

RESEARCH ARTICLE

Anterior component of Y-Balance test is correlated to ankle dorsiflexion range of motion in futsal players: A cross-sectional study

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Abstract

Background and purpose: Restricted dorsiflexion range of motion (DFROM) could impact dynamic balance in sports. This study aimed to investigate the relationship between dorsiflexion range of motion and the Y-Balance Test (YBT) in elite futsal players.

Methods: Sixty-one asymptomatic male futsal players (mean age 26.57 (5.64) years, a mean body mass index of 25.40 (2.69) kg/m²) were included. DFROM was measured by the weight-bearing lunge test (WBLT). DFROM data were obtained using smartphone-based motion capture. The Pearson correlation coefficient verified the correlation between the variables.

Results: Dominant and nondominant leg ankle DFROM was significantly correlated with the anterior component of YBT ($r = 0.27$ and 0.51 , respectively). The posteromedial component and the composite score of the YBT were also significantly correlated with nondominant leg ankle DFROM ($r = 0.31$ and 0.34 , respectively). The other measures were not statistically significant. DFROM explained between 7% and 24% of the variation of the distances reached in the YBT.

Conclusion: Dorsiflexion range of motion measured by weight bearing lunge test is positively correlated with dynamic balance in futsal players.

KEYWORDS

dynamic balance, lower extremity, range of motion, sports

1 | INTRODUCTION

Futsal is a popular sport with high levels of lower limb injuries. Futsal has more than one million registered players around the world (López-Segovia et al., 2019). The reduced court and more intense physical demand increase the risk of injury compared to the 11-a-side football (Martinez-Riaza et al., 2017). Also, injury rates for male players during futsal matches are estimated to be 44.9 per 1000 h of exposure (Iñaki Ruiz-Pérez et al., 2020). Lower limb injuries accounted for 92.1% of all

injuries in the pre-season of a national futsal championship (López-Segovia et al., 2019). The prevalence of ankle joint injuries can reach 40% of total injuries (Angoorani et al., 2014). Thus, the ankle is a crucial joint for futsal players' participation.

Ankle dorsiflexion is essential during lower limb movements (Smith et al., 2019). Reduced ankle dorsiflexion may be associated with poor physical performance in futsal players due to its value in dynamic balance in futsal and jumping and landing tasks in football (Akbari et al., 2023; I Ruiz-Pérez et al., 2019). In addition, reduced

ankle dorsiflexion range of motion (DFROM) is a predictor factor of anterior cruciate ligament injury (Amraee et al., 2017; Wahlstedt & Rasmussen-Barr, 2015) and ankle sprain (Willems et al., 2005). Several methods are available to measure the DFROM, and the weight-bearing lunge test (WBLT) quantifies the DFROM during a forward lunge in a tandem stance (Powden, Hoch, & Hoch, 2015).

Y-balance test (YBT) is a clinical, time-efficient, and portable method to measure the lower limb dynamic balance (Donovan et al., 2022). YBT involves hip, knee, and ankle neuromuscular control alongside core stability and preserves the active range of motion of the lower extremity joints in the sagittal plane to complete the task. Prior research has shown that poor YBT performance is associated with higher injury rates in basketball players and Division 1 collegiate athletes (Hegedus et al., 2015; Plisky et al., 2006; Smith et al., 2015). Moreover, the anterior direction of the YBT is the most sensitive in identifying balance asymmetries (Stiffler et al., 2017). A moderate correlation between the DFROM and the anterior distance reached in YBT in healthy adults (Kang, Lee, et al., 2015), and patients with chronic ankle instability (Hoch et al., 2012) was previously described. Indeed, DFROM was the best predictor of the anterior direction of the YBT in healthy adults (Kang, Kim, et al., 2015) and healthy male military personnel (Nakagawa & Petersen, 2018). Although the relationship between DFROM and the distance reached in YBT has been described, there is still a lack of investigation, including different sports modalities.

The Y-Balance Test is related to the hip, knee, and ankle range of motion. Only one study investigated elite male futsal players, supporting a notable role of ankle mobility in sport-specific participation (I Ruiz-Pérez et al., 2019). Thus, exploring the relationship between dorsiflexion and Y-Balance Test might explain how dorsiflexion contributes to dynamic balance in futsal players. Therefore, this study aimed to investigate the relationship between DFROM and the YBT in futsal players. We hypothesized that the DFROM measured by the WBLT would positively correlate with the distance reached in the YBT.

2 | METHODS

2.1 | Study design

This is a cross-sectional study reported according to the requirements of Strengthening the Reporting of Observational Studies in Epidemiology (STROBE). The study was approved by the Ethics Committee of the Augusto Motta University Centre (UNISUAM), conducted following the Helsinki Declaration for research in humans (CAAE 28703520.5.0000.5235). Informed consent was obtained from all participants before the data collection.

2.2 | Participants

Elite male futsal players were recruited by convenience sampling from Division I local league teams in Paraná, Brazil who competed at

the national level between June and October 2020. Athletes aged over 18 years, members of a professional futsal team, and routinely participating in team training were included. Participants were excluded if they reported lower limb or back pain on the assessment day or could not complete the study protocol.

2.3 | Procedures

A self-administered questionnaire collected demographic characteristics (age, body height, and mass), sports participation (hours per week), and leg preference. A single self-reported item determined the participant's leg preference ("If you would shoot a ball on a target, which leg would you use to shoot the ball?"). Afterwards, the DFROM was measured by the WBLT. All participants' data were obtained from examiner 1 (CZR), a physiotherapist with 10 years of clinical experience in movement assessment.

2.4 | Y-Balance test

The YBT is the instrumented version of the Star Excursion Balance Test. This instrument is a compound of a central platform and three plastic tubes that extend in the anterior, posteromedial, and posterolateral directions (WCS tecnologia, Brazil). The posterior tubes are positioned at 45 and 135° relative to the anterior tube (Picot et al., 2021). This test measures the dynamic balance of the support lower limb during a single leg reaching task. The participants were oriented to push a plate to reach three different directions (anterior, posteromedial and posterolateral) as far as possible with the non-stance foot. Greater distances represent better dynamic balance (Powden et al., 2019). The test was repeated if the participant touched the floor before returning to the starting position, moved any part of the support foot, or kicked the box to achieve a better result (Bulow et al., 2019). The test order was similar for all participants (anterior, posteromedial, and posterolateral). The maximum distance reached after three trials was recorded in centimetres and then normalised using the length of each participant's leg, measured with a tape from the anterior superior iliac spine to the medial malleolus in the supine position (Bulow et al., 2019). We calculated the relative distance in each direction (maximum reached distance/limb length $\times$ 100). A composite score of YBT performance was calculated using the following equation: Composite score = average of the reached distance in the 3 directions [(anterior, posteromedial, and posterolateral)/(3 $\times$ limb length) $\times$ 100]. This test has demonstrated excellent intra-rater reliability, with median intraclass correlation coefficient values of 0.88 (anterior), 0.88 (posteromedial) and 0.90 (posterolateral) (Powden et al., 2019). Participants with ≥ 0.04 m of difference between the right and left distances reached in the anterior component of the YBT were classified as asymmetric players with increased risk of injury (Plisky et al., 2006).

2.5 | Weight bearing lunge test

The participant was positioned on the central platform of the YBT. Initially, the foot was placed behind a line marked on the platform. A box measuring 1-m height was positioned 10 cm in front of the line of the central block of the YBT instrument to provide bodyweight support during the test (Figure 1). The lunge movement was performed in the anterior direction with knee and hip flexion. If the knee touched the box, it was moved 1 cm forward. Each participant performed three practice trials before the data acquisition. Ankle dorsiflexion was measured when the maximum range of motion was reached without touching the box. The test was repeated if any foot part lost contact with the platform. This test has demonstrated excellent inter-rater reliability, with intraclass correlation coefficient values ranging from 0.80 to 0.99 (Powden et al., 2015), evaluating the maximum advance of the tibia on the talus with weight support (Hoch & McKeon, 2011).

2.6 | Smartphone-based motion capture

DROM was obtained during the WBLT. The movements were recorded with two smartphones (Xiaomi Redmi 5 plus; 12 megapixels 4000 × 3000 pixels resolution; 1.25 µm pixel size; 30 frames per second). The smartphones were positioned in the sagittal plane 1 m and a half from the YBT central platform on a tripod at a height of 0.2 m. Before performing the tests, examiner 1 drew three reference marks on the participants' legs (fibular head, lateral malleolus, and fifth metatarsal head) with a black pen. Maximum ankle dorsiflexion angles were defined as the angle between a vertical line starting at the lateral malleolus and a second line connecting the lateral malleolus and the fibular head (Dingenen et al., 2019). Image processing was done using the software Kinovea® (version 0.9.3), a valid and reliable tool for measuring angles up to 5 m long (Puig-Diví

et al., 2019). We calculated the inter-examiner reliability of the DFROM during the WBLT between two examiners. Examiner 2 (GFT), a physiotherapist with 9 years of experience in movement analysis, was blinded to the results of examiner 1 (CZR). Before the study, the examiners underwent three online meetings (4 hours) for specific image and video analysis training.

We estimated the interrater reliability of measurements using a 2-way random-effects model of the intraclass correlation coefficients (ICCs) with the consistency type. DFROM measurements obtained during the WBLT were used by examiners 1 and 2 (ICC_{2,1}). The inter-examiner reliability of the measurements was good to excellent (ICC_{2,1} between 0.971 and 0.973). The standard error of the measurement (SEM = SD pooled × √1-ICC) was also estimated (Supplementary Table S1).

2.7 | Sample size

The sample size calculation was based on a previous study that investigated the correlation between DROM and the Y-Balance Test in physically active participants (Kang, Lee, et al., 2015). We estimated a minimum Pearson correlation coefficient of 0.4 between the WBLT and the Y-balance test. A total of 61 participants was necessary, using an alpha of 5% and 90% of power on a two-sided correlation test. Considering 25% participant exclusion due to data collection errors, we recruited 75 participants (Stiffler et al., 2017). The sample calculation was estimated using the G*Power Software version 3.1.9 (Heinrich-Heine-Universität, Düsseldorf, Germany).

2.8 | Statistical analysis

Descriptive analysis of sociodemographic and clinical data was performed. Continuous variables were presented as mean and standard

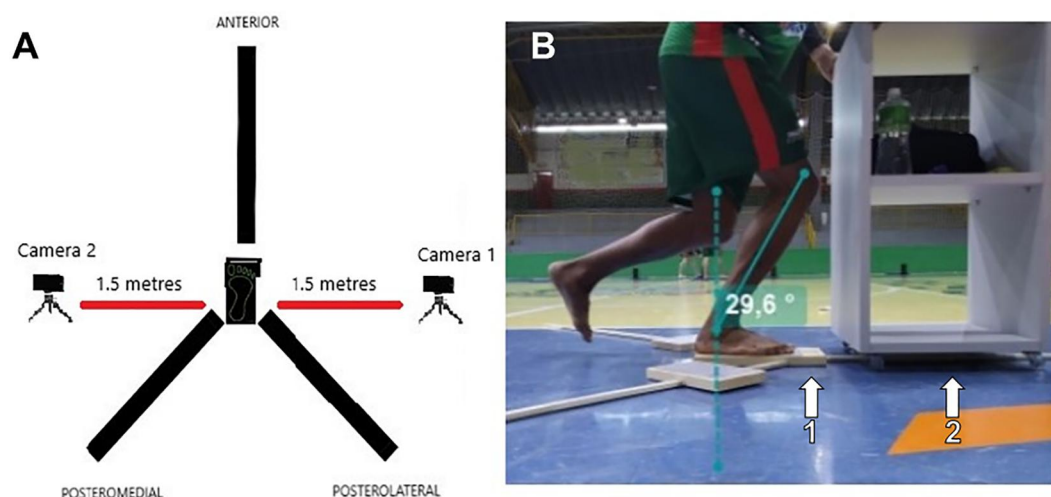


FIGURE 1 Experimental set-up and measurement of the ankle dorsiflexion range of motion. (a), The Y-Balance Test and cameras position scheme (up view). (b), Participant's position during the ankle dorsiflexion range of motion assessment (side view). 1, Y-Balance Test central platform. 2, bodyweight support box.

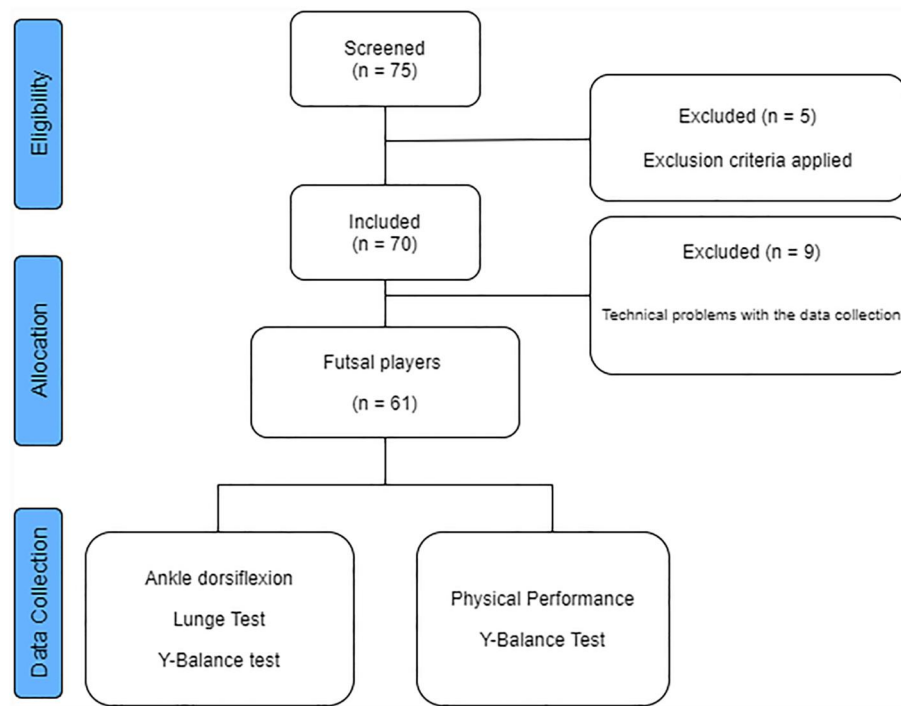


FIGURE 2 Study flowchart.

deviation (SD), and the categorical variables were presented in absolute values and proportions (%). The normality of distribution was assessed by the Shapiro-Wilk test. Statistical analysis was performed using GraphPad Prism (GraphPad Software, San Diego, CA, USA). The Pearson correlation coefficient was used to assess the correlation between the DFROM and the YBT (anterior, posteromedial, posterolateral) scores. The values were expressed as correlation coefficients and confidence intervals (95%). The correlation above 0.90 was interpreted as very high, from 0.70 to 0.89 as high, from 0.50 to 0.69 as moderate, from 0.30 to 0.49 as low, and below 0.29 as mild (Hinkle et al., 2003). For each correlation analysis, the percentage of explained variance (R^2) was calculated through linear regression analysis.

2.9 | Sensitivity analysis

We performed sensitivity analyses to verify the correlation between DFROM and YBT scores considering futsal players at risk of injury (Supplementary Tables S2 and S3).

3 | RESULTS

Seventy-five participants were screened, 5 were excluded as they reported pain, and 9 due to data collection errors (Figure 2). All 61 remaining participants completed the study without adverse events. The mean age of the participants was 26.57 (5.64) years, a mean BMI of 25.40 (2.69) kg/m², and a mean training exposure of 17.77 (4.07) hours per week. The demographic and clinical characteristics of the participants are summarised in Table 1.

TABLE 1 Demographic and clinical characteristics of the participants.

Variables	Values
Age (years)	26.57 (5.64)
Body Mass index (kg/m ²)	25.40 (2.69)
Educational level	
Lower secondary school, n (%)	3 (4.92)
Higher secondary school, n (%)	43 (70.49)
Higher education, n (%)	15 (24.59)
Training exposure (hour/week)	17.77 (4.07)
Length of time in the profession (years)	9.21 (5.85)
Position	
Goalkeeper, n (%)	12 (19.67)
Defender, n (%)	11 (18.03)
Winger, n (%)	28 (45.90)
Pivot, n (%)	10 (16.39)
Self-reported leg preference (right), n (%)	46 (75.41)
Y-Balance test asymmetry n (%)	21 (34.40)

Note: Continuous variables are presented as mean (standard deviation) and categorical variables in absolute values (percentage).

Abbreviation: kg/m², kilograms per metre squared.

The descriptive values of the DFROM and YBT are presented in Table 2.

A positive statistically significant correlation was found between the DFROM and the anterior component ($r = 0.27$, 95%CI 0.02–0.49)

of the Y-Balance Test for the dominant leg. Furthermore, a positive statistically significant correlation was found between the DFROM and the anterior component ($r = 0.51$, 95%CI 0.30–0.67), posteromedial component ($r = 0.31$, 95%CI 0.06–0.52) and the composite score ($r = 0.34$ 95%CI 0.10–0.54) of the YBT for the nondominant leg. According to the percentage of explained variance (R^2), DFROM explained between 7% and 24% of the variation of the distances reached in the YBT. Correlation and R^2 values are presented in Table 3.

Sensitivity analysis revealed similar results for futsal players without the risk of injury, except for the anterior component of the dominant leg. Futsal players with a risk of injury did not demonstrate a correlation between DFROM and YBT (Tables S2 and S3 in the supplemental material).

4 | DISCUSSION

The hypothesis appears to be supported since the DFROM measured by WBLT was related to dynamic balance in futsal players, especially in the anterior component of the dynamic balance. Futsal players

TABLE 2 Descriptive values of the ankle dorsiflexion Weight-Bearing Lunge Test and the reached distance in the Y-Balance Test.

	Dominant leg	Nondominant leg
WBLT (degrees)	36.63 (5.08)	35.77 (5.41)
Y-Balance test (%)		
Anterior	51.80 (6.88)	51.83 (6.82)
Posteromedial	108.76 (15.39)	106.24 (12.98)
Posterolateral	108.76 (14.08)	108.24 (13.27)
Composite score	89.78 (10.85)	88.77 (9.63)

Note: Values represented as mean and standard deviation.
Abbreviation: WBLT, Weight-Bearing-Lunge Test.

TABLE 3 The correlation between Y-balance test scores and ankle dorsiflexion range of motion according to ankles' leg preference.

	WBLT			
	Dominant leg		Nondominant leg	
Y-BT	r (95% CI)	r^2	r (95% CI)	r^2
Anterior	0.27* (0.02, 0.49)	0.07	0.51* (0.30, 0.67)	0.24
Posteromedial	0.16 (−0.01, 0.39)	0.10	0.31* (0.06, 0.52)	0.08
Posterolateral	0.23 (−0.01, 0.46)	0.08	0.24 (−0.01, 0.47)	0.05
Composite score	0.23 (−0.02, 0.46)	0.05	0.34* (0.10, 0.54)	0.12

Note: Values represented as correlation coefficient and confidence intervals.

Abbreviations: CI, confidence intervals; WBLT, weight-bearing lunge test.

* $p < 0.05$.

presented mild-to-moderate correlations between DFROM and the anterior and posteromedial components, besides the composite score of the YBT. Current findings confirmed the role of the DFROM, explaining between 7% and 24% of the distance reached by the YBT.

Our study has strengths and limitations. Physical performance and ankle movement are poorly investigated in elite futsal players, who are a target population for ankle disorders in sports. Conversely, we did not control the hip and knee kinematics, which play a role in the lower extremity dynamic balance (Nelson et al., 2021). Additionally, the dynamic DFROM might differ from the one obtained during the WBLT. Exploring DFROM during the YBT could explain the relationship between these two tests. The external validity should be interpreted cautiously because our sample was composed of asymptomatic futsal players. Thus, our data may not be extrapolated to injured athletes or other sports.

Our findings demonstrated that DFROM is related to lower limb dynamic balance in futsal players, corroborating previous reports in healthy adults (Hoch et al., 2012; Kang, Lee, et al., 2015) and participants with chronic ankle instability (Hoch et al., 2011). Likewise, past research showed that DFROM explained between 20.7% (López-Valenciano et al., 2019) and 50% (Kang, Kim, et al., 2015) of the YBT anterior distance, in the same way as the current findings. Salas-Gómez et al. found that hip strength and DFROM explained 66% of the variance in the YBT anterior direction in patients with ankle fracture surgery (Salas-Gómez et al., 2020). Moreover, we found a mild correlation between DFROM and the posteromedial component of the YBT in the nondominant leg. The posteromedial component can be used to assess balance impairments in athletes with chronic ankle instability (Udompanich et al., 2021). The relationship between DFROM and YBT composite score also needs to be considered because of the association between the composite score and the risk of lower limb injuries (Plisky et al., 2006). Our findings suggest that ankle DFROM has a small but relevant contribution to the dynamic balance of the lower limb.

DFROM was more frequently correlated with the YBT in the nondominant leg than in the dominant leg. The assessment of leg dominance is essential in football and futsal studies due to specific sports demands (González-Fernández et al., 2022). The nondominant leg likely stays standing longer than the dominant leg in futsal, leading to a high degree of lower extremity dynamic balance. Studies including YBT usually consider the lower limbs as right and left instead of dominant and nondominant (Plisky et al., 2006; Smith et al., 2015), and heterogeneity of the included sport modalities might explain this rationale (Smith et al., 2015; Wright et al., 2017). However, leg dominance must be considered during dynamic balance assessment.

The restriction in DFROM measured by the WBLT can partly explain the forward lunge movement performance. Hip and knee movement should also be considered in the lower extremity assessment due to the movement's contribution. Thus, the evaluation of the DFROM on a firm surface is encouraged for sports professionals. Future research should investigate the potential influence of previous lower extremity injuries or the presence of the ankle injury on

the physical performance. Dorsiflexion range of motion measured by weight bearing lunge test is positively correlated with dynamic balance in futsal players.

5 | IMPLICATIONS FOR PHYSIOTHERAPY PRACTICE

Ankle DFROM contributes mildly to the lower limb's dynamic balance. Clinicians should be aware that ankle DFROM restriction could impact the lower limb dynamic balance. Adding dorsiflexion assessment may assist in a more comprehensive lower limb evaluation in futsal players. A simple weight-bearing lunge test helps clinicians to identify a possible contribution of the ankle DFROM on the dynamic task of futsal players.

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CONFLICT OF INTEREST STATEMENT

The authors report that there are no competing interests to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The study was approved by the Ethics Committee of the Augusto Motta University Centre (UNISUAM) conducted following the Helsinki Declaration for research in humans (CAAE 287035 20.5.0000.5235).

PATIENT CONSENT STATEMENT

Informed consent was obtained from all participants before the data collection.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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