Relationship Between Unilateral Jumping Ability and Asymmetry on Multidirectional Speed in Team-Sport Athletes

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Abstract

Lockie, RG, Callaghan, SJ, Berry, SP, Cooke, ERA, Jordan, CA, Luczo, TM, and Jeffriess, MD. Relationship between unilateral jumping ability and asymmetry on multidirectional speed in team-sport athletes. *J Strength Cond Res* 28(12): 3557–3566, 2014—The influence of unilateral jump performance, and between-leg asymmetries, on multidirectional speed has not been widely researched. This study analyzed how speed was related to unilateral jumping. Multidirectional speed was measured by 20-m sprint (0–5, 0–10, 0–20-m intervals), left- and right-leg turn 505, and modified T-test performance. Unilateral jump performance, and between-leg asymmetries, was measured by vertical (VJ), standing broad (SBJ), and lateral (LJ) jumping. Thirty male team-sport athletes (age = 22.60 ± 3.86 years; height = 1.80 ± 0.07 m; mass = 79.03 ± 12.26 kilograms) were recruited. Pearson's correlations (r) determined speed and jump performance relationships; stepwise regression ascertained jump predictors of speed ($p \leq 0.05$). Subjects were divided into lesser and greater asymmetry groups from each jump condition. A 1-way analysis of variance found between-group differences ($p \leq 0.05$). Left-leg VJ correlated with the 0–10 and 0–20-m intervals ($r = -0.437$ to -0.486). Right-leg VJ correlated with all sprint intervals and the T-test ($r = -0.380$ to -0.512). Left-leg SBJ and LJ correlated with all tests ($r = -0.370$ to -0.729). Right-leg SBJ and LJ related to all except the left-leg turn 505 ($r = -0.415$ to -0.650). Left-leg SBJ predicted the 20-m sprint. Left-leg LJ predicted the 505 and T-test. Regardless of the asymmetry used to form groups, no differences in speed were established. Horizontal and LJ performance related to multidirectional speed. Athletes with asymmetries similar to this study (VJ = ~10%; SBJ = ~3%; LJ = ~5%) should not experience speed detriments.

Key Words between-leg imbalance, linear speed, change-of-direction speed, horizontal power, lateral power

Introduction

Leg power is a necessary part of the physiological make-up of athletes from team sports (6,7,21), which include field-based sports such as the football codes, and court sports such as basketball and European handball. Lower-limb power should manifest within the step patterns for running gait (31). However, when considering the implications on a team-sport athletes' gait, it is important to note that these athletes must be able to sprint in multiple directions (39,45). Multidirectional speed encompasses both linear and change-of-direction speed (24). Linear speed involves straight-line maximal running; change-of-direction speed combines the ability to accelerate and decelerate rapidly, and change direction, which is also a component of agility (45). Leg power has been stated to be an essential component of both linear (21,31) and change-of-direction speed (39,45).

Leg power is often extrapolated through performance in jump tests (32). Although jumping does not provide a direct measure of power, jump assessments are easy to administer by a strength and conditioning coach, and they provide a valid assessment of an athlete's physical capacity (6). As an example, higher-level football players perform better in assessments such as the vertical jump (VJ) and standing broad jump (SBJ) when compared with players from lower levels (13,40). The relationship between power measured by jump tests and speed has been investigated within the literature. The consensus is that team-sport athletes with better jump performance will tend to be faster in multidirectional speed tests (13,21,40). However, most research that has analyzed this relationship has used bilateral assessments, including the vertical countermovement (3,7,21) and squat jumps (3,7); SBJs (13,35,42); and

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drop jumps from certain heights (7,21). In contrast, there is less research investigating relationships between unilateral jump performance and multidirectional speed (4,15,26,28,32). This is despite the fact that multidirectional sprinting is a cyclic activity, which stresses an athlete's ability to generate unilateral power (39,45).

Brughelli et al. (5) stated that when relating leg power to physical performance, it should be specifically defined in regards to direction (e.g., vertical, horizontal, or lateral), and the type of projection (i.e., bilateral or unilateral). Maulder and Cronin (26) found that unilateral vertical countermovement and squat jumps related to the 20-m sprint (correlation coefficient [r] = −0.52 to −0.73). Unilateral VJ performance has also been related ($r = -0.71$) to 25-m sprint time in female collegiate soccer players (28), whereas unilateral horizontal jump performance, restricted to a concentric-only take-off, was a significant predictor ($r = -0.73$ to -0.86) of 20-m sprint performance in athletes from a variety of sporting backgrounds (26). In contrast, Meylan et al. (32) found that unilateral VJ ($r = -0.248$ to -0.410) and LJ ($r = -0.284$ to -0.288) were relatively poor predictors of a change-of-direction speed test that involved 2 up-and-back cuts over a 5-m distance in physical education university students. However, a physical education student may not be as conditioned as an experienced team-sport athlete in making maximal changes of direction, highlighting the need to investigate this capacity specifically in this population. Indeed, in line with Maulder and Cronin (26), Meylan et al. (32) suggested that the unilateral horizontal jump performance could be used as a predictor for speed, and investigation into team-sport athletes could confirm this. Because of the relative paucity of research, the relationship between unilateral power measured by typical jump tests and multidirectional sprinting specific to team-sport athletes requires further analysis.

Although there is value in determining the relationship between unilateral jump performance and multidirectional speed, there may be an even greater need to ascertain the impact that jump and power asymmetries between the legs has upon sprint performance. Indeed, previous research has shown that greater between-leg isokinetic strength asymmetries measured for the knee flexors and extensors can negatively impact multidirectional speed (24). Given that unilateral jumping does provide an indication of lower-limb function (2,4,34,37), there is limited research that has documented the influence of leg power asymmetries as measured through jump performance on linear and change-of-direction sprinting. Bračič et al. (4) observed greater asymmetries in track sprinters, measured by unilateral vertical countermovement jumps from each leg, related to slower sprint starts due to a lower impulse generated on the track starting blocks. However, between-leg asymmetries may not impact team sport–specific performance (15,37). When considering asymmetries defined by unilateral VJ performance, Hoffman et al. (15) found that they did not relate to change-of-direction speed as measured by the 3-cone drill in collegiate football players. However, Hoffman et al. (15) did not measure asymmetries defined by horizontal jumps or LJs. Given the practicality of using jump performance as a measure of leg power, there is a need to further analyze how unilateral jump performance and asymmetry may relate to multidirectional speed in team-sport athletes.

Therefore, this study will analyze the relationship that unilateral jumping measured by single-leg VJ, horizontal jump, and LJs, has with multidirectional speed in team-sport athletes. Multidirectional speed will be measured by the 20-m sprint, 505 change-of-direction speed test, and modified T-test. The 505 is also a popular test for team sports, as it can isolate cutting off 1 leg (9). This test has been used to assess athletes from sports such as soccer (25), rugby league (12), and cricket (20) because of the 180° direction changes required in certain situations for these athletic activities. The T-test has also been used for a range of athletes who perform linear sprint accelerations, lateral shuffling, and back pedaling in their sport, including basket ballers (8), volley ballers (11), and general team-sport athletes (36,38). A modified version that shortens the test distance makes the assessment more team sport specific (36). Subjects will also be split into lesser and greater asymmetry groups for each jump condition, whereby any differences in speed performance between the groups will be determined. It is hypothesized that those subjects who demonstrate better jump performances and lesser asymmetries in between-leg unilateral jumping will also possess faster multidirectional speed. This research has significance for strength coaches in that it will document the relationship between unilateral jumping and linear and change-of-direction speed, and demonstrate the movement planes in which team-sport athletes should develop power. Furthermore, this study will also show whether asymmetries in multidirectional leg power can impact linear and change-of-direction speed in experienced team-sport athletes, providing guidance in conditioning programs for these athletes.

Methods

Experimental Approach to the Problem

This study examined the relationship between unilateral jump performance (vertical, horizontal, and lateral), and between-leg asymmetries derived from the jumps, with multidirectional speed (20-m sprint, 505, and modified T-test) in team-sport athletes. A cross-sectional analysis of experienced team-sport athletes was conducted. Pearson's correlation analysis determined significant relationships between unilateral jump performance and multidirectional speed. Stepwise multiple regressions ascertained the primary jump predictors of speed within the current study. Finally, subjects were split into lesser and greater asymmetry groups according to each jump condition to analyze any differences between the groups in multidirectional speed. The dependent variables were: 20-m sprint time, including the 0–5 m, 0–10 m, and 0–20-m intervals; time in the 505 for turns off the left and right feet; modified T-test times with movement initiation to

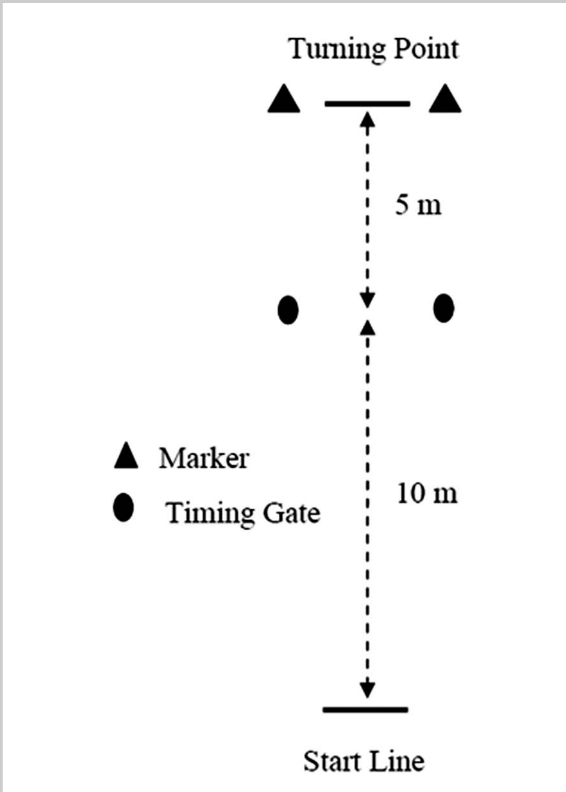

Figure 1. Layout of the 505. Subjects sprinted over the 10-m distance through the timing gate and over the 5-m distance to the turning point. They then planted either their left or right foot on the turning point to stop and change direction, before returning back through the timing gate.

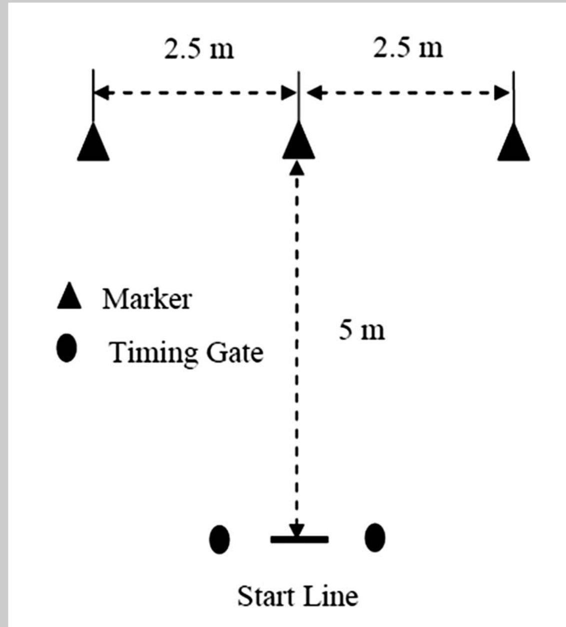

Figure 2. Layout of the modified T-Test. Subjects sprinted forwards 5 m to touch the top of the middle marker. They then side-shuffled 2.5 m to the left or right to touch the next marker, side-shuffled 5 m in the opposite direction to touch the next marker, side-shuffled 2.5 m back to touch the middle marker again, before back-pedaling past the start line.

the left and right; distances for the unilateral VJ, horizontal jump, and LJ; and the between-leg percentage differences in the height and distance for jumps in each plane of movement.

Subjects

Thirty male recreational team-sport athletes (age = 22.60 ± 3.86 years; height = 1.80 ± 0.07 m; mass = 79.03 ± 12.26 kg) volunteered to participate in this study. Subjects were recruited if they (a) were aged 18 years or older, (b) currently participated in a team sport (e.g., soccer, basketball, baseball, rugby league, rugby union, Australian football, and touch football), (c) had a team sport training history (≥2 times per week) that extended over the previous year, (d) were currently training for a team sport (≥3 $h \cdot wk^{-1}$), (e) maintained their normal physical activity during the duration of the study, and (f) did not have any medical conditions compromising participation in the study. Although there may be certain differences in traits between different sport participants, the analysis of performance regarding physical characteristics common to athletes from assorted team sports has been conducted within the literature (21,24,36,38). All subjects were familiar with the tests performed in this study, which occurred within the competition season for all subjects. The institutional ethics committee approved the methodology and procedures used in this study. All subjects received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained before testing.

Procedures

Testing was conducted over 2 sessions, separated by 1 week. Each session lasted for 30–40 minutes in duration. Day 1 consisted of the 20-m sprint, and the jump tests, which were performed in the order documented in the methods. The 505 and modified T-test were completed on day 2. All assessments were conducted in the biomechanics laboratory at the university, which had a textured concrete floor. Before data collection on day 1, the subject's age, height, and body mass were recorded. Height was measured barefoot using a stadiometer (Ecomed Trading, Seven Hills, Australia). Body mass was recorded using electronic digital scales (Tanita Corporation, Tokyo, Japan). A standardized warm-up, consisting of 10 minutes of jogging at a self-selected pace on a treadmill, 10 minutes of dynamic stretching, progressive speed runs over the testing distances, and practice jumps, was completed before each session. Subjects were tested at the same time of day for both testing sessions, did not eat for 2–3 hours before their sessions, and refrained from intensive exercise and any form of stimulant in the day before testing. Subjects were permitted to consume water ad libitum throughout the sessions. Three-minute recovery was allocated between speed test trials; 2-minute recovery was

TABLE 1. Descriptive data (mean ± *SD*; 90% confidence intervals [CI]) for the 0–20-m sprint (0–5, 0–10, and 0–20-m intervals), 505 with turns off the left and right leg, T-test with initial movement to the left or right, and unilateral vertical, standing broad, and lateral jump, and between-leg asymmetries for each jump condition.

Speed and jump variables	Subject mean ($n = 30$)	90% CI
0–5 m (s)	1.033 ± 0.075	1.010–1.056
0–10 m (s)	1.760 ± 0.010	1.729–1.791
0–20 m (s)	3.039 ± 0.164	2.988–3.089
505 left (s)	2.398 ± 0.093	2.369–2.427
505 right (s)	2.397 ± 0.110	2.362–2.430
T-Test left (m)	6.281 ± 0.082	6.167–6.395
T-Test right (m)	6.285 ± 0.368	6.181–6.388
Left leg vertical jump (m)	0.39 ± 0.08	0.37–0.42
Right leg vertical jump (m)	0.40 ± 0.07	0.38–0.42
Vertical jump between-leg asymmetry (%)	10.4 ± 10.8	7.0–13.7
Left leg standing broad jump (m)	2.05 ± 0.19	1.99–2.11
Right leg standing broad jump (m)	2.03 ± 0.17	1.98–2.08
Standing broad between-leg asymmetry (%)	3.3 ± 3.0	2.4–4.3
Left leg lateral jump (m)	1.86 ± 0.19	1.80–1.92
Right leg lateral jump (m)	1.82 ± 0.21	1.76–1.89
Lateral jump between-leg asymmetry (%)	5.1 ± 3.9	3.9–6.3

provided between jump test trials. For each jump test, 3 trials were performed for each leg; the best jump trial for each leg was used for analysis. The order of which leg was tested first was randomized between subjects (18). Bilateral asymmetries were expressed as a percentage through the formula: (better performing leg − lesser performing leg)/better performing leg × 100 (24,34). The better performing leg was defined as the leg with the greater jump height or distance.

Twenty-Meter Sprint

Twenty-meter sprint time was recorded by a timing lights system (Fusion Sports, Coopers Plains, Australia). Gates were positioned at 0, 5, 10, and 20 m, at a height of 1.2 m. Sprints over 5 m (20,21), 10 m (20,21,37), and 20 m (8,26) have been used in the assessment of team-sport athletes. Subjects began each sprint from a standing start 0.3 m behind the start line to trigger the first gate. Once ready, subjects were allowed to start in their own time and were instructed to run maximally through all timing gates once they initiated their sprint. If the subject rocked backwards or forwards before starting, the trial was disregarded and repeated following the required rest interval. Time for each distance was recorded to the nearest 0.001 seconds. Subjects completed 3 trials, with the fastest trial used for analysis.

Unilateral Vertical Jump

The VJ was used as an indirect measure of leg power in the vertical plane. A Yardstick apparatus (Swift Performance Equipment, Wacol, Australia) was used to measure VJ performance (35). The subject initially stood side-on to the Vertec (on the subjects' dominant upper-limb side), and while keeping his heels on the floor, reached upward as high as possible, fully elevating the shoulder to displace as many vanes as possible. The last vane moved was recorded as the subject's standing reach height and zero reference. The jump involved the subject leaping as high as possible using a 1-foot take-off, with no preparatory step, and then landing on both feet. Height was recorded in centimeters from highest vane moved, by subtracting the standing reach height from the jump height. This measurement was converted to meters for the final analysis. No restrictions were placed on the knee angle during the eccentric phase of the jump. The procedures used for the unilateral VJ, with a countermovement freely chosen by subjects and the contribution of arm swing, have been used previously within the scientific literature (27,34,37), and thus were adopted for this study. All subjects were instructed to use a countermovement; if they did not, the trial was disregarded and reattempted.

Unilateral Standing Broad Jump

The SBJ was used as an indirect measure of horizontal power. The subject placed the toes of both feet on the back of the start line, before balancing on the leg to be tested. With a simultaneous arm swing and crouch, the subject then leaped as far forward as possible, taking off from 1 leg, before landing on 2 feet (32). Subjects had to "stick" the landing for the trial to be counted. If the subject did not do this, the trial was disregarded and another was attempted. Subjects were instructed to use a countermovement, and no restrictions were placed on body angles attained during the preparatory phase of the jump or the arm swing used, which was as per the unilateral VJ (27,34,37). The distance was measured to the nearest 0.01 m using a standard tape measure (HART Sport, Aspley, Australia), perpendicular from the front of the start line to the posterior aspect of the back heel at the landing (13,35).

Lateral Jump

Lateral jump performance was used as an indirect measure of lateral power for each leg. The subject started by standing on the testing leg with the medial border of the foot of the leg being tested level with the start line (32), and self-selected the preparatory crouch distance. Subjects then jumped laterally to the inside, and landed on 2 feet. To be consistent

TABLE 2. Correlations between 0- and 20-m sprint (0–5, 0–10, and 0–20-m intervals), 505 with turns off the L and R leg, T-test with initial movement to the L or R, and unilateral VJ, SBJ, and LJ, and between-leg asymmetries for each jump condition.*

	0–5 m	0–10 m	0–20 m	505 L	505 R	T-Test L	T-Test R
Left-leg VJ							
r	−0.328	−0.437	−0.486	−0.033	−0.238	−0.202	−0.232
p	0.077	0.016†	0.006†	0.863	0.206	0.285	0.218
Right-leg VJ							
r	−0.400	−0.454	−0.512	−0.062	−0.224	−0.380	−0.452
p	0.029†	0.012†	0.004†	0.746	0.235	0.039†	0.012†
VJ asymmetry							
r	−0.176	−0.145	−0.132	0.073	0.083	0.124	0.061
p	0.353	0.443	0.485	0.701	0.664	0.514	0.747
Left-leg SBJ							
r	−0.560	−0.662	−0.729	−0.370	−0.535	−0.558	−0.642
p	0.001†	<0.001†	<0.001†	0.044†	0.002†	0.001†	<0.001†
Right-leg SBJ							
r	−0.464	−0.574	−0.650	−0.306	−0.484	−0.561	−0.569
p	0.010†	0.001†	<0.001†	0.100	0.007†	0.001†	0.001†
SBJ asymmetry							
r	0.076	0.062	0.059	0.027	0.036	0.060	0.000
p	0.691	0.743	0.755	0.889	0.849	0.755	0.999
Left-leg LJ							
r	−0.451	−0.582	−0.646	−0.472	−0.585	−0.665	−0.721
p	0.023†	0.001†	<0.001†	0.009†	0.001†	<0.001†	<0.001†
Right-leg LJ							
r	−0.415	−0.508	−0.599	−0.318	−0.474	−0.467	−0.546
p	0.023†	0.004†	<0.001†	0.087	0.008†	0.009†	0.002†
LJ asymmetry							
r	−0.066	−0.004	−0.027	0.189	0.176	0.029	−0.081
p	0.727	0.983	0.888	0.316	0.352	0.878	0.672

*L = left; R = right; VJ = vertical jump; SBJ = standing broad jump; LJ = lateral jump; *r* = correlation coefficient; *p* = significance.
†Significant ($p \leq 0.05$) relationship between variables.

with the other jump tests (27,34,37), subjects were instructed to use a countermovement, and no restrictions were placed on the arm swing used or the range of the preparatory crouch. The distance jumped was measured with a standard tape measure (HART Sport) to the nearest 0.01 m, perpendicular from the start line to the lateral margin of the take-off leg. If subjects did not "stick" the landing and over-balanced, the trial was disregarded and reattempted.

505 Change-of-Direction Speed Test

As previously acknowledged, the 505 was used in this research due to its utilization in team-sport assessment, as it isolates change-of-direction ability for each leg (12,20,25). The methodology used for the 505 was instituted as per established methods (9), with 1 timing gate (Fusion Sports, Coopers Plains, Australia) used to record time. The set-up is shown in Figure 1. During the warm-up, subjects were allowed to familiarize themselves with the movement patterns required for the 505. Subjects used a standing start with the same body position as per the 20-m sprint, with their front foot 0.3 m behind the start line. The subjects sprinted through the timing gate to the turning line, indicated by a line marked on the floor and markers. Subjects placed either the left or right foot, depending on the trial, on or behind the turning line, before sprinting back through the gate. Three trials were recorded for turns off the left and right leg, the order of which was randomized among the subjects. Time was recorded to the nearest 0.001 seconds. If the subject changed direction before hitting the turning point, or turned off the incorrect foot, the trial was disregarded and the subject completed another trial after the rest period. The fastest trial for each of the 505 conditions was used.

Modified T-Test

As stated, the T-test incorporates linear sprints, lateral shuffling, and back pedaling, which are actions required of team-sport athletes, and thus, this test is often used in their assessment (8,11,36,38). A modified T-test, incorporating shorter distances, was used for this research (36). The smaller distances between markers are representative of the sprint accelerations required in team sports, were designed to make the T-test more specific to field and court sport athletes, and

Table 3. Stepwise linear regression analysis between 0- and 20-m sprint (0–5, 0–10, and 0–20-m intervals), 505 with turns of the left and right leg, and modified T-test with initial movement to the left or right (dependent variables), and unilateral vertical, standing broad, and lateral jump, and between-leg asymmetries for each jump condition.*

Best predictors of the speed tests	*r*	r^2	Significance (*p*)
0–5-m interval			
Left-leg SBJ	0.560	0.313	0.001
0–10-m interval			
Left-leg SBJ	0.662	0.438	<0.001
0–20-m interval			
Left-leg SBJ	0.729	0.532	<0.001
505 L			
Left-leg LJ	0.472	0.222	0.009
505 R			
Left-leg LJ	0.585	0.343	0.001
T-test L			
Left-leg LJ	0.665	0.442	<0.001
T-test R			
Left-leg LJ	0.721	0.519	<0.001

*L = left; R = right; *r* = multiple regression correlation coefficient; *p* = significance; SBJ = standing broad jump; LJ = lateral jump.

are a reliable assessment of change-of-direction speed (36). Markers were positioned as shown in Figure 2, with a start line indicated by tape on the laboratory floor, 0.3 m behind the 1 timing gate used in the test (Fusion Sports). Subjects faced forwards at all time during the modified T-test. To start the test, subjects sprinted 5 m forwards to touch the top of the middle marker. They then side-shuffled 2.5 m to the left or right, depending on the trial, to touch the next marker, side-shuffled 5 m in the opposite direction to touch the next marker, side-shuffled 2.5 m back to touch the middle marker, before back-pedaling to pass through the timing gate again to finish. 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. Failure to adhere to this meant the trial was stopped and another attempted after the required rest period. Six trials were completed in total; 3 with movement initiation at the middle marker to the left, and 3 with movement initiation to the right. The order of trials was randomized among the subject group, and the best trial from each T-test condition was analyzed.

Statistical Analyses

Descriptive statistics (mean ± *SD* and 90% confidence intervals) were used to provide the profile for each measured parameter. The Levene statistic was used to determine homogeneity of variance of the data. Pearson's 2-tailed correlation analysis ($p \leq 0.05$) determined relationships between speed test times (0–5, 0–10, 0–20 m, 505 with left- and right-leg turns, and T-test with initial movement to the left or right), and unilateral jump performance and between-leg asymmetries for the VJ, SBJ, and LJ. The strength of the correlation coefficient was designated as per Hopkins (17). For the purpose of this study, an r value between 0 and 0.3, or 0 and −0.3, was considered small; 0.31 to 0.49, or −0.31 to −0.49, moderate; 0.5 to 0.69, or −0.5 to −0.69, large; 0.7 to 0.89, or −0.7 to −0.89, very large; and 0.9 to 1, or -0.9 to −1, near perfect for predicting relationships. Additionally, stepwise multiple regression analyses ($p \leq 0.05$) were conducted for the 20-m sprint, 505, and T-test, to further analyze their relationships with VJ, horizontal jump, and LJ performance and asymmetries. Each speed test acted as a dependent variable.

To extend the analysis of unilateral jump performance and asymmetries, subjects were split into groups of lesser and greater asymmetry derived from each jump condition. To ensure that the groups were composed of subjects with different levels of jump asymmetry, a cutoff point was established through the formula mean + (0.2 × *SD* of the mean) (23). Multiplying the between-subjects *SD* by 0.2 provides the smallest worthwhile change in the mean for this sample (16). By providing a cutoff point above the overall jump asymmetry mean for either VJ, SBJ, or LJs as measured in this study, ensured that subjects higher than this value had greater jump asymmetry. Therefore, subjects above this cutoff point were placed in the greater asymmetry group; subjects below this were placed in the lesser asymmetry group. A 1-way analysis of variance ($p \leq 0.05$) calculated significant differences between the dependent variables (i.e., the multidirectional speed test times). All statistics were computed using the Statistics Package for Social Sciences Version 20.0 (IBM, Armonk, NY, USA).

Results

The descriptive data for this study is shown in Table 1. The mean unilateral VJ asymmetry was larger (10.4 ± 10.8%) than that for the SBJ (3.3 ± 3.0%) and LJ (5.1 ± 3.9%). Seven of 14 correlations for the unilateral VJs were significant (Table 2). For both the horizontal and lateral unilateral jumps, 13 of 14 relationships were significant. None of the between-leg jump asymmetry measures correlated with any of the multidirectional speed tests.

All significant correlations were negative, indicating that greater jump heights or distances were associated with faster speed test times. The left-leg VJ moderately correlated with the 0–10 and 0–20-m intervals of the 20-m sprint. The right-leg VJ correlated with all intervals in the 20-m sprint, ranging from moderate to large, and the T-test with initial movement to the left (moderate). The left-leg SBJ correlated with all the speed test times; 1 correlation was moderate (505 with

Table 4. Descriptive data for the unilateral VJ, SBJ, and LJ A, 0–20-m sprint (0–5, 0–10, and 0–20-m intervals), 505 with turns off the L and R, T-test with initial movement to the L or R, when subjects are split into groups of LA and GA based upon between-leg A for each jump condition.*

	Vertical jump			Standing broad jump			Lateral jump		
	LA (n = 20)	GA (n = 10)	p	LA (n = 22)	GA (n = 8)	p	LA (n = 17)	GA (n = 13)	p
VJ A (%)	4.5 ± 3.5	22.1 ± 11.0	<0.001†	11.4 ± 11.8	7.6 ± 7.3	0.407	9.6 ± 7.9	11.4 ± 14.0	0.670
SBJ A (%)	3.2 ± 2.7	3.6 ± 3.8	0.749	1.8 ± 1.4	7.4 ± 2.4	<0.001†	2.4 ± 2.2	4.5 ± 3.6	0.059
LJ A (%)	4.7 ± 3.6	5.7 ± 4.5	0.515	4.4 ± 3.7	7.0 ± 4.0	0.101	2.3 ± 1.7	8.7 ± 2.8	<0.001†
0–5 m (s)	1.049 ± 0.077	1.001 ± 0.063	0.102	1.031 ± 0.075	1.039 ± 0.080	0.784	1.036 ± 0.064	1.029 ± 0.089	0.813
0–10 m (s)	1.776 ± 0.105	1.727 ± 0.083	0.208	1.759 ± 0.098	1.762 ± 0.113	0.940	1.760 ± 0.093	1.758 ± 0.112	0.967
0–20 m (s)	3.057 ± 0.172	3.001 ± 0.149	0.387	3.036 ± 0.156	3.046 ± 0.197	0.881	3.042 ± 0.155	3.033 ± 0.181	0.888
505 L (s)	2.395 ± 0.103	2.404 ± 0.093	0.811	2.401 ± 0.087	2.392 ± 0.116	0.828	2.393 ± 0.091	2.405 ± 0.123	0.726
505 R (s)	2.391 ± 0.120	2.405 ± 0.093	0.756	2.394 ± 0.088	2.402 ± 0.164	0.861	2.388 ± 0.102	2.405 ± 0.123	0.689
T-test L (s)	6.263 ± 0.364	6.318 ± 0.392	0.704	6.292 ± 0.334	6.253 ± 0.474	0.804	6.267 ± 0.345	6.299 ± 0.409	0.819
T-test R (s)	6.306 ± 0.342	6.242 ± 0.333	0.632	6.287 ± 0.303	6.279 ± 0.434	0.957	6.306 ± 0.294	6.257 ± 0.392	0.696

*A = asymmetries; L = left; R = right; VJ = vertical jump; SBJ = standing broad jump; LJ = lateral jump; r = correlation coefficient; LA = lesser asymmetry; GA = greater asymmetry; p = significance.

†Significant ($p \le 0.05$) difference between the groups.

left-leg turn), 5 were large, and 1 was very large (0–20-m interval). The SBJ for the right leg related to all but the 505 with the left-leg turn, and correlations ranged from moderate (0–5-m interval) to large (0–20-m interval). The LJ mirrored the results of the SBJ, with the left leg correlating with all speed test times; 2 correlations were moderate, 4 were large, and 1 was very large (T-test with initial movement to the right). The right-leg LJ moderate to largely correlated with all speed tests bar the left-leg turn 505.

The models produced only 1 variable as the primary contributor to the best predictive relationships between the speed tests and measures of unilateral leg jump performance and asymmetry from the current study (Table 3). For all intervals of the 20-m sprint, performance in the left-leg SBJ was the significant predictor. For all the change-of-direction speed tests, the left-leg LJ was the significant predictor.

Table 4 displays the data for the jump asymmetries. These data were used to split the subjects into groups of lesser and greater asymmetry. The cutoff point for group division on behalf of the VJ, SBJ, and LJ symmetries was 12.6, 3.9, and 5.8%, respectively. For each jump condition, only the asymmetry that was used to split the sample was significant. There were no significant differences between any lesser or greater asymmetry groups for any of the speed tests.

Discussion

Although acknowledged as an important component of multidirectional speed, unilateral jump performance in team-sport athletes has not been widely analyzed within the current literature. The influence that between-leg asymmetries defined by unilateral jumping may have upon multidirectional speed has also not been thoroughly investigated. Therefore, this study examined the effect that unilateral leg power, as measured by single-leg jump tests (vertical, horizontal, and lateral), and between-leg jump asymmetries, had upon performance in a 20-m sprint, 505, and modified T-test. The results indicated that horizontal jump and LJ performance related to multidirectional speed. Asymmetries as measured by between-leg differences in jump performance in the 3 different planes of motion did not seem to significantly relate to multidirectional speed. To an extent, this may have been a consequence of the sample group, in that collectively the subjects from the current study generally did not demonstrate overly pronounced asymmetries (i.e., above 15%). Correlation analyses do have limitations, in that factors such as subject body mass, physique, flexibility, technique, and leg strength can have an effect on the statistical models that are derived (5). This interplay of physiological and technical factors would have contributed to the fact that only 2 of 34 significant correlations were very large (left-leg SBJ and 0–20-m sprint; left-leg LJ and T-test with movement initiation to the right). However, the size of the correlations found in this research is similar to those established in the literature analyzing relationships between leg power and running speed (21,28,32,35).

Regarding unilateral jump performance, the findings from this study support previous research, as well as confirm aspects of coaching logic. What is important to consider is that technique associated with unilateral jumps is specific (32,33). This would affect any transfer to sport-specific performance, including multidirectional speed. An example of this was shown with the unilateral VJ. Previous research has established a relationship between unilateral VJ performance and a 20- (26) and 25-m (28) sprint, and this was supported to an extent by the current study for both the left and right legs (Table 2). Interestingly, VJ performance from either leg did not correlate with the 505, and there was only 1 correlation with the modified T-test. The right-leg VJ moderately correlated with the T-test with movement initiation to the left, with only 14% of the common variance explained (Table 2). To effectively change direction, athletes will tend to lower their center of gravity (41), and place a greater emphasis on lateral movement (43). This would suggest a reduced emphasis on vertical power when changing direction, which is reflected in the results drawn from this research.

The unilateral SBJ established significant relationships with all 3 speed tests. For the left-leg SBJ and the speed tests, the common variance ranged from 14% for the 505 with a left-leg turn, and up to 53% for the 0–20-m sprint interval. Better performance in the bilateral SBJ has been linked to faster linear sprint performance over distances of less than 30 m (1), and improvements in short (i.e., less than 20 m) linear sprints have been associated with increased horizontal power (22,35). More specifically, the unilateral SBJ has also been linked to linear 10-m sprint performance, and change-of-direction speed in a test requiring 180° cuts, in male physical education students (32). As there are similarities in the mechanics for the unilateral SBJ and the sprint step (30), it is not surprising that there would be an association with a maximal linear sprint. This was further confirmed by the predictive relationships that the left-leg SBJ had with each interval of the 20-m sprint (Table 3). Furthermore, both the 505 and modified T-test feature linear accelerations over short distances (Figures 1 and 2). Given the importance of an increased step length for acceleration, and how this has been linked to horizontal power (22), change-of-direction tests that feature these accelerations should also have a relationship with unilateral horizontal jump performance.

The single-leg LJ tests for both legs also correlated with speed over all the 20-m sprint intervals (Table 2). Although linear sprinting does not involve lateral projection, the muscles recruited required for explosive straight-line sprints, and for maximal jumping, are similar. For example, the hamstrings, quadriceps, and gluteal muscles are all active during a unilateral jump (14). These muscles are also recruited during the sprint step (19). Thus, similar recruitment of muscles required for maximal sprinting and lateral jumping would provide some basis for the significant relationships found in this study. More specifically, better LJ performance for both legs correlated with faster times in the 505 and modified T-test (Table 2). This is contrary to previous research that suggested that lateral power, as measured by a LJ test, did not significantly relate to change-of-direction speed (32). The highest explained common variance was 52% for the left-leg LJ and T-test with movement initiation to the right. The LJ for the left leg was also the most significant predictor for performance in all conditions for both the 505 and T-test in this study (Table 3). The specific movements required for the 2 change-of-direction speed tests (i.e., the 505 featured a hard 180° cut to change direction within the test; the T-test involved lateral shuffling) illustrate why unilateral jump performance and power would relate to these assessments. Previous literature has suggested that the ability to complete explosive movements laterally will contribute to change-of-direction speed (39,45). The results from this research provide support to this notion.

When considering isokinetic strength asymmetries between particular muscle groups, differences of less than 15% are generally viewed as not being functionally significant (2,29,37). Using this value as a guide, the mean values, when considering all subjects from the current study, demonstrate that any between-leg differences would generally not be deemed functionally significant (VJ = 10.4 ± 10.8%; SBJ = 3.3 ± 3.0%; LJ = 5.1 ± 3.9%; Table 1). Previous analysis of collegiate-aged athletes has also shown relatively minor between-leg differences for unilateral jump tasks, such as a VJ (2,29,33), SBJ and LJ (33), or hop for distance (2). The VJ asymmetries were also similar to those detailed for collegiate football players (9.7 ± 6.9%) (15). As further evidence of the between-leg jump differences recorded being functionally insignificant, asymmetries for the vertical, SBJ, or LJ did not correlate with any measure of multidirectional speed (Table 2). Nevertheless, a novel cutoff point, which involved splitting the subjects into lesser and greater asymmetry groups considering a value that was 1 *SD* above the group mean (16,23), was used to further investigate the influence of asymmetries for each unilateral jump condition. The specificity of unilateral jumps is highlighted in this study (5,32,33), as when groups were split into lesser and greater asymmetry groups, only the particular jump in question exhibited a significant difference (e.g., when splitting groups according to unilateral VJ symmetry, only the VJ asymmetry was significantly different between the groups; Table 4). However, even after this process, there were no significant differences in any measure of multidirectional speed when considering asymmetries defined by the unilateral VJ, SBJ, or LJs (Table 4).

These results suggest that the asymmetries defined by unilateral jump tests do not relate to multidirectional sprint performance. This supports Hoffman et al. (15), who found VJ asymmetries did not significantly affect change-of-direction speed. These results may be related to certain inherent technique adjustments athletes will make in response to strength or power imbalances between the limbs. Yoshioka et al. (44), who used computer modeling to examine vertical jumping with leg strength differences, found that the stronger leg compensated for the weaker leg by allowing some lateral movement within the body to more evenly distribute the load. Furthermore, any strength or power imbalances between the limbs will tend to reduce as a team-sport athlete's training age increases (10). Given that all the subjects in this study were adults and experienced team-sport athletes, the sample from this research may have relatively lesser leg power asymmetries than other athletic populations. Indeed, the greater asymmetry groups as defined by the SBJ (7.4 ± 2.4%) and LJ (8.7 ± 2.8%), still had between-leg differences well under the suggested 15% functional significance value (2,29,37). In addition, the size of the greater asymmetry groups was less than half the sample in each case (VJ = 10; SBJ = 8; LJ = 13; Table 4). It would be of benefit to test the multidirectional speed capabilities of team-sport athletes that have unilateral vertical, horizontal, and lateral asymmetries in excess of 15%. Nevertheless, the results from this study imply that as long as jump asymmetries are not excessive (i.e., not greater than 15%), then there should be no negative effects to multidirectional speed.

Practical Applications

This research has several practical applications for the strength and conditioning professional. First, this study provides confirmation of coaching logic regarding the value of unilateral and horizontal power to multidirectional speed. Team-sport athletes should ensure they possess sufficient single-leg horizontal and lateral power, which can be defined by unilateral standing broad and lateral jumping. These types of assessments are relatively straightforward to administer by strength and conditioning coaches, providing a further indication of their benefits. Unilateral horizontal and lateral power should assist with acceleration, both linearly and after a direction change as measured in this study (i.e., after a 180° cut, or transitioning to lateral shuffling and back pedaling). Unilateral vertical power should also contribute to linear speed. To develop these capacities concurrently, exercises that involve explosive actions in these planes of movement (e.g., hopping, bounding, lateral bounds, zig-zag bounds) would be of benefit. Further to this, the results from this study indicate that functional asymmetries defined by unilateral jump performance of less than 15% should not be a detriment to multidirectional speed. For athletes with relative symmetry between the legs, bilateral jump tests as measurements of leg power are still of value as a monitoring tool. Nonetheless, strength and conditioning coaches should monitor unilateral power in their athletes, and training practices should still be directed towards achieving leg power symmetry. Future research should analyze the influence of leg power asymmetries defined by jump performance on multidirectional speed when the sample features individuals with a pronounced unilateral difference (i.e., greater than 15%). Investigation of the effects that a specific training intervention could have on unilateral jump performance, and by extension multidirectional speed, would also be of benefit for team-sport athletes.

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References

1. Baker, JS and Bell, W. Anaerobic performance and sprinting ability in elite male and female sprinters. *J Hum Mov Stud* 27: 235–244, 1994.
2. Barber, SD, Noyes, FR, Mangine, RE, McCloskey, JW, and Hartman, W. Quantitative assessment of functional limitations in normal and anterior cruciate ligament-deficient knees. *Clin Orthop Relat Res* 255: 204–214, 1990.
3. Berthoin, S, Dupont, G, Mary, P, and Gerbeaux, M. Predicting sprint kinematic parameters from anaerobic field tests in physical education students. *J Strength Cond Res* 15: 75–80, 2001.
4. Bračič, M, Supej, M, Peharec, S, Bačić, P, and Ćoh, M. An investigation of the influence of bilateral deficit on the counter-movement jump performance in elite sprinters. *Kines* 42: 73–81, 2010.
5. Brughelli, M, Cronin, J, Levin, G, and Chaouachi, A. Understanding change of direction ability in sport: A review of resistance training studies. *Sports Med* 38: 1045–1063, 2008.
6. Burr, JF, Jamnik, VK, Dogra, S, and Gledhill, N. Evaluation of jump protocols to assess leg power and predict hockey playing potential. *J Strength Cond Res* 21: 1139–1145, 2007.
7. Cronin, JB and Hansen, KT. Strength and power predictors of sports speed. *J Strength Cond Res* 19: 349–357, 2005.
8. Delextrat, A and Cohen, D. Strength, power, speed, and agility of women basketball players according to playing position. *J Strength Cond Res* 23: 1974–1981, 2009.
9. Draper, JA and Lancaster, MG. The 505 test: A test for agility in the horizontal plane. *Aust J Sci Med Sport* 17: 15–18, 1985.
10. Fousekis, K, Tsepis, E, and Vagenas, G. Lower limb strength in professional soccer players: Profile, asymmetry, and training age. *J Sports Sci Med* 9: 364–373, 2010.
11. Gabbett, T, Georgieff, B, Anderson, S, Cotton, B, Savovic, D, and Nicholson, L. Changes in skill and physical fitness following training in talent-identified volleyball players. *J Strength Cond Res* 20: 29–35, 2006.
12. Gabbett, TJ, Kelly, JN, and Sheppard, JM. Speed, change of direction speed, and reactive agility of rugby league players. *J Strength Cond Res* 22: 174–181, 2008.
13. Ghigiarelli, JJ. Combine performance descriptors and predictors of recruit ranking for the top high school football recruits from 2001 to 2009: Differences between position groups. *J Strength Cond Res* 25: 1193–1203, 2011.
14. Hart, JM, Garrison, JC, Kerrigan, DC, Palmieri-Smith, R, and Ingersoll, CD. Gender differences in gluteus medius muscle activity exist in soccer players performing a forward jump. *Res Sports Med* 15: 147–155, 2007.
15. Hoffman, JR, Ratamess, NA, Klatt, M, Faigenbaum, AD, and Kang, J. Do bilateral power deficits influence direction-specific movement patterns? *Res Sports Med* 15: 125–132, 2007.
16. Hopkins, WG. How to interpret changes in an athletic performance test. *Sportscience* 8: 1–7, 2004.
17. Hopkins, WG. A scale of magnitude for effect statistics. 2009. Available at: www.sportsci.org/resource/stats/index.html. Accessed May 1, 2013.
18. Keeley, DW, Plummer, HA, and Oliver, GD. Predicting asymmetrical lower extremity strength deficits in college-aged men and women using common horizontal and vertical power field tests:

A possible screening mechanism. *J Strength Cond Res* 25: 1632–1637, 2011.

19. Kyröläinen, H, Avela, J, and Komi, PV. Changes in muscle activity with increasing running speed. *J Sports Sci* 23: 1101–1109, 2005.
20. Lockie, RG, Callaghan, SJ, and Jeffriess, MD. Analysis of specific speed testing for cricketers. *J Strength Cond Res* 27: 2981–2988, 2013.
21. Lockie, RG, Murphy, AJ, Knight, TJ, and Janse de Jonge, XA. Factors that differentiate acceleration ability in field sport athletes. *J Strength Cond Res* 25: 2704–2714, 2011.
22. Lockie, RG, Murphy, AJ, Schultz, AB, Knight, TJ, and Janse de Jonge, XA. The effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power in field sport athletes. *J Strength Cond Res* 26: 1539–1550, 2012.
23. Lockie, RG, Schultz, AB, Callaghan, SJ, and Jeffriess, MD. The effects of isokinetic knee extensor and flexor strength on dynamic stability as measured by functional reaching. *Isokinet Exerc Sci* 21: 301–309, 2013.
24. Lockie, RG, Schultz, AB, Jeffriess, MD, and Callaghan, SJ. The relationship between bilateral differences of knee flexor and extensor isokinetic strength and multi-directional speed. *Isokinet Exerc Sci* 20: 211–219, 2012.
25. Maio Alves, JM, Rebelo, AN, Abrantes, C, and Sampaio, J. Short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities. *J Strength Cond Res* 24: 936–941, 2010.
26. Maulder, P and Cronin, J. Horizontal and vertical jump assessment: Reliability, symmetry, discriminative and predictive ability. *Phys Ther Sport* 6: 74–82, 2005.
27. McCurdy, KW, Langford, GA, Doscher, MW, Wiley, LP, and Mallard, KG. The effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. *J Strength Cond Res* 19: 9–15, 2005.
28. McCurdy, KW, Walker, JL, Langford, GA, Kutz, MR, Guerrero, JM, and McMillan, J. The relationship between kinematic determinants of jump and sprint performance in division I women soccer players. *J Strength Cond Res* 24: 3200–3208, 2010.
29. McElveen, MT, Riemann, BL, and Davies, GJ. Bilateral comparison of propulsion mechanics during single-leg vertical jumping. *J Strength Cond Res* 24: 375–381, 2010.
30. Mero, A and Komi, PV. EMG, force, and power analysis of sprint-specific strength exercises. *J Appl Biomech* 10: 1–13, 1994.
31. Mero, A, Komi, PV, and Gregor, RJ. Biomechanics of sprint running: A review. *Sports Med* 13: 376–392, 1992.
32. Meylan, C, McMaster, T, Cronin, J, Mohammad, NI, Rogers, C, and Deklerk, M. Single-leg lateral, horizontal, and vertical jump assessment: Reliability, interrelationships, and ability to predict sprint and change-of-direction performance. *J Strength Cond Res* 23: 1140–1147, 2009.
33. Meylan, CM, Nosaka, K, Green, JP, and Cronin, JB. Variability and influence of eccentric kinematics on unilateral vertical, horizontal, and lateral countermovement jump performance. *J Strength Cond Res* 24: 840–845, 2010.
34. Newton, RU, Gerber, A, Nimphius, S, Shim, JK, Doan, BK, Robertson, M, Pearson, DR, Craig, BW, Hakkinen, K, and Kraemer, WJ. Determination of functional strength imbalance of the lower extremities. *J Strength Cond Res* 20: 971–977, 2006.
35. Peterson, MD, Alvar, BA, and Rhea, MR. The contribution of maximal force production to explosive movement among young collegiate athletes. *J Strength Cond Res* 20: 867–873, 2006.
36. Sassi, RH, Dardouri, W, Yahmed, MH, Gmada, N, Mahfoudhi, ME, and Gharbi, Z. Relative and absolute reliability of a modified agility T-test and its relationship with vertical jump and straight sprint. *J Strength Cond Res* 23: 1644–1651, 2009.
37. Schlitz, M, Lehance, C, Maquet, D, Bury, T, Crielaard, J-M, and Croisier, J-L. Explosive strength imbalances in professional basketball players. *J Athl Train* 44: 39–47, 2009.
38. Sekulic, D, Spasic, M, Mirkov, D, Cavar, M, and Sattler, T. Gender-specific influences of balance, speed, and power on agility performance. *J Strength Cond Res* 27: 802–811, 2013.
39. Sheppard, JM and Young, WB. Agility literature review: Classifications, training and testing. *J Sports Sci* 24: 919–932, 2006.
40. Sierer, SP, Battaglini, CL, Mihalik, JP, Shields, EW, and Tomasini, NT. The National football league combine: Performance differences between drafted and nondrafted players entering the 2004 and 2005 drafts. *J Strength Cond Res* 22: 6–12, 2008.
41. Spiteri, T, Cochrane, JL, Hart, NH, Haff, GG, and Nimphius, S. Effect of strength on plant foot kinetics and kinematics during a change of direction task. *Eur J Sport Sci* 13: 646–652, 2013.
42. Sporis, G, Jukic, I, Ostojic, SM, and Milanovic, D. Fitness profiling in soccer: Physical and physiologic characteristics of elite players. *J Strength Cond Res* 23: 1947–1953, 2009.
43. Wheeler, KW and Sayers, MG. Modification of agility running technique in reaction to a defender in rugby union. *J Sports Sci Med* 9: 445–451, 2010.
44. Yoshioka, S, Nagano, A, Hay, DC, and Fukashiro, S. The effect of bilateral asymmetry of muscle strength on jumping height of the countermovement jump: A computer simulation study. *J Sports Sci* 28: 209–218, 2010.
45. Young, W and Farrow, D. A review of agility: Practical applications for strength and conditioning. *Strength Cond J* 28: 24–29, 2006.