

## Original Article

# Gender-Specific Relationships Between Ankle Mobility, Foot Strength, and Trunk Control in Futsal Players: A Cross-Sectional Study

Íñigo Asurmendi<sup>1,2</sup>, María Oficialdegui<sup>2,3</sup>, Pedro J. Marín<sup>2</sup><sup>1</sup>CD Osasuna Magna Xota Futsal, Navarra, Spain;<sup>2</sup>CYMO Research Institute, Valladolid, Spain;<sup>3</sup>CD Osasuna Xota, Navarra, Spain

## Abstract

**Objectives:** This study investigated the relationships between ankle dorsiflexion, first toe strength, and core stability in male and female futsal players. **Methods:** Fourteen male professional players from the Spanish first division and 22 female players from the second division were evaluated. Ankle dorsiflexion range of motion was measured using the LegMotion® system. Core stability was assessed via the OCTOcore app during single-leg deadlift (SLD) and bird-dog (BD) exercises. Toe flexor strength (TFS) was measured with a handheld dynamometer, and plantar flexor endurance was evaluated using the heel-raise test (HR). Statistical correlations were analyzed to explore neuromuscular relationships. **Results:** In males, a moderate positive correlation ( $p < 0.01$ ) was found between ankle dorsiflexion and TFS, suggesting enhanced ankle mobility may increase toe strength. A negative correlation between TFS and SLD performance indicated stronger toe flexors correlated with better core stability. In females, a negative correlation between ankle dorsiflexion and BD performance implied greater ankle mobility improved core stability. Conversely, a positive correlation between TFS and SLD performance suggested stronger toe flexors were linked to poorer core stability. **Conclusions:** Ankle mobility and toe strength enhance core stability in males, while females employ distinct neuromuscular strategies, highlighting the need for gender-specific training programs.

**Keywords:** Core-stability, Dorsiflexion, Gender, Performance, Toe-strength

## Introduction

Futsal is a fast-paced team sport requiring high levels of physical, technical, and tactical skills. Played on a 20x40 meter court, it involves two teams of five players (one goalkeeper and four field players) competing in an environment that demands intense, multi-directional actions<sup>1</sup>. The sport is characterized by frequent accelerations, decelerations, sprints, and brief recovery

periods, making it more physically demanding than other team sports such as soccer, handball, and basketball. The total distance covered per match varies by level, with professional and amateur players covering  $5087 \pm 1104$  m and  $4528 \pm 1248$  m, respectively. Among female players, the average distance is significantly lower, at  $2737 \pm 207$  m. Average heart rates during matches also differ by level and gender, with professionals reaching  $89.8 \pm 5.8\%$ , amateurs  $86.2 \pm 6.7\%$ , and women  $83 \pm 3\%$ <sup>1,2</sup>.

The risk of injury in futsal is notable, with men experiencing 61.1 injuries per 1,000 match hours and 9.9 injuries per 1,000 training hours. Most injuries (92.1%) affect the lower limb, with the ankle, knee, thigh, and adductor being the most commonly injured areas. Non-contact mechanisms account for the majority of these injuries<sup>3-5</sup>. Similar trends are observed in women, who sustain 57.87 injuries per 1,000 match hours and 2.9 injuries per 1,000 training hours. The lower limb remains the most affected region,

Pedro J. Marín is the developer of the CheckyourMOtion system. The remaining authors have nothing to declare.

Corresponding author: Pedro J. Marín, PhD., CYMO Research Institute, Valladolid, Spain  
E-mail: pjmarin@cymori.com

Edited by: G. Lyritis  
Accepted 28 May 2025



particularly the quadriceps, ankle, and knee. For both sexes, non-contact mechanisms are the predominant cause of injury<sup>6</sup>. Injuries not only impact players' performance but can also disrupt team dynamics and, in severe cases, lead to long-term health problems or early retirement.

Given the high prevalence of injuries, functional assessment and the identification of injury risk factors are critical for injury prevention in futsal. Teams commonly use a variety of tools, including functional and flexibility tests, asymmetry evaluations, questionnaires, maximal repetition tests, orthopedic assessments, and isokinetic measurements, to assess risk<sup>7</sup>.

One critical risk factor for lower limb injuries is limited ankle dorsiflexion. Reduced dorsiflexion has been linked to ankle sprains, anterior cruciate ligament (ACL) injuries, decreased dynamic postural control, impaired landing mechanics, and even low back pain<sup>8,9</sup>. Similarly, foot strength, particularly of the first toe, plays a vital role in maintaining plantar stability during both bipedal and unipedal actions. This strength is closely related to core stability and helps minimize injury risks<sup>10,11</sup>. Additionally, proximal trunk control significantly influences the biomechanics of the distal extremities, affecting foot pronation, knee valgus, and susceptibility to injuries such as stress fractures, Achilles tendinopathy, ankle sprains, and ACL tears<sup>10,12</sup>.

Therefore, the purpose of our study is to identify correlations between ankle dorsiflexion, first toe strength, and trunk control in futsal players, aiming to elucidate potential compensatory mechanisms and biomechanical differences between male and female athletes.

It was hypothesized that positive correlations would be observed between ankle dorsiflexion, first toe strength, and trunk control. Furthermore, it was posited that these relationships would differ significantly between male and female futsal players, reflecting variations in biomechanical strategies and neuromuscular control. These relationships are expected to highlight key biomechanical factors critical for optimizing performance and reducing injury risk in futsal.

## Materials and Methods

### Experimental Design

Prior to data collection participants were informed of the requirements associated with participation and provided written informed consent. Participants were encouraged to maintain their dietary, sleeping, and drinking habits during participation in the study.

### Participants

This study involved 14 professional futsal players from the Spanish first division (age  $25.29 \pm 5.04$  years, height  $175.43 \pm 3.65$  cm, weight  $70.24 \pm 5.3$  kg) and 22 female futsal players from the Spanish second division (age  $22.86 \pm 3.78$  years, height  $163.59 \pm 5.57$  cm, weight  $59.59 \pm 5.45$  kg). The professional players trained 5 days a week

for 2 hours per training session and competed once a week in the national league. The female players trained 3 days a week for 1 hour 30 minutes per session and competed once a week. The exclusion criteria were: (1) any cardiovascular, respiratory, abdominal, neurological, musculoskeletal, or other chronic diseases, and (2) any previous musculoskeletal injuries. This research project was conducted in accordance with the Declaration of Helsinki, with informed consent signed by each study participant.

All measurements were taken on two separate days, 24 hours apart, and within the same time window, at 09:00 am, to ensure that circadian rhythms were not altered.

### Procedures

#### Ankle Dorsiflexion (DF)

The ankle dorsiflexion range of motion (ROM) was evaluated using the LegMotion<sup>®</sup> system (Check your MOTion<sup>®</sup>, Albacete, Spain). The participants, who were previously familiarized with the procedure, performed the measurements barefoot to avoid interference. The evaluated foot was placed on the device platform, ensuring that the second toe and the center of the heel were aligned with the central line of the measurement scale. The contralateral foot remained free and placed on the ground outside the platform. The participants adopted a stance with their hands on their hips to standardize the position. They were instructed to perform a forward lunge, bending the knee of the evaluated foot to try to touch a metal bar initially placed 10 cm away. If they were able to maintain contact between the knee and the bar without lifting the heel, the evaluator progressively moved the bar forward to determine the maximum distance reached. The dorsiflexion range was defined as the maximum distance between the toe and the bar, maintaining contact for at least 3 seconds and without lifting the heel. Each limb was evaluated in three attempts, with 10-second rests between them, and the highest value was selected for data analysis<sup>13,14</sup>.

#### OCTOcore – Core stability

Core stability was evaluated using the OCTOcore mobile application (Check your MOTion<sup>®</sup>, Albacete, Spain) through two main exercises: the Single-Leg Deadlift (SLD) and the Bird-Dog (BD). For the SLD, participants began standing, with their backs to the wall and two feet away from it, feet parallel and hip-width apart, and arms crossed over their chest. The protocol included instructions to keep the gaze forward at all times. From the starting position, according to the random instructions from the application ("left" or "right"), the subjects had to touch the wall with the corresponding heel, keeping the trunk straight, knees extended, and a slight forward lean. After each movement, they returned to the starting position to await the next command. A smartphone with a triaxial accelerometer was placed on the lumbar region, secured with an adjustable belt, to record the linear accelerations of the lower back during the exercise<sup>15,16</sup>.

For the BD, participants began in a quadruped position with the lumbar spine and pelvis in a neutral position. From the starting position, according to the random instructions from the application (“left” or “right”), they were to simultaneously lift the contralateral arm and leg to horizontal, keeping the trunk and pelvis as static as possible. The knees remained flexed at 90° and the toes pointed forward. The “left” or “right” signals indicated which leg to lift and, consequently, the contralateral arm. The arm had to be lifted while maintaining abduction at 90° and external rotation (thumb pointing up)<sup>9,16</sup>.

Both exercises were performed at the same time to minimize circadian variations. In both tests, 30 familiarization repetitions were performed, and after a three-minute rest, 50 evaluative repetitions were carried out, following a moderate pace of three seconds per repetition<sup>9,16</sup>. Higher lumbar acceleration (mm s<sup>-2</sup>) denotes diminished lumbopelvic control; lower values indicate superior stability.

#### Toe Flexor Strength (TFS)

Big toe strength was assessed using the PodoGRIP® dynamometer (Check your MOtion®, Albacete, Spain), a device designed to measure the force exerted by the toe. During the test, participants placed a card under their big toe, with a sheet of paper beneath it to maintain consistent friction after card removal. Participants performed an isometric downward press to hold the card in place while the evaluator attempted to remove it. The dynamometer recorded the maximum force required to extract the card. Three measurements were taken per foot, and the average of these repetitions was used as the representative value.

The protocol was conducted with participants seated, legs bent at 90°, feet flat on the floor, arms crossed, and ankles supported. The evaluator provided minimal support on the navicular bone to prevent heel elevation. If heel movement was detected, the test was repeated. Participants completed two familiarization trials prior to the final assessment, with a five-minute rest between sets and a 30-second rest between repetitions for each foot<sup>17,18</sup>. Force measurements (in newtons) were normalized relative to body weight.

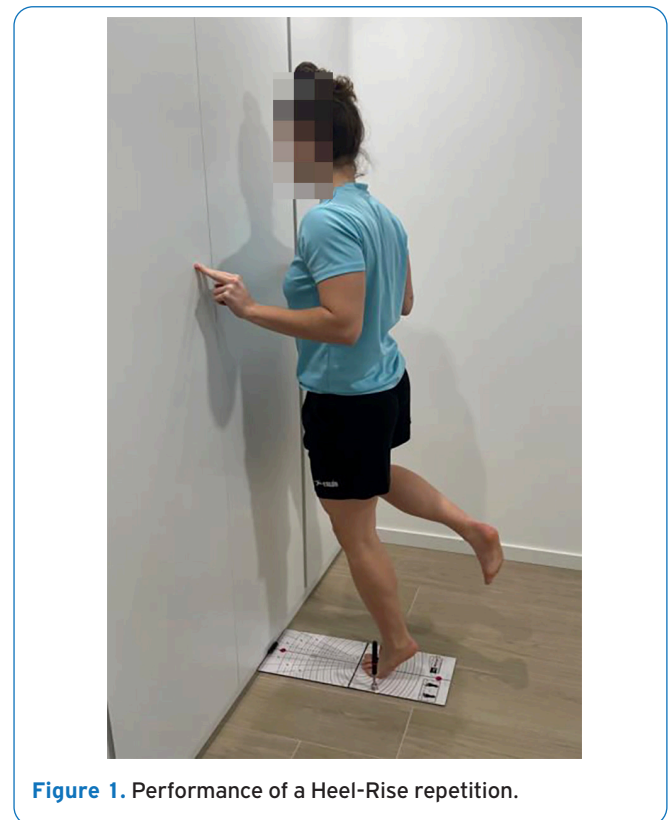
#### Single Heel Raise Test (HR)

The heel-rise test was conducted using the LegMotion® platform (Check your MOtion®, Albacete, Spain) (Figure 1). Metal rods were positioned at two marked locations along the platform’s width, and an elastic band was used to guide the movement and establish the maximum plantar flexion reference. Participants performed heel rises at a cadence of 1 second per repetition, maintaining a straight leg and stable trunk throughout. The test was terminated if participants failed to complete repetitions, maintain the prescribed cadence, or sustain proper posture. The total number of correctly executed heel rises was recorded as the primary outcome measure<sup>19</sup>. Additionally, the number of repetitions was normalized relative to body weight (HRN).

**Table 1.** Anthropometric and age characteristics of participants.

		Weight (kg)	Height (cm)	Age (years)
Men (n=14)	Mean	70.24*	175.43*	25.29
	SD	5.30	3.65	5.04
	Min.	62.00	168.00	20.00
	Max.	84.00	180.00	37.00
	Range	22.00	12.00	17.00
Female (n=22)	Mean	59.59	163.59	22.86
	SD	5.45	5.57	3.78
	Min.	50.00	150.00	17.00
	Max.	70.00	172.00	30.00
	Range	20.00	22.00	13.00

\* Statistically different compared to the women's group, p < 0.05.



**Figure 1.** Performance of a Heel-Rise repetition.

#### Statistical analyses

Data were analyzed using PASW/SPSS Statistics 20.0 (SPSS Inc, Chicago, IL, USA). Data normality was confirmed using the Kolmogorov-Smirnov test, validating the use of parametric statistical methods. Measurement reliability was

assessed using the Intraclass Correlation Coefficient (ICC), which demonstrated high consistency across all evaluated variables, ensuring robust and dependable results.

A two-way analysis of variance (2x2 ANOVA) was conducted for dependent variables distinguishing between dominant and non-dominant legs. The analysis considered two factors: gender (male and female) and leg dominance (dominant and non-dominant). For variables with statistically significant F-values, the Bonferroni post hoc test was applied to identify specific pairwise differences.

For variables not distinguishing between limbs (e.g., body weight, height, age, and measurements from the OctoCore application, such as bird-modified dog [BD] and single-leg deadlift [SLD]), independent samples t-tests were used to compare results between genders.

Correlation analyses were performed to examine relationships among neuromuscular variables, providing insights into potential associations and interdependencies. Correlations were classified as weak (0.10–0.29), moderate (0.30–0.49), strong ( $\geq 0.50$ ) with significance set at  $p < 0.05$ .

The significance level for all tests was  $p \leq 0.05$ , and results are reported as mean  $\pm$  standard deviation (SD). Cohen's formula for effect size (ES) was used and the results were based on the following criteria: trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79), and large (0.80 and greater)<sup>20</sup>.

## Results

All measurements demonstrated high levels of correlation between male and female participants across the assessed variables, with intraclass correlation coefficients (ICCs) ranging from 0.731 to 0.996. Detailed ICC values are presented in Table 2.

### Ankle Dorsiflexion (DF)

Ankle dorsiflexion measurements revealed similar values between male and female participants. For men, the results were  $11.96 \pm 2.27$  cm (non-dominant leg) and  $11.64 \pm 2.46$  cm (dominant leg). For women, the values were  $11.57 \pm 2.23$  cm (non-dominant leg) and  $11.72 \pm 2.22$  cm (dominant leg). No significant differences were observed between groups ( $p > 0.05$ ; ES = 0.174, trivial) or between legs ( $p > 0.05$ ; ES = -0.135, trivial).

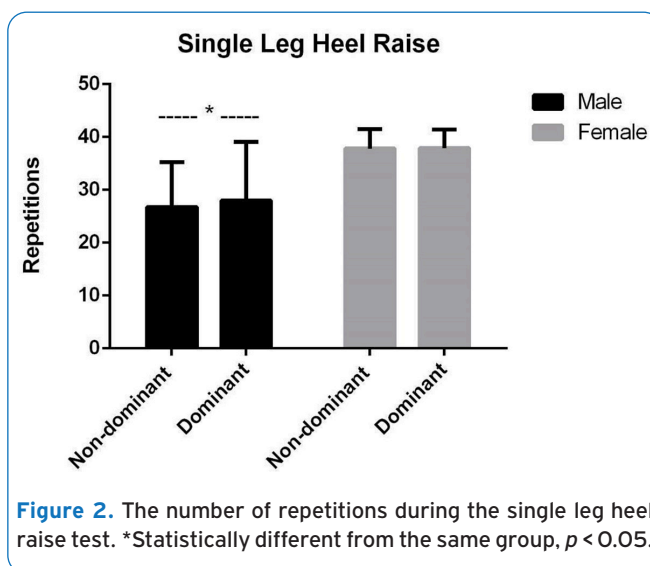
### Core Stability Tests

In the bird dog (BD) test, men scored  $8.66 \pm 2.08$  mm/s<sup>2</sup>, while women scored  $8.51 \pm 1.89$  mm/s<sup>2</sup> ( $p > 0.05$ ; ES = 0.076, trivial). For the single-leg deadlift (SLD) test, men achieved  $10.39 \pm 2.04$  mm/s<sup>2</sup>, and women scored  $9.88 \pm 2.67$  mm/s<sup>2</sup> ( $p > 0.05$ ; ES = 0.208, small). No significant differences were found between groups for either test ( $p > 0.05$ ).

**Table 2.** Intraclass correlation coefficients values.

	Male	Female
DF Non-dominant	0.996	0.966
DF Dominant	0.994	0.978
BD	0.761	0.842
SLD	0.878	0.731
TFS Non-dominant	0.944	0.855
TFS Dominant	0.900	0.791
HR Non-dominant	0.885	0.795
HR Dominant	0.961	0.859
HRN Non-dominant	0.995	0.991
HRN Dominant	0.993	0.991

DF: Ankle Dorsiflexion; BD: Bird Dog; SLD: Single Leg Dead; TFS: Toe Flexor Strength; HR: Raise Test; HRN: Raise Test normalized relative to body weight.



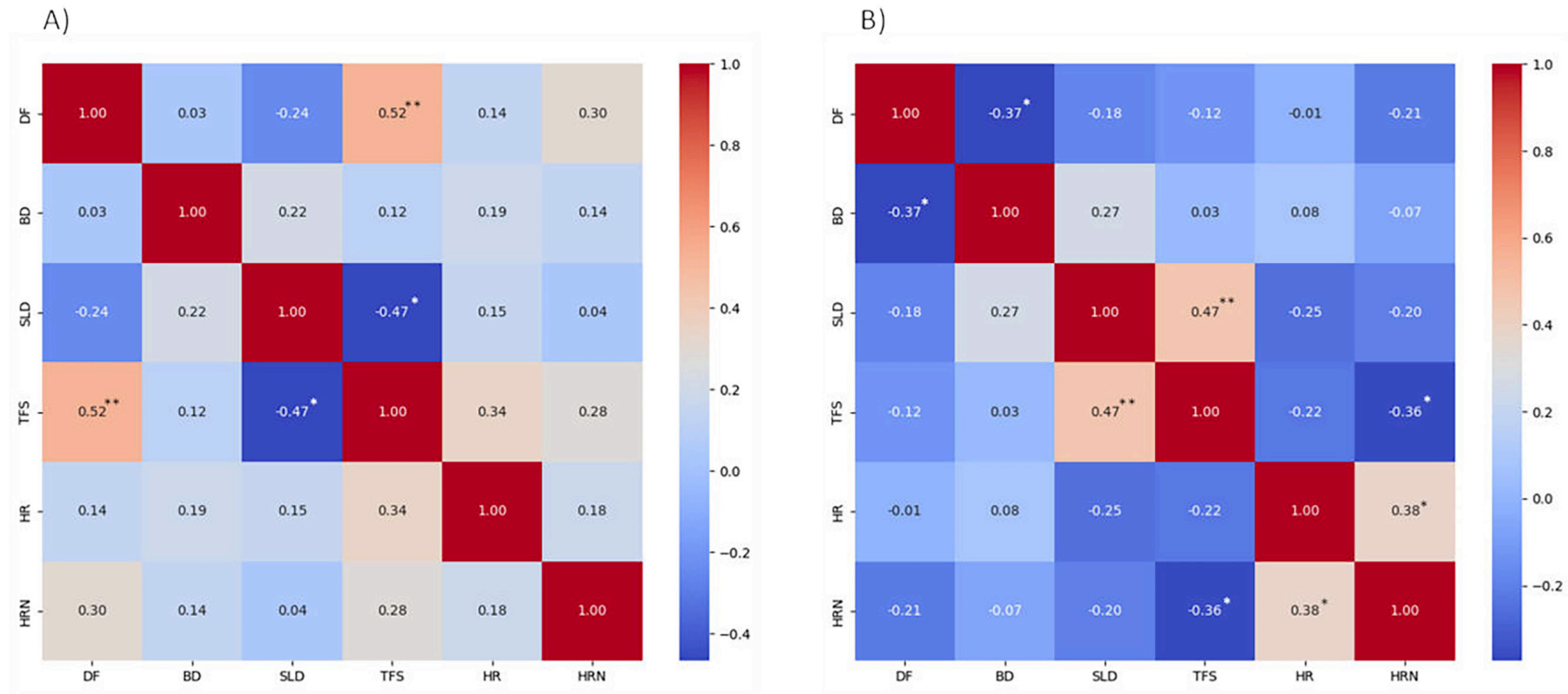
**Figure 2.** The number of repetitions during the single leg heel raise test. \*Statistically different from the same group,  $p < 0.05$ .

### Toe Flexor Strength (TFS)

TFS measurements showed comparable results between men and women. For men, the values were  $1.11 \pm 0.38$  N/kg (non-dominant leg) and  $1.14 \pm 0.40$  N/kg (dominant leg) ( $p > 0.05$ ; ES = -0.140, trivial). For women, the results were  $1.16 \pm 0.34$  N/kg (non-dominant leg) and  $1.27 \pm 0.38$  N/kg (dominant leg) ( $p > 0.05$ ; ES = 0.077, trivial). No significant differences were observed between groups or legs ( $p > 0.05$ ).

### Single Heel Raise Test

The number of repetitions is presented in Figure 2. Relative to body weight, men achieved  $0.36 \pm 0.12$  rep/



**Figure 3.** Correlation heatmaps for male (a) and female (b) participants. \* $p < 0.01$ ,  $p < 0.05$ . DF: Ankle Dorsiflexion; BD: Bird Dog; SLD: Single-Leg Deadlift; TFS: Toe Flexor Strength; HR: Heel-Raise Test; HRN: Heel-Raise Test normalized to body weight. The heatmaps display Pearson's  $r$  coefficients between foot-ankle variables and lumbar acceleration (higher values indicate poorer trunk control); darker shades represent stronger correlations.

kg (non-dominant leg) and  $0.43 \pm 0.18$  rep/kg (dominant leg), with statistically significant differences favoring the dominant side ( $p < 0.05$ ; ES = 0.458, small). In women, the results were  $0.61 \pm 0.34$  rep/kg (non-dominant leg) and  $0.63 \pm 0.35$  rep/kg (dominant leg) ( $p > 0.05$ ; ES = 0.058, trivial), with no significant differences between groups or legs ( $p > 0.05$ ).

The correlation analysis, as depicted in Figure 3, elucidates the relationships

between biomechanical assessments for both genders. For men, Ankle Dorsiflexion (DF) exhibited a notably positive correlation with Toe Flexor Strength (TFS) ( $r = 0.52$ ,  $p < 0.01$ ), indicating a strong association between these two variables. In contrast, Single-Leg Deadlift (SLD) showed a moderate negative correlation with TFS ( $r = -0.47$ ,  $p < 0.05$ ).

For women, the results (Figure 3) demonstrate a moderate negative correlation

between DF and the Bird Dog (BD) test ( $r = -0.37$ ,  $p < 0.05$ ), possibly indicating differing core stability dynamics related to ankle mobility. Additionally, the SLD test for women showed a moderate negative correlation with TFS ( $r = -0.36$ ,  $p < 0.01$ ), which contrasts with the findings in men, underscoring possible gender-specific functional and physiological adaptations. The Heel Raise Test (HR) relative to body weight (HRN) also showed a moderate positive correlation in women ( $r = 0.38$ ,  $p < 0.05$ ), reinforcing the impact of body weight on lower limb strength and endurance capacities.

## Discussion

The findings of this study provide valuable insights into the relationships between ankle dorsiflexion, first toe strength, and core stability in male and female futsal players. The results highlight gender-specific biomechanical adaptations and suggest potential compensatory mechanisms that may influence performance and injury risk in this population.

The study revealed a moderate positive correlation between ankle dorsiflexion and first toe strength in male players, suggesting that greater ankle mobility may facilitate enhanced toe flexor strength<sup>10,11</sup>. This relationship aligns with previous research indicating that ankle dorsiflexion plays a critical role in optimizing foot biomechanics and force production during dynamic movements<sup>10,11</sup>. Specifically, adequate ankle dorsiflexion allows for efficient energy transfer during activities such as jumping, cutting, and landing, which are essential for futsal performance. Furthermore, the positive correlation between ankle dorsiflexion and toe strength supports the idea that a well-functioning foot complex contributes to overall stability and force generation. This finding is consistent with the work of Yazdani et al. (2019)<sup>21</sup>, who demonstrated that individuals with hyperpronated feet exhibit altered pelvic biomechanics, particularly increased anterior pelvic tilt, as a compensatory mechanism to maintain postural balance during gait. While their study focused on hyperpronation, the underlying principle—that proper foot function is critical for maintaining proximal stability—applies to our findings. In our study, the positive correlation between ankle dorsiflexion and toe strength in male players suggests that better foot function (e.g., greater ankle mobility and toe strength) may enhance core stability by optimizing the kinetic chain and reducing compensatory movements in the lumbar region. This is further supported by the negative correlation observed between single-leg deadlift (SLD) performance and first toe strength in men. It is important to note that higher values in the SLD test indicate poorer performance, as they reflect greater lumbar movement captured by the smartphone accelerometer. This suggests that players with stronger first toe strength may exhibit better core stability during single-leg tasks, as evidenced by reduced lumbar movement.

In female players, a significant negative correlation was found between ankle dorsiflexion and core performance during the Bird Dog (BD) test. Similar to the SLD test, higher values in the BD test indicate poorer performance, as they reflect greater lumbar instability. This suggests that greater ankle mobility in women may be associated with better core stability, potentially due to differing neuromuscular control strategies. Additionally, a positive relationship was found between first toe strength and SLD performance in women. Contrary to expectations, this indicates that stronger toe flexors may be associated with poorer core stability during single-leg tasks, as evidenced by increased lumbar movement. This counterintuitive finding may reflect a compensatory strategy in which greater toe strength is utilized to stabilize the distal segment, potentially at the expense of proximal control. This interpretation is supported by recent findings in female ballet dancers, where long-term high-load training involving tiptoe postures resulted in selective hypertrophy of the flexor digitorum brevis and lumbricals—muscles critically involved in distal postural control under demanding conditions<sup>22</sup>.

In other words, women with stronger toe flexors may rely more on distal stability, which could lead to reduced activation or coordination of core muscles during single-leg tasks. This phenomenon is consistent with previous research highlighting sex-based differences in neuromuscular control, where female athletes often exhibit greater lateral trunk displacement and increased knee abduction moments during dynamic tasks<sup>12,23</sup>. These differences may stem from anatomical and biomechanical variations, such as wider pelvic structures and greater ligamentous laxity, which can influence movement patterns and stability.

The heel raise test (HR) results further emphasized gender-specific adaptations, with men demonstrating significantly better performance on the dominant side. This asymmetry may reflect the demands of futsal, which often requires unilateral dominance during kicking and cutting maneuvers. In contrast, women showed no significant differences between limbs, which could indicate a more balanced neuromuscular profile or differing biomechanical strategies to mitigate injury risk.

The observed relationships between ankle dorsiflexion, toe strength, and core stability are consistent with prior research highlighting the importance of these variables in athletic performance and injury prevention. For instance, limited ankle dorsiflexion has been linked to altered landing mechanics, increased knee valgus, and a higher risk of ACL injuries<sup>8,9</sup>. Similarly, toe flexor strength has been shown to influence plantar stability, propulsion efficiency, and performance in multidirectional movements<sup>10,24</sup>. The findings of this study extend this body of knowledge by demonstrating gender-specific correlations and potential compensatory mechanisms in futsal players. However, given the cross-sectional design, these findings represent associations and do not permit inference of temporal or causal relationships.

Beyond their theoretical implications, these findings

also offer practical relevance for applied settings. The observed sex-specific associations may inform the design of individualized training protocols tailored to the neuromuscular demands of futsal. Specifically, male athletes may benefit from incorporating ankle-mobility and toe-flexor strengthening exercises aimed at improving proximal stability through enhanced distal control. In contrast, female athletes may prioritise core-stability interventions that leverage lower-limb mobility to optimise postural control and motor efficiency. These targeted approaches align with the mechanistic interpretations of our findings and may contribute to performance optimisation and injury risk mitigation in sport-specific contexts.

The lack of significant differences in most neuromuscular variables between dominant and non-dominant limbs aligns with the findings of Guillén-Rogel et al. (2017)<sup>9</sup>, who reported similar symmetry in lower limb function among athletes. However, the observed asymmetry in the heel raise test for men suggests that sport-specific demands may influence limb dominance and strength profiles. This finding underscores the importance of individualized assessments and training programs tailored to the unique biomechanical demands of futsal.

#### Study Limitations

While this study offers valuable insights, several limitations must be acknowledged. First, the relatively small and homogeneous sample limits the generalisability of the findings to broader populations, including athletes of varying ages, skill levels, and sporting disciplines. Male participants trained approximately 10 h·wk<sup>-1</sup> and competed in the first professional division, whereas female participants trained approximately 5 h·wk<sup>-1</sup> in the second division. These disparities in competitive level and training load may partially explain the sex-related neuromuscular differences observed and limit the applicability of the results across different tiers of competition.

Although OCTOcore and PodoGRIP® have demonstrated excellent intra-session reliability in futsal players, multi-centre studies involving ethnically and athletically diverse populations are required prior to widespread clinical adoption. Future research should include larger and more heterogeneous cohorts to validate these findings and investigate potential variability across demographic and sport-specific groups.

Second, the cross-sectional nature of the study precludes any inference of causality regarding the relationships between ankle dorsiflexion, toe flexor strength, and core stability. Longitudinal studies are necessary to determine whether these variables influence injury risk and athletic performance over time. Furthermore, incorporating advanced biomechanical tools such as motion capture systems and surface electromyography could provide deeper insights into the neuromuscular mechanisms underpinning the observed associations.

## Conclusions

In conclusion, this study reveals distinct gender-specific correlations among ankle mobility, foot strength, and core stability in futsal players. The findings underscore the importance of considering gender-specific biomechanical profiles when designing training and rehabilitation programs. For men, the positive correlation between ankle dorsiflexion and first toe strength highlights the interconnectedness of distal and proximal factors in optimizing performance. In women, greater ankle mobility in women may be associated with better core stability. Prospective and interventional studies are necessary to verify the directionality of the relationships observed. Future research should explore these relationships in broader populations and investigate their long-term implications for injury prevention and performance optimization in futsal and other high-intensity sports.

#### Ethics approval

*The study received ethical approval from the CyMO Research Institute (Approval No. 1.300.421) and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki 1964 and its later amendments.*

#### Authors' contributions

*Iñigo Asurmendi and Pedro J. Marín made substantial contributions to the conception and design of the manuscript. Iñigo Asurmendi and María Oficialdegui were primarily responsible for data acquisition, analysis, and interpretation. All authors contributed to drafting the manuscript and critically revised its content. All authors read and approved the final version of the manuscript.*

#### Acknowledgments

*The authors would like to thank all the participants for their excellent cooperation.*

## References

1. Beato M, Coratella G, Schena F, Hulton AT. Evaluation of the external & internal workload in female futsal players. *Biol Sport* 2017;34:227-231.
2. Makaje N, Ruangthai R, Arkarapanthu A, Yoopat P. Physiological demands and activity profiles during futsal match play according to competitive level. *J Sports Med Phys Fitness* 2012;52:366-374.
3. López-Segovia M, Vivo Fernández I, Fernández F, Rubén RR, Carrasco H, Blanco FP. Preseason injury characteristics in Spanish professional futsal players: The LNFS Project. *J Strength Cond Res* 2019;33:232-237.
4. Lopez-Alcorocho JM, Martinez-Riaza L, Herrero-Gonzalez H, Guillen-Garcia P, Fernandez-Jaen TF. Epidemiology of injuries in the Spanish national futsal male team: a five-season retrospective study. *BMJ Open Sport Exerc Med* 2017;3:e000229.
5. Oliveira JP, Sampaio T, Marinho DA, Barbosa TM, Morais JE. Exploring injury prevention strategies

- for futsal players: A systematic review. *Healthcare* 2024;12:1387.
6. Lago-Fuentes C, Jiménez-Loaisa A, Padrón-Cabo A, Calvo MM, García-Pinillos F, Rey E. Epidemiology of injuries in elite female futsal players: A prospective cohort study. *Int J Sports Med* 2020;41:885-890.
  7. Lago-Fuentes C, Jiménez-Loaisa A, Padrón-Cabo A, Mecías-Calvo M, Rey E. Perceptions of the technical staff of professional teams regarding injury prevention in Spanish national futsal leagues: A cross-sectional study. *PeerJ* 2020;8:e8817.
  8. Almansoof HS, Nuhmani S, Muaidi Q. Role of ankle dorsiflexion in sports performance and injury risk: A narrative review. *Electron J Gen Med* 2023;20:em534.
  9. Guillén-Rogel P, Emeterio CS, Marín PJ. Associations between ankle dorsiflexion range of motion and foot and ankle strength in young adults. *J Phys Ther Sci* 2017;29:1363-1367.
  10. Chuter VH, Janse de Jonge XAK. Proximal and distal contributions to lower extremity injury: A review of the literature. *Gait Posture* 2012;36:7-15.
  11. McKeon PO, Hertel J, Bramble D, Davis I. The foot core system: A new paradigm for understanding intrinsic foot muscle function. *Br J Sports Med* 2015;49:290.
  12. Hewett TE, Myer GD. The mechanistic connection between the trunk, hip, knee, and anterior cruciate ligament injury. *Exerc Sport Sci Rev* 2011;39:161-166.
  13. Adillón C, Gallegos M, Treviño S, Salvat I. Ankle joint dorsiflexion reference values in non-injured youth federated basketball players: A cross-sectional study. *Int J Environ Res Public Health* 2022;19:11740.
  14. Calatayud J, Martín F, Gargallo P, García-Redondo J, Colado JC, Marín PJ. The validity and reliability of a new instrumented device for measuring ankle dorsiflexion range of motion. *Int J Sports Phys Ther* 2015;10:197-202.
  15. Guillén-Rogel P, Franco-Escudero C, Marín PJ. Test-retest reliability of a smartphone app for measuring core stability for two dynamic exercises. *PeerJ* 2019;7:e7485.
  16. San Emeterio C, Cochrane D, Guillén-Rogel P, Marín PJ. Short-term effects of lumbopelvic complex stability training in elite female road cyclists. *J Musculoskeletal Neuronal Interact* 2022;22:62-69.
  17. Mansi MK, Chockalingam N, Chatzistergos PE. The enhanced paper grip test can substantially improve community screening for the risk of falling. *Gait Posture* 2024;108:157-163.
  18. Xu J, Goss DD, Saliba SA. A novel intrinsic foot muscle strength dynamometer demonstrates moderate-to-excellent reliability and validity. *Int J Sports Phys Ther* 2023;18:997-1008.
  19. Hébert-Losier K, Wessman C, Alricsson M, Svantesson U. Updated reliability and normative values for the standing heel-rise test in healthy adults. *Physiotherapy* 2017;103:446-452.
  20. Cohen J. A power primer. *Psychol Bull* 1992;112:155-159.
  21. Yazdani F, Razeghi M, Karimi MT, Salimi Bani M, Bahreinizad H. Foot hyperpronation alters lumbopelvic muscle function during the stance phase of gait. *Gait Posture* 2019;74:102-107.
  22. Fukuyama H, Maeo S, Kusagawa Y, Sugiyama T, Kanehisa H, Isaka T. Differences in the Size of Individual Plantar Intrinsic Foot Muscles Between Ballet Dancers and Non-Dancers. *J Dance Med Sci* 2025;29:91-97.
  23. Graci V, Van Dillen LR, Salsich GB. Gender differences in trunk, pelvis and lower limb kinematics during a single leg squat. *Gait Posture* 2012;36:461-466.
  24. Yamauchi J, Koyama K. Importance of toe flexor strength in vertical jump performance. *J Biomech* 2020;104:109719.