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EFFECT OF UNILATERAL DYNAMIC STABILITY ON LATERAL JUMP PERFORMANCE IN TEAM SPORT ATHLETES

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Abstract This study investigated the interaction between dynamic stability, as measured by unilateral functional reach in the Star Excursion Balance Test (SEBT), and lateral jump distance for each leg in 16 male team sport athletes. The SEBT measured reach distances in 8 directions (anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, anteromedial). Pearson's correlation analysis ($p \leq 0.05$) determined relationships between SEBT excursions and left and right leg lateral jump distance. A stepwise multiple regression analysis ($p \leq 0.05$) determined excursions that predicted lateral jump performance. Reaches in the lateral, posterolateral, posterior, posteromedial, and medial directions were significantly correlated with greater jump distances for each leg ($r = 0.514 - 0.823$). Right leg posteromedial and posterior reach (left stance leg) predicted the left leg lateral jump ($r = 0.936$; $r^2 = 0.877$). Right leg lateral and anterolateral reach (left stance leg) predicted the right leg lateral jump ($r = 0.867$; $r^2 = 0.751$). Relationships between dynamic stability as measured by the SEBT, and maximal lateral jumping, were established. This is likely due to similarities in joint movements and muscle involvement. The effect of dynamic stability was particularly noticeable for the dominant leg in a lateral jump, which was the left leg in this study.

Key words: Star Excursion Balance Test, lateral bound, dynamic balance, team sports, plyometrics

INTRODUCTION

Many team sports, including field sports such as the football codes (e.g. soccer, rugby, American football), and court sports such as European handball, basketball and netball, place great demands on a player's ability to change direction when running [1, 25]. Agility describes the ability to change body positions in sport-specific situations, and is a fast, whole-body movement with change of velocity or direction in response to a particular stimulus [26]. Previous research has demonstrated that higher-level team sport athletes possess superior agility when compared to their lesser athletes [8]. As a result, it is important to understand what physical capacities can contribute to agility performance in team sports. Two of the components that have been said to be important are leg power [26, 30], and dynamic stability [3, 26]. Interestingly, not only would these two physical capacities influence agility, but they would also likely interrelate to each other.

If there is a strong interrelationship between leg power and dynamic stability, this could affect how these capacities are trained in team sport athletes. The influence of leg power, as measured through either vertical [16] or horizontal [27] jump performance, on aspects of team sports (e.g. maximal speed or agility tests) has been analyzed within the research literature. Lateral power, as assessed by jumps such as lateral bounds, has been investigated to a lesser extent. This is an issue for team sport and strength and conditioning coaches, as Meylan et al [18] demonstrated that unilateral jump assessments involving vertical, horizontal, and lateral projection assess relatively independent qualities. Furthermore, Brughelli et al [4] stated that when relating leg power to physical performance, it should be specifically defined in regards to direction (i.e. vertical, horizontal, or lateral), and whether the jump involved bilateral or unilateral projection. This highlights the need for specific analysis of lateral jump performance in team sport athletes.

Given that lateral power could contribute to agility and change-of-direction ability [26, 30], it is important to designate capacities that would influence this aspect of an athlete's physiology. As for any jump performance, effective stretch-shortening capabilities of the muscles involved in lateral projection are necessary [19]. As a lateral jump is initiated from a unilateral stance position [18], it is likely that dynamic stability will contribute to the execution of this action. Dynamic stability is the ability to maintain balance while transitioning between static and dynamic states [29]. If an athlete can maintain balance during the eccentric portion of a lateral jump, before the initiation of the concentric, power-producing phase, they would be more likely to produce appropriate force and project further. Myer et al [20] has shown that multidirectional plyometrics training can improve dynamic stability as measured by time to stabilization for a hop-and-balance test in female athletes. However, the influence of lateral jumps was not isolated within the program, nor was there assessment of male athletes. As a consequence, there is still much scope for lateral jump performance to be more specifically analyzed, particularly in male team sport athletes.

Team sport athletes will often use plyometrics activities that emphasize lateral projection [20, 28]. Establishing the relationship between a maximal lateral jump and dynamic balance test that challenges unilateral stability would have great value for team sport athletes. This would document whether a lateral plyometric activity could also be used as a dynamic stability training exercise. Therefore, this research investigated the interaction between a single-leg lateral jump as a measure of lateral power, and dynamic stability, as measured by the Star Excursion Balance Test (SEBT). The SEBT assessed dynamic stability through the use of functional reaching of the lower limbs [21, 23]. Pearson's product-moment correlations were used to investigate the relationship between lateral power and dynamic stability. A stepwise multiple regression analysis was also conducted to determine whether particular excursions can predict lateral jump performance. It was hypothesized that there would be significant correlations between greater lateral jump distance, and longer functional reach distances. Significant correlations would be particularly noticeable in the more difficult excursions (e.g. posterior and posteromedial) in the SEBT. The more difficult excursions, which provide demonstrations of greater dynamic stability, would also predict lateral jump performance. Establishing an effect between excursions in the SEBT, and single-leg lateral jump performance, could highlight that lateral jumps may concurrently develop power and dynamic stability. This would be beneficial to any athlete who needs to produce multidirectional unilateral power.

METHODS AND MATERIALS

SUBJECTS

16 males (age = 23.31±5.34 years; height = 1.78±0.07 m; mass = 80.6±9.9 kilograms) were recruited for this study. Subjects were recruited if they: were currently active in a team sport (e.g. soccer, rugby league, rugby union, Australian football, basketball, cricket, ice hockey); had a general team sport training history (≥2 times·week^{-1}) extending over the previous 12 months; were currently training for a team sport (≥3 hours·week^{-1}); and did not have any medical conditions, balance disorders, or lower-limb pathologies that would compromise study participation. The methodology and procedures used in this study were approved by the University of Newcastle 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

The assessment of lateral power and dynamic stability was conducted during 1 session. Prior to data collection, the subject's age, height, and mass were recorded. Height was measured using a portable stadiometer while the subject was barefoot (Seca 213, Ecomed Trading, Australia), and recorded to the nearest 0.01 centimeters (cm). Body mass was recorded to the nearest 0.1 kilograms using digital scales (BF-522, Tanita Corporation, Japan). A warm-up, which consisted of 5 minutes of jogging on a treadmill at a self-selected velocity, 5 minutes of dynamic stretching of the lower limbs, and practice lateral jumps, were used for all subjects.

LATERAL JUMP

For the lateral countermovement jump, the subject started by standing on the testing leg with the foot at the start line [18]. The subject was allowed to self-select the distance of the preparatory crouch before jumping laterally to the inside as far as possible and landing on 2 feet. The distance jumped was measured to the nearest 0.01 m from the start line to the lateral margin of the take-off leg with a standard tape measure. Each subject completed 3 trials for each leg, and the best trial was used for analysis. 2 minutes recovery was allocated between trials. The order in determining which leg was tested first was randomized amongst the subjects. Bilateral differences in lateral jump performance were expressed as a percentage through the formula: *(powerful leg – weaker leg)/powerful leg x 100*. The more powerful leg was defined as the leg with the greater jump distance.

STAR EXCURSION BALANCE TEST (SEBT)

Following the lateral jump assessment, dynamic stability was assessed by using the SEBT. The reliability of the SEBT test has been established [12]. The testing grid consisted of 8 standard tape measures taped to the laboratory floor, each 120 cm long. 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 each excursion was based on the direction of reach from the stance leg (Figure 1).

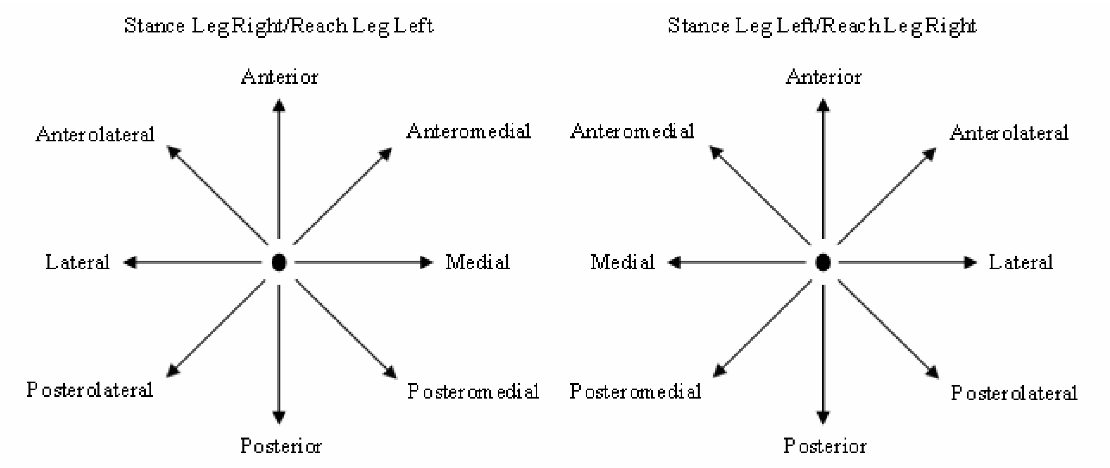

Figure 1. Reaching directions for each leg during the Star Excursion Balance Test

Subjects stood on the origin of the SEBT, 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, beginning in an anterior direction and working clockwise around the grid. During the excursion attempt, the subject reached as far as possible along each line and made 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 excursion distance after each attempt. A trial was disregarded if the subject used the reaching leg for an extended period of support, removed the stance leg from the origin, or was unable to maintain balance. If the trial was disregarded, the subject was informed and was instructed to conduct a re-trial. The same researcher measured the SEBT for all subjects. A minimum of 3 practice trials were used prior to data collection to familiarize subjects with 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 [9], and were expressed as a percentage according to the formula: *relative reach distance = reach distance/leg length x 100*.

STATISTICAL ANALYSIS

Means and standard deviations for all subjects were derived for the dependent variables (i.e. lateral jump distances, percentage difference in between-leg jump distance, and SEBT reach distances). Q-Q plots were used to check the data distribution for each variable. A paired-samples t-test was used to ascertain whether there was a significant ($p \leq 0.05$) difference in lateral jump distance between the left and right legs. Pearson's product-moment correlation analysis ($p \leq 0.05$) was then conducted to examine the relationships between lateral jump distances, between-leg differences in jump distance, and excursion distances. The strength of the correlation coefficient (r) was described as: less than 0.30 considered small; 0.31 to 0.49 moderate; 0.50 to 0.69 large; 0.70 to 0.89 very large; and 0.90 and higher near perfect for predicting relationships [14].

A stepwise multiple regression analysis ($p \leq 0.05$) was conducted to explain relationships between left and right leg lateral jump performance (dependent variables), and functional reach in the 16 excursions. The strength of the stepwise regression was described by the multiple correlation coefficient (r) and coefficient of determination (r^2). All statistical analyses were computed using the Statistics Package for Social Sciences (Version 20.0; IBM Corporation, New York, USA).

RESULTS

The data for the single-leg lateral jump distances is shown in Figure 2. A paired samples t-test found a significant ($p = 0.005$) between-leg jump difference of 5.87% ± 6.23%, with a greater jump distance achieved by the left leg. The mean functional reach distances, expressed as a percentage of leg length, for the SEBT are shown in Table 1.

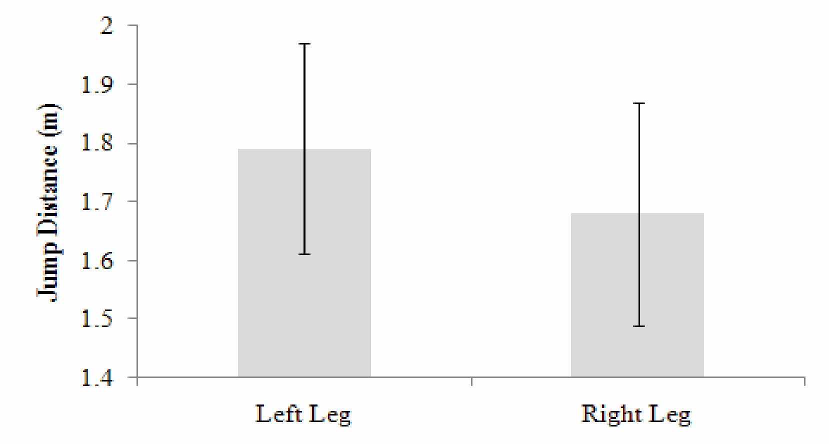

Figure 2. Descriptive data for the left leg and right leg lateral jump distance in team sport athletes (n = 16)

Table 1. Relative reach distance, as a percentage (%) of leg length, during the Star Excursion Balance Test for right leg stance/left leg reach, and left leg stance/right leg reach

	Stance Leg Right/Reach Leg Left (%)	Stance Leg Left/Reach Leg Right (%)
Anterior	87.44 ± 0.08	87.39 ± 0.06
Anterolateral	90.46 ± 0.07	90.01 ± 0.06
Lateral	88.97 ± 0.08	87.70 ± 0.09
Posterolateral	86.55 ± 0.08	85.89 ± 0.09
Posterior	85.43 ± 0.09	85.26 ± 0.10
Posteromedial	79.45 ± 0.08	79.39 ± 0.12
Medial	71.09 ± 0.10	71.83 ± 0.15
Anteromedial	69.41 ± 0.06	69.67 ± 0.06

The correlations between the lateral jump measures and excursions for when the right leg was used for stance, and the left leg reached, are displayed in Table 2. Right leg lateral jump distance significantly correlated with excursions in the posterolateral ($r = 0.548$; $p = 0.028$), posteromedial ($r = 0.660$; $p = 0.005$), and medial ($r = 0.567$; $p = 0.022$) directions. Left leg lateral jump distance correlated with excursions in the posterior ($r = 0.514$; $p = 0.014$) and posteromedial ($r = 0.588$; $p = 0.017$) directions. All correlations were large, and indicated that a greater lateral jump distance was related to a further functional reach in the particular SEBT direction. There were no significant correlations with the between-leg difference in jump distance and left leg excursions.

The correlations between the lateral jump measures and excursions for when the left leg was used for stance, and the right leg reached, are shown in Table 3. 5 out of 8 excursion directions significantly correlated with the lateral jump distance for the right leg, with the correlation strength ranging from large to very large. These included the lateral ($r = 0.708$; $p = 0.002$), posterolateral ($r = 0.649$; $p = 0.007$), posterior ($r = 0.562$; $p = 0.024$), posteromedial ($r = 0.823$; $p = 0.000$), and medial ($r = 0.706$; $p = 0.002$) reaches. For the left leg lateral jump distance, significant, large relationships were established with 4 out of 8 excursions, including the lateral ($r = 0.676$; $p = 0.004$), posterolateral ($r = 0.614$; $p = 0.011$), posterior ($r = 0.534$; $p = 0.033$), and posteromedial ($r = 0.633$; $p = 0.009$) reaches. As for the left leg excursions, greater right leg excursions were associated with greater lateral jump distances. There were no significant correlations with the between-leg difference in jump distance and right leg excursions.

Table 2. Pearson's product-moment correlations between lateral jump (LJ) distance for the right and left legs, and percentage jump distance difference between the legs, and reach distance for the left leg while the right leg was used for stance in team sport athletes (n = 16); r = correlation coefficient; p = significance

		Right Leg LJ	Left Leg LJ	LJ Difference
Anterior	r	0.045	-0.004	0.122
	p	0.868	0.987	0.652
Anterolateral	r	0.191	0.175	0.033
	p	0.478	0.516	0.904
Lateral	r	0.423	0.442	-0.038
	p	0.103	0.086	0.889
Posterolateral	r	0.548	0.486	0.060
	p	0.028*	0.056	0.824
Posterior	r	0.424	0.514	-0.157
	p	0.101	0.014*	0.562
Posteromedial	r	0.660	0.588	0.037
	p	0.005*	0.017*	0.892
Medial	r	0.567	0.481	0.130
	p	0.022*	0.059	0.632
Anteromedial	r	0.056	-0.145	0.358
	p	0.836	0.591	0.173

* Significant ($p \leq 0.05$) relationship between variables

Table 3. Pearson's product-moment correlations between lateral jump (LJ) distance for the right and left legs, and percentage jump distance difference between the legs, and reach distance for the right leg while the left leg was used for stance in team sport athletes (n = 16); r = correlation coefficient; p = significance

		Right Leg LJ	Left Leg LJ	LJ Difference
Anterior	r	0.020	-0.061	0.162
	p	0.942	0.824	0.549
Anterolateral	r	0.152	0.075	0.130
	p	0.573	0.783	0.632
Lateral	r	0.708	0.676	0.015
	p	0.002*	0.004*	0.957
Posterolateral	r	0.649	0.614	0.024
	p	0.007*	0.011*	0.929
Posterior	r	0.562	0.534	0.006
	p	0.024*	0.033*	0.981
Posteromedial	r	0.823	0.633	0.239
	p	0.000*	0.009*	0.373
Medial	r	0.706	0.448	0.332
	p	0.002*	0.082	0.209
Anteromedial	r	0.254	0.019	0.419
	p	0.343	0.945	0.106

* Significant ($p \leq 0.05$) relationship between variables

Table 4 displays the stepwise multiple regression data for the left and right leg lateral jumps. For the left leg lateral jump, the posteromedial reach distance achieved by the right leg (left stance leg) predicted performance ($r = 0.823$; $r^2 = 0.677$; $p < 0.001$). Prediction strength for the left leg lateral jump improved when right leg posterior reach was added to the stepwise process ($r = 0.936$; $r^2 = 0.877$; $p < 0.001$). Excursion distances recorded for the right leg, while the left leg was used for stance, also served as predictors for right leg lateral jump performance. Right leg lateral reach ($r = 0.676$; $r^2 = 0.457$; $p = 0.004$), and then this reach combined with right leg anterolateral reach ($r = 0.867$; $r^2 = 0.751$; $p = 0.001$), predicted the right leg lateral jump.

Table 4. Stepwise linear regression analysis between lateral jump distance for the right and left legs (dependent variables) and reach distances for each leg during the Star Excursion Balance Test; r = multiple correlation coefficient; r^2 = coefficient of determination

Variables	r	r^2	Significance
Right Leg Lateral Jump			
Right Leg Lateral Reach	0.676	0.457	p = 0.004
Right Leg Lateral Reach, Right Leg Anterolateral Reach	0.867	0.751	p < 0.001
Left Leg Lateral Jump			
Right Leg Posteromedial Reach	0.823	0.677	p < 0.001
Right Leg Posteromedial Reach, Right Leg Posterior Reach	0.936	0.877	p < 0.001

DISCUSSION

This study analyzed the effect and influence of dynamic stability as measured by the SEBT on maximal lateral jump performance. The ability to maintain balance during the preparation phase prior to a lateral jump should allow for greater range of motion during stance, which can aid in superior jump performance [6]. The actions of swing, or free leg, during a lateral jump will also contribute to dynamic stability. Prior to take-off for a maximal lateral jump, subjects will attempt to externally rotate and extend the hip of the free leg, such that it is positioned posterior to the body prior to take-off. At take-off, the hip will internally rotate and flex to bring the free leg back towards alignment with the stance leg prior to landing on two feet. If an athlete can effectively control the movements of the free leg, they will be better placed at jump take-off. Given the movements required within the lateral jump, it was hypothesized that there would be significant interactions between jump distances and functional reach distances. As will be discussed, to an extent this was proven correct.

There were several significant relationships between lateral jump performance and excursions in particular directions in the SEBT (Tables 2 and 3). There were no significant relationships for the between-leg jump differences and functional reaches. The shared variance for significant relationships ranged from 26% (left leg lateral jump and left leg posterior reach), up to 68% (right leg lateral jump and right leg posteromedial reach). Significant relationships were particularly evident at the more difficult excursions - anterolateral, lateral, posterolateral, and posteromedial [13]. There were similarities in the movements required within these excursions, and those produced during a lateral jump. For instance, greater posterolateral, posteromedial and medial reaches are achieved through an increase in hip flexion and internal rotation of the stance leg [23]. As stated, a maximal lateral jump requires the hip of the stance leg to flex and internally rotate to reposition the body during the preparatory phase. Greater plantar and dorsi flexion of the ankle aids posterior and anterior reach, while greater ankle inversion and eversion facilitate medial and lateral excursions [10]. As restricted ankle joint range of motion can affect vertical jump performance [22], the same could be expected for lateral jump performance. Given the similarities in joint mobility for lateral jumping and certain excursions similarities, it would be expected that plyometric activities involving lateral projection could be used to stress dynamic stability in the training of team sport athletes.

There may also be similarities in muscle recruitment patterns between functional reaching and lateral jumps. Single-leg squats, which are the foundation for SEBT excursions, heavily recruit the muscles about the hip, including the rectus femoris, gluteus maximus, and gluteus medius [2]. In the posterior excursions (posterolateral, posterior, and posteromedial), the hamstrings are heavily recruited [7]. Additionally, greater reach distances in the posteromedial and medial directions are reliant on greater hip flexion of the stance leg, which demands greater activity in the vastus muscles [7]. In regard to a unilateral horizontal jump performance in male soccer players, the vastus lateralis, hamstrings, and gluteus medius muscles are all active [11]. Although there is limited analysis on the muscle activity in maximal lateral jumps, it would be expected that these muscles, with contributions from the hip abductor and adductor muscles [5], would be critical for maximizing lateral jump distance. The results provide further support for the use of lateral jump exercises in training to improve lateral power and dynamic stability, due to the recruitment of muscle groups important for both capacities.

The excursions that predicted lateral jump performance for both the right and left legs involved right leg reaches, which meant the left leg was used for stance (Table 4). When considering jump performance, the left leg was dominant (Figure 2). Ross et al. [24] suggests that the dominant leg has greater proprioceptive function when compared to the non-dominant leg. Greater proprioceptive function of the left leg within this subject group may have impacted the unilateral activity of the lateral jump to a greater extent. As evidence of this, the posteromedial and posterior excursions for the right leg, while the left leg was used for stance significantly ($r = 0.936$; $r^2 = 0.877$; $p < 0.001$), predicted the left leg lateral jump. As stated, these excursions are the most difficult [7, 13], and neuromuscular control within the stance leg would be essential for these excursions, in addition to the jump performance itself.

For the right leg lateral jump, the excursions in the lateral and anterolateral direction for the right leg were involved in the significant stepwise regression process (Table 4). Interestingly, these relationships were established with the free leg (i.e. the dominant left leg), and not the stance leg (i.e. the right leg). Thus, the proprioceptive function of the free, dominant leg can influence the power performance of non-dominant stance leg. The range of motion of the free leg can aid valuable momentum to a movement that requires translation [15]. The dominant left leg, with potentially enhanced proprioceptive function [24], may have undergone greater abduction and flexion at the hip to assist with jump projection. A greater range of motion of the lower limbs can enhance jump performance [6]. A dominant leg that can reach further laterally, which was the left leg for subjects in the current study, could also translate this mobility to a maximal lateral jump.

A limitation of this study is that only one form of lateral jump was used (i.e. a lateral bound). Other lateral projection exercises, such as a zig-zag or crossover bound, may have elicited different relationships with excursions in the SEBT. Furthermore, motion and electromyographic analysis of the lateral jump could be used to confirm several of the assumptions raised in this analysis. Nonetheless, the results from this study indicate that there are relationships between unilateral dynamic stability and lateral jump performance. This has implications for team sport and strength and conditioning coaches, especially in regard to programming lateral jump exercises for speed and power development. Coaches can be confident that single-leg exercises involving lateral projection will stress not only the stretch-shortening capacities of the leg muscles, but also the dynamic stability of the legs as well.

CONCLUSION

This research illustrated that there are relationships between dynamic stability, as measured by functional reach distance in the SEBT, and a maximal lateral jump. The influence of dynamic stability was particularly noticeable for the dominant leg in a lateral jump. The incorporation of lateral jump exercises in the strength and conditioning programs of team sport athletes should not only improve lateral power, but dynamic stability as well.

PRACTICAL APPLICATION

Due to these relationships between dynamic stability and lateral jump performance, it is recommended that lateral jump exercises be consistently incorporated into the training regimes of team sport athletes. This could be done through using specific plyometrics activities, such as lateral, zig-zag, or crossover bounds. Given that previous research has demonstrated that appropriately designed plyometrics training programs can improve linear sprinting speed [17], it would be expected that a training program that includes lateral jump exercises specific to an athlete's sport should engender a degree of crossover into agility. Strength and conditioning practitioners who use lateral jump exercises in their programs can do so with the expectation that there should be improvements in lateral power and dynamic stability.

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