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The Relationship between Dynamic Stability and Multidirectional Speed

Brief Running Head: Dynamic Stability and Multidirectional Speed

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Abstract

Dynamic stability is said to contribute to multidirectional (linear and change-of-direction) speed, although little research confirms this. This study analyzed the relationship between dynamic stability as measured by lower-limb functional reaching in six directions (anterolateral, lateral, posterolateral, posteromedial, medial, anteromedial) within a modified Star Excursion Balance Test, and multidirectional speed (40-meter [m] sprint: 0-10, 0-20, 0-40 m intervals; T-test; Change-of-Direction and Acceleration Test [CODAT]). Sixteen male field sport athletes (age = 23.31 ± 5.34 years; height = 1.78 ± 0.07 m; mass = 80.60 ± 9.89 kilograms) completed testing. A one-way analysis of variance determined significant ($p < 0.05$) differences in excursions between faster and slower subjects. All data was pooled for a Spearman's correlation analysis ($p < 0.05$). Faster subjects had greater left-leg medial reach (76.24 ± 5.33% vs. 65.94 ± 10.75%), right-leg posteromedial reach (85.20 ± 8.07% vs. 73.59 ± 12.64%), and a smaller between-leg difference in lateral reach (2.26 ± 1.85% vs. 6.46 ± 4.29%). Longer reach distances (greater dynamic stability), correlated with faster speed test times (ρ = -0.499--0.664). Dynamic stability relationships were pronounced for the change-of-direction speed tests. For example, smaller between-leg excursion differences in anterolateral, lateral, posterolateral, and posteromedial reaches related to faster T-test and CODAT times (ρ = 0.502-0.804). There is a relationship between dynamic stability as measured by functional reaching and multidirectional speed in field sport athletes, possibly due to similarities in movement demands and muscle recruitment. Dynamic stability training could strengthen muscles for multidirectional sprinting, and develop functional joint motion.

Key words: modified Star Excursion Balance Test, linear speed, change-of-direction speed, agility, dynamic balance

INTRODUCTION

Linear speed, agility, and change-of-direction speed, are necessary components of a field sport athlete's physical abilities. This is because the inherent design of field-based team sports (e.g. the football codes, field hockey, and lacrosse) places a great emphasis on the ability to run fast and change direction during a game. As an example, soccer players can complete approximately 20 to 60 maximal sprints over a variety of distances (41), and over 600 direction changes (3), during a 90-minute match. Adding further emphasis to the need for multidirectional (i.e. linear and change-of-direction) speed for field sport athletes is that players from higher levels of competition tend to be faster in linear sprints, and change-of-direction speed tests (e.g. pro-agility shuttle, three-cone drill), when compared to their lower-level counterparts (12). Therefore, it is important for field sport coaches and strength and conditioning practitioners to understand the physical components that can contribute to multidirectional speed.

Faster field sport athletes in linear sprinting (8), and speed tests that demand direction changes (12), have been found to have greater lower-limb power as measured by the vertical jump. Reactive power as measured by a drop jump has also been linked to faster linear acceleration in field sport athletes (27). Superior concentric (40) and relative (2) strength as measured by squat exercises in male athletes will contribute to enhanced sprinting ability. Furthermore, greater imbalances in eccentric strength of the knee flexor muscles can lead to slower multidirectional sprint performance (28). These studies highlight the importance of the interaction between strength and power in the lower limbs, as well as balance in these characteristics between each leg. However, another less researched component of multidirectional speed is dynamic stability. This is despite suggestions that dynamic stability is essential for effective sports performance (5, 25, 39).

Dynamic stability has been defined as the ability to maintain balance while transitioning from a dynamic to static state (45). Within multidirectional sprint movements, athletes must maintain a degree of stability and balance when transitioning from a dynamic (deceleration) to a static (stopping to change direction), before returning to a dynamic (re-acceleration) state. Dynamic stability would aid an athlete in maintaining a stable center of gravity during these sport-specific movements (5, 25). There are several laboratory-based protocols that have been used to assess dynamic stability. One of the more popular assessments is the Star Excursion Balance Test (SEBT) (18, 33, 36). The SEBT can assess dynamic stability through the use of functional reaching of the lower limbs, and has been shown to be valid and reliable (13, 17). This test typically involves a subject adopting a unilateral stance and performing a series of single-leg squats while attempting to maximally reach with the other leg in eight different directions; three anterior, two lateral, and three posterior. There is also research that has also used only selected reaches, as opposed to all eight (18, 19, 32, 43). Nevertheless, the subject's stability is challenged, in that the body's center of gravity is moved in relation to the base of support every time a reach is attempted (17). A greater functional reach, measured in relation to the subject's leg length, provides an indication of greater dynamic stability.

The measurement of dynamic stability within the research literature has tended to have more of a clinical focus, with the SEBT often being used to measure and monitor deficits in relation to injuries in the lower limbs (6, 15). There has been minimal analysis of how dynamic stability, as measured by functional reaching, relates to sport-specific actions such as multidirectional sprinting. Therefore, this research will investigate whether dynamic stability, as measured by functional reaching in selected directions, could affect linear speed and change-of-direction speed. This will be done by comparing the differences in functional reach, as well as between-leg excursion differences, of faster and slower field sport athletes, which will be determined via a median split (11, 27, 28). Subject data will be pooled for a correlation analysis between the dynamic stability measures and speed test times (27, 28). It is hypothesized that faster field sport athletes in both linear and change-of-direction sprints will exhibit greater functional reach in six excursion directions as measured by a modified SEBT (mSEBT), and smaller differences in unilateral functional reach between each leg. Additionally, there will be significant correlations between a greater functional reach, and smaller between-leg differences in functional reach, and faster speed test performance. This research has significant implications for field sport and strength and conditioning coaches, who may need to incorporate dynamic stability development in their athletes to further improve multidirectional speed.

METHODS

Experimental Approach to the Problem

This study analyzed the relationship between dynamic stability, as measured by functional reaching, and multidirectional (i.e. linear and change-of-direction) speed. A cross-sectional analysis of field sport athletes was conducted. The subjects were split into faster and slower groups according to total time from the speed tests (i.e. 40-m time + T-test time + Change-of-Direction and Acceleration Test [CODAT] time), to indicate whether functional reach in a particular direction, and differences in reach between the legs, was associated with faster multidirectional speed. Spearman's correlation analysis was also used to determine significant interactions between dynamic stability and multidirectional speed. Specifically, the aim of this study was to ascertain the relationship between dynamic stability, as measured by functional reach in the mSEBT, and multidirectional speed. The independent variable was the sample group – faster or slower. The dependent variables were: 40-m sprint time, including time in the 0-10 m, 0-20 m, and 0-40 m intervals; T-test and CODAT time; reach distance in six directions from the mSEBT (anterolateral, lateral, posterolateral, posteromedial, medial, and anteromedial); and between-leg differences in reach distance for these six directions.

Subjects

Sixteen experienced, recreational male field sport athletes (age = 23.31 ± 5.34 years; height = 1.78 ± 0.07 m; mass = 80.60 ± 9.89 kilograms [kg]) were recruited for this study. Subjects were recruited if they: were currently active in a field sport (e.g. soccer, rugby league, rugby union, Australian football); had a history of physical activity (≥two times·week^{-1}) extending over the previous six months; were available for the two testing sessions for the study; and did not have any existing medical conditions, balance disorders, or significant lower-limb pathologies that would compromise participation in the study. The methodology and procedures used in this study were approved by the institutional ethics committee. All subjects received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained prior to testing.

Procedures

Testing was conducted over two days, separated by 48 hours. Day 1 consisted of the speed tests – 40-m sprint, T-test and CODAT. All speed tests were conducted on an indoor basketball court with a sprung wooden floor. Prior to data collection on Day 1, the subject's age, height, and mass were recorded. Height was measured using a stadiometer (Ecomed Trading, Seven Hills, Australia) and recorded to the nearest 0.01 centimeters (cm). Subjects were measured barefoot, and they stood on the base of the stadiometer with their feet together and the heels, buttocks and upper back touching the scale. Body mass was recorded using electronic digital scales (Tanita Corporation, Tokyo, Japan), and recorded to the nearest 0.01

kg. A standardized warm-up, consisting of 10 minutes of jogging, 10 minutes of dynamic stretching of the lower limbs, and progressive speed runs over the testing distances, was used on Day 1. Day 2 consisted of the mSEBT assessment. The Day 2 warm-up consisted of 10 minutes of low-intensity cycling on a bicycle ergometer, followed by three circuits of the mSEBT, the specifics of which will be documented later in the Methods. Depending on the subject's availabilities, testing was conducted in the late morning, afternoon, or early evening. Subjects were tested at the same time of day for both testing sessions and in the same order, did not eat for 2-3 hours prior to their testing sessions, and refrained from intensive lower-body exercise and any form of stimulant (e.g. caffeine) in the 24 hours prior to testing. Subjects were permitted to consume water *ad libitum* in the 24-hour period before testing, and throughout the testing sessions.

40-metre Sprint

40-m sprint time was recorded by a timing lights system (Fusion Sports, Coopers Plains, Australia). Gates were placed at 0 m, 10 m, 20 m, and 40 m, at a height of 1.2 m, to measure the 0-10 m, 0-20 m, and 0-40 m intervals. Sprints over 10 m (27), 20 m (42), and 40 m (21) have been previously used in the assessment of field sport athletes, and the 40-m sprint has been found to be a reliable assessment (typical error of measurement = 1.2%) (23). Subjects began the sprint from a standing start 30 cm behind the start line, so as to be able to trigger the first gate (28), and were instructed to accelerate from the starting line and sprint through all sets of timing lights. If the subject rocked backwards or forwards prior to starting, the trial was disregarded and repeated, following the required rest interval. Time for each distance was recorded to the nearest 0.01 s. Three trials were completed with three minutes recovery between each trial. The best trial was used for analysis.

T-Test

The T-test was assessed because it features anterior, posterior, and lateral movements, and the methodology was adapted from previous research (37, 38). This test has also been found to be reliable (intra-class correlation coefficient [ICC] = 0.97) (37). Markers were positioned and taped to the floor as shown in Figure 1, with a start line clearly indicated by tape positioned on the floor. One timing gate (Fusion Sports, Coopers Plains, Australia) was used for this test, and subjects were required to face forwards throughout the test. Subjects completed practice trials during the warm-up. Subjects began the sprint from a standing start 30 cm behind the start line (Marker 1) (28). Subjects sprinted forwards 9.14 m to touch the top of the middle marker. They then side-shuffled 4.57 m to the left to touch the next marker, side-shuffled 9.14 m to the right to touch the next marker, side-shuffled 4.57 m to touch the middle marker again, before back pedaling past the start line to finish the test. The hand that was on the same side as the shuffle direction (i.e. the left hand when shuffling to the left, and the right hand when shuffling to the right) was used to touch the marker. Subjects were not to cross their feet when side-shuffling, or touch a marker with the wrong hand; if they did, the trial was stopped and another attempted after the required rest period. Time was recorded to the nearest 0.01 s from when the subject broke the gate the first time, until they returned through the gate following the last back pedal. Three trials were attempted with three minutes recovery between each trial, and the best time was used for analysis.

INSERT FIGURE 1 ABOUT HERE

Change-of-Direction and Acceleration Test (CODAT)

The dimensions and movement direction for the CODAT is shown in Figure 2. The CODAT was used for this assessment as it contains movement patterns common to many field sports (i.e. sprinting forwards while completing lateral cuts), and has been shown to be a valid and reliable assessment of change-of-direction speed (ICC = 0.84) (29). Two timing gates (Fusion Sports, Coopers Plains, Australia) were used; one positioned at the start, and the other at the finish of the test. As for the T-test, subjects completed practice trials during the warm-up. Subjects started 30 cm behind the start line (28). Subjects were required to face forwards at all times during the CODAT, and were required to stay outside the markers when running. If subjects cut across or over a marker, the trial was stopped and another attempted after the required rest period. Three trials were completed with three minutes recovery between each trial. Time was recorded to the nearest 0.01 s, and the best time was used for the analysis.

INSERT FIGURE 2 ABOUT HERE

Modified Star Excursion Balance Test (mSEBT)

Dynamic balance was assessed by using a modified version of the SEBT, which used six excursion directions. Hertel et al. (18) suggested that the posteromedial, medial, and anteromedial reaches best represented the SEBT, and were the only excursions necessary. However, given the lateral shuffles and cuts required in the T-test and CODAT, the lateral excursions (anterolateral, lateral, and posterolateral) were also analyzed in this study. The six distances used in the mSEBT have been found to be reliable for assessing dynamic stability (ICC = 0.78-0.96) (17). The testing grid consisted of six standard, 120-cm long, tape measures taped to the laboratory floor. Each tape measure extended from an origin at 45º increments, which was measured by a goniometer. The middle of the grid was indicated with a black marker. The language for the excursion direction was based on the direction of reach from the stance leg (Figure 3). The anterolateral and anteromedial directions required the subject to reach in front of their body. Subjects' abducted the reach leg to the side of their body for the lateral reach. The subject reached behind their body for the posterolateral and posteromedial excursions. The medial reach involved the subject adducting their stance leg to a position behind the body, before extending the leg medially. These excursions are all displayed in Figure 4.

INSERT FIGURE 3 ABOUT HERE

INSERT FIGURE 4 ABOUT HERE

Prior to completing the mSEBT, subjects completed 10 minutes of cycling on a bicycle ergometer at a self-selected pace. Subjects were then required to stand on the center marker of the mSEBT, with the ankle malleoli aligned with the lateral tape measures. This was visually assessed by the researcher. Subjects then used their free leg to reach about the star, beginning in an anterolateral direction and working clockwise around the grid. With each attempt, the subject attempted reach as far as possible along each line and make a light touch on the ground with the most distal part of the reaching leg. The subject then returned the reaching leg to a bilateral stance, without allowing contact to affect overall balance. A researcher noted the reach distance after each attempt. A trial was disregarded if the researcher felt the subject used the reaching leg for an extended period of support, removed the stance leg from the center of the grid, or was unable to maintain balance. The same researcher measured the mSEBT for all subjects. A minimum of three practice trials were used prior to data collection to familiarize subjects to the movements required, and to serve as a warm-up. The order of the stance leg used during testing was randomized amongst the subject group.

Reach distances were considered relative to the subject’s leg length (14, 15). Relative reach distances were expressed as a percentage according to the formula *relative reach* *distance = reach distance/leg length x 100*. The differences in relative reach distances between the stance legs was also calculated, and derived from the formula: (*stance leg with greater reach distance – stance leg with lesser reach distance)/stance leg with greater reach distance x 100.*

Statistical Analysis

Descriptive statistics (mean ± standard deviation; 95% confidence intervals) for all subjects were derived for the dependent variables (i.e. speed test times and mSEBT reach distances). Subjects were median split into two groups – faster and slower – according to their total time across the 0-10 m, 0-20 m, and 0-40 m intervals from the linear sprint, the T-test, and the CODAT (11, 27, 28). A one-way analysis of variance determined whether there were significant ($p < 0.05$) differences between the sprint times, reach distances for each leg, and percentage difference in reach distance between the legs, of the faster and slower groups. The Levene statistic determined homogeneity of variance of the data. Effect sizes (ES) were used to describe the magnitude of the any differences between the faster and slower groups. ES were calculated according to the methods of Cohen (7), where the difference between the means was divided by the pooled standard deviations. Interpretation of ES results were adapted from Rhea (35). For the purpose of this study, an ES of 0.25-0.49 was considered a small effect; 0.50-1.00 a moderate effect; and greater than 1.00 a large effect.

All data from both groups was combined for a Spearman's rank order correlation analysis. This analysis was used to determine the relationships between times in the different speed tests, and dynamic stability as measured by functional reach distance and between-leg reach differences. Significant correlations were reported at alpha levels of $p < 0.01$ and $p < 0.05$. The strength of the Spearman's rho (ρ) value was assigned a descriptor as designated by Hopkins (20). A ρ value less than 0.3 was considered small; 0.31 to 0.49 moderate; 0.5 to

0.69 large; 0.7 to 0.89 very large; and 0.9 and higher near perfect for predicting relationships. All statistical analyses were computed using the Statistics Package for Social Sciences (Version 20.0; IBM Corporation, New York, USA).

RESULTS

Subjects were median split into faster (age = 21.63 ± 2.45 years; height = 1.78 ± 0.05 m; mass = 76.81 ± 10.57 kg), and slower (age = 25.00 ± 6.97 years; height = 1.79 ± 0.09 m; mass = 84.39 ± 8.08 kg) groups following data collection. There were no significant between-group differences in age ($p = 0.217$), height ($p = 0.845$), or mass ($p = 0.130$). Speed test times are shown in Table 1. The faster group had significantly faster times for the 0-20 m and 0-40 m intervals, as well as the T-test and CODAT. The between-group difference in 0-10 m time was not significant, but had a moderate effect.

INSERT TABLE 1 ABOUT HERE

The relative reach distances achieved by left leg (right stance leg), the right leg (left stance leg), and the between-leg percentage reach differences, for each group are shown in Table 2. The faster group had a significantly greater medial left leg reach when compared to the slower group. Even though significance was not established, there were moderate effects for the faster group's greater left leg reach in the posterolateral, posteromedial, and anteromedial directions. The faster group had a significantly greater right leg reach in the posteromedial direction. Moderate, non-significant effects were found in the lateral, posterolateral, medial, and anteromedial directions. The slower group had a significantly greater difference in between-leg lateral reach distance. There were moderate, non-significant, effects for the greater reach disparities displayed by the slower group in the anterolateral, posterolateral, posteromedial, and anteromedial directions.

INSERT TABLE 2 ABOUT HERE

The correlations between the speed tests and functional reach for when subjects used the right leg for stance and reached with the left leg are shown in Table 3. Significant correlations were negative, demonstrating that greater reach distances related to faster speed test times. 0-40 m sprint time correlated with the posteromedial and medial reach distances. The T-test had a significant correlation with the medial reach distance, while the CODAT correlated with the posteromedial and medial reach distances. The speed test correlations when subjects used the left leg for stance and reached with the right leg are displayed in Table 4. The only significant correlations were found between CODAT time and reach distances in the posteromedial, medial, and anteromedial directions.

INSERT TABLE 3 ABOUT HERE

INSERT TABLE 4 ABOUT HERE

Table 5 displays the correlations between speed test times and the percentage differences in between-leg reach distance. Significant correlations were positive, indicating that greater differences in between-leg reach distance were related to slower speed test times. There was a significant correlation between the 0-10 m time and the between-leg difference in posteromedial reach. T-test time had significant relationships with between-leg reach differences in the anterolateral and lateral directions. CODAT time significantly correlated with the anterolateral, lateral, posterolateral, and posteromedial directions.

INSERT TABLE 5 ABOUT HERE

DISCUSSION

Multidirectional speed, which comprises linear and change-of-direction speed, should require not only great muscle force development at a high velocity, but also dynamic balance. Dynamic balance allows an athlete to maintain a more stable center of gravity during sport-specific movements (5, 25). However, there is little research that has investigated the interaction between dynamic stability and running speed. Therefore, this study analyzed whether dynamic stability, as measured by functional reaching from a mSEBT, related to linear (40-m sprint) and change-of-direction (T-test and CODAT) speed. It was hypothesized that athletes with superior dynamic stability, as shown through greater reach distances, and more balanced stability between the legs, would also exhibit faster sprint times. Greater functional reach would also correlate with faster linear and change-of-direction speed. The faster group is this study performed better than experienced Australian football players over 10 m (~1.84 s), 20 m (~3.24 s), and in the CODAT (~6.10 s) (29), and were superior to male track athletes over 10 m (31), and recreationally-active males over 40 m (23). Furthermore, the faster group was quicker in the T-test when compared to physically active men (10.08 ± 0.46 s) (37) and male collegiate athletes (9.94 ± 0.50 s) (34). This indicates that even though the sample size was relatively small (n = 8), the faster group would still have physical characteristics typical of quicker field sport athletes when considering established means.

In line with the study's hypothesis, the faster group did demonstrate superiority in dynamic stability for particular excursions (Table 1). These excursions are typically those that distinguish individuals with superior or inferior dynamic stability (18), as they are more difficult to complete. There are also certain movements of the stance leg that are synonymous with excursions in these directions, and all indicate the benefits a greater joint range of motion. Greater posterolateral, posteromedial, and medial reach is achieved through an increase in hip flexion and internal rotation of the stance leg (36). Greater knee flexion assists with increased anteromedial reach, with a contribution from hip abduction (36). Greater ankle inversion and eversion facilitates medial and lateral excursions (16). With regards to multidirectional speed, increased range of motion of the lower-limb joints has also been linked to improved sprinting ability (24, 44). Lateral cutting, as demonstrated in the T-test and CODAT, will require the hip of the stance leg to flex and internally rotate to reposition the body, in conjunction with ankle inversion and eversion, which illustrates clear links to the actions of functional reaching. These results suggest that a faster field sport athlete should exhibit enhanced dynamic stability in the excursions from the mSEBT, and the benefits in both instances could be linked to greater joint mobility. The relationships between multidirectional speed and dynamic stability were examined more closely through the correlation analyses, particularly when considering additional factors such as muscle recruitment.

No significant correlations were found between 0-10 m and 0-20 m sprint times and functional reach when considering excursion distance. Sprints within 20 m will generally encompass acceleration (9). As the time spent in contact with the ground is longer during acceleration (27), this may lessen the impact of dynamic stability with the concurrent emphasis on force production during the initial stages of a sprint. There was, however, a significant, positive correlation with 10-m sprint time and the difference in posteromedial reach distance between the legs (Table 4), indicating that a greater difference in excursion distance related to slower sprint time. Imbalances between the legs in eccentric strength (28) and vertical jump power (4), have been related to reduced multidirectional speed performance and lower-limb force production, respectively. The results from this study suggest that greater between-leg imbalances in dynamic stability, as measured by functional reaching in a posteromedial direction, relate to poorer linear sprint acceleration.

Sprints over 40 m would generally allow field sport athletes to reach their maximum running velocity (9). There were no significant correlations between 0-40 m time and any right leg excursions (Table 3), or between-leg differences in excursion distance (Table 4). There were, however, significant relationships between 0-40 m time, and the posteromedial and medial distances of the left leg (Table 2). As stated, greater reach distances in these two more difficult directions are reliant on greater hip flexion of the stance leg, which demands greater activity in the vastus muscles (10). One of the kinematic factors that can affect the generation of a high maximum sprinting velocity is the range of motion at the hip. Mann et al. (30) suggests that the hip flexors, which include the vastus muscles, are the primary muscle group for increasing linear running speed. Additionally, posteromedial reaches will recruit the biceps femoris to control the squat and reach (10). Prior to ground impact when running, the hamstring muscles are active prior to ground contact, and also strongly contribute to increased running speed (26). A field sport athlete that can recruit the muscles about the hip to a greater extent could demonstrate this ability in both excursion actions and maximal linear sprinting.

The T-test involves linear sprinting, lateral shuffling, and backwards running, which places a great demand on the ability change direction quickly while maintaining stability. The CODAT also assesses change-of-direction speed and stresses dynamic stability, by incorporating decelerations, 45° cuts, and accelerations. The correlation analyses documented significant, positive interactions between functional reach and the change-of-direction speed tests. With the right leg used for stance, the left leg medial reach distance significantly correlated with T-test and CODAT time (Table 3). CODAT time also related to posteromedial reach for the left leg. For the right leg excursions (left stance leg), posteromedial, medial, and anteromedial reach distances all largely correlated with CODAT time (Table 4). Even though there are no posterior running actions within the CODAT, similarities in the muscles recruited for posterior stability, and dynamic movement changes of direction, document why these relationships were found. There is the activity of the vastus muscles of the stance leg for the three medial reach excursions (10), and these muscles are essential for speed generation when running (30), which is a needed after a direction change. As stated, in the posterior and posteromedial excursions the hamstrings are heavily recruited (10). The hamstrings also help to facilitate braking and re-acceleration when changing direction (1, 25), as well as increasing running speed (26). Another contributing factor in posteromedial reaches is the action at the ankle. Greater dorsi flexion is required (16), which activates the tibialis anterior (10). The tibialis anterior dorsi flexes the foot to facilitate ground clearance when running, and prepares the foot for impact (22). These results highlight the interaction between muscle groups in the legs, and how they may contribute to both dynamic stability and multidirectional speed.

This point is further emphasized when considering differences, or asymmetries, in reach distances between the legs. The slower group had a significantly greater lateral excursion asymmetry when compared to the faster group (Table 2). Four other between-leg asymmetries that were greater for the slower group had moderate effects (Table 2). T-test time correlated with the between-leg differences in anterolateral and lateral excursions, and the large relationships suggested that a slower time was linked to greater differences in between-leg dynamic stability. Additionally, greater asymmetries in four out of six reach directions related to a slower CODAT time, with a very large correlation for the anterolateral excursion (Table 5). Between-leg differences in dynamic stability in otherwise healthy individuals can underscore joint instability (33). In addition to this, although leg strength dominance wasn't directly measured in this study, a weaker stance leg would limit the reach distance for the contralateral leg (15, 18, 33). With regards to multidirectional speed, greater between-leg knee flexor eccentric strength differences can contribute to slower 40-m sprint and T-test times (28). Given the agility-based movements will commonly demand direction changes using both legs, field sport athletes should aim for balanced strength, mobility, and dynamic stability between the legs.

The results from this study suggest that dynamic stability, as measured by functional reaching, is related to multidirectional speed. Differences in dynamic stability between faster and slower field sport athletes, as measured by functional reaching, are evident in the more difficult mSEBT reaches (i.e. medial and posteromedial). Furthermore, the more difficult excursions significantly correlated to maximal linear sprinting (i.e. medial and posteromedial), and change-of-direction speed (i.e. medial, posteromedial and anteromedial). Imbalances in dynamic stability assessed between the legs (anterolateral, lateral, posterolateral, and posteromedial excursions) were also related to slower change-of-direction speed. The relationships between dynamic stability and multidirectional speed were particularly pronounced with the T-test and CODAT, where multiple changes of direction were required when sprinting.

PRACTICAL APPLICATIONS

The findings from this study provide clear practical applications for the strength and conditioning practitioner. Functional range of motion and strength in the legs are important components for both dynamic stability and multidirectional speed in field sport athletes. Restricted joint range of motion and inefficient muscle recruitment would adversely affect dynamic stability, which could also contribute to slower multidirectional speed in field sport athletes. This is particularly true for movements requiring sharp, lateral changes of direction (i.e. the T-test and CODAT). Therefore, strength and conditioning coaches should ensure that a component of a field sport athlete's conditioning program is directed towards developing dynamic stability. Dynamic stability training could strengthen the muscles for sprinting and changing direction, as well as developing functional joint motion in field sport athletes. Strength and conditioning coaches should also ensure that there is balance in the dynamic stability of each leg. A deficiency in one leg may reduce an athlete's ability to rapidly perform alternate and multiple direction changes during sprint efforts.

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Figure Legend

Figure 1: Dimensions for the T-test. m = meters.

Figure 2: Change-of-Direction and Acceleration Test (CODAT) dimensions and completion route. m = meters.

Figure 3: Reaching directions for each leg during the Star Excursion Balance Test.

Figure 4: Modified Star Excursion Balance Test performance with a left stance leg and right reach leg for the (A) anterolateral; (B) lateral; (C) posterolateral; (D) posteromedial; (E) medial; and (F) anteromedial excursions.

Table 1: Time (seconds: s) in the 0-10 meter (m), 0-20 m, and 0-40 m interval in a 40-m sprint, and time to complete the T-test and Change-of-Direction and Acceleration Test (CODAT) (mean ± standard deviation; 95% confidence intervals), for the faster (n = 8) and slower (n = 8) groups.

	Faster	Slower	Effect Size
0-10 m (s)	1.74 ± 0.06 (1.69-1.79)	1.78 ± 0.03 (1.76-1.80)	0.84
0-20 m (s)	3.03 ± 0.10 (2.94-3.12)	3.14 ± 0.08* (3.07-3.21)	0.96
0-40 m (s)	5.39 ± 0.18 (5.24-5.53)	5.64 ± 0.17* (5.49-5.78)	1.43
T-Test (s)	9.89 ± 0.35 (9.60-10.18)	10.95 ± 0.44* (10.58-11.32)	2.67
CODAT (s)	5.79 ± 0.17 (5.64-5.94)	6.24 ± 0.38* (5.93-6.55)	1.53

* Significantly ($p \leq 0.05$) different from the faster group.

Table 2: Left (right stance leg) and right (left stance leg) relative reach distance (reach distance/leg length x 100) as measured by the modified Star Excursion Balance Test, and the percentage (%) difference between the legs (mean ± standard deviation; 95% confidence intervals), for faster (n = 8) and slower (n = 8) field sport athletes. ES = effect size.

	Left Leg Relative Reach Distance (%)			Right Leg Relative Reach Distance (%)			Between-Leg Difference in Reach (%)		
	Faster	Slower	ES	Faster	Slower	ES	Faster	Slower	ES
Anterolateral	90.84 ± 4.14 (87.37-94.30)	90.01 ± 9.49 (82.15-98.02)	0.11	90.35 ± 5.51 (85.74-94.96)	89.68 ± 7.45 (83.45-95.90)	0.10	1.95 ± 1.99 (0.29-3.62)	4.11 ± 2.62 (1.93-6.30)	0.93
Lateral	90.33 ± 6.38 (84.99-95.66)	87.61 ± 8.80 (80.26-94.97)	0.35	90.36 ± 7.42 (84.16-96.56)	85.04 ± 10.08 (76.61-93.46)	0.60	2.26 ± 1.85 (0.71-3.81)	6.46 ± 4.29* (2.87-10.05)	1.27
Posterolateral	89.26 ± 4.97 (85.11-93.41)	83.84 ± 10.01 (75.47-92.20)	0.69	88.24 ± 8.42 (81.20-95.28)	83.54 ± 9.17 (75.87-91.20)	0.53	3.62 ± 3.10 (1.02-6.21)	6.26 ± 6.16 (1.10-11.41)	0.54
Posteromedial	83.05 ± 6.45 (77.66-88.45)	75.85 ± 8.69 (68.59-83.11)	0.94	85.20 ± 8.07 (78.45-91.95	73.59 ± 12.64* (63.02-84.15)	1.09	4.74 ± 3.93 (1.45-8.02)	9.01 ± 5.95 (4.03-13.99)	0.85
Medial	76.24 ± 5.33 (71.78-80.69)	65.94 ± 10.75* (56.95-74.92)	1.21	77.58 ± 10.21 (69.04-86.11)	66.08 ± 17.79 (51.20-80.95)	0.79	10.26 ± 5.87 (5.36-15.17)	13.09 ± 11.94 (3.10-23.07)	0.30
Anteromedial	71.71 ± 6.90 (65.94-77.48)	67.10 ± 5.09 (62.84-71.65)	0.76	72.16 ± 5.69 (67.41-76.92)	67.18 ± 4.81 (63.15-71.20)	0.95	2.58 ± 3.48 (0.33-5.49)	4.08 ± 2.36 (2.11-6.05)	0.50

* Significantly ($p < 0.05$) different from the faster group.

Table 3: Spearman's rank order correlations between times for the 0-10 meter (m), 0-20 m, and 0-40 m intervals of a 40-m sprint, and T-test and change-of-direction and acceleration test (CODAT) times, and reach distance for the left leg while the right leg was used for stance in field sport athletes (n = 16).

	0-10 m	0-20 m	0-40 m	T-Test	CODAT
Anterolateral	0.224	0.272	0.385	0.350	0.256
Lateral	-0.032	0.097	0.126	0.129	-0.100
Posterolateral	0.137	-0.041	-0.166	-0.153	-0.358
Posteromedial	0.018	-0.228	-0.553*	-0.426	-0.638**
Medial	-0.124	-0.213	-0.506*	-0.603*	-0.606*
Anteromedial	0.032	0.015	0.015	-0.177	-0.133

** Significant ($p < 0.01$) relationship between variables.

* Significant ($p < 0.05$) relationship between variables.

Table 4: Spearman's rank order correlations between times for the 0-10 meter (m), 0-20 m, and 0-40 m intervals of a 40-m sprint, and T-test and change-of-direction and acceleration test (CODAT) times, and reach distance for the right leg while the left leg was used for stance in field sport athletes (n = 16).

	0-10 m	0-20 m	0-40 m	T-Test	CODAT
Anterolateral	0.324	0.188	0.285	0.224	0.179
Lateral	-0.147	-0.115	-0.097	-0.138	-0.321
Posterolateral	-0.056	0.015	-0.088	-0.156	-0.426
Posteromedial	-0.119	-0.101	-0.327	-0.284	-0.664**
Medial	0.079	0.099	-0.141	-0.085	-0.529*
Anteromedial	-0.208	-0.127	-0.141	-0.322	-0.499*

** Significant ($p < 0.01$) relationship between variables.

* Significant ($p < 0.05$) relationship between variables.

Table 5: Spearman's rank order correlations between times for the 0-10 meter (m), 0-20 m, and 0-40 m intervals of a 40-m sprint, and T-test and change-of-direction and acceleration test (CODAT) times, and percentage difference in reach distance achieved for the left leg (right stance leg) and right leg (left stance leg) in field sport athletes (n = 16).

	0-10 m	0-20 m	0-40 m	T-Test	CODAT
Anterolateral	0.157	0.149	0.446	0.502*	0.804**
Lateral	0.103	0.181	0.394	0.679**	0.547*
Posterolateral	0.232	-0.131	0.050	0.218	0.597*
Posteromedial	0.682**	0.319	0.429	0.379	0.594*
Medial	0.065	0.000	0.135	-0.109	0.176
Anteromedial	0.201	0.171	0.233	0.313	0.112

** Significant ($p < 0.01$) relationship between variables.

* Significant ($p < 0.05$) relationship between variables.

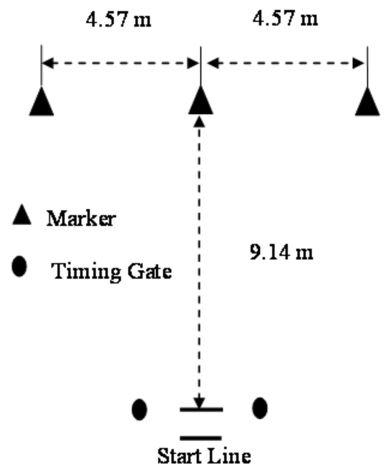

Figure 1: Dimensions for the T-test. m = meters.

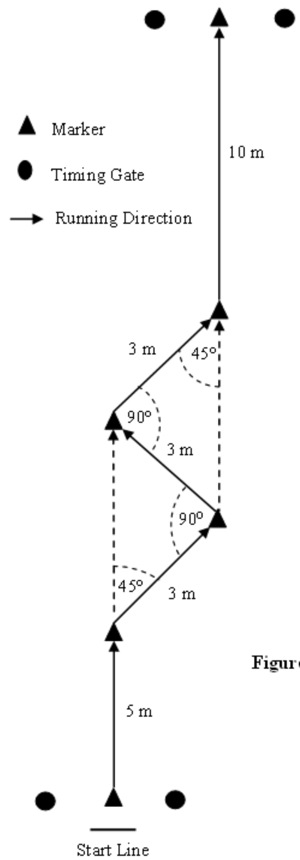

Figure 2: Change-of-Direction and Acceleration Test (CODAT) dimensions and completion route. m = meters.

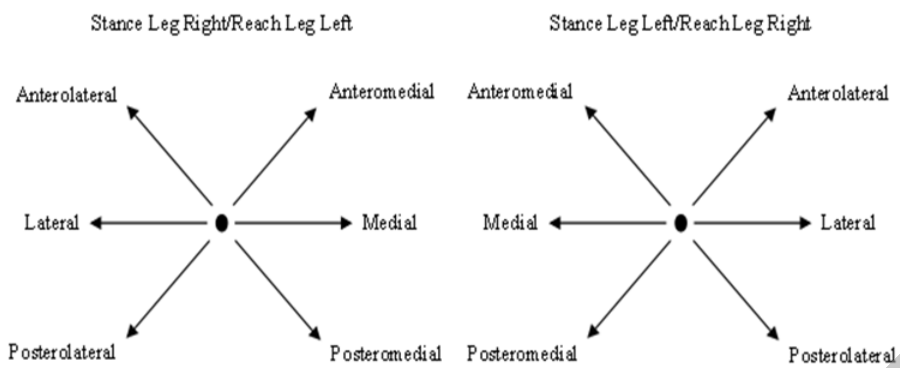

Figure 3: Reaching directions for each leg during the Star Excursion Balance Test.

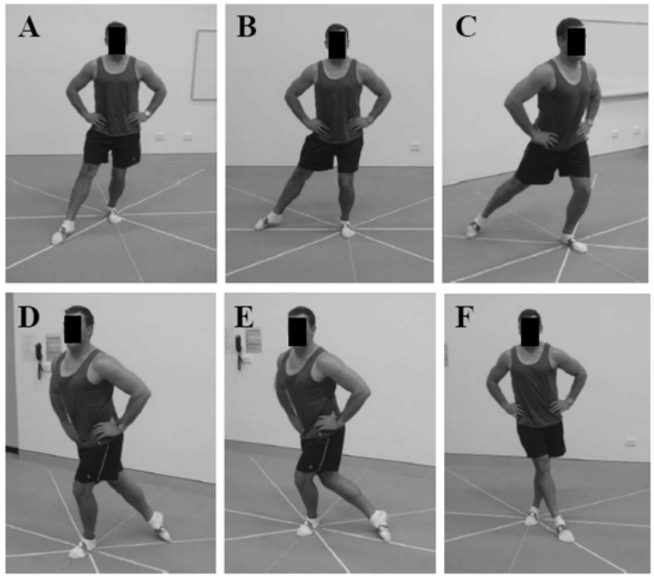

Figure 4: Modified Star Excursion Balance Test performance with a left stance leg and right reach leg for the (A) anterolateral; (B) lateral; (C) posterolateral; (D) posteromedial; (E) medial; and (F) anteromedial excursions.