both the dominant eye and hand on the right side. The remaining 31 right-handed fencers (42.46%) exhibited crossed laterality. Among left- handed fencers, crossed laterality was dominant: 18 out of 24 (75%) had this profile, while only 6 (25%) had ipsilateral laterality.

Table 7. Performance Profile by Weapon Type and Laterality Characteristic.

Characteristic	Épée Fencer (Predominantly Ipsilateral)	Foil/Sabre Fencer (Predominantly Contralateral)
Laterality Profile	Tends to be right-eye and right-hand dominant (ipsilateral/homogeneous).	Higher prevalence of crossed laterality (e.g., left-eye dominant and right-hand dominant).
General Decision-Making Time (DM)	Generally slower in complex decision-making tasks, with high variability—possibly due to greater tactical analysis and multiple target areas.	Significantly faster in complex decision-making tasks, indicating superior agility in decision processing. This may be linked to fewer valid targets and thus fewer response options.
Leftward Movement Reaction Time (DML)	Slower, with lower variability in leftward responses. Suggests fewer perceived options or a more rigid, less prioritized strategy on this side. Since épée involves the whole body as target and typically uses direct counterattacks without parries, responses may focus more on precision.	Faster leftward responses. Accustomed to parrying and responding, foil and sabre fencers may have more internalized lateral actions.
Midline Reaction Time (DMM)	Slower, with higher variability in central responses. Possibly due to more decision-making options given the broad target area in épée.	Faster and more consistent in central responses, aligned with more defined frontal targets and fewer decision pathways in foil and sabre.
Rightward Movement Reaction Time (DMR)	Slower, despite using the dominant side, and with higher variability. May reflect the need for fine-tuned adaptation in épée.	Fastest responses in the study, with lower variability. Suggests superior optimization of dominant-side actions—critical in foil and sabre, where regaining or claiming priority quickly is essential.
Predominant Fencing Style	Based on test results, these fencers appear to favor patience, tactical analysis, distance control, and exploiting openings. They tend to prioritize precision and anticipation over raw speed, adapting to a broader set of target zones.	Based on the results, these fencers are characterized by speed, aggressive attacks, and rapid counterattacks. They excel in fast-paced exchanges and quick shifts of initiative, capitalizing on their mental and physical agility—crucial in foil and sabre, where the right-of-way rule and complex parries are key elements.

ms in the ipsilateral group ($p < 0.001$); in the central decision-making movement (DMM), times were 1112 ± 187 ms vs. 1250 ± 251 ms ($p = 0.005$), both with medium effect sizes. These results reinforce the idea that contralateral laterality may confer an advantage in tasks involving high perceptual and motor demands.

Combining the results from Tables 4 and 5, we can propose an interpretative analysis that outlines potential performance profiles by weapon type, based in the variables with the highest relation of laterality and reaction times:

DISCUSSION

The findings of this study confirm the relevance of visual dominance and laterality in fencing performance [9], offering new insights into the comparative advantages in reaction speed, agility, and perceptual-motor demands associated with different laterality profiles.

This pattern allows visual input (integrated across both hemispheres but functionally biased by the dominant eye) and motor output (coordinated by the hemisphere contralateral to the dominant hand) to be integrated within the same cerebral hemisphere. This configuration avoids the need for interhemispheric transfer, which has been shown to require additional processing time [8], potentially resulting in faster response times for crossed-laterality profiles.

These findings are consistent with previous research in other disciplines, where athletes with crossed laterality are overrepresented compared to the general population—particularly in sports requiring coordinated mobility and precision, such as golf and football [7, 8]. This suggests that crossed laterality may provide a specific competitive advantage in tasks demanding high levels of visuo-motor integration. In contrast, in disciplines without a direct opponent —such as gymnastics, archery, or pistol shooting—non-crossed profiles tend to be more prevalent or show no significant influence on performance [13, 16]. This reinforces the hypothesis that the functional utility of crossed laterality depends on the specific motor and tactical demands of the sport.

Left-handed fencers with crossed laterality may benefit from more efficient sensorimotor integration, improved visuo-motor alignment toward the opponent, and faster reaction capabilities. Moreover, manual dominance—widely recognized for its influence on combat style and tactical decision-making [6]—may be further enhanced when combined with a crossed laterality profile.

From a performance standpoint, the distribution of laterality profiles is not uniform across competition levels. Crossed laterality was significantly more frequent among athletes competing at the national and international levels, while ipsilateral laterality predominated in the regional and amateur levels. Statistical analysis ($p = 0.001$) confirms that this distribution is not random, suggesting a significant association between laterality type and the competitive level attained.

A relevant relationship was also identified between the type of weapon used and the fencer's laterality. Specifically, contralateral laterality was more prevalent among *foil* and *sabre* fencers, whereas ipsilateral laterality predominated in épée. This pattern may be linked to the specific technical and tactical demands of each weapon and presents a promising avenue for future research on optimal laterality profiles according to weapon type. When combined with existing knowledge on reaction time, physical preparation, and psychological factors [20, 21], these findings could contribute to the development of more tailored training programs for elite athletes, optimized for each fencing discipline.

In parallel, the analysis of reaction times revealed that fencers with contralateral laterality consistently outperformed their ipsilateral counterparts in the most demanding tasks—particularly those requiring decision-making and complex motor execution. These differences were statistically significant in tests with higher cognitive and motor load, such as decision-making with displacement (DMR), in which the contralateral group demonstrated substantially faster response times and large effect sizes. This finding aligns with studies in elite football players, which indicate that crossed laterality (hand-eye-foot) is associated with quicker reaction times in response and directional change tasks, particularly in unpredictable contexts [22].

This research demonstrates a significant relationship between ocular dominance and laterality type. Specifically, left-eyed fencers exhibit a significantly higher proportion of crossed laterality (left-eye dominance combined with right-hand dominance).

Higher levels of competition (national and international) are characterized by a predominance of fencers with contralateral

laterality, whereas ipsilateral laterality is more common at regional and amateur levels. This suggests that crossed laterality may confer an advantage in reaching elite performance levels in fencing.

Fencers with contralateral laterality displayed significantly faster reaction times in several tasks, particularly those involving greater cognitive and motor complexity. The most pronounced difference was observed in the DMR test, where contralateral fencers were substantially quicker. This suggests a performance advantage in processing speed and responsiveness under conditions requiring both mental and physical agility. Fencers with contralateral laterality displayed significantly faster reaction times in several tasks, particularly those involving greater cognitive and motor complexity. The most pronounced difference was observed in the DMR test, where contralateral fencers were substantially quicker. This suggests a performance advantage in processing speed and responsiveness under conditions requiring both mental and physical agility.

Although contralateral laterality was associated with faster responses in cognitively demanding tasks, no statistically significant differences were found between the ipsilateral and contralateral groups in the elective reaction time (ERT) or the Go/No-Go (G/NG) task. This indicates that the advantage of crossed laterality may be more pronounced in contexts with higher cognitive or motor load, rather than in simpler or less demanding situations.

A statistically significant association was also found between weapon type (épée, foil, or sabre) and laterality. Contralateral laterality was notably more prevalent among foil fencers, suggesting it may provide a specific advantage or represent a common trait in this weapon. In contrast, ipsilateral laterality predominated clearly in épée. In sabre, laterality distribution was more balanced, although a slight predominance of contralateral profiles—similar to foil—was observed. These differences may reflect the unique technical and tactical demands of each weapon.

CONCLUSION

Overall, the findings of this study suggest that crossed laterality —particularly the combination of left-eye dominance with right-hand dominance—may be linked to an optimal perceptual-motor profile in fencing. This configuration is associated with higher competitive achievement and faster reaction times, especially in situations requiring complex decision-making. Understanding this "optimal laterality profile" could be crucial for developing more personalized and effective training strategies aimed at enhancing speed and decision-making efficacy during bouts.

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Revisiones

Molecular mechanisms of the role of aerobic and resistance exercise in increasing adiponectin levels in humans as a control of energy expenditure: a systematic review

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ABSTRACT

Background: Insulin resistance, chronic inflammation, and impaired energy balance are closely linked to obesity and type 2 diabetes mellitus, two increasingly common metabolic diseases. In these conditions, decreased adiponectin levels contribute to metabolic dysfunction by disrupting glucose regulation and fatty acid oxidation. Exercise has been shown to be a non-pharmacological therapy that increases adiponectin.

Objectives: The aim of this study was to determine the effect of aerobic and resistance physical exercise on adiponectin levels.

Methods: A number of journal databases, including Science Direct, Web of Science, Pubmed, and Scopus, were examined for this study. Among the factors taken into account in this analysis were studies on the effects of resistance and aerobic exercise on adiponectin levels that were published between 2020 and 2025. Papers that did not fit the inclusion criteria such as non-experimental research or articles not found in our pre-established databases were not included in this systematic review. Using databases from Pubmed, Science Direct, Web of Science, and Scopus, 689 publications in all were located. Ten carefully chosen, peer-reviewed studies discuss the necessity of this systemic change. Standard operating procedures for this inquiry were established using the Preferred Standards for Reporting Systematics and Meta-Analysis (PRISMA).

Results: The study's findings demonstrated both resistance and aerobic exercise raised people's adiponectin levels noticeably.

Conclusion: Resistance training and aerobic exercise have been demonstrated to significantly raise human adiponectin levels. Improving insulin sensitivity, controlling blood sugar, and having anti-inflammatory properties are all made possible by increasing adiponectin. It has been demonstrated that both forms of exercise have a beneficial effect on general metabolic health. Thus, consistent aerobic and resistance training could be a useful tactic for managing and preventing metabolic diseases.

Keywords: Aerobic; Resistance; Physical Exercise; Adiponectin; Good Health and Well-being.

Mecanismos moleculares del papel del ejercicio aeróbico y de resistencia en el aumento de los niveles de adiponectina en humanos como control del gasto energético: revisión sistemática

RESUMEN

Antecedentes: La resistencia a la insulina, la inflamación crónica y el deterioro del equilibrio energético están estrechamente relacionados con la obesidad y la diabetes mellitus tipo 2, dos enfermedades metabólicas cada vez más frecuentes. En estas condiciones, la disminución de los niveles de adiponectina contribuye a la disfunción metabólica al alterar la regulación de la glucosa y la oxidación de ácidos grasos. Se ha demostrado que el ejercicio es una terapia no farmacológica capaz de aumentar la adiponectina.

Objetivos: El objetivo de este estudio fue determinar el efecto del ejercicio físico aeróbico y de resistencia sobre los niveles de adiponectina.

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Métodos: Para este estudio se revisaron varias bases de datos científicas, entre ellas ScienceDirect, Web of Science, PubMed y Scopus. Entre los factores considerados en este análisis se incluyeron estudios sobre los efectos del ejercicio de resistencia y aeróbico sobre los niveles de adiponectina publicados entre 2020 y 2025. Los artículos que no cumplían los criterios de inclusión, como investigaciones no experimentales o trabajos no encontrados en las bases de datos previamente establecidas, no fueron incluidos en esta revisión sistemática. A través de las bases de datos PubMed, ScienceDirect, Web of Science y Scopus se localizaron un total de 689 publicaciones. Diez estudios cuidadosamente seleccionados y revisados por pares abordaron la necesidad de este cambio sistémico. Los procedimientos operativos estándar de esta investigación se establecieron siguiendo las directrices Preferred Reporting Items for Systematic Reviews and Meta-Analyses, PRISMA.

Resultados: Los hallazgos del estudio demostraron que tanto el ejercicio de fuerza como el ejercicio aeróbico aumentaron de forma notable los niveles de adiponectina en humanos.

Conclusión: Se ha demostrado que el entrenamiento de resistencia y el ejercicio aeróbico aumentan significativamente los niveles de adiponectina en humanos. El incremento de la adiponectina contribuye a mejorar la sensibilidad a la insulina, controlar la glucemia y ejercer propiedades antiinflamatorias. Se ha demostrado que ambas formas de ejercicio tienen un efecto beneficioso sobre la salud metabólica general. Por tanto, la práctica regular de ejercicio aeróbico y de resistencia podría constituir una estrategia útil para el manejo y la prevención de enfermedades metabólicas.

Palabras clave: aeróbico; resistencia; ejercicio físico; adiponectina; salud y bienestar.

Mecanismos moleculares do papel do exercício aeróbio e de resistência no aumento dos níveis de adiponectina em humanos como controlo do gasto energético: revisão sistemática

RESUMO

Antecedentes: A resistência à insulina, a inflamação crónica e o comprometimento do equilíbrio energético estão estreitamente associados à obesidade e à diabetes mellitus tipo 2, duas doenças metabólicas cada vez mais frequentes. Nestas condições, a diminuição dos níveis de adiponectina contribui para a disfunção metabólica ao alterar a regulação da glicose e a oxidação dos ácidos gordos. O exercício tem demonstrado ser uma terapia não farmacológica capaz de aumentar a adiponectina.

Objetivos: O objetivo deste estudo foi determinar o efeito do exercício físico aeróbio e de resistência nos níveis de adiponectina.

Métodos: Para este estudo foram analisadas várias bases de dados científicas, incluindo ScienceDirect, Web of Science, PubMed e Scopus. Entre os fatores considerados nesta análise incluíram-se estudos sobre os efeitos do exercício de resistência e aeróbio nos níveis de adiponectina publicados entre 2020 e 2025. Os artigos que não cumpriam os critérios de inclusão, como estudos não experimentais ou artigos não encontrados nas bases de dados previamente estabelecidas, não foram incluídos nesta revisão sistemática. Através das bases de dados PubMed, ScienceDirect, Web of Science e Scopus, foram localizadas 689 publicações no total. Dez estudos cuidadosamente selecionados e revistos por pares abordaram a necessidade desta mudança sistémica. Os procedimentos operacionais padrão desta investigação foram estabelecidos de acordo com as diretrizes Preferred Reporting Items for Systematic Reviews and Meta-Analyses, PRISMA.

Resultados: Os resultados do estudo demonstraram que tanto o exercício de resistência como o exercício aeróbio aumentaram de forma evidente os níveis de adiponectina em humanos.

Conclusão: Foi demonstrado que o treino de resistência e o exercício aeróbio aumentam significativamente os níveis de adiponectina em humanos. O aumento da adiponectina contribui para melhorar a sensibilidade à insulina, controlar a glicemia e exercer propriedades anti-inflamatórias. Demonstrou-se que ambas as formas de exercício têm um efeito benéfico na saúde metabólica geral. Assim, a prática regular de exercício aeróbio e de resistência poderá constituir uma estratégia útil para a gestão e prevenção de doenças metabólicas.

Palavras-chave: aeróbio; resistência; exercício físico; adiponectina; saúde e bem-estar.

Introduction

Currently the fifth most prevalent primary cause of death worldwide, obesity is a rapidly expanding global health concern that affects people of all ages and genders[1]. One of the most urgent global public health issues of the twenty-first century is obesity. Approximately 43% of adults are overweight or obese by 2022, and over 1 billion people worldwide roughly one in eight adults are obese (body mass index ≥30)[2]. Since 1990, the prevalence of obesity has more than doubled in adults and more than quadrupled in youngsters[2]. Experts have described obesity as a global epidemic or perhaps a "pandemic" due to these striking patterns[3]. In other words, people in almost every part of the world are now affected by excess body fat; it is no longer a problem that only exists in a select few nations.

One of the biggest organs in the human body is adipose tissue. Abnormal adipose deposition and adipocyte expansion in a number of anatomical places, including the subcutaneous and visceral areas like the intra-abdominal region, are characteristics of obesity[4,5]. In addition to storing extra energy as fat, visceral adipose tissue (VAT) has a significant role in energy regulation[6]. An imbalance in the availability of substrates can cause mitochondrial malfunction, which may have an effect on oxidative respiration and energy production[7]. Despite having relatively low mitochondrial density, adipocytes are crucial for a number of cellular metabolic processes[7]. Therefore, via changing adipogenesis as well as the lipogenic and lipolytic pathways, mitochondrial dysfunction invariably impacts adipocyte dynamics[8]. When compared to those who are not obese, adipocytes in obese people have mitochondria with an ambiguous inner membrane, a lesser capacity to produce energy, and a lower capacity to oxidize fatty acids[9].

Apart from storing energy, adipose tissue also functions as an active endocrine organ. By secreting bioactive adipokines like leptin, resistin, and adiponectin, this tissue controls energy balance[10], which functions by signaling pathways that are endocrine, paracrine, and autocrine[11]. Additionally, these adipokines affect a number of physiological functions, including immune system and

Table 1. Inclusion criteria

Web search engines	**Pubmed, Science Direct, Scopus, and Web of Science**
Publishing period	2020 – 2025
Keyword	Aerobic and resistance training, adiponectin, and obesity
Language	English
Type of article	Original research article
Full Text	Articles matched the purpose and/or topic of the research.

cardiovascular function, metabolic regulation, and inflammatory response modulation[12]. Four separate research teams identified adiponectin, a protein hormone released by adipose tissue, in the late 1990s[12]. Its clinical significance was initially unknown. When it was shown that low serum levels were associated with obesity and increased visceral fat, interest in this adipokine grew[13]. This correlation highlights the preventive effect of adiponectin and its possible involvement in the emergence of metabolic diseases associated with obesity[14]. A higher risk of metabolic syndrome components is linked to lower adiponectin levels, and genetic factors seem to be crucial in controlling these concentrations[15]. One of the main causes of obesity and associated metabolic diseases is the dysregulation of adipocytokines, including resistin, leptin, and adiponectin[16]. Adiponectin is one of these factors that has positive regulatory effects on obesity and associated metabolic syndrome. These effects include coordinating the expansion and vascularization of adipose tissue, lowering inflammation, boosting metabolic flexibility, improving insulin sensitivity, modulating skeletal muscle, controlling cardiovascular disease, controlling liver function, and more[16].

It is well recognized that exercise and physical activity are crucial for enhancing general health and physical fitness[17,18]. Both are well known to be successful therapeutic and preventative strategies for a range of illnesses. Regular, moderate exercise in particular seems to be a particularly useful strategy for preventing metabolic disorders linked to obesity[19]. High-intensity exercise, either by itself or in conjunction with weight training, has been demonstrated in a number of recent studies to enhance inflammatory, immunological, and metabolic processes[20,21]. Specifically, it has been noted that during acute physical activity, tumor necrosis factor alpha expression declines while interleukin 6 and interleukin 10 levels ris[22]. The literature has a number of scientific research about changes in the expression of different cytokines after exercise regimens. These findings suggest that numerous organs and tissues contribute to the physiological changes brought on by exercise by secreting cytokines[22].

Additionally, certain adipocytokines that are secreted by adipose tissue play a role in controlling inflammation and energy metabolism[23]. Indeed, alterations in the expression of adipokines, particularly adiponectin, indicate the involvement of endocrine function, according to data from the literature[24]. Adipose tissue is the specialized site for the synthesis and release of adiponectin, a polypeptide of 244 amino acids, in the form of trimers (low molecular weight, LMW), hexamers (middle molecular weight, MMW), and high molecular weight oligomers (HMW)[25]. Adiponectin is an endocrine mediator that enhances energy metabolism and insulin sensitivity[25]. According to data from the literature, HMW oligomers are the most potent type of adipocytokines, which are involved in energy balance and body weight regulation[26]. Adiponectin, which is frequently assessed in research involving obese participants, has been found to be negatively correlated with inflammation, body fat percentage, and body mass index (BMI)[25].

According to the majority of research, in healthy men and women, serum adiponectin levels tend to rise with age[27,28], however, some research has indicated a decline[28] or no change[29]. In a very large population, Obata et al. also found a significant positive association between serum adiponectin levels and age in healthy subjects[26]. Numerous studies have demonstrated that both acute and regular exercise can raise blood levels of adiponectin[30]. There is ongoing discussion over the significance of the association between adiponectin levels and exercise. Furthermore, studies continue to disagree about the precise molecular processes by which regular exercise influences adiponectin levels. Thus, the purpose of this research was to ascertain how resistance and aerobic training affected adiponectin levels. Additionally, we sought to thoroughly investigate the underlying chemical pathways.

Materials and methods

Study Design

This study design is a systematic review, reviewing scientific papers according to criteria established by the researchers. The selection of papers regarding the effects of aerobic and resistance training on adiponectin levels in humans was determined by reviewing the scientific literature. The following search engines were used to locate scientific literature: Web of Science, Pubmed, Science Direct, and Scopus. The search terms used were aerobic and resistance training, adiponectin, and obesity. Publications were selected based on the following inclusion criteria: year of publication, experimental study, and articles related to humans.

Eligibility criteria

The study inclusion criteria were established by searching existing databases for material published between 2020 and 2025. Experimental studies on increasing adiponectin levels after aerobic and resistance exercise were also included. Among the search terms used was adiponectin levels. Furthermore, our study excluded papers that did not meet scientific validity standards or were not included in leading search indexes such as Scopus, Web of Science, PubMed, or Science Direct. Therefore, we screened the selected papers using our pre-established inclusion criteria.

Procedure

The full text, abstract, and title of each publication were added to the Mendeley database after review and confirmation. Using Scopus, Science Direct, Pubmed, and Web of Science, 689 publications were identified during the initial screening phase. 370 eligible papers were selected for the second screening phase after identifying duplicate articles and addressing the reasons behind title discrepancies. In the next phase, 180 papers were identified based on the concordance of the reviewed titles, abstracts, and keywords. After reviewing each paper, we determined that the study must be experimental in nature, the parameter used must be the biomarker adiponectin, the intervention must be aerobic or resistance exercise, and the samples used must be human. This was the final step in the process. We screened these publications to identify those that met our pre-defined inclusion criteria. After a rigorous review and observation process, ten papers that met the inclusion criteria were selected for analysis. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were followed for this study. This study reviewed previous literature that met bioethical and ethical standards.

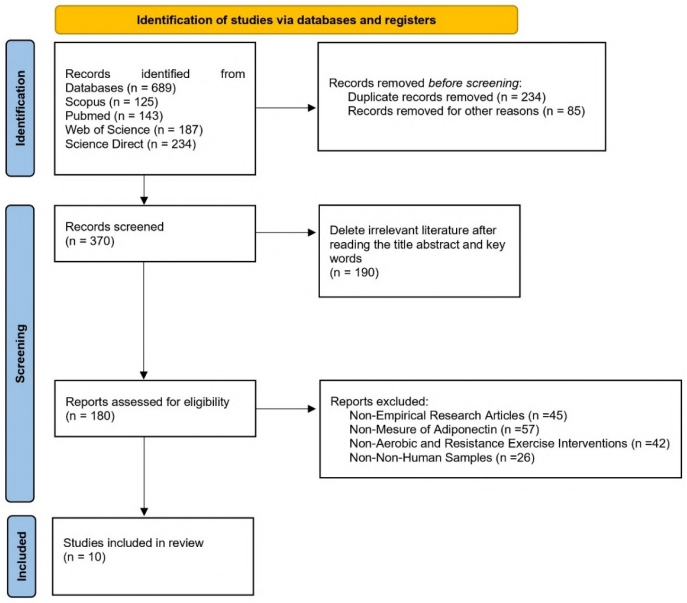

Figure 1. PRISMA flowchart of the article selection process

Results

Discussion

This study sought to ascertain how aerobic exercise affected the rise in adiponectin levels in people. The study's findings showed that adiponectin levels were significantly raised by aerobic activity. Previous studies have demonstrated a considerable increase in adiponectin levels in athletes who received cardiopulmonary exercise therapies and worked out on a bicycle ergometer until exhaustion[19]. Furthermore, following a 12-week intervention, other research has demonstrated that both HIIT and MICT exercise have an effect on raising adiponectin levels[31]. These results contradict the findings of Swisher et al.[39], They found that after 12 weeks of moderate-intensity aerobic exercise, women with breast cancer had a non-significant increase in blood adiponectin. Dieli-Conwright et al., however[40], demonstrated a noteworthy rise in adiponectin levels following a 16-week intervention in breast cancer that included both aerobic and strength training. Additionally, they looked at leptin levels, which also significantly decreased. This also has a beneficial effect on obese patients; Specifically, a 12-week resistance training regimen consisting of three sessions per week markedly raised adiponectin levels. Thus, it can be suggested that aerobic exercise helps avoid metabolic syndrome in obese people by raising adiponectin levels[32].

Additionally, resistance training has a beneficial therapeutic impact, especially for patients who are fat. Adiponectin levels were shown to be substantially elevated in obese patients who underwent three 50-minute resistance training sessions per week for a period of 12 weeks[33]. Additionally, the results of other studies on obese patients showed that walking, running, or a combination of the two, done three times a week for 24 weeks in a row, had a significant effect on raising adiponectin levels in addition to VO2max[30]. In addition to obesity, it was discovered that three times a week for four weeks, patients with type 2 diabetes mellitus who had 30-minute moderate-intensity treadmill workouts with rising pace and progressive incline significantly increased their levels of adiponectin[34]. Resistance training performed three times a week for 12 weeks with a protocol that included resistance training to increase endurance (low intensity), increase volume (moderate intensity), or increase strength (high intensity) had a significant impact on raising adiponectin levels, according to another study in patients with type 2 diabetes mellitus[35]. For individuals who are obese, exercise is an alternative form of treatment. Prior studies have demonstrated a considerable increase in adiponectin levels following a six-month course of aerobic resistance exercise[36].

Elderly adults over 70 years of age were also significantly impacted, in addition to obesity. Over the course of a year, participants engage in a typical exercise regimen that includes resistance and aerobic training at home and at a fitness facility. Adiponectin levels increased significantly as a result of the intervention[37]. The hormone adiponectin, which is mostly released by adipocytes, is linked to the regulation of insulin, glucose consumption, fatty acid oxidation, and inflammation[41,42]. According to a prior study, individuals with diabetic nephropathy had higher urine adiponectin levels than healthy controls, which may indicate that this molecule serves as a marker of impaired kidney function[43]. Urinary adiponectin levels rose following the final strength training session in our study, but not immediately following the first. These findings imply that a longer time period is required for the systemic synthesis and excretion of adiponectin in the urine in response to strength exercise. According to our long-term findings, a 10-week time is required to increase adiponectin production, which in turn leads to increased urine excretion. Our hypothesis is that a strength training regimen can increase adiponectin production both temporarily and over time[38].

Molecular Mechanisms of Aerobic and Resistance Exercise Increase Adiponectin

The metabolic effects of exercise have been found to be significantly mediated by adiponectin and its high molecular weight isoforms[44]. Numerous physiological processes, such as exercise-induced acute muscle signaling, adipose tissue response, and hormonal control, may be responsible for the observed alterations in adiponectin isoforms. The AMP-activated protein kinase (AMPK) and peroxisome proliferator-activated receptor gamma (PPARγ) pathways are both triggered by exercise and are crucial modulators of the release of adiponectin from skeletal muscle and adipose tissue[45]. Exercise is a potent physiological stimulus for AMPK activation, particularly aerobic exercises such as cycling, swimming, and running[46,47]. We can understand the different metabolic advantages since ATP is quickly used up in muscle cells, increasing AMP and AMPK activation[48].

AMPK's function in boosting glucose absorption by encouraging the translocation of GLUT4 to the muscle cell membrane and boosting fatty acid oxidation by facilitating the transport of fatty acids to the mitochondria[49,50]. The path to human fitness requires an understanding of these metabolic advantages. Exercise-induced AMPK activation is a life-changing process that motivates us to reach our fitness objectives and push ourselves to the limit. Our endurance is greatly increased, which is evidence of the ability of AMPK activation to motivate us to pursue greater levels of fitness[51]. AMPK is often referred to as the 'master switch of metabolism' because it helps coordinate the body's response to changes in energy levels[52]. Exercise is a potent and organic AMPK activator that enhances metabolic efficiency, mitochondrial health, and body composition[47]. Following activation, AMPK will additionally promote a rise in PGC-1(α)[53].

Generally found in high-energy-demanding tissues such as the heart, muscle, and brown adipose tissue, peroxisome proliferator-activated receptor coactivator (PPAR)-γ-1α (PGC-1α) has been identified as a key regulator of metabolic regulatory pathways such as the adenosine monophosphate-activated protein kinase (AMPK)-sirtuin 1 (SIRT1)-PGC-1α pathway[54]. Without a doubt, exercise modifies the AMP-to-ATP ratio, which activates AMPK in vivo[55]. PGC-1α is mostly involved in cellular respiration and mitochondrial biosynthesis, but it has also been shown to be an essential regulator of cell proliferation and differentiation[56]. In both

Table 2. Summary of the design and intervention of the studies

Author	Design	Participants	Participants Age	Intervention	Outcome
(Mallardo, et al., 2024)[19]	Randomized controlled trials	25 male amateur athlete	20–65 years	Exercise Intervention 1. A cardiopulmonary exercise test was used to determine maximal aerobic capacity. 2. An incremental exercise test on a bicycle ergometer intended to cause volitional exhaustion. 3. During riding, respiratory gasses were constantly monitored.	Following a physical activity session, adiponectin levels dramatically increased.
(Eskandari et al., 2021)	Randomized controlled trials	45 participants	57 years	Exercise Intervention 1. For 12 weeks, the intervention groups (HIIT and MICT) used a bicycle ergometer three days a week to complete their respective training regimens. 2. The CON group kept up their way of life.	Following an exercise regimen, adiponectin levels rise dramatically.
(Bagheri et al., 2024)	Randomized controlled trials	Sixty overweight and obese men	30-31 years	Exercise Intervention 1. For 12 weeks, the resistance training regimen includes three training sessions per week.	Following a physical activity regimen, adiponectin levels dramatically increased.
(Ataeinostrat & Vandusseldrop, 2022)	Randomized controlled trials	Forty-four males with obesity	27 years	Exercise Intervention 1. For 12 weeks, each resistance training group engaged in 50 minutes of supervised activity three days a week. 2. After 12 weeks of training and at baseline, measurements were collected.	Following an exercise regimen, adiponectin levels rise dramatically.
(Marta Mallardo et al., 2023)[30]	Randomized controlled trials	Thirteen obese male subjects	18-50 years	Exercise Intervention 1. For 24 weeks in a row, the exercise is walking, running, or a mix of the two, three times a week, while enjoying their regular lives.	Following an exercise regimen, adiponectin levels rise dramatically.
(Mudjanarko et al., 2023)	Randomized controlled trials	Twenty-two participants with T2DM	46-50 years	Exercise Intervention 1. Three times a week for four weeks, the experimental group trained on a moderately intense treadmill for thirty minutes at a steady inclination and increasing speed. 2. Each week, the control group exercised alone for 150 minutes. Prior to and following the four-week program, the clinical and laboratory parameters of the participants were evaluated.	Following an exercise regimen, adiponectin levels rise dramatically.
(Saeed Abedinzadeh et al., 2025)	Randomized controlled trials	Forty-four subjects with type 2 diabetes	52 years	Exercise Intervention 1. Three resistance training protocols were used in the training intervention program, which was carried out three days a week for twelve weeks. 2. Resistance training was incorporated into the programs to enhance strength (high intensity), volume (mid intensity), or endurance (low intensity).	Following an exercise regimen, adiponectin levels rise dramatically.
(Olan et al., 2020)	Randomized controlled trials	Sixteen obese adolescent boys	13-19 years	Exercise Intervention 1. Running on an elliptical and treadmill, together with several forms of general strength training (sit-ups, back extensions, squats, and push-ups) using only their body weight, comprises the aerobic exercise program. 2. During weeks 1 through 8, the first workout consists of two sets of 15 repetitions; during weeks 9 through 24, the workout consists of three sets of 15 repetitions. These exercises include chest pulls, leg extensions, leg curls, push-ups, reverse push-ups, chest presses, biceps presses, triceps presses, and shoulder presses. 3. The duration of both exercise treatments was six months.	Following an aerobic exercise regimen, adiponectin levels rise dramatically.
(Senkus & Crowe-white, 2022)	Randomized controlled trials	163 participants	70 years	Exercise Intervention 1. For 12 months, all individuals engage in a standardized exercise regimen that includes resistance and aerobic training, both at home and at a fitness facility. 2. Participants received specific recommendations from an exercise scientist and trainer to support their weekly aerobic and resistance training goals: two resistance training sessions and 90–150 minutes of moderate-to-intense cardiovascular exercise, respectively. 3. The main muscular groups of the upper and lower extremities were the focus of the resistance training, which was finished with resistance bands. Heart rate monitors were given to participants in order to ensure that the training sessions were conducted properly.	Following physical activity intervention, the female group's levels of adiponectin dramatically increased.

Author	Design	Participants	Participants Age	Intervention	Outcome
(Henrique et al., 2025)	Randomized controlled trials	Twelve untrained young men	20-31 years	Exercise Intervention 1. The training regimen consists of three movements, each lasting five seconds (two concentric and three eccentric), with three sets of 65% repetition maximum (1MR) and a 90-second rest in between. 2. For ten weeks, training sessions were conducted three times a week.	Following an exercise regimen, adiponectin levels rise dramatically.

human and rodent muscle, exercise dramatically increases PGC-1α overexpression[57], which, by changing the extracellular matrix's composition, including the amount of fibronectin, can cause satellite cell niche reorganization and affect the proliferative output of satellite cells[58]. Running exercise has been shown to increase PGC-1α expression in the hippocampal regions of depressed rats. PGC-1α is a target of antidepressant treatment because it promotes the growth of parvalbumin-positive interneurons[59]. Mechanistically, PGC-1α activates a variety of metabolic programs in various tissues through its ability to form heteromeric complexes with many nuclear hormone receptors, such as PPARγ[60] and estrogen-related receptors (ERRs)[61].

It is interesting to note that the AMPK/SIRT1 axis, which is involved in mitochondrial signaling and promotes exercise-induced tissue regeneration, controls PGC-1α[62]. As a result, PGC-1α has been demonstrated to play a crucial role in the adaptive response to exercise and may be a major regulator of the relationship between exercise-induced regeneration and mitochondrial biogenesis. Additionally, SIRT1-mediated deacetylation of PGC-1α, which increases its transcriptional activity, promotes mitochondrial biogenesis. This alteration makes it possible for PGC-1α to interact with PPARγ/ERRα/NRF1 and increase TFAM expression, which in turn promotes respiratory chain assembly and mitochondrial DNA replication[63,64]. It is important to remember that AMPK, SIRT1, and PGC-1α are all part of a complicated feedback system[65]. While PGC-1α creates a positive feedback loop by regulating SIRT1 expression and activity, AMPK and SIRT1 reciprocally reinforce each other's activity[66,67]. To boost PGC-1α's stability and transcriptional activity, AMPK phosphorylates it directly in addition to indirectly through SIRT1[68].

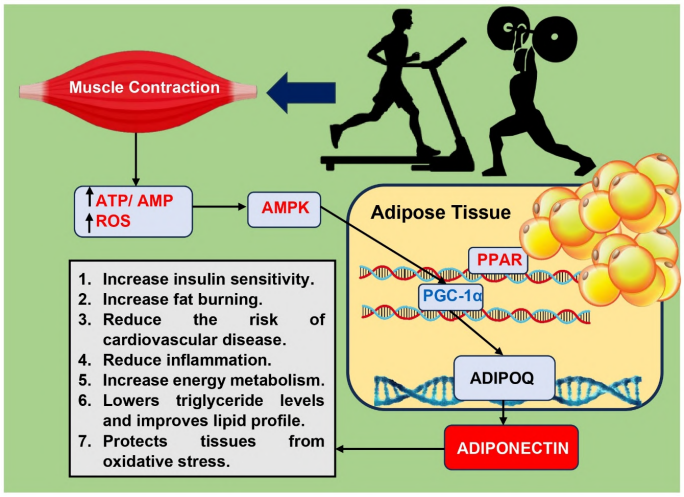

Figure 2. Molecular Mechanisms of Aerobic and Resistance Exercise Increase Adiponectin Levels

The regulation of metabolic homeostasis is significantly influenced by adiponectin[25]. Many aspects of the metabolic syndrome, including obesity, type 2 diabetes mellitus, hypertension, atherosclerosis, and coronary artery disease, have been closely linked to decreased levels of these adipokines in circulation[69]. Adiponectin expression and secretion are influenced greatly by a number of modifiable and non-modifiable factors, including age, sex, ethnicity, body mass index, nutrition, and degree of physical activity, in addition to genetic factors that contribute to individual variance in its concentration[70]. A crucial transcriptional coactivator, PGC-1α aids in the regulation of genetic programs that govern adipocyte activity, mitochondrial biogenesis, and energy metabolism. Increased PGC-1α expression in adipocytes has been demonstrated to modulate the expression profile of several important metabolic genes, including adiponectin (ADIPOQ), a well-known adipokine with anti-inflammatory and insulin-sensitizing effects, even though basal PGC-1α expression is relatively low in white adipose tissue compared to tissues such as muscle or brown adipose tissue[71]. The gene ADIPOQ causes an increase in adiponectin[12]. As a key regulator of glucose metabolism, adiponectin reduces inflammation and improves insulin sensitivity[72]. Research indicates that elevated levels of circulating adiponectin enhance insulin sensitivity[72,73], hence perhaps lowering the risk of type 2 diabetes[72].

Strength and Limitations

One benefit of this systematic review is that it eliminates the possibility of unclear cause-and-effect correlations by concentrating only on randomized controlled trials, which are the most trustworthy type of scientific data. Additionally, the human-focused samples that were gathered yielded consistent data and were not combined with samples from other categories, such as animal samples.

The dearth of knowledge regarding how exercise, especially aerobic and resistance training, can raise adiponectin levels is one of the limitations we found. In order to better understand how aerobic and resistance exercise impacts adiponectin levels and mitigates the negative impacts of metabolic illness, this study is deemed important. Resistance and aerobic exercise may help avoid metabolic disorders in general populations, including individuals with diabetes mellitus and obesity. This might, however, have to do with their undetermined effective duration and intensity. Therefore, more experimental research is required to ascertain the best time and intensity for raising human adiponectin levels.

Conclusions

According to the study's findings, both resistance and aerobic exercise help raise adiponectin levels in people, which helps control energy consumption and enhance metabolism. Molecular processes like AMPK activation and PPAR-γ modulation, which promote insulin sensitivity and fatty acid oxidation, are responsible for this rise in adiponectin. Although results may differ based on intensity, duration, and personal traits, both aerobic and resistance training showed beneficial effects. These results support exercise's importance as a non-pharmacological strategy for preventing metabolic diseases and obesity. However, the examined studies' variability and methodological differences suggest that more research with more consistent designs is required. All things considered, regular exercise has been demonstrated to be a successful tactic for boosting adiponectin and maintaining the body's energy balance.

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Conflicts of Interest

The authors declare no conflict of interest.

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Artículo Especial

CONCLUSIONES GRUPO DE TRABAJO "AVILÉS" DE MEDICINA DEL DEPORTE. XIV Jornadas de Trabajo. Málaga, octubre 2025

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CONCLUSIONS OF THE "AVILÉS" WORKING GROUP ON SPORTS MEDICINE. 14th Working Meeting. Málaga, October 2025

CONCLUSÕES DO GRUPO DE TRABALHO "AVILÉS" DE MEDICINA DESPORTIVA. XIV Jornadas de Trabalho. Málaga, outubro de 2025

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CONCLUSIONES

1. Resaltamos la importancia del reconocimiento médico-deportivo correctamente realizado cuyo objetivo es detectar factores de riesgo o patologías que pongan en riesgo la salud y el rendimiento. Este debe ser efectuado, de manera precisa e individualizada, por un médico especialista en medicina de la Educación Física y el Deporte quien debe contar con un profundo conocimiento de las alertas cardiológicas en deportistas y de las contraindicaciones cardiológicas para la práctica deportiva, prestando especial atención a los antecedentes familiares y personales.

2. El certificado de aptitud para la práctica deportiva, obtenido como resultado de un reconocimiento médico deportivo, es un documento de suma importancia que conlleva implicaciones legales. Debe ser elaborado con estricta rigurosidad y precisión, y tiene que ser concluyente: apto o no apto.

3. Para el adecuado estudio de los deportistas de alto nivel, las pruebas de esfuerzo realizadas deben ser específicas, objetivas y útiles, ajustadas a la especialidad y modalidad deportiva. Esto es particularmente importante en deportes que se desarrollan en condiciones ambientales específicas; la prueba de esfuerzo debería intentar replicar, de la forma más fiel posible, las circunstancias de la actividad deportiva, con el fin de lograr resultados que reflejen lo que ocurre en la práctica real.

4. En el control analítico de un deportista, se realiza un primer análisis completo previo inicio de temporada y una monitorización durante la temporada para controlar tanto temas de salud como de rendimiento deportivo. Los parámetros incluidos varían según la especialidad deportiva: monitorización del estrés oxidativo, parámetros inflamatorios, parámetros para detectar estados de déficit energético (RED), daño muscular, respuesta inmunológica, respuesta endocrina, sobrecargas o sobreentrenamientos.

5. Su valoración, en conjunto, debe ser realizada, única y exclusivamente, por un médico especialista en Medicina del Deporte, como máximo responsable de la salud del deportista evaluado.

6. La medicina hiperbárica se está definiendo como una herramienta de gran utilidad, no solo en el ámbito de la práctica de actividades subacuáticas sino también en la práctica médica en general, especialmente en la recuperación de lesiones. Pero hay que destacar que sólo es efectiva, siempre que se utilice con las presiones y aparataje adecuados. Se debe realizar una revisión médica previa, para descartar posibles contraindicaciones.

7. Hay que utilizar las nuevas tendencias en el entrenamiento de fuerza desde la perspectiva de la prescripción del ejercicio físico para la mejora de la salud a todas las edades.

8. Dado el gran aumento de casos de cáncer de piel, el médico deportivo debe insistir en estrategias de prevención de cáncer de piel, siguiendo las recomendaciones de la OMS. Los deportistas tienen un alto riesgo de cáncer de piel, por lo que el médico deportivo puede ser un primer eslabón en la cadena de prevención de este tipo de cáncer, siendo necesario potenciar la formación del médico deportivo en la detección de esta patología.

9. El deportista debe ser conocedor de los riesgos de la exposición solar inadecuada y de los mecanismos de protección existentes. Por esta razón, es necesario informar y formar a los deportistas para que puedan adoptar las medidas necesarias.

10. El ejercicio físico adecuadamente prescrito, programado y ejecutado, debe ser un componente importante del estilo de vida saludable para las personas que han sufrido un trasplante de órgano.

11. Reiteramos la necesidad de reanudar la formación de la especialidad de medicina del deporte para poder atender adecuadamente las necesidades médicas de los deportistas. La falta, cada vez más evidente, de profesionales de esta especialidad en los centros de medicina que atienden a deportistas, está ocasionando la dificultad para cubrir estas plazas con el consecuente detrimento de calidad asistencial a nuestros deportistas. Para ello es esencial las sinergias entre organismos administradores del deporte y de la sanidad.