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Sports performance

Effects of isoinertial training on lower limb fatigue index in under-20 footballers

Efectos del entrenamiento isoinercial sobre el índice de fatiga del tren inferior en futbolistas Sub 20

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ABSTRACT

Soccer is a sport where players perform multiple intermittent actions, leading to fatigue, which limits optimal performance. The objective was to determine the effects of isoinertial training on the lower body fatigue index in U20 soccer players. The sample (n=29) was randomly assigned to an experimental group (EG, n=15) and a control group (CG, n=14). The EG performed a 15-week isoinertial training protocol (2 sessions/week) in addition to their regular training, while the CG only performed their regular training. The fatigue index (FI), maximum power (Pmax), and minimum power (Pmin) were assessed using the Running-based Anaerobic Sprint Test (RAST) before and after the intervention. Following the protocol, the EG showed a statistically significant increase in minimum power (Pre: 358.6 ± 85.4 W vs. Post: 358.9 ± 85.1 W; p=0.043), whereas maximum power and fatigue index showed no significant changes ($p > 0.05$). No significant changes were observed in any variable for the CG ($p > 0.05$). A 15-week isoinertial training protocol improves minimum power levels and helps maintain a stable fatigue index in highly-trained U20 soccer players.

Keywords: footballers, isoinertial training, performance, RAST.

RESUMEN

El fútbol es un deporte donde los jugadores deben realizar múltiples acciones principalmente de carácter intermitente, lo que incurre en fatiga, siendo esta una limitante del rendimiento óptimo. El objetivo fue conocer los efectos del entrenamiento isoinercial sobre el índice de fatiga del tren inferior en futbolistas Sub 20. La muestra (n=29) fue distribuida aleatoriamente en un grupo experimental (GE, n=15) y un grupo control (GC, n=14). El GE realizó un protocolo de entrenamiento isoinercial de 15 semanas (2 sesiones/semana) además de su entrenamiento habitual, mientras que el GC solo realizó su entrenamiento habitual. Se evaluó el índice de fatiga (IF) y las potencias máxima (Pmáx) y mínima (Pmín) mediante el test RAST antes y después de la intervención. Tras el protocolo, el GE mostró un aumento estadísticamente significativo en la potencia mínima (Pre: 358.6 ± 85.4 W vs. Post: 358.9 ± 85.1 W; p=0.043), mientras que la potencia máxima y el índice de fatiga no presentaron cambios significativos (p > 0.05). No se observaron cambios significativos en ninguna de las variables para el GC (p > 0.05). Se concluye que un protocolo de entrenamiento isoinercial de 15 semanas mejora los niveles de potencia mínima y contribuye a mantener estable el índice de fatiga en futbolistas Sub 20 altamente entrenados.

Palabras clave: entrenamiento isoinercial, futbolistas, RAST, rendimiento.

INTRODUCTION

Football is a sport in which, over recent decades, various aspects such as physiological demands, morphological and mechanical behaviors, and performance profiles have been analyzed (Aslan et al., 2012). Due to its duration, football is classified as a sport that metabolically relies primarily on the aerobic system, although it includes multiple acyclic and repetitive actions such as running, sprinting, and jumping (Raya & Sánchez, 2018). These actions are mainly executed through anaerobic metabolic pathways, which can be repeated with varying recovery intervals depending on the phases and moments of the match or training session (Tlatoa et al., 2013).

The nature of football and the evolution of playing styles require conceptual analyses of game models and the identification of essential components (Martín & Martínez, 2019). Among the most frequent actions in football are sprints, which vary depending on factors such as speed, distance, ball possession, and whether opponents are surpassed (Padilla & Lozada, 2013). Sprint repetition can lead to fatigue, which may occur during training or competition (Barettini, 2016).

In the case of the English Premier League, players perform an average of 59 high-intensity sprints per match at a speed of 28.8 km/h, covering approximately 177 meters of the total 10.6 kilometers run per game (Bradley et al., 2009). These distances reflect significant physical demands, with speed being a predominant capacity. However, speed is limited by the onset of fatigue, a common occurrence that, if unmanaged, can negatively impact individual performance (Marqués et al., 2016). Fatigue levels can be improved through adaptations resulting from training and competition processes, tailored to the predominant and determinant capacities of each sport discipline (Serrato & Galeano, 2015).

Consequently, a substantial part of training aims to overcome fatigue, which contributes to reduced performance and increased injury risk (Hágglund et al., 2013). Therefore, physical preparation for football players often takes place outside the pitch, in environments such as pools, laboratories, and gyms (Torrebadella & Arrechea, 2019). Gym-based training focuses on enhancing various expressions of strength, a fundamental capacity in football (Sánchez et al., 2015).

Among advanced methodologies for strength development, inertial training has gained considerable attention due to its specific benefits for sports performance and rehabilitation (Guzmán, 2023). Unlike traditional free-weight methods that emphasize the concentric phase against gravity, inertial technology uses the inertia of a rotating flywheel to provide resistance that adapts to the athlete's effort throughout the entire range of motion, including both concentric and eccentric phases (Beato & Dello, 2020).

The most distinctive and advantageous feature of inertial training is its ability to generate eccentric overload, where the force required to decelerate the flywheel during the eccentric phase can exceed that produced during the concentric phase (Norrbrand et al., 2010). This eccentric overload is crucial for football players, as key actions such as abrupt stops, changes of direction, jumps, and ball strikes heavily depend on the muscle's ability to absorb force eccentrically (Fiorilli, 2020). Evidence suggests that this type of neuromuscular stimulus not only enhances strength and power but also induces neural adaptations that can optimize precision and speed in football-specific technical gestures (Fiorilli, 2020; Guzmán, 2023), in addition to being an effective method for injury prevention, particularly hamstring injuries (Askling, 2003).

Given the evidence on the potential benefits of inertial training for key football actions and injury prevention, it is pertinent to investigate its impact on fatigue resistance. Therefore, the main objective of this study was to examine the effects of an inertial training program on lower limb fatigue index in Under-20 football players. Additionally, the study aimed to assess variations in maximum and minimum power as indicators of anaerobic performance.

METHOD

A randomized controlled trial was conducted [...]. The sample consisted of 29 U-20 football players (daily training and competition one or two days per week) belonging to a club in the First Division of Colombian Professional Football. All participants had a minimum of 5 years of experience in structured football training within the club and previous experience in strength training programs with loads (squats, deadlifts, bench press, biceps curl, and lat pulldown) as an integral part of their regular physical preparation. However, none had previously participated in a systematic isoinertial training program. The sample was randomized using the negative coordinate method, assigning the 29 participants to the experimental group (n = 15) and the control group (n = 14).

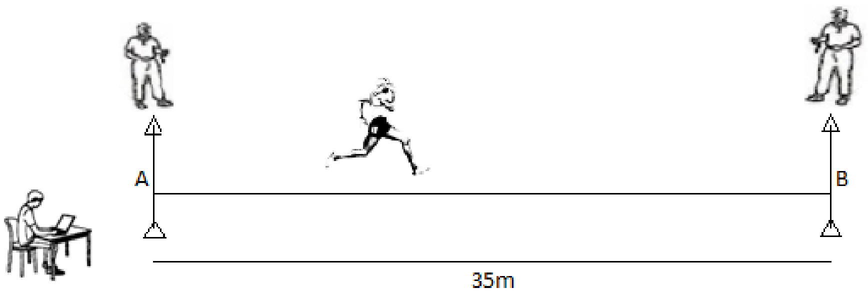
Inclusion criteria included belonging to the U-20 category, regular football training 5 days per week, and 5 years of seniority with the club; while exclusion criteria considered locomotor injuries, respiratory disease, surgeries, and other health conditions established by the researchers and the team's medical staff that would prevent participation or pose a risk at the start of the study.

All subjects were informed about the details, risks, and benefits, and signed the informed consent form. The study was approved by the Ethics, Bioethics, and Scientific Integrity Committee of Universidad Santo Tomás, Bucaramanga campus.

All participants underwent a preliminary evaluation using the Running-based Anaerobic Sprint Test (RAST), for which the following elements were considered: (1) a natural grass football field with a 35 m straight-line marking; (2) four cones to mark the two ends of the 35 m; (3) two stopwatches; (4) two timekeepers, one for the sprints and another for recording the time taken by the athlete to return (10 seconds); (5) an assistant responsible for recording each time and performing the necessary calculations.

For the athlete, the following aspects were considered: (1) weighing prior to the test; (2) 10-minute warm-up; (3) 5-minute rest; (4) completion of six speed series covering a distance of 35 meters at maximum intensity, with a 10-second rest interval between repetitions (Figure 1). The test was conducted at an ambient temperature of 23 °C, humidity of 93%, starting at 8:30 a.m., with participants having their last meal 2 hours before the test, allowing only hydration prior to the test.

Figure 1.
Circuit for performing the RAST test



Source: author's own elaboration.

Experimental Group: the experimental group undertook a modified inertial training protocol based on Romero et al. (2014), using Yoyo Full Body Inertial and Wheeler® Inertial Cone machines. Both devices are operated via Chronojump Boscosystem® software, which enables concentric and eccentric muscle contractions within short time intervals. The Yoyo device consists of a metal platform with dimensions of 100×50 cm and 90×40 cm, weighing 25 kg. The cone is mounted on a 30×30 cm base and also weighs 25 kg. Each machine allows for a maximum of six flywheels, each weighing 434 grams.
The protocol lasted a total of 17 weeks. The first week was dedicated to anthropometric measurements and the initial assessment of fatigue index using the Running-based Anaerobic Sprint Test (RAST). The following 15 weeks comprised the implementation of the modified inertial training protocol, with a consistent frequency of two sessions per week, performed at maximal velocity and with progressive load increments. All athletes began with two flywheels during weeks 2 and 3; four flywheels during weeks 4 to 6; and six flywheels from weeks 7 to 16. Training volume was structured as follows: 2×6 repetitions during weeks 2–6 (Phase 1), 2×6 repetitions during weeks 7–11 (Phase 2), and 3×6 repetitions during weeks 12–16 (Phase 3). Although each set included nine repetitions, only repetitions from the fourth onward were considered for analysis, as the initial three serve to generate the necessary impulse and calibrate the inertial devices.
Each training session included a recovery period of two minutes between sets and five minutes between exercises. Impulse, peak power, and concentric power loss were recorded (Table 1). Throughout the intervention, participants continued their regular football training sessions alongside the control group (i.e., the full squad). The final week was allocated to the post-intervention assessment of fatigue index, again using the RAST test.

Table 1.
Impulse, peak power and concentric power loss values during the 30 training sessions carried out by the experimental Group

Variable	Unit	Measure	SD
Impulse	N	10357	1822
Peak power	Watts	2518	1007
Power loss power concentric	%	12	23.8

The intervention was based on a 15-week periodised isoinertial training protocol. This programme, adapted from Romero et al. (2014), was structured with a frequency of two sessions per week and was based on the principle of progressive overload, systematically increasing the inertial load and work volume throughout the three training phases, while the intensity was maintained at the maximum possible execution speed (Table 2).

Table 2.
Training programme applied to the experimental group twice a week, modified from Romero et al. (2014)

	Training Protocol	
Initial assessment phase	Week 1	
Phase 1	**Weeks 2,3,4,5,6**	
Exercise	Work volumen series x rep	Intensity
Yoyo squat Yoyo Leg Curl Side thrust VP Hamstring kick VP VP Chain Opening VP Chain Closure VP Calf	2X6	Maximum speed
Phase 2	**Week 7,8,9,10,11**	
Ejercicio	Work volume series x rep	Intensity
Yoyo squat Yoyo Leg Curl Side lunge VP Hamstring kick VP Chain Opening VP VP Twin VP Chain Closure	2X6	Maximum speed

Phase 3	Weeks 12, 13, 24, 25, 16	
Exercise	Work volume series x rep	Intensity
Yoyo squat		
Yoyo Leg		
Curl		
Side thrust VP speed	3X6	Maximum speed
Hamstring Kick VP		
VP Chain Open VP		
Final assessment phase	Week 17	

Control group: This group continued with the club's regular training programme during the 15 weeks of the intervention, as did the experimental group. This programme consisted of five weekly training sessions on the pitch, lasting approximately 90 to 120 minutes per session. The sessions included technical-tactical work (rondos, possession games, finishing exercises, strategy), along with general physical preparation components (agility circuits, speed work and football-specific endurance). Like the experimental group, they underwent anthropometric measurements and the RAST test in week 1 and week 17.

Statistical Analysis

Stata 12.0 software was used to apply the Shapiro Wilk test to determine the distribution of continuous variables; these were analysed in terms of measures of central tendency and dispersion according to their distribution. The intragroup comparison of the change in the variables of interest before and after the intervention was performed using Student's t-test for paired data. The analysis comparing the positions of variables of interest before and after the intervention in the experimental and control groups was performed using the ANOVA test. Finally, a significance level of 5% was taken into account for the entire analysis.

RESULTS

The mean age of the sample analysed was 18.3 ± 0.72 years, height was 1.79 ± 0.06 m, weight was 76.9 ± 8.1 kg, BMI was 23.8 ± 2.01 kg/m2, and fat percentage was 11.8 ± 3.5% (Table 3).

Table 3.
Descriptive analysis of the sample

Variables		Total (n=29)	
		Mean	SD
Age	(years)	18.3	0.72
Height	(m)	1.79	0.06
Weight	Kg	76.9	8.1
BMI	(Kg/m^2)	23.8	2.01
% Fat	%	11.8	3.5

No statistically significant differences were found in anthropometric variables or performance variables when comparing baseline characteristics between the two groups ($p > 0.05$), confirming the homogeneity of the groups at the start of the study (Table 4).

Table 4.
Descriptive analysis of the sample, distinguishing between the control group, the experimental group and the total sample

Variables		Control (n=14)		Experimental (n=15)		Total (n=29)		Value
		Mean	SD	Mean	SD	Mean	SD	*p*
Age	(years)	18.2	0.89	18.5	0.51	18.3	0.72	0.245
Height	(m)	1.78	0.06	1.80	0.06	1.79	0.06	0.541
Weight	Kg	74.6	7.4	79.1	8.46	76.9	8.1	0.146
BMI	(Kg/m^2)	23.3	1.92	24.2	2.07	23.8	2.01	0.263
% Fat	%	10.6	3.2	12.8	3.48	11.8	3.5	0.099
Maximum power	Watts	649.5	150.9	589.6	124.3	618.5	138.6	0.252
Minimum power	Watts	363.7	76.7	358.6	85.4	361	79.9	0.866
IF	%	10.5	0.51	38.5	11.6	40.5	11.9	0.349

After 15 weeks of isoinertial training, a statistically significant increase in minimum power (p=0.043) was observed, from a mean of 358.6 ± 85.4 W to 358.9 ± 85.1 W. In contrast, no significant changes were found in either maximum power (p=0.613) or fatigue index (p=0.976), which remained stable (Table 5).

Table 5.
Power values and fatigue index achieved for pretest and posttest in the experimental group

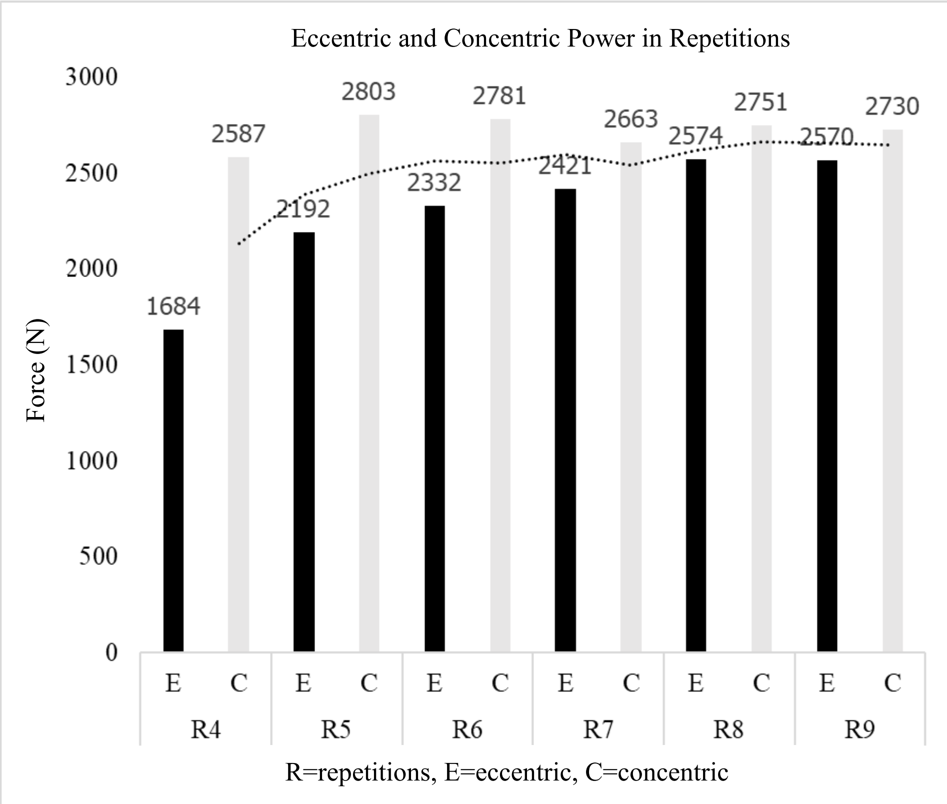
Variables		Pre-test		Pos-test		p-value
		Mean	SD	Mean	SD	
Maximum power	Watts	589.6	124.3	591.2	126.7	0.613
Minimum power	Watts	358.6	85.4	358.9	85.1	0.043**
IF	%	38.5	11.6	38.5	12.1	0.976

** Statistically significant result

It was found that the behaviour of concentric and eccentric force during repetitions recorded in iso-inertial training sessions. It was observed that, although the eccentric component did not exceed the concentric component, the difference between the two phases progressively decreased from repetition 4 (R4) to R9, suggesting increasing neuromuscular efficiency in the braking phase as the series progressed (Graph 1).

Graph 1.

Average eccentric and concentric power in repetitions throughout the 30 isoinertial training sessions



In contrast, the control group showed no significant changes in any of the performance variables at the end of the study period. Maximum power (p=0.191), minimum power (p=0.061) and fatigue index (p=0.546) remained at levels similar to those at baseline (Table 6).

Table 6.

Power values and fatigue index achieved for pre-test and post-test in the control group

Variables		Pre-test		Pos-test		*p*-value
		Mean	SD	Mean	SD	
Maximum power	(Watts)	649.5	150.9	637.1	162.3	0.191
Minimum power	(Watts)	363.7	76.7	345.4	87.8	0.061
Fatigue Index	(%)	10.5	0.51	43.9	15.2	0.546

When analysing the data according to playing position (Tables 6 and 7), no significant differences were found in the change (delta) in any of the performance variables between the different positions, both in the experimental group and in the control group (p > 0.05 in all cases) (Table 7 and 8).

Table 7.

Maximum power, minimum power and fatigue index values in the experimental group by playing position

Playing position	Variable	Mean	SD	P Value
Goalkeepers	Delta Pot. Máx. (Watts)	14,7	0	0,799
Defender		0,84	1,34	
Midfielders		0,73	1,64	
Forwards		0,56	25,6	
Goalkeepers	Delta Pot. Mín. (Watts)	0	0	0,511
Defender		0,26	0,56	
Midfielders		0,21	0,41	
Forwards		0,8	0,97	
Goalkeepers	Delta IF (%)	1,07	0	0,911
Defender		0,05	0,2	
Midfielders		0,01	0,17	
Forwards		-0,4	3,64	

Table 8.

Maximum power, minimum power and fatigue index values in the control group by playing position

Playing position	Variable	Mean	SD	P Value
Goalkeepers	Delta Pot. Máx. (Watts)	-18,7	0	0,907
Defender		-22,6	37,4	
Midfielders		-8,9	6,8	
Forwards		-5,4	48,6	
Goalkeepers	Delta Pot. Min. (Watts)	-35,3	0	0,961
Defender		-13,7	20	
Midfielders		-16,4	61,4	
Forwards		-20	20,3	
Goalkeepers	Delta IF (%)	3,3	3,3	0,881
Defender		-1,5	-1,5	
Midfielders		2,3	2,3	
Forwards		2,1	2,1	

DISCUSSION

This study shows that fifteen weeks of isoinertial training, twice a week, in a group of youth footballers increases minimum power without altering maximum power and fatigue index, as measured by the RAST test.

In professional footballers, evidence has shown that strength training that includes decelerations that favour eccentric work can generate additional benefits for injury prevention (Askling, 2003), (Norrbrand et al., 2010; Pazmiño et al., 2024), which in turn produces an improvement in changes of pace, sustained sprint repetition and explosive lower body strength (Pérez et al., 2021), and is established as a methodology that aids in injury prevention and rehabilitation (Mosteiro & Domínguez, 2017). The change from 358.6 to 358.9 W is statistically significant (p=0.043), but the magnitude is almost zero increase in the minimum power obtained in the athletes subjected to iso-inertial work in the present study. However, it may suggest that this type of training allows them a greater ability to respond to fast game situations or changes of direction (Fousekis, 2022). Therefore, this lower level of power decline in the experimental group should be an important factor for the technical staff to take into account during weekly training planning (Avrillon, 2017).

Most professionals prescribe two weekly sessions of isoinertial training during the preseason and during the competitive period. These training units consist mainly of squats, often accompanied by a variety of exercises such as lunges, hip hinges, and open kinetic chain exercises (De Keijzer et al., 2022). Our protocol was based on that used by Romero et al. (2014) and included the variety of movement patterns described above, doubled the weekly training frequency, and reduced the dosage in phase 3 of training by two repetitions. Taking the above into account, and considering that the study by Romero et al. (2014) showed no post-intervention changes, it is necessary to continue adjusting iso-inertial training protocols to demonstrate variability in maximum power and fatigue index for the type of population analysed.

It is important to consider that the test used is versatile and includes a movement pattern common in footballers. It is also low cost, which means it can be easily incorporated into routine training. In this regard, the results in terms of the psychometric properties of the RAST test, specifically Zagatto et al. (2009), declare this test to be reliable and valid when applied to 40 military personnel.

Another possible reason that may help justify the limited changes in the power variables analysed by the RAST test is the ceiling effect, bearing in mind that the two groups analysed showed normal power levels for their characteristics, even close to those of elite athletes when we relate the result to body weight (W/kg). (Jastrzębska, 2023; Konopka & Harber, 2014; Popadic et al., 2009; Schoenfeld et al., 2015). Furthermore, it is important to note that most of the individuals analysed had experience in using iso-inertial machines.

It is suggested that future research take into account new isoinertial training protocols that include upper body work, as well as the types of exercises applied by playing position.

This research leads to the conclusion that the implementation of a 15-week isoinertial training protocol, applied twice a week as a complement to regular football training, induces a statistically significant, albeit small, improvement in minimum power levels in highly trained U-20 footballers. Although maximum power and fatigue index were not modified, the maintenance of these performance indicators, in contrast to the non-significant downward trend in the control group, suggests that isoinertial training is an effective tool for counteracting the effects of fatigue accumulated during the season and sustaining the ability to perform repeated efforts. Therefore, isoinertial training is proposed as a valuable strategy not only for seeking peak performance, but also for ensuring the stability and robustness of anaerobic performance throughout a demanding competitive cycle.

PRACTICAL APPLICATIONS

Taking into account the background information found and the results obtained in this study, the maximum power, minimum power and fatigue index values are viable for quantifying these elements of the anaerobic component before, during and after the season, and this, in turn, following iso-inertial training plans which, with future research, can be improved upon to propose protocols for footballers based on the positions they play, their morphophysiological and morphofunctional profiles, among other variables.

LIMITATIONS

The main limitation of this research was the number of subjects analysed, who were selected for convenience, since a larger sample size would have yielded more significant results. Therefore, it is suggested that future research use a larger sample size and design different types of isoinertial protocols for footballers based on their playing positions.

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CONFLICT OF INTEREST

The authors of this research declare that they have no conflict of interest in relation to this study.

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