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Original Article

# Smartphone-Assessed Single-Leg Deadlift Stability is Associated with Sprint Velocity in Youth Soccer Players: A Cross-Sectional Study

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## Abstract

**Objectives**: To investigate the relationship between core stability and neuromuscular performance (i.e., sprint velocity and change-of-direction speed) among adolescent male football players. **Methods**: In this cross-sectional study, sixteen high-level male football players were divided into higher and lower core stability groups based on their performance in a partial range single-leg deadlift (SLD) test, assessed using a smartphone application (OCTOcore© app). Neuromuscular performance was assessed with a 30-m maximal sprint test (with 5-m split intervals) and a V-cut test, and these outcomes were correlated with SLD test results. **Results**: Statistically significant differences were observed between higher and lower core performance groups in the SLD test ($p = 0.001$) and between SLD non-dominant and 30-m maximal sprint test ($p = 0.001–0.005$), while no differences were founded between SLD performance and V-cut test ($p>0.05$). A large correlation was found between non-dominant SLD and 10-m sprint performance ($r = 0.765$, $p = 0.001$), while moderate correlations were observed for the 15-, 20-, 25-, and 30-m sprints ($r = 0.508–0.562$, $p = 0.023–0.044$). No significant correlations between SLD performance and the V-cut test ($p>0.05$). **Conclusion**: Core stability appears to be positively associated with sprint performance (0–30 m) but not with change-of-direction speed, suggesting that it plays a greater role in linear acceleration than in multidirectional tasks.

**Keywords:** Core, Football, Neuromuscular, Team-Sports

## Introduction

Football (soccer) is a team sport, characterized by short bouts of high-intensity training interspersed with low-moderate intensity periods[1,2]. It is well established that football players must possess a combination of technical, tactical, physical and psychological skills to perform at a high level[3,4]. From a physical standpoint, competitive football players require a combination of high levels of muscle strength/power, change-of-direction (COD) speed and velocity in short-distances[5] reported superior neuromuscular performance in elite football players compared to their sub-elite and recreational counterparts[6]. These findings suggest that strength and power capabilities are critical determinants of performance in competitive football particularly at the elite level, moreover, when combined with adequate core stability, these qualities may enhance a player's ability to maintain balance while dribbling, shielding the ball from opponents, or performing sudden changes of direction[7].

Trunk muscle strength and stability play a crucial role in transferring energy between the lower and upper body during intermittent movements, such as accelerations,

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decelerations, changes of direction or sprinting, which are characteristic demands of football match play[8]. Consequently, effective sprinting performance requires not only powerful lower-limb propulsion but also a stable trunk that ensures efficient energy transfer throughout the kinetic chain[8]. The lumbopelvic-hip complex functions as the central link in this process, and insufficient control of this region (i.e., described as poor core stability) can lead to energy dissipation, excessive trunk motion, and suboptimal force transmission to the ground[9]. Thus, single-leg deadlift (SLD) is a dynamic task that challenges this control in a unilateral stance, mimicking the demands of maintaining a stable pelvis during the alternating limb action of sprinting and serve as a functional proxy for an athlete's ability to stabilize their core during dynamic, performance-oriented movements like maximal acceleration. These claims have been previously made in relation to other intermittent sports, such as volleyball[10] and American football[11], which showed significant associations between strength core stability values and neuromuscular performance in maximal sprint values, COD speed and jump performance, however, less evidence has been reported in the football performance field. However, to our knowledge, only one previous study developed by Imai et al (2016), has analyzed the effects of trunk stabilization exercises on balance and physical performance in youth football players reported trunk stabilization exercise enhance static and dynamic balance, vertical jump performance and cardiovascular performance in football players[12], while no studies have examined the relationship on neuromuscular performance between groups (i.e. higher core performance versus lower core performance) it is necessary to establish these potential differences to address this gap in the literature. Thus, the first aim of this study was to investigate the relationship between core stability and sprint and COD speed values among young male football players. The second aim was to analyze the differences between higher and lower core performance players and neuromuscular performance.

## Material and Methods

### *Participants*

Sixteen high-level male football players (all of them were players from the Real Valladolid Club de Fútbol, S. A. D.) were recruited to participate in this study (age: 17.2 ± 0.9 years; height 174.7 ± 5.2 cm; body mass 69.18 ± 5.4 kg). All testing was conducted at the players' home ground and football players. Prior to the onset of the study, data on body mass, stature, medical history, and training frequency (expressed as hours of practice per day and per week) were recorded. The dominant limb was determined based on the preferred leg used for kicking, in accordance with established criteria in the literature[13].

### *Experimental procedure*

An a priori sample size calculation using G*Power (version 3.1.9.2; University of Düsseldorf, Düsseldorf, Germany) indicated that a minimum of fifteen athletes was required to detect statistically significant differences for a matched-pair t-test analysis, assuming an effect size of 0.80, β = 0.80, and two-tailed α = 0.05. This calculation was based on a previous investigation that found a benefit of this magnitude using different neuromuscular test[12]. Prior to the experimental trials, football players completed two familiarization sessions with the test battery to minimize potential learning effects. On the day of testing, athletes performed a standardized 15-minute football-specific warm-up, which included jogging, technical drills, and dynamic stretching, conducted at a moderate intensity corresponding to a heart rate of approximately 135 beats·min$^{-1}$ controlled by a chest strap sensor device (Polar H10, Polar Electro Oy, Kempele, Finland)[14]. To ensure standardization of the measurements, all tests were performed in the same order and using the same testing devices which always were handled by the same researcher. Participants realized a neuromuscular battery consisted in partial range single leg deadlift, sprint test (i.e., with 5-m split intervals) and V-cut test. All evaluations were performed at the same time of day (i.e., evening, 18:00-19:30 p.m.) and under similar environmental (i.e., 20.2-21.3°C temperature, 41-43% relative humidity) to avoid effects associated with circadian rhythms on neuromuscular performance[15].

### *Partial range single leg deadlift (SLD)*

Football players were instructed to adopt an upright stance with their backs aligned against a wall. They were then positioned approximately two foot-lengths away from the wall, maintaining feet parallel and separated at hip-width. Also, their arms were placed crossed on their chests, and they were instructed to look forward at all times. Once a subject was placed in the starting position, a mark was placed on the ground so that the subject had a reference for where it should be placed. According to the order given by the mobile app, "left" or "right", the subject touched the right or left heel to the wall, keeping the trunk and leg straight while slightly tilting the trunk forward (Figure 1). Data acquisition was performed using an iPhone® 6 (Apple Inc., Cupertino, CA, USA) running iOS 12.5.5 with the OCTOcore app (Version 1.8.4)[16]. The primary outcome from the OCTOcore app is the mean acceleration magnitude (in mm·s$^{-2}$), calculated as the average of the acceleration data series over a 3-second window for each repetition. This metric quantifies the total motion of the lumbopelvic region during the task. Consequently, lower values indicate less extraneous trunk movement and are interpreted as superior core stability, whereas higher values denote poorer control. The device was secured with a belt at the midline of the lower back, positioned at the level of the iliac crests and corresponding to the fourth lumbar vertebra. To enhance participants', focus during testing, EarPods® headphones (Apple Inc., Cupertino, CA, USA) were provided. The accelerometer sampling frequency was fixed at 100 Hz

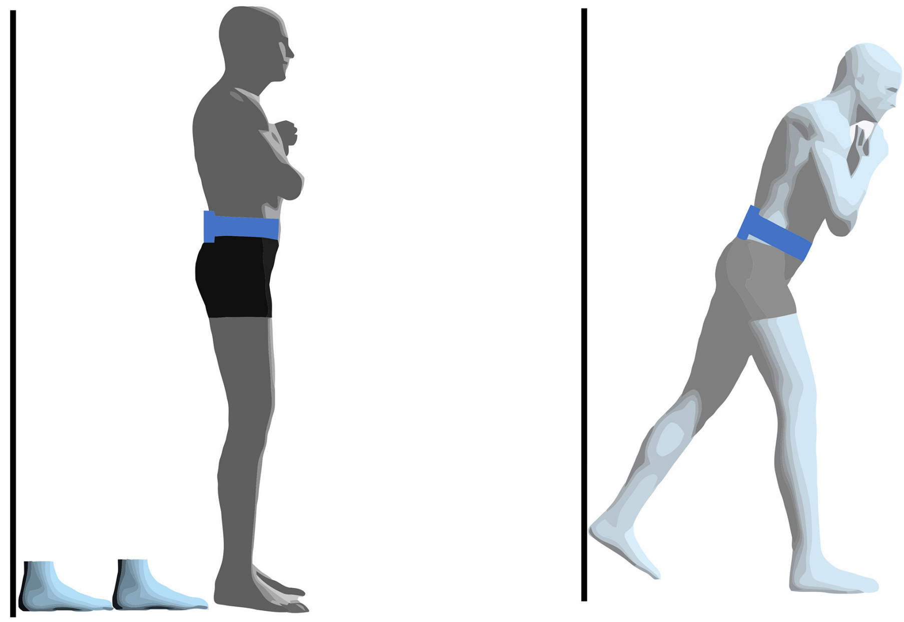

**Figure 1.** Partial-range single-leg deadlift (SLD) test protocol.

across all assessments, and the gravitational component was removed by the application's internal filtering algorithms prior to analysis. For each trial, the initial two repetitions were excluded, and data were analyzed over a 3-s window per repetition. A familiarization trial of 30 repetitions was performed, followed by a 3-minute rest. After that, a measurement trial of 50 repetitions was conducted, followed by another 5-minute rest period. Participants executed the exercise at a controlled cadence of ~3 s per repetition under all conditions. Mean acceleration values were derived from the average of the acceleration magnitude series. Previous research has demonstrated the iPhone® accelerometer to be a valid and reliable tool for movement assessment. It is worth to mentioned that iPhone's accelerometer is a valid and reliable tool for measuring movements[17,18]. The test-retest reliability of this procedure has been previously established, demonstrating high intraclass correlation coefficients (ICC = 0.73–0.96) for measuring core stability during dynamic exercises 0.71 to 0.84[19].

*Maximal sprint performance (30-m sprint)*

Sprint performance was assessed over 30 m using a standing start, with split times recorded at 5, 10, 15, 20, and 25 m using the MySprint application (Apple Inc., USA), a validated smartphone-based video-timing system[20]. Split times (5, 10, 15, 20, 25, and 30 m) were derived through frame-by-frame video analysis using cone markers placed at each split distance. The dominant foot was positioned 0.5 m behind the initial timing gate. Each athlete completed two 30-m sprint trials, interspersed with a minimum of three minutes of passive recovery, and the best performance was used for analysis. The same researcher performed all analyses to ensure consistency, with intra-rater reliability confirmed from the cited validation study (ICC = 0.97–0.99)[20] and verified within this dataset (ICC = 0.98–0.99).

*V-cut test (V-cut)*

V-cut test consisted of a 25-m sprint incorporating four changes of direction (COD) of 45°, each performed after a 5-m segment. Youth soccer players initiated the sprint with the front foot positioned 0.5 m behind the first timing gate (Witty, Microgate, Bolzano, Italy)[21]. Cones and floor markings were used to indicate the points of direction change. For a trial to be considered valid, participants were required to cross the designated line with one foot at every turning point; otherwise, the attempt was repeated. The lateral spacing between cone pairs was set at 0.7 m. Each player completed two trials, separated by a minimum of three minutes. Time in the fastest trial was recorded for analysis and ICC was 0.87-0.95[21].

## Statistical Analysis

Descriptive statistics are reported as mean ± standard deviation to summarize all parameters. Data normality was

**Table 1.** Differences between higher and lower core performance sprint /COD speed tests.

| | GOOD CORE (≤7.25 mm/s2) (n=8) Median (BCa 95% CI) | POOR CORE (>7.25 mm/s2) (n=8) Median (BCa 95% CI) | MW- U | P Value | r_rb | Magnitude |
|---|---|---|---|---|---|---|
| SLD_Non-Dominant (mm/s^2) | 5.10 (4.00, 6.00) | 10.10 (8.00, 16.00) | 0 | **0.001** | 1.000 | Near perfect |
| SLD_Dominant (mm/s^2) | 7.80 (5.00, 8.00) | 6.65 (6.00, 10.25) | 61 | 0.458 | -0.219 | Trivial, non-significant difference |
| SLD_Composite (mm/s^2) | 6.20 (4.75, 7.00) | 8.38 (7.70, 11.00) | 0 | **0.001** | 1.000 | Near perfect |
| V_Cut | 6.68 (6.51, 6.91) | 6.83 (6.64, 6.98) | 57 | 0.279 | 0.344 | Small, non-significant difference |
| 5-m Split | 1.00 (1.00, 1.00) | 1.10 (n/a) | 56 | 0.234 | 0.375 | Small, non-significant difference |
| 10-m Split | 1.70 (n/a) | 1.80 (n/a) | 3.5 | **0.001** | 0.891 | Large |
| 15-m Split | 2.30 (n/a) | 2.50 (n/a) | 7 | **0.005** | 0.781 | Large |
| 20-m Split | 2.90 (2.90, 3.00) | 3.10 (n/a) | 4.5 | **0.002** | 0.859 | Large |
| 25-m Split | 3.50 (3.45, 3.50) | 3.70 (n/a) | 3.5 | **0.003** | 0.828 | Large |
| 30-m Split | 4.05 (4.00, 4.10) | 4.20 (4.20, 4.30) | 4.5 | **0.002** | 0.859 | Large |

***Abbreviations**: s: seconds; m: meters; SLD: single-leg deadlift (SLD); mm/s$^2$: millimeters per second squared. MW-U = Mann-Whitney U test statistic. r_rb = Rank-Biserial Correlation Coefficient (signed value). Positive r_rb indicates the Poor Core group has higher ranks (worse performance/higher mm/s^2 or longer time). BCa 95% CI calculated via Bootstrapping (2000 samples). n/a indicates 95% BCa CI could not be computed. Significance is based on the Benjamini-Hochberg (BH) False Discovery Rate (FDR) adjustment.*

verified using Q–Q plots and the Shapiro–Wilk test. For non-parametric data, results are presented as medians with 95% bias-corrected and accelerated (BCa) confidence intervals. Associations between single-leg deadlift (SLD) and sprint variables were examined using Spearman's rank correlation (ρ), with statistical significance set at $p \le 0.05$. Correlation according to Hopkins et al. (2009) were reported as trivial (ρ < 0.3), small (0.31–0.49), moderate (0.5–0.69), large (0.7–0.89), and nearly perfect (ρ ≥ 0.9)[22], with equivalent thresholds for negative values. Athletes were dichotomized into a higher core performance (HCP) and a lower core performance (LCP) group based on a median split of their composite SLD score (≤ 7.25 mm·s$^{-2}$). The composite score was calculated as the arithmetic mean of the non-dominant and dominant leg scores. Between-group comparisons were conducted with the Mann–Whitney U test, and the corresponding U-statistic was reported. Effect sizes were calculated using the rank-biserial correlation coefficient (r_rb) and interpreted using the same thresholds as Spearman's ρ. To enhance precision, 95% BCa confidence intervals for medians were obtained via bootstrapping (2,000 samples). To control for false discovery due to multiple comparisons (10 variables tested), the Benjamini–Hochberg procedure was applied. The adjusted significance threshold followed the BH criterion, with unadjusted $p \le 0.05$. All analyses were performed using SPSS (Version 20.0; IBM Corp., New York, USA).

## Results

Statistically significant differences between high core performance (HCP) (≤7.25 mm/s$^2$) and lower core performance (LCP) (>7.25 mm/s$^2$) groups between non-dominant SLD and composite SLD were found (p=0.001, r_rb=1, *near perfect*), although no differences were reported in dominant SLD between groups (p=0.458, r_rb=-0.219, *trivial*). In addition, statistically significant differences were obtained between HCP and LCP football players in the sprint test 10-m/15-m/20-m/25-m and 30-m sprint test, with greater values being found in the HCP group (p=0.001-0.005, r_rb=0.781-0.891, *large*). Finally, no differences were reported between groups in the V-cut test (p=0.279, r_rb=0.344, *small*) (Table 1).

Correlations between the SLD test and sprint and COD values test were reported (Table 2). Large between left SLD and 10-m sprint (r=0.765, p=0.001) and moderate correlations were reported in 15-m/20-m/25-m/30-m sprint were reported (r=0.508-0.562, p=0.023-0.044), with no differences in 5-m sprint (r=0.371, p=0.158). No differences were found between right SLD and sprint

**Table 2.** Correlations between the SLD test and sprint /COD speed tests.

| | | | V_Cut | 5-m | 10-m | 15-m | 20-m | 25-m | 30-m |
|---|---|---|---|---|---|---|---|---|---|
| Partial range single leg deadlift (SLD) | No-dominant | Spearman | 0.274 | 0.371 | ***0.765*** | ***0.508**** | ***0.551**** | ***0.521**** | ***0.562**** |
| | | *P* | 0.304 | 0.158 | *0.001* | *0.044* | *0.027* | *0.039* | *0.023* |
| | Dominant | Spearman | -0.062 | 0.248 | 0.077 | -0.304 | -0.165 | -0.236 | -0.062 |
| | | *P* | 0.820 | 0.354 | 0.777 | 0.252 | 0.543 | 0.378 | 0.819 |
| | Composite | Spearman | 0.286 | 0.452 | ***0.771**** | ***0.497**** | ***0.568**** | ***0.520**** | ***0.596**** |
| | | *P* | 0.283 | 0.079 | *0.000* | *0.050* | *0.022* | *0.039* | *0.015* |

test (r=-0.304-0.248, p=0.252-0.777). In addition, no differences were identified between SLD (non-dominant, dominant and composite) and V-cut test (r= -0.062-0.274, p= 0.079-0.354).

## Discussion

The aim of this study was to investigate the relationship between core stability and neuromuscular performance (i.e., sprint velocity and COD speed) among adolescent male football players. To the best of the authors' knowledge, this is the first study to investigate the relationship between APP-based measures of core stability and neuromuscular performance in male football players. The primary findings of the present study were the significant correlations observed between non-dominant SLD and sprint performance from 0 to 30 m (except for the 0–5 m split), whereas no associations were found between SLD and change-of-direction performance.

Maximum acceleration (i.e., 0-30-m) occurs in football during the initial phases of sprinting[23], typically from stationary, low-, or moderate-speed starts, when players exhibit the greatest changes in velocity[24]. In particular, football players often initiate all-out sprints from moderate-speed movements, making this ability crucial for football performance[25,26]. In this study, significant correlations were found between non-dominant SLD performance and maximal sprint outcomes in the high core performance (HCP) group, whereas no significant relationships were observed for the dominant leg. Notably, short sprint distances (0–10 m) showed stronger correlations than longer sprints (0–30 m), likely because greater distances amplify trunk motion and energy loss, reducing the efficiency of force transfer through the kinetic chain[12]. Significant differences were only observed for the non-dominant leg SLD, while no differences were found for the dominant side. These differences may reflect sport-specific adaptations in soccer players, where the dominant leg is primarily responsible for skill-related actions such as passing, shooting, and ball control, whereas the non-dominant leg plays a more stabilizing role during these movements[5,27]. Consequently, the non-dominant limb is often more involved in supporting single-leg stance tasks that require trunk and pelvic stability, such as during changes of direction, deceleration, or maintaining balance after kicking[7]. This functional asymmetry may explain why core stability, as measured by the non-dominant SLD, showed a stronger relationship with sprint performance. During sprinting, the non-dominant limb contributes to postural control and energy transfer from the lower extremities through the lumbopelvic region, ensuring efficient acceleration mechanics[9] Conversely, the dominant leg may exhibit lower variability and greater motor automatization in soccer players, making core stability differences less apparent in this limb. Previous studies reported that an increase of core stability improves neuromuscular performance in short-sprint distances, vertical jump and balance performance[27] or 5000m time trial test[28] which is in according to our data.

COD speed refers to the ability to accelerate, decelerate, reverse, or change movement direction and re-accelerate[29], representing a key performance determinant in multidirectional sports such as football, particularly among youth players[30]. According to the COD speed values, no statistically significant correlations were reported between SLD and V-cut test, although other studies have reported improvements between trunk test and COD speed performance[12]. These differences may be attributed to the COD speed tests used in the studies (V-Cut vs. 5-0-5 agility test) and to the competitive level of the players. Thus, in our study, the sample consisted of players competing at the national or international level, whereas in the study developed by Imai et al. (2016) included only regional-level players[12]. Additionally, differences may also be influenced by the perceptual–decision-making processes involved, which could have affected the study outcomes.

Despite its strengths, the present study has several limitations that should be acknowledged to enhance its applicability to real-world sports contexts. First, we examined the relationship between core stability and neuromuscular performance (i.e., sprint velocity and COD values) only in adolescent male football players and during a single period of the competitive season. Therefore, future studies should assess these relationships across different phases of the season. Second, although this study focused on youth male players, further research with broader samples, including female athletes and players across different competition levels, that is recommended to strengthen the evidence base on this topic, as factors such as sex[31], training status, or playing level may influence neuromuscular performance responses. Third, future studies should determine whether alternative COD assessments such as the 505, pro-agility, or soccer-dribbling variants better represent sport-specific performance qualities.

## Conclusion

The results suggest that greater core stability is positively associated with maximal sprint performance in short distances (0-30 meters), whereas no significant between-group differences were observed between core stability and COD speed performance.

*Ethics approval*

*The study was approved by the Ethics Committee of the SAD Club and the CYMO Research Institute (approval ID: 1.200.646) and was conducted in accordance with the principles of the 1964 Declaration of Helsinki and its later amendments.*

*Consent to participate*

*Written informed consent was obtained from all participants, and from parents/legal guardians for individuals under 18 years of age*

*Authors' contributions*

*Pedro J. Marín and Alvaro López-Samanes. has given substantial contributions to the data analysis and to the manuscript draft; Raúl Zarzuela-Martín, Daniel Rabadan-García and Sergio Sánchez-García contributed to the data and measurements acquisition; Pedro J. Marín, Raúl Zarzuela-Martín, Daniel Rabadan-García and Sergio Sánchez-García contributed to the coordination of the measurements. All authors read and approved the final version of the manuscript.*

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