Original Article

Interlimb asymmetry in collegiate American football players: Effects on combine-related performance

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ABSTRACT

The assessment of interlimb asymmetry has been of interest to researchers and practitioners who desire to maximize sport performance. The aim of this study was to explore the relationships between interlimb asymmetry and Combine-related performance testing in collegiate American football players. Twenty-four skill position players (e.g., running backs, defensive backs, and wide receivers) from a Division II university completed all study-related procedures including unilateral countermovement (CMJ) and drop jumps on a force plate, 3-repetition maximum Bulgarian split squats with bar movement tracked by a 3D motion capture system, and their annual spring performance tests (L-drill, pro-agility, 40-yard dash, broad jump, and vertical jump). Using an alpha-level of .05, significant, positive Spearman's correlations between performance in the L-drill test (Change of Direction test; CoD) and asymmetries in mean peak velocity (r_s = .491, p = .015), mean peak power (r_s = .467, p = .021), and mean average power (r_s = .455, p = .026) were observed. A significant, negative Pearson correlation between unilateral CMJ height asymmetry and vertical jump performance was observed (r = .578, p = .003). Asymmetry in mean peak velocity, mean peak power, and mean average power may negatively influence CoD ability within collegiate American football players.
Keywords: Assessment; Performance; Training; Team sport; Strength.

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INTRODUCTION

Successful performance in sports depends on specific skill-based proficiencies and physical attributes that are often position and game specific. In American football, recognized features include high levels of upper and lower body strength and power, high running speeds, and the ability to rapidly accelerate, decelerate, and change direction (Fullagar et al., 2017). Widespread testing of related proficiencies and attributes occurs in collegiate and professional levels through Combine-related performance tests (i.e., L-drill, pro-agility, 40-yard [yd] dash, broad jump, and vertical jump).

Several combine-related tests are dependent upon an athletes' change of direction (CoD) ability and/or linear acceleration, as well as power production capacity in vertical and/or horizontal movements (Robbins, 2012). Specifically, lower extremity maximal strength, eccentric strength and reactive strength have well-documented associations with CoD, linear acceleration, cutting, and vertical and horizontal jump performance across various athletic populations (Flanagan & Comyns, 2008; Fullagar et al., 2017; Jones et al., 2017; Peterson et al., 2006; Spiteri et al., 2014; Taber et al., 2016).

There is also considerable interest in how deficiencies in these physical attributes may detract from an athletes' proficiency when testing. For example, lower extremity interlimb asymmetry in maximal strength has been the target of specific investigations. Interlimb asymmetry is evaluated by the comparing limb performance bilaterally. Recent studies indicate that interlimb asymmetries, calculated in different ways, adversely impact CoD performance (Bishop et al., 2019; Bishop et al., 2019; Madruga-Parera et al., 2019), sprint acceleration (Bishop et al., 2019; Bishop et al., 2019; Madruga-Parera et al., 2019), and vertical power production (Bishop, Brashill, et al., 2019). One method to calculate bilateral strength asymmetry is using the equation strong minus weak divided by strong multiplied by 100 (Impellizzeri et al., 2007). This method has been noted as acceptable (Bishop et al., 2018) and used in work by Bishop and colleagues (Madruga-Parera et al., 2020).

Only one study relating interlimb asymmetries to skill-based performance in American football athletes could be found (Hoffman et al., 2007). The study indicated no correlation between differences in unilateral leg power (evaluated from a countermovement jump [CMJ] and CoD measured via the three-cone drill) (Hoffman et al., 2007). Speculatively, the use of the single task for assessment of interlimb asymmetry may have contributed to the lack of findings. For example, a contemporary investigation found that interlimb asymmetry assessed via a drop jump (DJ) task was significantly associated with CoD speed performance in cricket athletes, while interlimb CMJ height asymmetry was not associated with CoD in these athletes.(Bishop et al., 2019) The discrepancy in significant association between DJ, but not the CMJ, and the performance may relate to task specificity.

The aim of the present study was to determine if interlimb asymmetry in lower-extremity maximal power production capability and ground reaction force data (e.g., peak force, peak eccentric force) were associated with Combine-related performance tests commonly utilized within American football testing. The inclusion of multiple performance and asymmetries tests promotes the alignment of asymmetry with task specificity. Based on previous studies (Jones et al., 2017; Peterson et al., 2006; Robbins, 2012; Spiteri et al., 2014);·Hobara et al., 2011), we hypothesized that influential asymmetries may come from metrics extracted from (a) lower extremity maximal power production capability assessed through the Bulgarian split squat (BSS) as well as (b) ground reaction force data extracted from unilateral CMJ and DJ tasks.

MATERIALS AND METHODS

Participants

The University of Central Missouri's (UCM) Institutional Review Board approved all the study procedures. All eligible participants had the opportunity to take as much time as desired to review the risks, ask questions, and receive an answer prior to signing the informed consent, and beginning the study procedures.

Study participants included running backs, defensive backs, and wide receivers (often referred to as skill position players) on the current roster. These positions were of interest as successful role execution is predicated, in part, on CoD and acceleration performance. Participants were instructed to refrain from vigorous lower-body resistance exercise in the 48 hours prior to testing, and all participants were cleared by athletic training staff to engage in football-related activities. Individuals experiencing acute illness or musculoskeletal injury were excluded from study participation.

Testing procedures for session one

Participants arrived to the UCM Kinesiology Human Performance Laboratory wearing comfortable athletic clothing. Supportive garments (e.g., knee wrap, ankle brace) and weightlifting belts were prohibited during testing procedures. After consent, anthropometric data (height, weight, and body composition) were collected in the Human Performance Laboratory. Participants were then taken to the UCM Biomechanics Laboratory for the warmup and collection of their unilateral ground reaction force and CMJ and DJ height data with the Kistler Force Plate (Kistler 9286A portable force plate, Kistler, Novi, MI) and Qualisys Motion Capture System (Qualisys AB, Göteborg, Sweden). Finally, participants returned to the Human Performance Laboratory for testing lower-extremity maximal power production capability via the BSS.

Anthropometric data

Height was measured barefoot using a Seca stadiometer (Seca®, Chino, CA) and recorded in centimetres (cm). Mass was measured using an electronic Befour PS 7700 scale (Befour®, Saukville, WI) and recorded in kilograms (kg). Body composition was estimated using the InBody® 570 (Cerritos, CA).

Warmup

Prior to testing, each participant performed a dynamic warmup, using a 45-lb. plate. The warmup was a team-employed strategy to which all participants were accustomed. Participants progressed to a more specific warmup in which they were allowed two practice jumps on each limb with verbal guidance provided by researchers. After warmup, super spherical markers were placed on the participant's left and right greater trochanter of the hip for delineation of the subphases of movement (e.g., eccentric, amortization, concentric).

Unilateral countermovement jump

The best of two unilateral CMJ attempts (with respect to jump height) for each leg was used to assess the dependent variables. One minute of rest was completed after participants performed the unilateral CMJ. Participants were instructed to stand upright on the force plate, as still as possible, until given the command "*jump*", after which they dropped to their preferred depth as rapidly as possible and jumped up as fast and as high as possible. Upper-body involvement was minimized by a PVC pipe being held behind the head across the shoulders.

The Kistler Force Plate and Qualisys systems were used to acquire ground reaction force data that included peak eccentric force, overall peak force, and reactive strength index modified (RSImod). Peak eccentric force was defined as the peak force achieved throughout the eccentric portion of the CMJ. Peak overall force was defined as the peak force achieved throughout the entire CMJ. The CMJ height was calculated as "$1/2g(t/2)^2$" (where g = gravity; 9.81 m/s^2 and t = time in air). RSImod was calculated by dividing the unilateral CMJ height in cm by time to take-off (Kipp, Kiely, & Geiser, 2016). Each bilateral strength asymmetry was assessed as (strong – weak)/strong x 100 (Impellizzeri et al., 2007).

Unilateral drop jump

A total of three minutes was allotted between the unilateral CMJ and DJ procedures. The best of two unilateral DJ attempts (with respect to jump height) for each leg was used to assess the dependent variables. One minute of rest was completed between the completion of unilateral DJ attempts. Upper-body involvement was again minimized by a PVC pipe held behind the head across the shoulders. Dropping from a 30-cm platform, participants landed on the force plate and attempted to jump as fast and as high as possible, attempting to minimize time on the ground. Researchers acquired ground reaction force data to calculate reactive strength index (RSI). RSI was calculated by dividing unilateral DJ height by time on the ground (Flanagan & Comyns, 2008). Unilateral DJ height was calculated as previously described [$1/2g(t/2)^2$]. The asymmetry calculation was noted previously for unilateral CMJ. Following the jump procedures, the super-spherical markers were removed.

Bulgarian split squat

Participants returned to the Human Performance Laboratory for the BSS. A total of five minutes was given between the completion of the unilateral DJ procedures and the start of the warmup for the BSS. The BSS was performed within a power rack. A single leg squat roller was used to elevate and support the rear foot. The warmup consisted of participants performing ten repetitions with a load approximating 40% of their respective estimated 1-RM for the lift. For the second set, participants performed five repetitions after researchers added approximately 10-20% more weight (Lockie et al., 2017). For the third set onward, three repetitions were performed with an increased weight until the 3-RM was achieved. A successful repetition necessitated the femur of the working leg to be parallel to the floor before commencement of the concentric phase of the lift. This technique is in line with current recommendations (McCurdy et al., 2004; Lockie et al., 2017). Visual assessment by members of the research team and verbal cues were provided to participants to ensure proper technique during all sets. Participants were asked to perform the concentric portion of the movement as explosively as possible. Standardized, three-minute rest periods were utilized between sequential attempts. After completion of the first leg, the second leg was tested in accordance. Spotter bars were positioned for safety.

Mechanical power and velocity applied to the bar were measured using the EliteForm® 3D motion capturing system, a valid and reliable tool (EliteForm®, Lincoln, Nebraska) (Bradford, 2017). The EliteForm® captured data at 30 Hz via dual 3D cameras and provided a digital readout from which researchers recorded mean peak velocity (mPV) and mean average velocity (mAV), as well as mean peak power (mPP) and mean average power (mAP) for the final successful 3-RM lift for each leg (for the concentric portion of the lift). Computations for mPV, mAV, mPP, and mAP are calculated based on proprietary algorithms. Again, the asymmetry was calculated as noted previously.

Testing procedures for session two

Session two occurred at the Audrey J. Walton stadium during spring football testing and included a standardized warmup and Combine-related performance testing. Participants arrived wearing comfortable athletic clothing and football cleats. All participants performed the L-drill, pro-agility, 40-yd dash, broad jump, and vertical jump. Testing occurred by position group, so the order was not controlled by the research team (i.e., testing occurred orderly but was not randomized). Three people were responsible for hand-capturing times for the L-drill, pro-agility, or 40-yd dash. The same person captured times for all participants on their respective Combine-related performance test.

The L-Drill

The L-drill, also called the three-cone drill, was one measure of CoD. The method was derived from its usage within the National Football League (NFL). The three cones were placed five yds apart. The distance covered totaled 30 yds and consisted of six short sprints. Participants started in a three-point stance. The best of three attempts was used in analysis. A successful attempt involved the participant completing the drill from start cone to the finish cone (same cone) without contacting any cone.

Pro-Agility drill

The pro-agility drill, also called the 5-10-5 drill, was another measure of CoD. The method was derived from established professional procedures and is a popular test to measure CoD performance within this population (Haff & Tripplet, 2016). The test is set up with two lines set 10 yds apart and a third line directly in the middle, five yds from each end. The participants started in a three-point stance, with one foot on either side of the centre line. On a signal, the participant turned and sprinted five yds to their left, touched the line, turned 180°, and sprinted ten yds in the other direction, before turning 180° a final time, and sprinted for five yds through the line at which they started (Haff & Tripplet, 2016). The best of three attempts was used in analysis. The timer was started upon the first movement of the participant. A successful attempt involved the participant contacting the line at which they were turning with their hand.

40-Yard dash

The 40-yd dash was conducted with participants beginning in a three-point stance and running as fast as possible for 40-yd (Kuzmits & Adams, 2008). The best of three attempts was used in analysis.

Broad jump

For the broad jump, participants began from a standing position and jumped as far as possible horizontally (from the starting line to the rearmost heel strike) (Koch et al., 2003). Participants were allowed three attempts with the best being used in analysis. A successful attempt involved a jump from the starting line and the participants landing without falling back.

Vertical jump

The vertical jump data was recorded using the Just Jump System (Probotics, Inc., Huntsville, AL). Participants stepped onto the mat, dropped forcefully to their preferred depth, and jumped as high as possible. The task was performed bilaterally with use of an arm swing. Participants were allowed three attempts with the best being used in analysis. A successful attempt involved the participants jumping from and landing back on the measuring mat.

Analyses

All data were assessed for normality using a Shapiro-Wilk statistic and screened for influential outliers (step of 1.5 x interquartile range) prior to all inferential tests. No outliers were identified. Both non-parametric (Spearman’s Rho; rs) and parametric (Pearson; r) analyses were used to assess relationships between participants’ physical attributes and skill-based performance tests. All analyses were run in SPSS version 24.0 (IBM, Inc., Armonk, NY), and statistical inferences were made using an α level of .05. All data are presented as means (M) ± standard deviations (SD).

RESULTS

A convenience sample comprised of 26 participants was recruited from a competitive, Division II school. Two participants who sustained non-study related injuries did not participate in the Combine-related performance testing. Accordingly, 24 participants engaged in the study (age = 19.8 ± 0.9 years, height = 179.0 ± 3.4 cm, and mass = 83.2 ± 5.7 kg; *n* = 19 for body fat = 9.9 ± 3.1% and lean mass = 43.6 ± 2.9 kg). Training age of the 24 participants (years in the UCM collegiate strength and conditioning program) was 1.9 ± 0.9 years.

Combine-Related performance test descriptive statistics

Table 1 presents the descriptive data for the Combine-related performance tests, as well as comparative values from the recognized, collegiate American football designations Division I Non-Power 5 and Division I Power 5. As the benchmark, athletes playing for the Power 5 conference schools are recognized to compete at the highest level of collegiate football in the United States.

Table 1. Descriptive characteristics for the Combine-related performance tests.

Combine-related performance tests	Division II Sample (*n* = 24)	Division I Non-Power 5 (*n* = 503)	Division I Power 5 (*n* = 1156)
L-drill (s)	6.95 ± 0.22	7.04 ± 0.26	7.03 ± 0.25
Pro-agility (s)	4.25 ± 0.13	4.20 ± 0.16	4.19 ± 0.15
40-yard dash (s)	4.52 ± 0.14	4.55 ± 0.11	4.54 ± 0.11
Broad jump (m)	2.89 ± 0.2	3.03 ± 0.2	3.02 ± 0.1
Vertical jump (cm)	86.2 ± 5.8	89.7 ± 7.6	89.6 ± 7.5

Note. Non-Power 5 and Power 5 data retrieved from publicly available information (https://www.pro-football-reference.com/play-index/nfl-combine-results.cgi) from 1997-2018.

Asymmetry metrics descriptive statistics

Table 2 presents the descriptive data for all asymmetry metrics, including the mean and standard deviations for the higher (i.e., stronger value) and lower (i.e., weaker value) performing limbs.

Table 2. Descriptive characteristics of the higher and lower performing limbs for three asymmetry tests (*n* = 24 unless specified).

Asymmetry metrics for CMJ	Higher Performing Limb (M ± SD)	Lower Performing Limb (M ± SD)	% Difference
CMJ height (cm)	29.0 ± 0.03	26.0 ± 0.03	9.3 ± 6.5
Peak Eccentric Force (N) (*n* = 23)	1534.0 ± 224.3	1436.3 ± 209.6	5.2 ± 4.3
Peak Overall Force (N)	1814.6 ± 171.6	1741.4 ± 160.2	4.3 ± 2.5
RSImod	0.42 ± 0.09	0.38 ± 0.08	10.1 ± 9.6
Asymmetry metrics for DJ			
DJ height (cm)	26.0 ± 0.04	25.38 ± 0.04	6.2 ± 6.5
Reactive Strength Index	0.69 ± 0.14	0.59 ± 0.11	13.8 ± 8.8
Asymmetry metrics for BSS			
mPV (m/s)	0.66 ± 0.12	0.53 ± 0.12	18.0 ± 12.8
mAV (m/s)	0.42 ± 0.07	0.36 ± 0.07	14.5 ± 9.1
mPP (W)	740.92 ± 183.3	599.77 ± 196.4	18.0 ± 12.8
mAP (W)	660.58 ± 174.0	538.15 ± 168.4	16.0 ± 11.8

CMJ = countermovement jump; DJ = drop jump; RSImod = reactive strength index modified; BSS = Bulgarian Split Squat; mPV = mean peak velocity; mAV = mean average velocity; mPP = mean peak power; mAP = mean average power; Avg = average.

Relationships between combine-related performance tests and asymmetry metrics

For the L-drill test, several asymmetry metrics demonstrated significant relationships with participants' performance. Extracted from the BSS test, there were moderate, positive correlations between asymmetry in mPV (r_s = .491, n = 24, p = .015), MPP (r_s = .467, n = 24, p = .021), and mAP (r_s = .455, n = 24, p = .026) and L-drill performance.

For the vertical jump test, there was a moderate, negative correlation between CMJ height asymmetry (r = -.578, n = 24, p = .003) and vertical jump performance.

DISCUSSION

The present study investigated the effect of interlimb asymmetry on Combine-related performance tests within Division II collegiate American football players. We hypothesized that larger interlimb asymmetry would negatively influence performance on selected Combine-related performance tests. These data reveal that interlimb asymmetries in mPV, mPP, and mAP negatively influence performance in the L-drill test, and interlimb asymmetry in CMJ height negatively influences performance in the vertical jump test. There were no significant correlations revealed between other measures of asymmetry and performance.

To our knowledge, only one other study has investigated asymmetry effects on physical performance tests in American football players. In their study, Hoffmann et al. (2007) had collegiate players perform a unilateral CMJ test prior to performing the L-drill. They found the correlation to be weak and not significant. Within our present study, asymmetry in mPV, mPP, and mAP were negatively related to CoD performance assessed via the L-drill. Lockie et al. (2017) similarly used this assessment task to identify asymmetry to assess effect on sprint acceleration performance. A negative relationship (n = 8, p = .015) between unilateral mean force asymmetry in the BSS and 0-5 meter velocity split in a 20 meter sprint was found (Lockie et al., 2017). The indication was that a faster initial acceleration was associated with a lower unilateral asymmetry in mean force production capability between legs. Our study also revealed that asymmetry in CMJ height negatively influences performance in the vertical jump test. This corroborates recent findings that asymmetry in CMJ height can have a negative impact on vertical jump performance (Bishop et al., 2018). As American football performance most typically relies on CoD and lower extremity power production capability, knowing that asymmetry impacts this outcome is useful for athletes and practitioners.

Beyond the primary questions of interest, there are two additional findings worthy of discussion. First, even though performance in the L-drill and pro-agility tests were significantly related (r = 0.75), the L-drill showed greater sensitivity to interlimb asymmetry. We surmise this may be resultant to athletes choosing which leg they utilize for CoD in the pro-agility drill. Conversely, within the L-drill, athletes are forced into a CoD with both lower limbs (i.e., both legs are forced to plant and serve as the base for reacceleration). This would suggest that the L-drill may be a better fit for practitioners wanting to assess the effects of interlimb asymmetry on CoD performance due to its ability to control for potential limb preference bias in athletes' execution of the pro-agility test. Second, based on recent evidence from Bishop and colleagues (Bishop et al., 2019; Bishop et al., 2019), we anticipated that the unilateral DJ test would produce asymmetry metrics significantly related to our CoD performance measures. We did not find significant correlations between DJ height asymmetry and the Combine-related performance tests. Bishop et al. (2019) had athletes drop from a box height of 18 cm, whereas participant's in our study dropped from 30 cm (Bishop et al., 2019). Future research could investigate if a particular DJ height shows greater sensitivity toward highlighting interlimb asymmetry as this may influence landing kinetics and kinematics (Hobara et al., 2011).

We understand that a disconnect can exist between performance tests and sport performance. Nevertheless, recent evidence does highlight the relationship between performance within Combine-related performance testing and actual on-field performance within American football (LaPlaca & McCullick, 2020). The results may be valuably extended beyond American football athletes by assessing multiple metrics of asymmetry in athletes across the sports spectrum.

Expanding further, future research may investigate the magnitude at which asymmetries begin to impact performance testing and/or athletic performance. At this time, asymmetry thresholds between 10 and 15% have been highlighted to impact different aspects of performance testing (Bishop et al., 2018; Hoffman et al., 2007; Lockie et al., 2017). Practitioners would benefit from knowing established asymmetry thresholds (given a specific assessment method and performance test of interest) to discriminate high- and low-performance.

The present study is not without its limitations. Although the BSS 3-RM is a valid and reliable means of assessing unilateral strength, it has recently been suggested that using a 5-RM for assessing interlimb asymmetries is also a valid and reliable means to conducting the test (Helme et al., 2019; McCurdy et al., 2004). A 5-RM testing method would have reduced the absolute loads during the submaximal and maximal attempts. Our participants were trained and skilled on the movement, but they were still challenged by a need to focus on stabilization and maintaining balance while producing maximal unilateral concentric force. Our participants reasonably demonstrate above average levels of lower body strength (mean unilateral 3-RM: 113 ± 19.9 kg). Some individuals squatted over 120 kg on a single leg during our testing. Yet, in working up to such a large load, some of our participants had trouble remaining balanced. It is unknown whether difficulty balancing influenced our data. Using a 5-RM, instead of a 3-RM, would reduce the absolute loads lifted and may reduce potential balance concerns in studies wishing to mimic these procedures. Arguably, the greatest limitation of this study is the fact that interlimb asymmetry was analysed from a single testing session. Recent evidence from Bishop et al. (2020), has shown that interlimb asymmetry may not track consistently over time (Bishop et al., 2020). Future research should include test-retest data.

The present study demonstrates that interlimb asymmetries negatively associate with CoD performance in Division II collegiate American football players. These findings, as well as the procedures used, may benefit practitioners wanting to assess the effects that interlimb asymmetry have on their athletes. Additionally, our findings indicate that particular assessments may be more sensitive at detecting underlying asymmetry. We suggest that researchers carefully select interlimb asymmetry and performance tests as task specificity may be a determinant of the statistical outcomes and relationship. Lastly, researchers will want to investigate intervention strategies, and the time course of effective interventions, to effectively address the asymmetry concerns.

AUTHOR CONTRIBUTIONS

Nicolas M. Philipp and Matthew J. Garver conceptualized the study design, facilitated its movement through human-subjects review, participated in all data collection, analysed data, and crafted the manuscript. Dustin W. Davis and Josie N. Hair significantly contributed to data collection and helped write the final manuscript. Derek A. Crawford analysed data and helped write the final manuscript.

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DISCLOSURE STATEMENT

The authors confirm that the procedure was undertaken in accordance with the Declaration of Helsinki. All experimental procedures complied with the current local, state, and federal laws of the United States of America. The authors have no conflicts of interest to declare.

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