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Effects of Strength Training with Inertial Devices and Subsequent Detraining in Female Professional Futsal Players

Efectos del entrenamiento de fuerza con dispositivos inerciales y posterior desentrenamiento en jugadoras profesionales de fútbol sala

Efeitos do treinamento de força com dispositivos inerciais e subsequente destreinamento em jogadoras profissionais de futsal

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ABSTRACT

This study aimed at evaluate the effects of strength training with inertial devices on the performance and body composition of female professional futsal players, and the subsequent detraining period. Eleven players from a first division Spanish league participated in six weeks of supervised training, followed by four weeks of strength training cessation. Specific on-court training was maintained throughout. Body fat percentage decreased after the intervention and remained low after detraining. Jump performance increased after the intervention and after detraining. Sprint performance was improved in the 5-, 10- and 20-meter distances only after the intervention. Velocity and power outcomes during the squat exercise showed significant improvement after the intervention and after detraining. Six weeks of twice-weekly strength training using inertial devices could be an optimal way to improve performance and body composition. These improvements were maintained after a four-week detraining period, during which the players only trained on the futsal court.

KEYWORDS: detraining, futsal, inertial technology, eccentric overload, neuromuscular training, strength training.

RESUMEN

El objetivo de este estudio fue evaluar el efecto del entrenamiento de fuerza con dispositivos inerciales sobre el rendimiento y la composición corporal de jugadoras profesionales de futbol sala, así como su evolución durante un periodo de desentrenamiento posterior. Once jugadoras de primera división de una liga española realizaron un entrenamiento supervisado de seis semanas, seguido de cuatro semanas de cesación del entrenamiento de fuerza, mientras mantenían el entrenamiento específico en pista. El porcentaje de grasa corporal disminuyó tras la intervención y se mantuvo tras el periodo de desentrenamiento. El rendimiento en los saltos aumentó después de la intervención y durante el periodo de desentrenamiento. El rendimiento en los *sprints* de 5, 10 y 20 metros de distancia mejoró solo después de la intervención, mientras que los resultados de velocidad y potencia durante el ejercicio de sentadilla mostraron mejoras significativas después de la intervención y el periodo de desentrenamiento. Seis semanas de entrenamiento de fuerza con dispositivos inerciales, dos veces por semana, podrían ser un estímulo óptimo para mejorar el rendimiento y la composición corporal. Estas mejoras se mantuvieron después de un periodo de cuatro semanas de desentrenamiento, en el que las jugadoras solo entrenaron en la pista de fútbol sala.

PALABRAS CLAVE: desentrenamiento, fútbol sala, tecnología inercial, sobrecarga excéntrica, entrenamiento neuromuscular, entrenamiento de fuerza.

RESUMO

O objetivo deste estudo foi avaliar o efeito do treinamento de força com dispositivos inerciais no rendimento e na composição corporal de jogadoras profissionais de futsal, bem como o seu desempenho após um período de destreinamento. Onze jogadoras que atuavam na primeira divisão espanhola participaram de um treinamento supervisionado de seis semanas, seguido de quatro semanas de interrupção do treinamento de força, enquanto o treinamento específico em quadra foi mantido. A porcentagem de gordura corporal diminuiu após a intervenção e se manteve após o destreinamento. O rendimento no salto aumentou após a intervenção e o destreinamento. O rendimento no sprint foi melhorado em 5, 10 e 20 metrôs de distância apenas após a intervenção, enquanto os resultados de velocidade e potência durante o exercício de agachamento apresentaram melhoras significativas após a intervenção e no período de destreinamento. Seis semanas de treinamento de força com dispositivos inerciais, duas vezes por semana, poderiam estimular a melhora do rendimento e da composição corporal. Essas melhorias foram mantidas após um período de quatro semanas de destreinamento, no qual as jogadoras treinaram apenas na quadra de futsal.

PALAVRAS-CHAVE: destreinamento, futsal, tecnologia inercial, sobrecarga excêntrica, treinamento neuromuscular, treinamento de força.

INTRODUCTION

Introduced in 1930, futsal is growing in popularity worldwide (Naser et al., 2017). Similar to soccer, futsal is played by two teams of five players each. Like soccer, futsal is regulated by the International Federation of Association Football (FIFA) (Ramos-Campo et al., 2016). Both soccer and futsal require a high level of technical and tactical skill. High-intensity actions, such as accelerations or sprints, are important for success in both sports, although the specific demands differ (Jiménez-Reyes et al., 2019).

At the same time, the visibility of women's futsal has increased around the world, along with investment from international confederations (Lago-Fuentes et al., 2020). In this scenario, the Spanish league is acknowledged as one of the top leagues in the world for both males (Jiménez-Reyes et al., 2019) and females (Jiménez-Reyes et al., 2019; Lago-Fuentes et al., 2020).

Futsal players need to improve their performance during high-intensity moments in the game (Naser et al., 2017). This kind of effort requires specific muscular strength, and strength training (ST) is an effective strategy for improving it (Falces-Prieto et al., 2021). ST has recently become one of the most popular strategies for enhancing performance in activities such as jumps, sprints, acceleration, deceleration, and change of direction (COD) (Falces-Prieto et al., 2020; Sabido et al., 2020).

These high-intensity actions are important for performing sport-specific tasks in team sports (Brien et al., 2020; Falces-Prieto et al., 2020; Gonzalo-Skok et al., 2017), and futsal is no exception (Jiménez-Reyes et al., 2019; Naser et al., 2017; Ramos-Campo et al., 2016). Body composition (BC) is a crucial factor in sports performance, playing an essential role in elite futsal competitions (Gómez-Campos et al., 2023).

Higher levels of body fat have a negative effect on performance in terms of speed, agility, and endurance (Castillo et al., 2022). The counter-movement jump (CMJ) has also been used in previous studies as a key measure of lower-limb power and strength (De Keijzer et al., 2022; Falces-Prieto et al., 2020), and it is also considered an important element in team sports (Ramos-Campo et al., 2016).

On the other hand, maximum acceleration and speed are generally achieved in 40 meters or less. However, in futsal, the distances are shorter (Jiménez-Reyes et al., 2019), so sprints should be assessed in 20 meters or less, because longer sprints are not replicated in actual futsal games (Ramos-Campo et al., 2016).

It is worth noting that ST influences structural and functional levels. For example, Núñez et al. (2019) focus on adaptations that occur during concentric (CON) or eccentric (ECC) phases of movement. Recently, velocity-based training, in which athletes perform each repetition at the intended maximum velocity, has shown greater improvements in jumping and sprinting skills (Galiano et al., 2022).

The use of ST with inertial devices (ID) has become a popular component of strength and conditioning programs (Raya-González et al., 2021).

Two of the most popular ID are inertial flywheel (Raya-González et al., 2021) and conic pulley systems (Sabido et al., 2020). ID appears to enhance ECC overload at the beginning (Norrbrand et al., 2011) and seems to be an exceptional way to stimulate the stretch-shortening cycle (Wonders, 2019). The purpose of ST using ID is to perform each repetition as close as possible to maximum velocity (Illera-Domínguez et al., 2018). However, ID may enhance performance more in the eccentric phase (De Keijzer et al., 2022).

According to scientific literature, ID can be considered a ST methodology that improves strength, speed, jumps and COD (De Hoyo et al., 2015; De Keijzer et al., 2022; Nevado-Garrosa et al., 2021; Núñez et al., 2018; Raya-González et al., 2021) through functional and morphological muscle adaptations (Illera-Domínguez et al., 2018).

Due to busy calendars, overtraining, load management or other factors, ST often cannot be performed regularly during some competition periods, which results in a reduction of players' usual training or the removal of some training stimuli from their usual activities (Cardoso Marques & González-Badillo, 2006). This phase is often referred to as a detraining or cessation period (Andersen et al., 2005; Cardoso Marques & González-Badillo, 2006; Pereira et al., 2020; Vassilis et al., 2019).

Detraining, defined as a reduction or total interruption in training loads (Pereira et al., 2020), can potentially cause changes in performance, strength, neural adaptations, and BC (Andersen et al., 2005; Vassilis et al., 2019). Short-term cessation of ST has been shown to cause no decrements in strength, power, and sprint performance. In fact, it has been shown to promote significant increases in CMJ (Pereira et al., 2020). Longer-term ST cessation has also not shown significant decrements in CMJ (Cardoso Marques & González-Badillo, 2006).

Given these considerations and the limited research on elite female futsal players, especially regarding the use of ID and the effects of ST cessation, further investigation is warranted. To our knowledge, no studies have examined the use of ST among female professional futsal players, nor have they studied the effects of cessation of this type of training.

Therefore, the aim of this study was to evaluate the effects of a ST period using ID on performance and BC in female professional futsal players, as well as the subsequent effects of detraining (cessation of ST). Our hypothesis was that ST using ID would improve jump, sprint and lower-limb power, and that these improvements would partially persist after a short detraining period.

METHODOLOGY

Experimental Approach to the Problem

This study used a quasi-experimental design to assess the impact of an ST program on BC and performance (Harris et al., 2006). The study examined female futsal players from a first division Spanish league to analyze the program's effects after six weeks. The intervention was followed by four weeks of ST cessation, during which specific training on the court was maintained.

Players were tested before the ST intervention (pre-test), after the ST intervention (post-test), and after four weeks of ST cessation (four-week detraining period). The dependent variables of the study included body composition, velocity/power tests, vertical jump, sprint, and COD.

Participants

Eleven female futsal players (n = 11; mean age = 21.55 ± 4.32 years; mean height = 1.62 ± 0.06 m; mean weight = 60.13 ± 8.03 kg) from a first division Spanish league who held a valid federation license allowing them to compete participated in this investigation. The participants were recruited from a female futsal team competing in the first division of the Spanish Futsal League (1ª RFEF) during the evaluation period.

We excluded goalkeepers but did not need to exclude any players due to injury. Participants were included in this study if they met the following criteria:

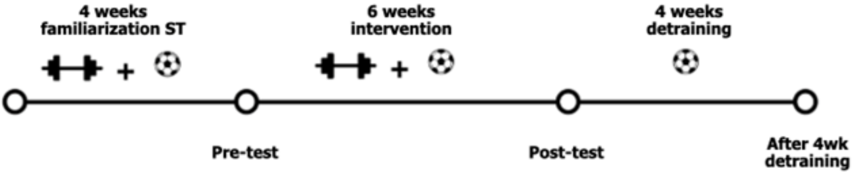
1. Had normal vision and no history of any neuropsychological conditions that could affect the experimental outcomes.
2. Were actively competing with a federation license.
3. Were injury-free during the previous two months.
4. Provided informed consent; and
5. Took part in at least 85% of the matches during the study period.

This study adhered to the ethical guidelines outlined in the 2013 Helsinki Declaration for Human Research and it received approval from the Research Ethics Committee at Universidad Pablo de Olavide (Code number: 24/5-1).

Procedures

This study was carried out during the season, with specific futsal training performed four days per week throughout the intervention period. The team received four weeks of ST familiarization training once a week without using ID. Pre-tests were conducted before the training, and post-tests were performed after six weeks to determine the effects of ST using a combination of rotational inertial devices and specific movements. After the six-weeks intervention period, the team resumed their usual futsal training, but ceased ST for four weeks. The players were evaluated again after the four-week detraining period (Figure 1).

Figure 1. *Experimental design timeline*



Note. Own elaboration.

Before performing any tests, the players completed a 10-minute standardized warm-up consisting of aerobic activity (running), dynamic stretching, progressive sprinting, and planned changes of direction. The participants were familiar with all of the exercises.

All measurements were performed at least 48 hours after match day (MD) on the first day of the training week (MD +2). The order of the tests remained consistent throughout. First, body composition was measured after a standardized warm-up. Then, blocks of mobility (cat-camel and backward rock), core (front plank and dead bug), and bodyweight strength (squats and front lunges) exercises were performed. Each block consisted of two sets of eight repetitions.

CMJ was measured after warming up, followed by a lower-limb power test involving the flywheel squat and linear sprint. All evaluations were performed at the same time and in the same space before the training session. Soccer players wore their usual clothing and footwear, and technical specialists supervised the evaluations.

Procedural Measures

Body Composition (BC)

Anthropometric assessment was the initial step in the testing process. BC was evaluated before training, at least two hours after eating. Participants wore a sports bra and shorts and removed any metal-containing items prior to the assessment. They refrained from any physical activity for 24 hours prior to testing.

Bioelectrical Impedance Analysis (BIA) was used to evaluate BC with a TANITA® segmental body composition scale (Tanita BC-602, Tokyo, Japan). BIA is a well-established technique for estimating lean mass, providing an economical, non-invasive way to assess fluid distribution and BC in team sports (Falces-Prieto et al., 2020).

A SECA 213 mobile stadiometer (SECA Deutschland, Hamburg, Germany) was used to measure height to the nearest millimeter. Participants were instructed to position their heads in the Frankfort horizontal plane.

Counter Movement Jump (CMJ)

The Chronojump-Boscosystem® (Chronojump, Barcelona, Spain) contact platform was used to test the CMJ. This platform has an intraclass correlation of 0.821-0.949 for jump height measurement (Falces-Prieto et al., 2021). Values were analyzed using Chronopic and recorded with Chronojump version 2.0.2. (Pueo et al., 2020).

After warming up, three jumps were performed, with one minute of recovery time between each attempt to minimize the effect of fatigue. The best jump was used to determine jump height. Participants were instructed to keep their hands on their hips during the CMJ to prevent upper body involvement and to land with their legs extended and their feet fully flexed. Participants were required to perform the test at maximal intensity, jumping as high as possible. If any of these requirements were not met, the trial was repeated.

Lower Limb Power Test

Participants stood on a ProSquat Proinertial® flywheel platform (Barcelona, Spain). The smallest load allowed by this device, 0.0335 kg/m^2 moment inertia, was used for testing. The platform was a non-gravity device that provided linear resistance via a tether wrapped around a vertical cylindrical shaft.

Participants performed a half squat, trying to generate maximum velocity and power for measuring vertical power. The movement began with the ECC phase, in which the athletes lowered themselves by flexing their hips, knees, and ankles. It concluded with the CON phase, in which the athletes extended their hips, knees, and ankles (also called triple extension).

Participants were encouraged to achieve maximum speed when changing from the ECC to the CON phase. In the transition from CON to ECC they must gently resist inertial force gently during the first third of the ECC action and apply maximal effort at the end of the movement. They performed three sets of eight maximum repetitions. The first three repetitions were excluded to allow for the inertial load to stabilize and the participants to reach maximum mechanical output, as is commonly recommended in flywheel training protocols (Brien et al., 2020; Sabido et al., 2020).

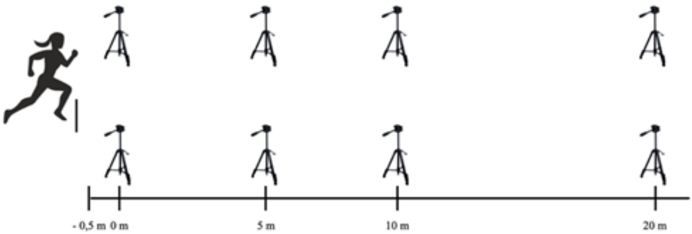
The best CON/ECC mean set was then selected for analysis of mean velocity (MV) and mean power (MP). Power output was measured using a Chronopic rotary encoder (Chronojump, Barcelona, Spain) with an accuracy of ± 1 mm and a sampling rate of 1000 Hz, as well as its associated open-source software model (Chronojump-Boscosystem®, Barcelona, Spain). The sensor was carefully installed on the flywheel (v1.6.0.0) (Illera-Domínguez et al., 2018). Chronojump is open-source software, and a complete repository of the used code and formulas can be found online (Chronojump, 2018).

Linear Sprint

A linear sprint assessment was performed using photoelectric cells were (Microgate, Bolzano, Italy) for 5-, 10- and 20- meter sprints. Each participant performed up to three sprints, with 3 minutes of rest between each attempt. The best sprint was selected for statistical analysis.

Photoelectric cells were placed at the starting point and at 5-, 10- and 20- meter intervals. Participants were required to sprint at their maximum speed from the first cell to the last. They started by placing one foot forward on the marked line 0.5 meters from the first photocell and leaning their torso slightly forward. To prevent variations caused by upper-limb movement, the first photocell was placed lower than the others. The remaining photocells were positioned at waist level to standardize the data (Figure 2).

Figure 2. *Sprint test*



Note. Own elaboration.

Training Intervention

The players participated in six weeks of supervised ST using ID twice a week. To ensure adequate recovery, a 48-hour resting period separated both sessions. The first training session was always performed at MD +2, and the second was always performed at MD -2. Before each ST, the players completed a standardized 15-minute warm-up, consisting of blocks of mobility (cat-camel and backward rocking), core (front plank, dead bug, mountain climbers, and TRX roll out) and bodyweight strength (squats and front lunges) exercises. Participants completed two sets of eight repetitions, as shown in Table 1.

Table 1. *Training intervention*

Exercise	Volume	Load for weeks 1-3	Load for weeks 4-6
Half Squat	3x8	0.0335 kg/m^2	0.0335 kg/m^2
Single Lateral Squat	3x8 each leg	0.0335 kg/m^2	0.0335 kg/m^2
Box Jump	3x8	50 cm	75 cm
Single Box Jump	3x8 each leg	25 cm	50 cm
First Step Pulley Conic	3x8 each leg	0.0335 kg/m^2	0.0335 kg/m^2
Crossing Step Pulley Conic	3x8 each leg	0.0335 kg/m^2	0.0335 kg/m^2
Split Stance Med Ball Chest Pass	3x8 each leg	3 kg	5 kg

Note. Own elaboration.

The first training session involved three sets of eight repetitions of bilateral and and single-leg squats on a flywheel device (ProSquat, Proinertial®, Barcelona, Spain), with two minutes of rest between sets. This was combined with three sets of eight repetitions of box jumps (50 cm height) and single-leg box jumps (25 cm height). The resistance used across all interventions was 0.0335 kg/m^2 moment of inertia on a non-gravity device that provided a source of linear resistance via a tether wrapped around a vertical cylindrical shaft.

Participants were instructed to apply maximum speed and force when changing from ECC to CON, and throughout the CON phase. In the transition from CON to ECC, they were required to gently resist the inertial force during the first third of the ECC action and then apply maximum effort and break at the end of the movement (Brien et al., 2020; Sabido et al., 2020). After three weeks of intervention, the height of the box was increased to 75 cm and 50 cm, respectively.

The second training session consisted of three sets of eight repetitions on a conical pulley device (Pulley Pro C3, Proinertial®, Barcelona, Spain), with two minutes of rest between sets. This was combined with three sets of eight repetitions of split-stance medicine ball chest pass. The smallest possible resistance was employed (0.0335 kg/m^2 moment of inertia) was used throughout the entire intervention with a non-gravity device. In this device, a tether wrapped around a cone-shaped horizontal shaft provided controlled linear resistance.

Players were instructed to apply maximum speed and force when changing from ECC to CON and throughout the CON phase. When changing from CON to ECC, players needed to gently resist inertial forces during the first third of the ECC action and apply maximum effort and break at the end of the movement (Brien et al., 2020; Sabido et al., 2020).

Statistical analysis

Data are expressed as the mean ± standard deviation (SD). The Shapiro-Wilk test confirmed that all variables followed a normal distribution. A repeated-measures ANOVA was conducted to evaluate changes between the testing periods, and Bonferroni post hoc tests were used to identify significant differences. A significance threshold of $p < 0.05$ was established. All statistical analyses were conducted using SPSS (version 19, SPSS Inc., Chicago, IL, USA). The effect size (ES), along with its 95% confidence interval (95%CI), was calculated for the selected variables (Cohen, 1988).

RESULTS

All participants completed at least 11 of the 12 sessions. Table 2 shows the changes in body composition that occurred during the six-week training intervention. Body fat percentage decreased significantly after the training period ($p < 0.05$), though there were no statistical changes in body mass or lean mass. After the four-week detraining period, body fat percentage remained lower than the pre-test values ($p < 0.01$). Although modest, these reductions in body fat percentage may positively contribute to performance by enhancing relative strength and movement efficiency.

Table 2. *Changes in body composition. Data are mean ± SD*

Female futsal players (n = 11)						
Variables	**Pre**	**Post**	**After 4-week detraining**	**Standardized differences (ES ± 95% CI) Pre and post**	**Standardized differences (ES ± 95% CI) Pre and after 4-week de-training**	**Standardized differences (ES ± 95% CI) Post and after 4-week de-training**
Body Mass (kg)	60.13±8.03	60.26±6.90	60.22±7.30	0.02±0.11	0.01±0.11	-0.01±0.07
% Body Fat	24.0±3.85	22.98±4.61	22.31±4.70	-0.26±0.24*	-0.43±0.25**	-0.16±0.28
Lean Mass (kg)	43.29±4.43	43.89±4.0	44.16±3.98	0.12±0.19	0.18±0.16*	0.06±0.17

Note. Significant differences ($p < 0.05$); **Significant differences ($p < 0.01$); kg (kilograms); ES (effect size); CI (confidence interval).
Own elaboration.

Table 3 shows the changes in performance parameters. Significant improvements were observed in jumping performance ($p < 0.01$), 5-m sprinting performance ($p < 0.05$), 10-m sprinting performance ($p < 0.05$), 20-m sprinting performance ($p < 0.01$), concentric mean velocity ($p < 0.01$), and concentric mean power ($p < 0.01$). After the four-week detraining period, jumping performance ($p < 0.01$), concentric mean velocity ($p < 0.05$) and concentric mean power ($p < 0.01$) remained statistically higher than the pre-test values. These improvements, particularly in jump height and sprint performance, indicate meaningful enhancements in neuromuscular function that can be directly applied to futsal-specific actions.

Table 3. *Changes in performance. Data means SD*

Female futsal players (n =11)						
Variables	**Pre**	**Post**	**After 4-week detraining**	**Standardized differences (ES ± 95% CI) Pre and post**	**Standardized differences (ES ± 95% CI) Pre and after 4-week detraining**	**Standardized differences (ES ± 95% CI) Post and after 4-week detraining**
CMJ height (cm)	25.88±5.11	28.51±4.71	28.51±5.60	0.47±0.23**	0.47±0.25**	0.00±0.19
Sprint 5 m (s)	1.08±0.08	1.05±0.08	1.05±0.09	-0.36±0.30*	-0.33±0.55	0.03±0.70
Sprint 10 m (s)	1.87±0.10	1.83±0.11	1.79±0.25	-0.32±0.25*	-0.64±1.11	-0.32±1.16
Sprint 20 m (s)	3.28±0.15	3.22±0.15	3.25±0.17	-0.36±0.22**	-0.22±0.32	0.15±0.39
CON mean velocity (m/s)	0.62±0.07	0.67±0.06	0.68±0.08*	0.77±0.39**	0.84±0.69*	0.07±0.43
CON mean power (w)	723.29±153.15	1011.61±169.20	1004.86±178.45*	1.74±0.75**	1.70±0.70**	-0.04±0.42

Note. *Significant differences ($p < 0.05$); **Significant differences ($p < 0.01$); ES (effect size); CI (confidence interval); CMJ (countermovement jump); cm (centimeters); s (seconds); m/s (meters per second); w (watts). Own elaboration.

DISCUSSION

This study aimed to evaluate the effects of a supervised ST period using ID on performance and BC in female professional futsal players, as well as the subsequent effects of ST cessation. The main findings of the present study showed that six weeks of supervised ST using ID twice a week was an optimal stimulus for improving BC, sprint performance, brie and velocity and power outcomes during the squat exercises. These enhancements were maintained after four weeks of ST cessation. These results align with previous findings in other team sports that used similar training protocols.

The objective of using regular ST in football is twofold: (1) to improve players' ability to perform specific and relevant football actions optimally during competitive games, and (2) to reduce markers of muscle damage post-training and post-match to minimize injury risk (Owen et al., 2013).

Previous studies have also shown improvements in body composition among team sports athletes following an intervention period (Núñez et al., 2018; Suárez-Arrones et al., 2018). There were also greater power enhancements in the squat exercise (Illera-Domínguez et al., 2018; Núñez et al., 2018). Similar improvements in jumping and sprinting ability have been demonstrated in athletes from various team sports (Raya-González et al., 2021), junior elite soccer players (De Hoyo et al., 2015), basketball players (Cabanillas et al., 2020), female U23 soccer players (Nevado-Garrosa et al., 2021), and female basketball players (Brien et al., 2020). However, to our knowledge no studies have been conducted with professional female futsal players. Therefore, it is not possible to make comparisons within the same sport.

However, based on previous studies of other team sports have shown that strength training with inertial devices improves the jumping and sprinting performance of female athletes (Arede et al., 2020; Brien et al., 2020). Due to busy calendars, ST often cannot be performed regularly during some competition periods, which means a reduction in players' usual training or removal of certain training stimuli from their activities, such as regular strength training, during the microcycle (Cardoso Marques & González-Badillo, 2006).

BC is a key fitness parameter in many sports, including football (Falces-Prieto et al., 2020), yet scientific research on female futsal players is limited (Castillo et al., 2022; Ramos-Campo et al., 2016). This study found that body fat percentage was the only parameter that decreased significantly after the training period ($p < 0.05$), while body mass and lean mass remained unchanged.

In terms of body fat percentage, our data aligns with a previous study of elite male soccer players (Suárez-Arrones et al., 2018) though we observed no changes in lean mass. The differences in lean mass changes may be explained by the duration of the intervention (six weeks vs. one full season). These results suggest that a longer period of ST with ID may be necessary to increase lean mass in elite female futsal players. Additionally, training volume is one of the most important factors in terms of morphological changes in muscle (Illera-Domínguez et al., 2018).

Regarding body fat percentage, our players showed better results after the intervention (22.98%) than in previous studies of elite female futsal players (26.70%) (Ramos-Campo et al., 2016). Additionally, changes in body fat percentage were maintained after four weeks of ST cessation.

The effectiveness of ST with ID on jumping performance has been scientifically demonstrated (Allen et al., 2023; Raya-González et al., 2021). Our study showed that elite female futsal players experienced substantial improvements in CMJ after the training intervention (small ES: 0.32; $p < 0.01$). A systematic review analyzing the effects of flywheel training on young females also reported statistical improvements in jumping ability (De Keijzer et al., 2022).

In this study, the reference values for the CMJ pre-test were similar for female athletes (25.9 cm) and for female futsal players in previous studies (26.7 cm) (Ramos-Campo et al., 2016). After the intervention period and four weeks of ST cessation, however, the values were slightly higher (28.5 cm and 28.5 cm, respectively) than the reference values presented in the previous study with female futsal players (Ramos-Campo et al., 2016). Similar improvements were also shown in previous research (Brien et al., 2020) involving four weeks of flywheel training in female basketball players (10.7% vs. 10.2%).

After 4 weeks of ST cessation, female futsal players did not show a significant reduction in jumping performance. Our findings align with those of previous studies (Cardoso Marques & González-Badillo, 2006), which found that CMJ did not decreased significantly after ST cessation. This finding is very interesting because the new style of competition with busy schedules does not allow for regular ST during the season. Therefore, other alternatives, such as microdoses, should be prescribed during these periods. However, contrary to our results, a brief interruption in training can improve CMJ performance ($p = 0.02$) (Pereira et al., 2020). In this case, there was a total cessation of training, therefore, jump ability could have increased due to off-season fatigue being lower than in-season fatigue.

Female futsal players showed statistical improvements in sprint performance (5-, 10-, and 20-meter sprints) after the six-week intervention period of ST with ID ($p < 0.05$). The enhancements in 5-meter sprints (ES: -0.36) align with previous findings (Gonzalo-Skok et al., 2022) in which young basketball players, divided into two different groups with lateral and horizontal vectors, improved in 5-meter sprints (ES: 0.29 and 0.50, respectively).

Similar to our findings, a program using rotational inertial devices increased high-intensity acceleration in U23 female soccer players (Nevado-Garrosa et al., 2021). Enhanced 5-meter sprints times are related to high-intensity acceleration and play a key role in soccer and futsal competition (Jiménez-Reyes et al., 2019). Similar results were observed in 10-meter sprints (Brien et al., 2020) in which an increase in sprint performance was found in amateur female basketball players after four weeks of twice weekly flywheel training (-1.9% vs. -2%). Consistent with our findings, improvements in 20-meter sprints were also observed in junior elite soccer players (ES: 0.36) (De Hoyo et al., 2015).

The results of the current study showed no significant changes in 5-, 10- and 20- meter sprints after the 4-week detraining period (ST cessation) compared to post intervention times in ($p > 0.05$). These results align with those of previous studies (Pereira et al., 2020), which found no changes in 10-meter sprint times in U20 elite soccer players after 26 days of ST cessation. This information is useful for coaches trying to manage different training stimuli during busy microcycles.

Regarding neuromuscular adaptations, the results showed substantial statistical improvements after the intervention. Velocity and power increased significantly ($p < 0.01$). Lower body muscle power is crucial for athletes performing intermittent, high-intensity actions, such as jumping or sprinting (Naser et al., 2017). In this regard, the outcomes of velocity and power showed significant enhancements (9% and 41%, respectively). Our study aligns with previous findings showing improvements in power in active male populations (Illera-Domínguez et al., 2018; Núñez et al., 2018) and amateur female basketball players (Brien et al., 2020).

ID promote maximal or near-maximal action with each repetition (Illera-Domínguez et al., 2018), which may lead to improved power outcomes. The magnitude of change in power outcomes (ES: 1.74) was greater than that observed in previous study of elite male soccer players over the course of a full season intervention (ES: 0.45-0.50) (Suárez-Arrones et al., 2018). These differences can be attributed to the athletes' prior level of experience.

In fact, the effect was similar in elite male handball players who were experienced in ST but not accustomed to rotational inertial devices (ES: 1.41) (Sabido et al., 2017), indicating that these devices are effective even for well-trained ST athletes. There were no changes in velocity or power outcomes after four weeks of ST cessation ($p = 0.715$ and 0.832, respectively). These findings align with those of Vassilis et al. (2019), who found that neuromuscular adaptation in isokinetic strength was maintained during four weeks of ST cessation in youth elite soccer players ($p > 0.05$).

Six weeks of supervised ST using ID twice a week, in addition to regular court training, may be an optimal stimulus for improving BC, sprint performance, CMJ, and velocity and power outcomes during the squat exercise. These improvementes were maintained after four weeks of detraining, during which time the players only trained on the futsal court. These findings can help coaches and athletes plan training programs during competitive periods, particularly for futsal teams.

Limitations and Practical Applications

Our study has some limitations. First, the number of players was limited due to the small squad size of futsal squads. Second, we evaluated elite futsal players during a competitive season, which preventing us from including a control group. From an ethical standpoint, including a control group would have meant preventing some players from participating in training interventions, which could have negatively impacted team performance. This issue has been discussed in previous studies (Arede et al., 2020; Falces-Prieto et al., 2021; Pérez Muñoz et al., 2021; Suárez-Arrones et al., 2018). Finally, we did not control for the effect of diet on BC.

Additionally, while BIA is a practical and validated method in team sports contexts, its precision may be limited compared to laboratory-based techniques, such as DXA. Furthermore, the absence of objective markers of neuromuscular fatigue or muscle damage hinders the physiological interpretation of observed adaptations.

It would be interesting to replicate this study with different teams, increase the number of participants, and introduce a control group. Future research with larger number of players would benefit from controlling the participant's diets and using a control group to compare differences between them. This intervention improved sprint performance over 5-, 10-, and 20-meters distances and vertical jump height.

Our findings align with previous literature. Enhancements in performance and body composition should result in improved specific performance during competitions. In our view, variety in force-vectors is also important. In our study, one session focused on vertical force vectors, while the other focused on horizontal vectors. These enhancements can be maintained throughout the season with ST cessation. After the intervention, BC and power improved, which are key factors for performance in team sports.

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