A Novel Case Study Approach to the Investigation of Leg Strength Asymmetry and Rugby League Player's Multidirectional Speed.

ABSTRACT

Leg strength and multidirectional speed qualities have repeatedly been linked with increased performance during Rugby League (RL) match play and associated with career attainment. However, very little of this evidence for strength has been gained through unliteral measurements with no study available that has examined the impact of strength asymmetry, in this population, on speed qualities in RL players. Therefore, this study examined the association between unilateral strength and as a novel development the subject with the most extreme asymmetry was identified for further analysis. 50 RL players undertook the rear foot elevated split squat five repetition maximum, 20 m linear sprint and modified 505 change of direction test. The mean leg strength for the group was 88.92 ±12.59 kg, when divided by body weight the mean relative strength (REL) was 1.03 ±0.17 kg/kg and the mean asymmetry was 3.21 ±5.70 %. The participant with the greatest asymmetry (subject A) had an imbalance of 33% and a mean leg strength of 75 kg (REL = 0.78 kg/kg) and a body mass one standard deviation above the group mean. Analysis of the group's data and that of subject A did not indicate that leg strength asymmetry was either frequent or harmful, with respect to speed performance. However, relative leg strength was associated with both improved linear and multidirectional speed. Practitioners are recommended to prioritise the development of relative leg strength and disregard the aspiration for between leg performance symmetry.

Keywords

Change of direction, sprint, acceleration, rear foot elevated split squat, relative strength, absolute strength

INTRODUCTION.

The importance of lower-body strength has been well established as an important deterministic quality of sporting performance (43). Such an observation is clearly exemplified in the sport of Rugby League (RL). As an intermittent high-intensity locomotor sport characterised by repeated player collisions, the relevance of strength can be seen in all facets of the game, ranging from tackle success (41) to career attainment (46). However, the evidence supporting the importance of lower-body strength to RL players has typically been derived from bilateral measures tests (12, 13, 16, 42), for example the back squat three repetition maximum. Based on the requirement for RL players to run at high velocities and simultaneously execute technical skills, one may question the validity of such an approach, favouring a hypothetically more transferable unilateral approach.

As high-intensity locomotor sport, both linear and change of direction (COD) speed, are additional physical qualities that influence RL performance and success. Gabbett (25) found there was a significant difference between the number of accelerations performed by winning and losing teams, (winning 91.7 ±7.1, losing 71.4 ±5.5, $p < 0.05$) in an elite competition. Additionally, evidence suggests (27) players who were selected to start games had significantly faster sprint times at 10m (1.71+0.07 s vs 1.76+0.08 s, $p < 0.05$) and 40m (5.19+0.19 s vs 5.37+0.13 s, $p < 0.05$) than those selected as substitutes and non-selected players. COD speed has been researched as a physiological quality in RL players numerous times (2, 23, 24, 26-28) and has been identified as an underpinning physical capacity for agility (40). Gabbett and Benton (22) reported that elite RL players had significantly better agility (faster movement and decision times), than sub-elite players ($p < 0.05$, large = 1.39, and moderate = 0.62, effect sizes (ES) respectively), demonstrating the importance of COD speed, within the umbrella of agility. Furthermore, both linear sprint speed and COD speed have both been significantly associated with greater lower-body strength (43). Consequently, there is substantial evidence that acceleration (linear and COD) is a highly desirable physical quality in RL players and are both related to and developed by increased strength.

The current body of literature has established the need for increasing leg strength in RL players, yet within this, gaps remain. Two such under-researched areas are the importance of unilateral lower-body strength and associated asymmetries between the limbs. These concepts can be considered synergistically as unilateral lower-body strength lends itself to the comparison of one limb to the other. In addition, the concept of asymmetrical function between each limb has become a contemporary and contentious area of research, within the field of strength and conditioning. More specifically, there have been strides to better quantify and classify asymmetry, creating a more standardised approach to its measurement (4, 6, 19, 38) and determination of its validity and reliability. Through this increased volume of examination, the notion of asymmetry being a cause of concern has diminished somewhat. For example, there has been a long-standing heuristic that between limb differences would be injurious. However, in a review by Helme et al (30) this perspective was challenged as no evidence was found to support the increased risk of injury from any reported lower-body functional imbalance. A recent review (1) has proposed that the inter-limb discrepancy displayed by athletes should be embraced as a naturally occurring phenomenon and as described by Maloney (34) be thought of as fluctuating, both in magnitude and direction. This notion of fluctuation is illustrated by the findings of Bishop et al (7) who reported low agreement in the direction of asymmetry (Kappa coefficient range -0.54 to 0.62) in unilateral counter-movement jump performance, in soccer players, across five separate post-match assessments.

The nature of published materials in the field of strength and conditioning asymmetry, skews the evidence towards the effects on groups of subjects, affording the practitioner an opportunity to consider inferential statistics in decision-making. However, practitioners do not coach a homogenised group of people. Instead within any cohort there is a range of varying individuals which do not conform to the reported group norms. Such variation is demonstrated in the data reported by Dos'Santos et al (17) whereby the standard deviation of asymmetry in force production, measured through an isometric mid-thigh pull, exceeded the mean asymmetry for peak force and all time epochs reported.

More specifically there may exist athletes whose asymmetry deviates dramatically, from any reported mean value to such an extent that the literature could not reasonably be applied to them. In such cases there may, or may not be, implications resulting from imbalances which are not observed in the reporting of more centrally distributed athletes. To date the exploration of such asymmetrical outliers has not been undertaken and therefore remains one aspect of asymmetry that requires further understanding.

This study aimed to explore the association of both unilateral lower-body strength and associated interlimb asymmetries to markers of locomotor performance in RL players. Furthermore, using these metrics examine if there are implications for the most extreme case of asymmetry on speed performance, compared to the mean athlete. This study hypothesised that there would be significant relationships between unilateral leg lower-body strength and both linear sprint and CODS, yet asymmetry would not.

METHODS.

Experimental Approach to the Problem

A cross-sectional research design was implemented to investigate the effects of unilateral lower-body strength and asymmetry on the ability to perform a linear sprint (20 m sprint) and change direction speed (modified 505 test (505_{MOD})). Sub-elite RL players were recruited from three different teams and testing was conducted on two separate days, separated by 48 hours.

SUBJECTS

With institutional ethical approval, 78 subjects were recruited from three sub-elite RL teams (one senior, two academy). When exclusion criteria were applied (free from injury for six weeks prior to testing and available to attend both test dates) 28 were removed and 50 subjects were retained for testing (age 21.66 ±5.07 years, mass = 88.2 ±11.2 Kg, Height = 1.82 ± 0.1 m). Gatekeeper consent was gained from heads of department of the respective clubs, as well as subject consent prior to data collection. Medical screening was performed prior to data collection and each club had an appointed sports medicine professional present throughout testing who deemed each subject fit to participate. Post-hoc power analysis (G*power, (21)) found a 68 % probability for an ES of 0.5 and alpha level of error of 0.05, for this sample size.

PROCEDURES

Strength Testing

Strength testing took place during the first week of pre-season training at the training facilities of each of the respective participating clubs. Leg strength was measured using the rear foot elevated split squat five repetition maximum test (RFESS 5RM), which has been previously demonstrated as a reliable measure of load (ICC = 0.93, CI 0.88-0.96) and asymmetry (ICC = 0.73, CI 0.39, 0.89 , Kappa = 0.60) (29).

Asymmetry Measurement

The percentage difference method (PDM) (6) was applied to the values of each leg for the measurement of asymmetry. Asymmetry values were recorded as magnitude only and magnitude with direction. To ascertain the magnitude of asymmetry which exceeded the noise of test the minimum detectable asymmetry (MDA) was calculated, adopting the symmetry threshold calculation applied by Helme et al (29).

MDA = Mean load asymmetry + (1.64 x Standard error of the mean (SE))

Each subject's left and right leg scores were converted to mean value and reported as absolute strength (ABS), relative strength (REL) and the asymmetry (ASY) between each limb.

Speed Testing

Speed testing (20m and 505_{MOD}) was conducted on an artificial surface and data was recorded using a Witty timing system (Microgate, Italy), using beams placed at approximately the subject's waist height to record their centre of mass passing the timed distance (44). Prior to speed testing an athletic warm-up of approximately 15 mins, including mobility and running specific exercises were performed. For both tests subjects were instructed to start 0.5 m behind the start line in a split, two-point stance, before being given the command "Go". The clubs performed between one and three repetitions, based on their testing constraints. Where multiple trials were performed a minimum of four minutes' rest were taken between trials, to ensure sufficient recovery. Each subject's best performance was used for analysis.

Linear sprint speed was measured using the 20 m sprint (linear) including a 10 m split time. Mean velocity was calculated for each timed section (0 to 10 m, 10 m to 20 m and 0 to 20 m). Sprint performance at 10 m and 20 m has previously been demonstrated as a reliable method of measuring sprint performance in Rugby (League and Union) players, with a typical error of 0.05 s (10 m) and 0.06 s (20 m), representing coefficient of variation (CV) values of less than 5 % (15).

COD performance was measured after completion of the linear sprint performance and was the time to complete the 505_{MOD}. Gabbett et all (28) have previously been shown the 505_{MOD} test to be a reliable test of COD, in an RL population (ICC = 0.92, CV = 2.5 %). The change of direction deficit (CODD) (37) was determined using each subjects 0-10m time from the aforementioned recorded 20m sprint.

STATISTICAL ANALYSES

Data was imported into R (39) and analysed using a code written specifically for this study. A two tailed approach to statistical analysis was adopted for inferential analysis using an alpha level of 0.05 and all values are reported with 95% confidence intervals (CI), where appropriate. As the sample consists of subjects from different levels of competition (Senior n=18, Academy n=32), each group was analysed separately and Fisher's r to z transformation performed to allow for comparisons in correlation. Where non-significant differences in correlation coefficients exist (-1.96 < 1.96), the sample was considered as a homogenous group and all subject data analysed collectively. This specifically required the application of correlation analysis to detect univariate associations and multiple linear regressions to determine the predictive qualities of all variables.

For all outcome measures, ABS, REL, ASY, age and mass were included in the initial predictive model. A backwards stepwise approach to multiple linear regression (MLR) analysis was adopted until the minimal adequate model (MAM) was achieved. This was determined when all components of a model were either significant (p >0.05) or tending to be significant (p 0.05 ≥ 0.1). For each variable up to four iterations of the initial model were created, eliminating the variable with the highest p value on each occasion. For all models analysed, comparison of Aikake information criterion (AIC) values was conducted to determine the probability of information loss between models. This was achieved through determining the relative likelihood ratio, using the following equation:

$$\mathrm{Exp}\ ((AIC_{MIN} - AIC_{i})/2)$$

The model's adjusted R^2, p value and AIC were reported along with the p value of each component included. In the case of AIC_{MIN} and MAM being achieved in different models, the author's judgement as to which model represented best overall fit was applied.

Further analysis of the association between individual predictor and outcome variables was undertaken using a Pearson product moment correlation (PMCC) (35) where data was normally distributed. Alternatively, in non-normally distributed data a Spearman rank order correlation (SROC) was used (33). A magnitude-based decisions (MBD) approach was adopted to report findings for both tests (3). Cohen (11) identified an *r* (or ρ) value of 0.1, as the smallest clinically important correlation, therefore, this was set as the threshold of analysis for all correlational inferences. The MBD were analysed, based on the probability that the correlation observed was greater than 0.1 and classified as follows; <0.5% almost certainly not; 0.5-5% very unlikely; 5-25% unlikely; 25-75% possibly; 75-95% likely; 95-99.5% very likely; >99.5% almost certainly, where there was a greater than 5% chance of both a negative and positive result, the inference was deemed unclear (31).

A dual approach to data analysis was undertaken within this study. The first approach was to consider asymmetry as a continuous variable and apply statistical techniques relevant to this data type.

Case Study analysis

To interpret data from each of the selected cases all individual subject data was converted to z scores, using the methods described by Turner et al (47). The subject with the greatest asymmetry magnitude was selected and denoted as Subject A.

RESULTS.

All strength variables were found not to be normally distributed, using the Shapiro-Wilks test, therefore, non-parametric statistical tests were applied. An MBD analysis of differences in strength between the senior and academy players found trivial or unclear differences between groups, none of which achieved a level of statistical significance ($p > 0.05$). Fisher's r to z transformation analysis showed no significant differences in correlations between senior and academy players relating to any strength variables with any speed variables. Therefore, the whole sample was used collectively for further statistical analysis and discussion. Descriptive data for all strength and speed metrics including between group inferential analysis is provided in the supplementary materials.

****INSERT TABLE 1 ABOUT HERE ****

Descriptive data of lower-body strength and asymmetry is presented in table 1. The MDA was found to be 0.34 SD's greater than the mean asymmetry value. These threshold values are depicted in figure 1 along with the distribution of subjects around these boundaries. Using the MDA, subjects were separated into SYM (n=40) or ASYM (n=10). Seven subjects were observed to have a large asymmetry, all of which were classified in the weaker quadrant (mean relative leg strength = <1.03 kg/kg). Only one subject from the ASYM group, was classified as being stronger (Mean relative leg strength =1.26 kg/kg) and they had a moderate leg strength imbalance (8.33 %). In this subject, both limbs were greater than 1SD above the group mean relative strength.

**** INSERT FIGURE 1 ABOUT HERE *****

MLR analysis found a small, significant model for predicting mean velocity for the 20 m sprint (adjusted R^2 = 0.19), which explained 19 % of the variance. This model included only body mass (p <0.01) after all other leg strength related variables (ABS, REL, ASY and body mass) were removed. Details of the MLR models are provided in the supplementary materials. By compartmentalising the sprint into early (0-10 m) and late (10 m and 20 m) accelerative phases, different relationships were identified. A MAM was not able to be achieved for 0-10m mean velocity, however a small MAM (R^2 = 0.27, p = <0.01) was found for mean velocity between 10 m and 20 m. This model included all measured variables, and no backwards steps improved the predictive ability. Within this model asymmetry and relative leg strength were, however, identified as only trending towards significance (p = 0.07). Spearman rank order correlations (SROC) found a non-significant, unclear correlation between absolute leg strength and 10 m to 20 m mean velocity (ρ = 0.23, CI -0.26, 0.63, p =>0.05), but a most likely moderate positive correlation (ρ = 0.40, CI 0.14, 0.61, p = <0.05) for relative leg strength. This suggests that strength, relative to body mass, had a greater relevance to late-stage acceleration than absolute strength, yet neither were related to early stage (0 to10 m) acceleration.

Moderate predictive models were found for both 505_{MOD} (adjusted R^2 = 0.32) and CODD (adjusted R^2 = 0.40) respectively. Unilateral leg strength asymmetry was included in both predictive models for 505_{MOD} and CODD, however, the magnitude of effect estimate was small. For both 505_{MOD} and CODD absolute strength was a significantly small negative predictor of time, whereas relative strength was removed during the backwards steps in each outcome. SROC analysis of leg strength asymmetry was found to have unclear association with 505_{MOD} performance. Analysis of mean absolute strength found non-significant, most likely small negative correlation to both 505_{MOD} (ρ = -0.20, CI -0.46, -0.08) and CODD (ρ = -0.25, CI -0.49, -0.03). Although removed as a significant contributor to models predicting 505_{MOD} and CODD, relative strength was found to be significantly correlated to COD speed. As illustrated in Figure 2, an almost certain moderate negative correlation was found with 505_{MOD} (ρ = -0.49, CI -0.69, -0.23) and most likely moderate negatively with CODD (ρ = -0.41, CI -0.63, -0.13).

**** INSERT FIGURE 2 ABOUT HERE *****

CASE STUDY

Details of the Z scores of subject A can be found in Table 3, which shows an asymmetry magnitude of 33.3 % (Z = 5.29 AU's), which was a result of a greater weakness in right leg (Z = -1.84 AU's, 60kg, 0.62 kg/kg), compared to the left (Z = -1.58 AU's, 90 kg, 0.94 kg/kg). Therefore, the subject not only showed a greater imbalance than the group, but a large decrement in left and right leg strength (30 Kg), which may compound any possible implications from strength asymmetry. An air of caution must be taken when considering this case study approach to asymmetry, which is indicative of the mathematical challenges associated with asymmetry research. Subject had had a difference of 30 Kg between limbs, equating to an asymmetry of 33%. However, if this same imbalance was applied to the participant with the strongest performance (120 Kg) and weakest subject (70 Kg) the asymmetry would have been 25 % and 43 % respectively. In this study subject A had both the largest percentage asymmetry and absolute difference between limbs.

INSERT TABLE 2 ABOUT HERE *

Other non-asymmetrical cases were identified (body mass Z ≥1.00 AU's, REL Z ≤ -1.00 AU's, ASY < MDA), for comparative purposes that were identified as subjects B, C and D (see table 3). Subject A demonstrated large decrements in mean velocity which was more pronounced between 10 m and 20 m than between 0 and 10m. Subjects B, C and D, who were relatively heavier and weaker than the mean, but more symmetrical, also demonstrated slower sprint velocities. Subject A displayed a moderate to large increase in time taken to perform the $505_{MOD,}$ in both directions and associated CODD (Z= 0.92 to 2.13 AU's). Similar decrements were also found in the additional three cases analysed, of comparable mass and strength. In summary, subject A had the greatest asymmetry in unilateral strength, plus a higher body mass and lower relative strength than the group mean. This subject performed poorly in both the 20 m sprint and 505_{MOD}, yet not observably different from subjects who had similarly higher mass and lower strength but were more symmetrical. Therefore, this subject did not provide evidence that large leg strength asymmetry (33 %) was more detrimental to linear and multidirectional speed performance, than low relative leg strength and high body mass.

DISCUSSION.

This study hypothesised that there would be no significant relationships between unilateral leg strength asymmetry and either linear sprint or CODS. The findings of this study do not reject this hypothesis. Unilateral leg strength asymmetry was included in all significant models predicting mean velocity, and COD time, except the initial 10 m interval of the 20 m linear sprint. These predictive models achieved the alpha level of significance ($p < 0.05$) and range from small (adjusted $R^2 = 0.16$) to moderate (adjusted $R^2 = 0.41$). These outcomes would initially indicate that unilateral leg strength asymmetry was related to accelerative performances. Although included in significant models, the magnitude of estimates provided by asymmetry, within these models, was small. When analysed in a univariate manner, unilateral leg strength asymmetry was not associated with mean linear velocity or performance in the 505_{MOD} ($\rho < 0.2$, $p = > 0.05$). Therefore, the evidence presented in this study supports the hypothesis that, at the group level, unilateral leg strength asymmetry does not negatively affect either linear sprint or CODS performance.

The distribution of subject strength asymmetries, in this study, does highlight the value of taking a case study approach. Of the 50 athletes tested, only 10 subjects to exceed the MDA, suggesting that asymmetry is not frequently occurring in this population and does not afford the opportunity to undertake inferential statistical analysis. The data provided from the sample did not indicate that leg strength asymmetry was related to any performance measure in this study. As subject A has an asymmetry 5.29 SD's greater than the mean, these conclusions may not best describe the implications for this individual. Subject A had a greater mass (Z = 1.03 AU's), slower mean 20 m velocity (Z = -1.13 AU's), longer 505_{MOD} times (left Z = 0.75 AU's, right Z = 1.93 AU's) and greater CODD (left Z = 0.92 AU's, right Z = 2.13 AU's) than the group mean. These values demonstrate that the subject with the greatest asymmetry performed poorly in the tests and therefore asymmetry at this magnitude is detrimental to performance. However, other factors confound this assumption such as a higher body mass and poor relative strength in both legs (left Z = -1.49 AU's, right Z = -1.58 AU's). When compared to symmetrical subjects, of similar mass and strength, subject A performed equitably in both the 20 m sprint and 505_{MOD}. The experiences of subject A suggest that an asymmetry of 33 % in unilateral leg strength is not more detrimental to performance than the combination of increasing body mass and reduced relative strength, supporting the notion that leg strength asymmetry may not be an inhibitor of athletic performance in RL players.

Previous research into leg strength asymmetry and associations with either linear sprints or COD tasks is very limited. Aside from the current study, only one other (18) has examined unilateral, multi-joint strength asymmetry with performance. That study found no association between isometric mid-thigh pull (IMTP) peak force asymmetry and a modified version of the 505 test, when turning either left (p =0.48) or right (p = 0.48). The studies by Coratella et al (14) and Lockie et al (32) investigated single joint force asymmetries, finding no association ($r = \leq 0.20$) between knee function peak torque, recorded at 60 $°\cdot s^{-1}$, and either linear sprint or COD performance. Although both studies (14, 32) observed significant asymmetries at higher angular velocities (>180 $°\cdot s^{-1}$) their findings were contradictory and only occurred in a small proportion of the metrics collected. These studies demonstrate that although limited in number there is little to no evidence to support the association of a functional measure of leg strength imbalance with performance in either a linear sprint or COD task.

The current study examined the performance in a closed kinetic chain, multi-repetition, multi-joint task, whereby the completion of the exercise is the result of vertical ground reaction force expression for approximately two seconds (one second eccentric phase, one second concentric phase). The studies discussed above (14, 32) have reported measures of peak force, representing leg force output for 0.001 s of the performance. As such comparing strength asymmetries found by Dos'Santos et al (18), Coratella at al (14) and Lockie et al (32) with that of the current study represents two contrasting ends of a force-time analysis. The difference in kinetic parameters reported may suggest that different physical qualities have been analysed (peak force vs impulse). Nevertheless, despite this contrast no meaningful discrepancies in findings have been observed, relating to the impact of kinetic asymmetry on accelerative performance. This would suggest, despite the limited body knowledge, that leg strength asymmetries are not related to either linear or COD speed.

To understand why this may be the case, the findings of Newton et al (36), maybe insightful. Newton et al (36) found asymmetries in strength focused tasks did not significantly (p = >0.05) correlate to the rate of force development-based tasks (<0.25 s), such as jumps and hops. The implications of those findings mean it cannot be assumed that the asymmetry observed during a RFESS 5RM, IMTP or isokinetic dynamometry assessment, would be the same, in either direction or magnitude, as observed during the act of accelerating, decelerating, or turning. Even if this were the case, the carry-over of asymmetry from strength test to sprint performance is only theoretically proposed to inhibit performance. Previous research (10, 20) has demonstrated that within the act of sprinting subjects display kinetic and kinematic asymmetries which were not related to the maximum velocity achieved during the sprints. Thomas and colleagues (45) described asymmetries in the penultimate and final foot contact forces between dominant and non-dominant legs (p = <0.001), when performing the 505 test. Despite these differences in force production, no differences between sides were observed for COD time (dominant turn direction = 2.54 ±0.06 s, non-dominant turn direction = 2.53 ±0.09 s. p = 0.11). These intra-task findings, in both linear and COD speed, suggest that biomechanical asymmetries exist, yet are not detrimental to performance. Therefore, the notion of identifying non-task specific asymmetries appears to be a thankless task, as there is increasing evidence that they may not transfer to accelerative performance (36) and if they did, have little impact on the outcome (10, 20, 45).

This study presents data reflecting subject's asymmetries at a single time point, at the commencement of their pre-season period. However, practitioners should be wary about this may relate to any asymmetries they may measure. Several studies have presented a lack of test retest reliability in asymmetry as a measure of performance, both in direction and magnitude (5, 8, 9). Such data would suggest that asymmetry does not have the required level of reliability to be a trustworthy measure of physical performance. However, these studies were undertaken using bilateral countermovement jump performance. By contrast both Blagrove et al (9) and Helme et al (29) have both shown measures of strength to have acceptable between day reliability for asymmetry. Consequently, it appears that the reliability of asymmetry is very task and metric dependent, favouring more strength-based tasks, than ballistic jump movements. Practitioners should be cognisant of this when interpreting this study and be wary of considering asymmetry as a blanket term, instead should establish the test-retest reliability of the performance task they wish to investigate.

The applied nature of this study presented several constraints, which limited the outcome of the study. This study recruited three sub-elite teams during the first exposure of their pre-season training. Consequently, the subjects would have undertaking varying degrees of physical preparation during their off-season. Had the testing events taken place later in the pre-season when all subjects would have experienced a greater and more standardised strength and sprint exposure their physical performance may have been altered, affecting the observed relationships. Furthermore, all teams were sub-elite, two of which being academy groups. The level of player standard and experience does not represent all competitive levels of RL. Therefore, practitioners should be mindful of the transferability of the study's results in different RL populations.

PRACTICAL APPLICATIONS.

The current study adds to the growing body of literature which demonstrate that athletes display asymmetries in tests of bio-motor capacities, but these are not detrimental to athletic performance. However, this study provides several novel insights into this paradigm. Firstly, by applying a mathematical model of asymmetry classification it demonstrates a low prevalence of strength asymmetry, specifically in this RL cohort. Practitioners may therefore be mindful that asymmetry is not a commonly occurring issue and may only be impacting, if it all, a minority of their athletes. Such information can significantly improve the efficiency of practitioners, who may wish to develop asymmetry related interventions with their athletes. Secondly, those subjects with an asymmetry are typically lower in strength than their symmetrical peers, suggesting an under-performance in that task alongside inter-limb differences. Practitioners are encouraged, therefore, to review data diagnostically and identify higher order problems, for example, lower strength vs leg strength imbalances. To aide practitioners in this diagnosis, case study analysis in this study observed that the most asymmetrical individual performed no worse than peers of similar mass and relative leg strength. Consequently, there appears little practical value having targeted asymmetry interventions, instead the development of relative leg strength seems a more efficacious approach, in RL players.

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FIGURES

FIGURE 1: An illustration of interaction between unilateral leg strength asymmetry (%) and mean relative leg strength (kg/kg)

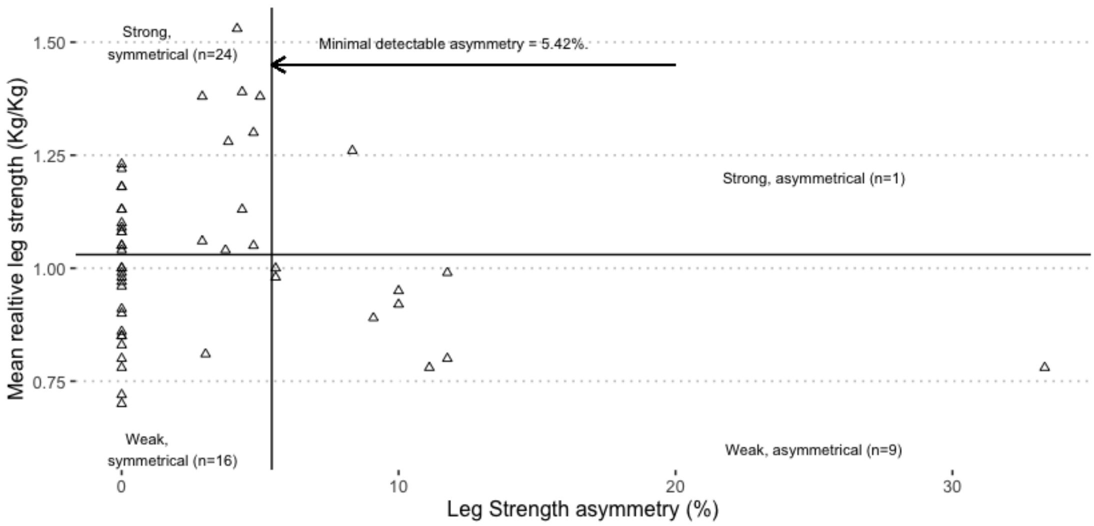
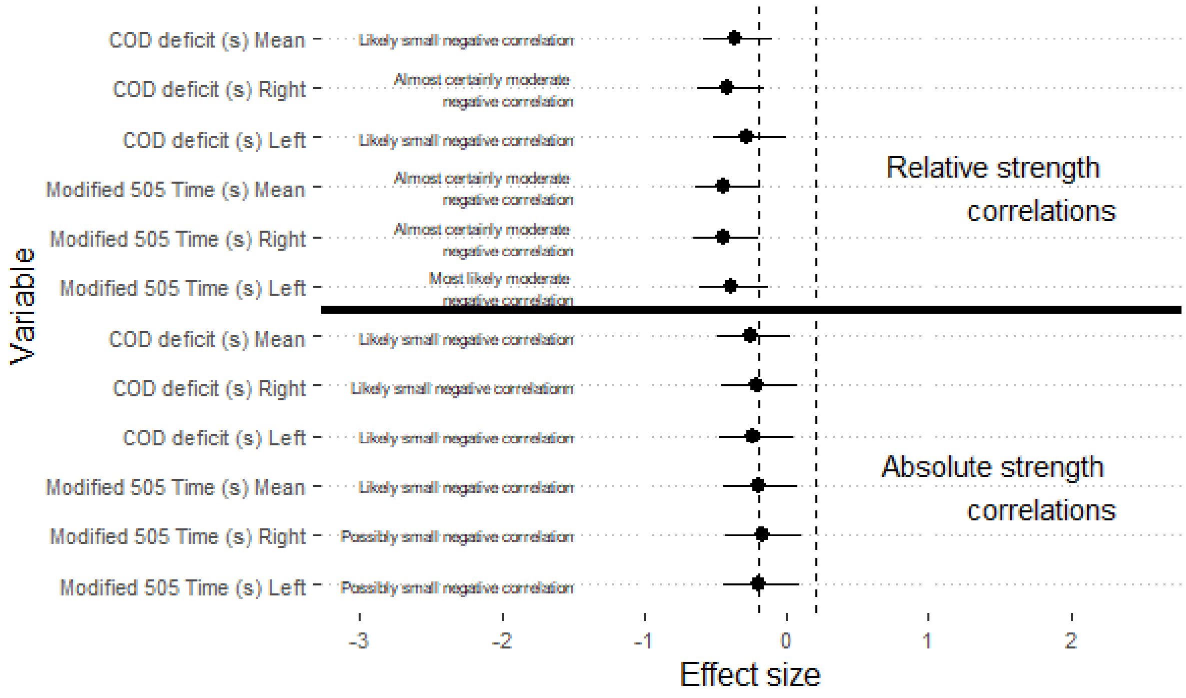

Strong,
symmetrical (n=24)
Minimal detectable asymmetry = 5.42%.
Strong, asymmetrical (n=1)
Weak,
symmetrical (n=16)
Weak, asymmetrical (n=9)
Mean realtive leg strength (Kg/Kg)
1.50
1.25
1.00
0.75
0
10
20
30
Leg Strength asymmetry (%)

Figure 2: Comparison of the effect sizes for correlation between mean 5RM RFESS strength and CODS performance



COD deficit (s) Mean
Likely small negative correlation
COD deficit (s) Right
Almost certainly moderate negative correlation
COD deficit (s) Left
Likely small negative correlation
Modified 505 Time (s) Mean
Almost certainly moderate negative correlation
Modified 505 Time (s) Right
Almost certainly moderate negative correlation
Modified 505 Time (s) Left
Most likely moderate negative correlation
Relative strength correlations
COD deficit (s) Mean
Likely small negative correlation
COD deficit (s) Right
Likely small negative correlation
COD deficit (s) Left
Likely small negative correlation
Modified 505 Time (s) Mean
Likely small negative correlation
Modified 505 Time (s) Right
Possibly small negative correlation
Modified 505 Time (s) Left
Possibly small negative correlation
Absolute strength correlations
Variable
-3
-2
-1
0
1
2
Effect size

TABLES

Table 1: Descriptive strength data and between group inferential analysis of performances in the Rear foot elevated split squat.

Variable	**WHOLE SAMPLE**	**SENIOR**	**EMERGING**	**MAGNITUDE BASED DECISION**
Mean RFESS 5RM (kg)	88.92 ±12.59	89.03±14.51	89.33±12.17	Unclear difference (p =0.88, ES =-0.04 CI -0.50, 0.44)
Mean RFESS relative to body mass, (kg/kg)	1.01 ±0.17	0.97±0.19	1.06±0.19	Possibly trivial difference. (p =0.11 d =-0.48 CI -1.07, 0.12)
Asymmetry magnitude without direction (%)	3.21 ±5.70 %	5.00±8.31	2.20±3.25	Unclear difference (p =0.32, ES = -0.12 CI -0.35, 0.57)
Asymmetry of RFESS 5RM (%)	96.98 ±12.20	102.48±9.43	100.03±3.95	Unclear difference (p =0.41, ES =-0.12 CI -0.37, 0.55)

Minimum detectable asymmetry (MDA)	Moderate asymmetry	Large asymmetry
5.42 %	4.35 %	> 8.91 %

Table 2: Comparison of strength, speed and change of direction Z scores between selected cases from the larger sample.

	ABS	**REL**	**ASY**	**Mean velocity. 0-10 m**	**Mean velocity. 10 m- 20m**	**Mean velocity. 0 m – 20 m**	**Mean 505_{MOD} time**	**Mean CODD**	**Mass**
Subject A	-1.10	-1.31	5.29	-1.25	0.96	-0.22	1.62	-1.81	1.03
Subject B	-0.33	-1.31	1.39	0.39	-2.22	-1.30	3.12	3.15	1.88
Subject C	0.45	-0.57	1.19	0.06	-0.81	-0.48	1.00	1.00	1.36
Subject D	-1.49	-1.73	-0.56	-0.22	-1.56	-1.13	1.62	1.42	1.03

*ABS (Absolute Strength), REL (Relative Strength), ASY (Magnitude of asymmetry)