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Mediolateral Postural Sway Velocity as a Possible Indicator of Ground Reaction Force-Derived 180^0 Turn Performance in Male Soccer Players: A Cross-Sectional Study

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ABSTRACT

The main aim of the study was to investigate the relationship between ground reaction force (GRF) derived postural sway and 180° turn performance in soccer players on the axis of dominant and non-dominant legs. Twenty-seven male soccer players (mean age 22.45 ± 2.7 years) from the same league level agreed to participate in the study. The participants underwent GRF-derived postural sway and 180⁰ turn tests using a force plate in separate sessions, with at least 24-hour intervals between sessions. Postural sway was assessed in anteroposterior and mediolateral directions during a single-leg stance, while the 180° turn performance was evaluated through GRF-derived turn time and turn sway. The correlation, multiple regression, and group differences were computed to test study hypotheses. Positive correlations were observed between postural sway measures and 180⁰ turn time for dominant and non-dominant legs (r-range from 0.384 to 0.550). No measure of postural sway was significantly related to the 180⁰ turn sway ($p > 0.05$). Multiple stepwise regression analysis indicated that mediolateral sway velocity explained 30% and 17% of the variance of 180⁰ turn time for dominant and non-dominant legs, respectively. No statistical inter-limb differences were noted for 180⁰ turn and postural sway parameters. The results suggest that improving single-leg postural performance may enhance male soccer players' 180° turn performance. Therefore, unilateral stability in the mediolateral direction should be considered a potential indicator of change of direction-based performances.

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INTRODUCTION

Soccer is a team sport based on space-time interaction patterns in which two teams frequently use dynamic movements to dominate each other (Folgado et al., 2014). Players should be able to adjust maneuvers with and without the ball in line with the varying conditions during the competition (Travassos et al., 2012). Using unpredictable and creative movement patterns impacts reactions to defensive (i.e., preventing the dribbling or passing of attackers) and offensive (i.e., scoring situations) actions (Coutinho et al., 2018; Faude et al., 2012; Sasaki et al., 2015). In relation to the change in the form of the soccer game over the years, linear speed, explosive and high-intensity maneuvers (i.e., jump, acceleration, and deceleration), change of direction (COD), and functional mobility are considered prominent concepts for performance optimization (Falces-Prieto et al., 2022). COD ability is an important component of movements based on multidirectional changes at high speed and intensity. It is a parameter whose value increases, especially in the critical moments of the competition (Taylor et al., 2019). However, the variability of the criteria for determining the COD ability should be accepted as a factor that limits the interpretation of this information.

The 180^0 turn, which has a similar movement sequence to the COD speed, is among the crucial characteristics in sports where versatile movement patterns are used intensively (Dos'Santos et al., 2019). In soccer, one of the primary sports that fit this definition, the essential reflections of the 180^0 turn movement are defensive-offensive transitions (and vice versa) and sudden maneuvers to beat the opponent (Dos' Santos et al., 2021). When examined in biomechanical terms, sequential formations such as 180° change in the direction of movement, the horizontal momentum approaching zero, body rotation, horizontal braking, and re-acceleration take place (Jones et al., 2017). In this case, the player must perform speed and mechanical tasks optimally and support this movement sequence using their physical capacity (Dos' Santos et al., 2021; Spiteri et al., 2015). Moreover, unlike other COD and agility-modeled field tests, the 180° turn movement is closer to the actions in actual game conditions (Jordet, 2005). Falch et al. (2019) reported that time-domain evaluations conducted using electronic photocells usually obtained a COD-based ability with a complex structure. However, such an evaluation causes COD, an essential athletic and sport-specific performance criterion, to be interpreted from a single perspective. The 180^0 turn movement is generally interpreted as a combination of start and forward movement, turn, and finally finishing, which is a problematic approach. In fact, the most crucial segment of the 180^0 turn is the exact turning moment in terms of velocity and postural control. Furthermore, the performance outputs of the dominant and non-dominant legs during the turning moment cannot be fully explored. Contrary to this approach, the 180^0 turn movement, which can be tested as ground reaction force (GRF)-derived data obtained from a force plate (Rezaei et al., 2021), represents various data, including horizontal propulsive force, horizontal braking, and faster approach to the center of mass point (Dos' Santos et al., 2021; Schrier et al., 2014). On the other hand, this sudden turn movement suggests that postural control may affect the turn performance.

The dynamic nature of soccer enables COD-based movements and motor coordination skills to come to the fore (Alesi et al., 2015). In this respect, postural control is considered one of the most fundamental elements of motor coordination. As expected, keeping the body in balance during a dynamic task can increase the movement's effectiveness (Holden et al., 2014). Accordingly, it has been reported that postural evaluations performed unilaterally are helpful in terms of identifying possible lower-limb asymmetries instead of bilateral assessment (Yalfani & Raeisi, 2022). Additionaly, postural stability assessment on a single-leg stance is considered more accurate than a double-leg stance as many sports skills are performed on one leg, for competitive athletes (Meiners & Loudon, 2020). Furthermore, it has been emphasized that balance and stability exercises increase control in the knee area (frontal plane) during static and dynamic tasks (Waldén et al., 2012). The aforementioned information makes it worth examining the relationship between postural control and COD in producing a dynamic task. This phenomenon has been tested in a recent study, indicating that COD is associated with the asymmetry index (Trecroci et al., 2020). Sekulic et al. (2013) reported similar results, stating that balance might be an agility predictor for trained adult males. However, an all-round postural analysis (i.e., sway path, velocity, and area) specific to the dominant and non-dominant legs seems necessary to obtain more explicit findings on this possible relationship.

Due to the increasing use of force plates in sports sciences in recent years, valid and accurate axial force-centered biomechanical and posturographic data can be obtained (Beckham et al., 2014). Owing to GRF-derived measurements to be performed in laboratories, postural sway measures will be evaluated in anteroposterior and mediolateral directions. Moreover, a time and postural sway-oriented evaluation will be possible by focusing only on the moment of turn, not all segments of the 180° turn movement (Schrier et al., 2014). To our knowledge, this is the first trial to evaluate GRF-derived 180^0 turn performance in male soccer players. Therefore, the main aim of the study was to investigate the relationship between GRF-derived postural sway and 180° turn performance in soccer players on the axis of dominant and non-dominant legs. Moreover, we also aimed to determine the potential inter-limb differences of athletes in postural sway and 180^0 turn measurements. We hypothesized that

GRF-derived postural sway parameters would correlate with 180° turn performance (hypothesis 1), and dominant/non-dominant leg GRF-derived postural sway and 180° turn performance parameters would not significantly differ (hypothesis 2).

METHODS

Participants

Twenty-seven uninjured male trained soccer players (mean age 22.45 ± 2.7 years, ranging from 18 to 24; n = 24 right-limb dominant; n = 3 left-limb dominant) from the same league level (regional category) voluntarily participated in the study. All players were familiar with the study measurements. The preferred leg during shooting and/or passing a ball was determined as the dominant limb (van Melick et al., 2017). All participants attended team training sessions five times per week, plus one competitive match at the weekend. Table 1 contains the baseline characteristics of the study participants.

The inclusion criteria were determined as follows: being aged ≥ 18 years, having a personal competitive experience for a minimum of 3 years, not smoking, having no musculoskeletal injury and neurological, orthopedic, or cardiovascular diseases in the six months before the tests. The exclusion criteria were as follows: experiencing severe pain in the lower extremity during athletic tests and not participating in ≥ 80% of weekly training sessions. All participants were fully informed about the study procedures (i.e., athletic performance tests and sessions) and potential risks (Makaracı et al., 2021). The participants provided verbal and written informed consent before the study procedures. All procedures were in accordance with the Declaration of Helsinki and were approved by the clinical research ethics board at Karamanoğlu Mehmetbey University, Türkiye (Document no: 10-2022/14; Date: 08.11.2022).

Table 1
Demographic Characteristics of the Study Participants

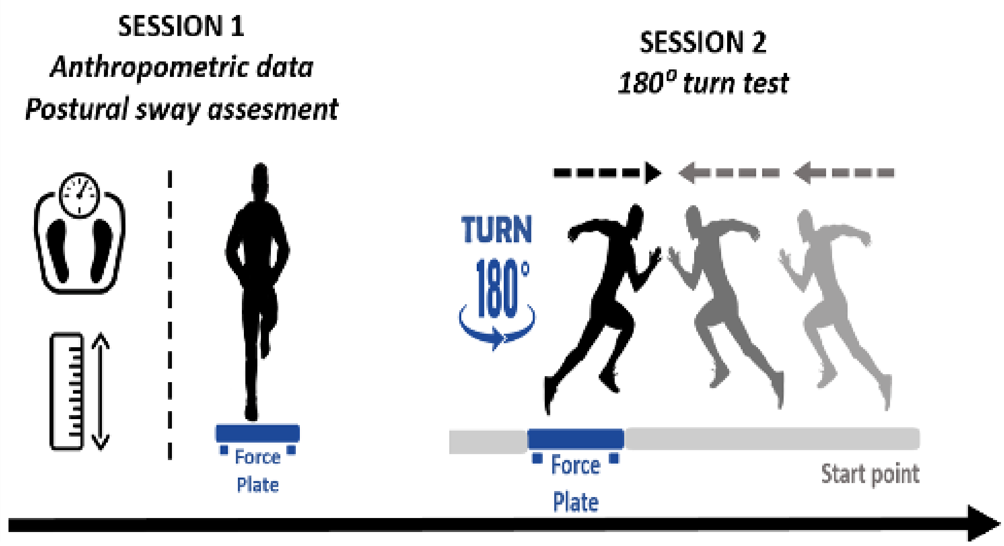
Variables	N = 27
Age (years)	22.45 ± 2.17
Body mass (kg)	72.33 ± 5.15
Body height (m)	1.79 ± 0.16
Body mass index (kg/m^2)	22.65 ± 3.07
Sports experience (years)	7.85 ± 1.64

Procedure

This cross-sectional study explored the correlation between GRF-derived single-leg postural sway and 180^0 turn performance on both legs. All tests were conducted during the in-season period. The study participants have not attended any training session and competition during the tests. The participants completed two testing sessions separated by at least 24 hours. Anthropometric and postural sway data were measured during session 1. Following an individual warm-up before the postural sway assessment, players performed practice trials for both legs to become familiar with the task. The warm-up was followed by at least five minutes of rest. The postural sway measures were then taken on the dominant and non-dominant legs, respectively.

The participants underwent a 180^0 turn test separately for each limb (dominant and non-dominant) during session 2. Before the test trials, the players carried out a standardized warm-up consisting of 5 minutes of low-to-moderate speed running, dynamic stretching, and submaximal pre-planned right and left-limb turns, lasting 10 minutes (Fletcher & Monte-Colombo, 2010). All testing procedures (5 p.m. to 7 p.m.) were carried out at the same time of the day and supervised by the same researchers. All athletes' clothing was typical soccer players' wear during the athletic tests. Figure 1 shows the experimental design of the study.

Figure 1
Schematic Design of the Study



Data Collection Tools

The GRF-derived postural sway and 180^0 turn were sampled at 1000 Hz from a portable force plate (Kistler, Winterthur, Switzerland; type 9260AA6; 600x500x50 mm). A 16-ch data acquisition system (type 5691A; Switzerland; USB 2.0) and BioWare software were used to send the force plate signals to a personal laptop computer (HP Probook 450 G6 with Core i7) and then exported to Excel (version 2016, Microsoft Corp., Redmond, WA, USA). Kistler MARS software (Kistler MARS, S2P Ltd., Ljubljana, Slovenia) was used to analyze the quantified test parameters related to single-leg postural sway and 180^0 turn performance (Šarabon, 2011).

Anthropometrics

Before the first test trial, the force plate measured body mass with light clothes and without shoes. A portable calibrated stadiometer (seca 220, Seca, Hamburg, Germany) was used to measure body height. The body mass index was calculated as weight/height squared (kg/m^2).

Assessment Of Postural Sway

The single-leg postural sway measures through the center of pressure (CoP) data were recorded in the anteroposterior and mediolateral directions of sway. Postural sway measures were conducted for dominant and non-dominant leg stances with closed eyes using the protocol performed by Makaracı et al. (2021). During the postural sway assessment, the participants were asked to stay as still as possible and avoid any postural movements and talking. During the measurements, participants wore their running shoes and standardized ankle-height athletic socks (Barrons & Heise, 2020). The trials for each stance lasted 10 seconds due to the difficulty of testing. The players were tested consecutively in dominant and non-dominant leg stances, and the average of the three repetitions was used for further analysis.

The postural sway-related parameters obtained from MARS were computed for further analysis: Total Sway Path (TSP), Anteroposterior Sway Path (APSP), Mediolateral Sway Path (MLSP), Total Sway Velocity (TSV), Anteroposterior Sway Velocity (APSV), Mediolateral Sway Velocity (MLSV), Total Sway Area (TSA), Anteroposterior Sway Area (APSA), Mediolateral Sway Area (MLSA), and Ellipse Area 100% (EA 100%; Kozinc et al., 2021; Makaracı et al., 2021).

180^0 Turn Test

COD or changing locomotion is a widespread movement in different sports based on agility and quickness (Dos'Santos et al., 2019). 180^0 turn is a GRF-derived clinical test carried out on an anti-slip textured finish force plate, unlike the traditional field test measurement procedures. All participants underwent a standardized 180^0 turn test protocol on an anti-slip textured force plate fixed on a flat, rigid floor. A rubber gym flooring was used to ensure alignment between the running track and force plate, effectively preventing potential slip on the force plate (see Figure 1). Participants were positioned at least two steps away from the force plate (start point) while in an unloaded state (zero offset) before commencing the measurement.

During the test, participants were instructed to run forward for at least two steps ("running mode" as the gait type on the setup panel). They were then prompted to perform a sudden 180^0 turn on the force plate using a single leg (the tested leg), following the online instructions provided by MARS. Subsequently, after the turning movement, participants were required to run back to the start point using a minimum of two steps to obtain GRF-derived data with a natural movement pattern (Rezaei et al., 2021). The measurement automatically terminated upon the proper completion of the test. If a trial was not performed according to the test procedure (i.e., without contact with the plate or an incomplete 180^0 turn), the device software deemed it invalid. The trials were performed for the dominant and non-dominant legs, respectively. Each participant completed the 180^0 turn test three times, allowing for one minute of rest in between, and the average of three repetitions was recorded for analysis. Participants utilized their running shoes in all trials.

The GRF-derived 180º turn test parameters obtained from Kistler MARS included the following: turn time (the time required to perform the 180º in-place turn on the force plate) and turn sway (the average CoP velocity during the turn time refers to postural stability and is measured in millimeters per second; Rezaei et al., 2021).

Data Analysis

Data was analyzed using SPSS software (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to determine data normality. After normal distribution, Pearson's correlation coefficient was used to establish correlations between postural sway and 180^0 turn performance. The magnitude of the correlation (r) between the test parameters was interpreted as follows: ≤0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; and 0.9–1.0, almost perfect, respectively, in line with the guidelines (Hopkins et al., 2009). Scatter plots were produced for the selected postural sway and 180^0 turn performance parameters. Subsequently, the stepwise multiple regression analysis was used to determine the best predictor model for 180^0 performance for both limbs. To determine the significance of the correlations, crude and adjusted coefficients of determination (R^2) were utilized. The players' inter-limb differences in postural sway and 180^0 turn performances were tested by the independent sample t-test. Effect sizes (ES) for the *t*-test were calculated using the thresholds as suggested by Cohen (1988), where 0.2–0.49 is a small effect, 0.5–0.79 is a moderate effect, and ≥ 0.8 is a large effect. The level of significance was set at $p < 0.05$.

RESULTS

Correlations

A positive (moderate to large) correlation was found between postural sway measures and 180^0 turn time for both dominant and non-dominant legs ($p < 0.05$). No measure of postural sway was significantly related to the 180^0 turn sway for both legs ($p > 0.05$). Table 2 presents a correlation matrix for the dominant and non-dominant leg measures.

Table 2

Correlations Between Postural Sway Measures and 180^0 Turn Test

Parameters	Limb		TSP (mm)	APSP (mm)	MLSP (mm)	TSV (mm/s)	APSV (mm/s)	MLSV (mm/s)	TSA (mm2)	APSA (mm*s)	MLSA (mm*s)	EA 100% (mm2)
Turn time (s)	DL	r	0.536	0.435	0.538	0.548	0.424	0.550	0.492	0.056	0.441	0.311
		p	0.004*	0.023*	0.004*	0.003*	0.028*	0.003*	0.009*	0.781	0.021*	0.114
	NDL	r	0.384	0.211	0.501	0.383	0.197	0.506	0.383	0.334	0.129	0.306
		p	0.049*	0.291	0.007*	0.048*	0.325	0.005*	0.049*	0.089	0.522	0.120
Turn sway (mm/s)	DL	r	0.170	0.088	0.199	0.152	0.077	0.207	0.157	-0.012	0.350	0.217
		p	0.397	0.663	0.319	0.449	0.703	0.300	0.435	0.955	0.073	0.277
	NDL	r	-0.107	-0.102	-0.093	-0.111	-0.089	-0.097	0.013	-0.081	0.294	0.132
		p	0.595	0.611	0.645	0.580	0.658	0.630	0.950	0.688	0.137	0.512

Notes. TSP: Total Sway Path; APSP: Anterior-Posterior Sway Path; MLSP: Medial-Lateral Sway Path; TSV: Total Sway Velocity; APSV: Anterior-Posterior Sway Velocity; MLSV: Medial-Lateral Sway Velocity; TSA: Total Sway Area; APSA: Anterior-Posterior Sway Area; MLSA: Medial-Lateral Sway Area; EA 100%: Ellipse Area; DL: Dominant Leg, NDL: Non-Dominant Leg; *Denotes significant difference ($p<0.05$).

For the dominant leg, all postural sway parameters, except for APSA and EA 100%, were significantly correlated with turn time ($p < 0.05$; r-range from 0.424 to 0.550). TSP, MLSP, TSV, and MLSV were largely correlated (r = 0.50 - 0.70). For the non-dominant leg, TSP, MLSP, TSV, MLSV, and TSA were significantly correlated with turn time ($p < 0.05$; r-range from 0.384 to 0.506). MLSP and MLSV were largely correlated (r= 0.50 - 0.70). No correlation was detected for APSP, APSV, APSA, and MLSA ($p > 0.05$). The scatter plots for the correlations between postural sway measures and 180^0 turn time with large magnitudes (r values) for the dominant and non-dominant legs are presented in Figure 2.

Figure 2
Correlation of Mediolateral Sway Path and Mediolateral Sway Velocity with 180⁰ Turn Performance

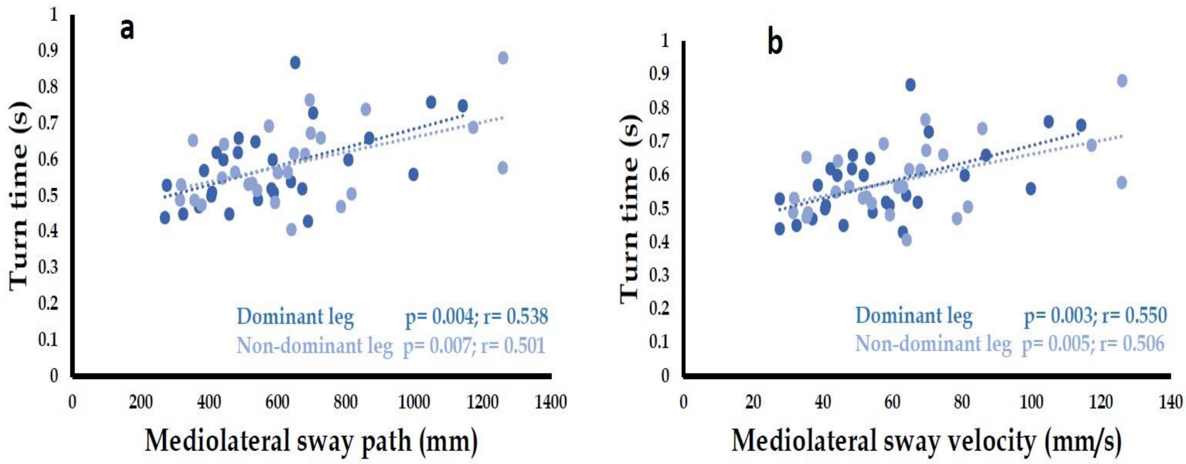


Figure 2 shows the correlation of MLSP and MLSV with 180⁰ turn performance for both legs. MLSP was positively correlated with turn time for both dominant (Figure 2a; r= 0.538) and non-dominant leg (Figure 2b; r= 0.501). MLSV was also positively correlated with turn time for both dominant (r= 0.550) and non-dominant leg (r= 0.506).

Multiple regression

The best-fitting equation for 180° turn time included only MLSV for both dominant and non-dominant leg measures. In the dominant leg 180° turn time, MLSV explained 30% of the variance (R^2= 0.302), while non-dominant leg MLSV explained 17% of the variance (R^2= 0.172) in the dominant leg 180° turn time. Table 3 contains stepwise multiple regression analysis results for MLSV.

Table 3
Stepwise Multiple Regression Analysis Results of Postural Sway Measures that Affected the Turn Time

	Limb	Model	Unstandardized Coefficients		Coefficients Beta	t	*p*	R^2 (adjusted R^2)
			B	S.E.				
Turn time (s)	DL	(Constant)	0.425	0.050	0.550	8.495	0.000	0.302 (0.374)
		MLSV (mm/s)	0.003	0.001		3.290	0.003*	
	NDL	(Constant)	0.494	0.050	0.415	9.901	0.000	0.172 (0.139)
		MLSV (mm/s)	0.002	0.001		2.281	0.031*	

Note. DL: Dominant Leg, NDL: Non-Dominant Leg; MLSV: Medial-Lateral Sway Velocity. *significant difference (p<0.05)

Comparisons

No statistical inter-limb differences were observed for the athletes during 180^0 turn and postural sway measures (p > 0.05). Table 4 presents the independent sample t-test results for detailed information.

Table 4
Inter-Limb Differences of 180^0 Turn Test and Postural Sway Measures

Parameters	Limb	Mean	S.D.	95% Confidence Interval	t	*p*	Effect size
Turn time (s)	Dominant	0.58	0.11	0.54 to 0.62	-0.738	0.464	0.19
	Non-dominant	0.60	0.10	0.56 to 0.64			
Turn sway (mm/s)	Dominant	1,065.0	599.2	839.0 to 1,291.0	-0.035	0.973	0.01
	Non-dominant	1,072.6	975.7	704.6 to 1,440.6			
TSP (mm)	Dominant	919.3	305.3	804.1 to 1,034.8	-0.761	0.450	0.20
	Non-dominant	982.3	302.9	868.1 to 1,096.5			
APSP (mm)	Dominant	588.6	174.0	523.0 to 654.2	-0.157	0.875	0.04
	Non-dominant	595.7	161.9	534.6 to 656.8			
MLSP (mm)	Dominant	584.6	229.1	498.2 to 671.1	-0.836	0.407	0.23
	Non-dominant	640.4	260.3	542.2 to 738.6			
TSV (mm/s)	Dominant	91.4	30.4	79.9 to 102.9	-0.815	0.419	0.22
	Non-dominant	98.2	30.5	86.7 to 109.7			
APSV (mm/s)	Dominant	59.2	17.5	52.6 to 65.8	-0.077	0.939	0.02
	Non-dominant	59.6	15.7	53.7 to 65.5			
MLSV (mm/s)	Dominant	58.0	22.8	49.4 to 66.6	-0.907	0.369	0.27
	Non-dominant	64.1	26.1	55.0 to 73.2			
TSA (mm^2)	Dominant	5,913.5	4,521.6	4,208.0 to 7,619.0	0.030	0.975	0.01
	Non-dominant	5,880.4	3,518.4	4,553.3 to 7,207.5			
APSA (mm*s)	Dominant	108.2	84.2	76.4 to 140.0	0.904	0.373	0.24
	Non-dominant	93.0	24.1	83.9 to 102.1			
MLSA (mm*s)	Dominant	107.2	39.7	92.2 to 122.2	-0.596	0.554	0.16
	Non-dominant	114.0	43.3	97.7 to 130.3			
EA (100%) (mm^2)	Dominant	590.7	562.1	378.7 to 802.2	0.418	0.678	0.11
	Non-dominant	537.4	353.2	404.2 to 670.2			

Notes. TSP: Total Sway Path; APSP: Anterior-Posterior Sway Path; MLSP: Medial-Lateral Sway Path; TSV: Total Sway Velocity; APSV: Anterior-Posterior Sway Velocity; MLSV: Medial-Lateral Sway Velocity; TSA: Total Sway Area; APSA: Anterior-Posterior Sway Area; MLSA: Medial-Lateral Sway Area; EA 100%: Ellipse Area.

DISCUSSION

The main originality of this study lies in the novel investigation of GRF-derived 180° turn performance on both lower limbs, a critical aspect for soccer-specific actions, specifically among male soccer players (Tang et al., 2018). In accordance with the study hypothesis, our findings demonstrated significant correlations (ranging from moderate to large) between most of the measured postural sway parameters (related to sway path, velocity, and area) with the 180^0 turn time using both the dominant and non-dominant legs. Additionally, MLSV was determined as a possible indicator of the 180° turn performance in the time context. We did not observe inter-limb differences for single-leg postural sway and 180° turn performance parameters.

Although the GRF-derived 180^0 turn test is a movement in COD form, it is biomechanically different. The COD performance is mainly evaluated in a time-specific manner, focusing on linear acceleration (Nimphius et al., 2017), while 180° turn requires reducing horizontal velocity to zero or close to it (Jones et al., 2017). Thus, it is impossible to interpret COD and 180° turn mechanics from the same perspective. Furthermore, GRF-derived COD protocols and the center of mass velocity, could be a more accurate and practically accessible method for a holistic and kinematic analysis of the 180° turn movement (Spiteri et al., 2013). The braking movement performed horizontally is critical for the turn time; therefore, we used an anti-slip textured finish force plate for the 180° turn movement. Our results showed that most of the GRF-derived postural sway parameters for both the dominant and non-dominant legs were correlated with the turn time (see Table 2). The GRF-derived postural sway parameters are CoP-based data in the anteroposterior and mediolateral directions. The body sway in the anterior direction is linked to increased knee flexion (Jiang et al., 2023) and ankle plantar flexion, especially during dynamic postural control in a single-leg stance (Nyland et al., 2002). Conversely, posterior sway corresponds to increased hip flexion (Lewis & Sahrmann, 2015) and ankle dorsiflexion (Amin & Herrington, 2014). Therefore, the correlation between anteroposterior sway (i.e., sway path and sway velocity) and 180° turn time may be attributed to the potential involvement of the hamstring and gastrocnemius muscles in the anterior direction and the iliopsoas and tibialis anterior muscles in the posterior direction. These muscles likely contribute to stabilizing the pelvic joint and facilitating the turn maneuver (De Ridder et al., 2014; Rouissi et al., 2018). A review study demonstrated that balance-based training could improve motor skills, although not as much as resistance training, resulting in increased power outputs (Hrysomallis, 2011). Overall, it can be interpreted that the lower limbs' postural control and explosive movements of the lower limbs may be correlated.

Unlike other studies, our study revealed the correlation between postural sway and 180° turn performance in dominant and non-dominant leg measures. Considering the strong correlation between lower-limb asymmetry and athletic performance in soccer players (Mala et al., 2020), the reflection of the 180° turn performance (i.e., time and velocity) on both legs is a noteworthy finding. Notably, we observed relatively higher correlation values in the dominant leg measures compared to the non-dominant leg (see Table 2), which is not surprising since the dominant leg is used in most movements and techniques in soccer-specific actions (Clemente et al., 2022). Two recent studies have investigated the relationship between COD ability, balance, and/or postural control. These findings are similar to ours, although no analysis has been performed from the unilateral perspective. Falces-Prieto et al. (2022) stated that the cross-hop test used as an indicator of dynamic balance was correlated with the 505 COD test (r= .440). Likewise, Ahmed, Saraswat, and Esht (2022) revealed that core strength, which is directly related to postural stability, and agility (t-drill) were negatively correlated (-0.579). However, when interpreting the correlation findings related to GRF-derived turn performance (i.e., time) and postural sway, it's essential to consider factors such as non-standard approach velocity to the turning point and the sole thickness and structure of the shoes used in the measurements for future studies. These factors could impact the results and contribute to a more comprehensive understanding of the relationship between GRF-derived turn performance and postural sway.

A different study reported balance ability as the strongest indicator of agility in male athletes from various team sports (Sekulic et al., 2013). Specifically, a deviation of the CoP along the x-axis indicates mediolateral sway (Zemková, 2014). Our multiple regression analysis revealed that MLSV was identified as the best predictor for 180° turn time in both the dominant and non-dominant legs (R^2= .302 and R^2= .172, respectively; see Table 3). This suggests that enhancing single-leg postural performance in the mediolateral direction could be an effective strategy to optimize the 180^0 turn performance of male soccer players. While the hip abductor and adductor muscles control mediolateral sway (Winter et al., 1993), the precise factors influencing this mechanism were unclear based on previous literature. Based on our findings, it should be noted that there is a correlation between postural stability and COD ability. This suggests a need for future research to explore postural performance in a unilateral form to obtain more precise and specific results related to COD and agility.

Although the primary aim of our study is to explore the correlation between postural sway and 180° turn performance, identifying a possible inter-limb difference should be considered a crucial aspect of the result interpretation. In this respect, GRF-derived postural measurements are among the most accurate analysis methods of inter-limb asymmetry (Newton et al., 2006). We did not observe a limb difference in the parameters obtained from 180° turn performance and postural sway parameters (see Table 4). Most soccer-specific drills (i.e., shooting, passing, and stopping) are realized with the effective use of the dominant leg (Bigoni et al., 2017). Zouhal et al. (2018) stated that the 180° turn movement was performed mostly with the support of the dominant leg. Like in many sports, in soccer, inter-limb asymmetry influences athletic performance adversely and is also expressed as a strong indicator of disability (Atkins et al., 2016). Furthermore, dynamic balance problems in soccer players are a factor that increases the risk of soccer-specific injury compared to the strength ratio between muscles (H/Q ratios; Behan et al., 2018). López-Valenciano et al. (2018) reported that dynamic balance-based training programs could reduce the risk of injury in female and male soccer players. Therefore, the absence of statistical inter-limb difference (postural sway and turn performance) for athletes in our study indicates that the participant group had a low risk of injury. Additionally, the determined partial bilateral balance can be considered a factor supporting the correlation findings discussed in detail above.

The study indeed presents valuable insights for the coaches and practitioners, yet several limitations must be acknowledged. The inability to measure the athletes' approach velocity until the turning moment during the 180^0 turn test and the lack of standardized shoe soles, even when striving to use similar ones, are significant constraints. Moreover, as the GRF-derived 180^0 turn test in our study was conducted for the first time in a trained group, comprehensive discussions about the obtained data are challenging, and generalizing the results is currently impractical, given the limited number of studies utilizing GRF-derived COD tests. While the study's outcomes are particularly relevant to soccer players, caution should be exercised when extending these findings to athlete profiles in other team sports. Furthermore, considering the dissimilarities in lower-limb movement patterns between female and male athletes (Bailey et al., 2015), a gender-based evaluation is essential for future studies.

CONCLUSION

In conclusion, a positive correlation was found between postural sway measures and 180^0 turn time for dominant and non-dominant leg measures. MLSP and MLSV were positively correlated with turn time for both legs. Furthermore, MLSV was determined as the possible indicator of 180^0 performance in the context of "time." This result may suggest that improving single-leg postural performance in the mediolateral direction could optimize the 180^0 turn performance of male soccer players. In addition to postural sway, associated with the 180° turn performance, different body stability assessments should also be considered in future studies.

PRACTICAL IMPLICATIONS

Our findings suggest that enhancing unilateral stability can improve agility and change of direction skills. Including unilateral stability exercises in training programs can help athletes develop better control and stability in one leg at a time, which is crucial for executing sudden turns and direction changes in dynamic situations. These exercises can target muscles and motor control specific to the mediolateral plane, improving the ability to maintain balance and control during lateral movements. Therefore, fitness coaches should assess individual athletes for deficits in mediolateral stability and design training programs targeting these areas.

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Authors' contribution

The first author contributed to the conception and design, analysis and interpretation, and original draft writing of the manuscript; the second author contributed to reviewing the conception and design, interpretation of the data, critical review, and editing; the third author contributed to reviewing the conception and design, data collection, interpretation of the data, critical review, and editing; the fourth author contributed to reviewing the conception and design, data collection, interpretation of the data, critical review, and editing; and the fifth author contributed to reviewing the conception and design, data collection, interpretation of the data, critical review, and editing. All authors have read and approved the final version of the manuscript.

Declaration of conflict interest

No potential conflict of interest was reported by the authors.

Ethics Statement

The study protocol was approved by the clinical research ethics board at Karamanoğlu Mehmetbey University, Türkiye (Document no: 10-2022/14; Date: 08.11.2022).

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