COMPARISON OF COUNTERMOVEMENT JUMP-DERIVED REACTIVE STRENGTH INDEX MODIFIED AND UNDERPINNING FORCE-TIME VARIABLES BETWEEN SUPER LEAGUE AND CHAMPIONSHIP RUGBY LEAGUE PLAYERS

Submission Type: Original Research

Funding Statement: No funding was received for this study.

Conflict of Interest Statement: There are no conflicts of interest concerning this study.

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ABSTRACT

The countermovement (CMJ) is regularly tested in rugby league (RL), with recent work reporting reactive strength index modified (RSI_{mod}) to distinguish between levels of play. Differences in CMJ-derived RSI_{mod} and underpinning force-time variables between English Super League (SL) and RL Championship (RLC) players are, however, unknown. As SL and RLC teams compete against each other, the present study addressed this knowledge gap. Sixty RL players from the English SL (n=30) and RLC (n=30) performed three CMJs on a force platform at the start the preseason training. The RSI_{mod} was calculated by dividing jump height (JH) by time to take-off (TTT) and several other variables were also extracted from the force-time record. The SL players achieved a significantly higher (large effect) RSI_{mod} by performing the CMJ with a significantly shorter (large effect) time to take-off, but a similar (small effect) JH. The SL players achieved the shorter TTT via a significantly reduced (large effects) relative displacement during both the countermovement (combined unweighting and braking displacement) and propulsion phases, but a significantly higher (moderate effects) propulsion peak force and power. The relationships between TTT and relative countermovement (r=0.719, p<0.001) and propulsion (r=0.771, p<0.001) displacement for combined group data were very large. Practitioners working in RL should, therefore, consider reporting RSI_{mod} and TTT, alongside JH, following CMJ force-time testing. We also suggest that RL players who produce lower RSI_{mod} scores would benefit from being trained to produce larger CMJ propulsion forces over a shallower range of hip, knee and ankle extension.

KEY WORDS

Vertical jump; force platform; jump monitoring; talent identification

INTRODUCTION

The importance of assessing countermovement (CMJ) performance as part of talent identification testing batteries within rugby league was recently highlighted (29), with the utilization of valid/accurate methods of doing so, such as force platform analysis, subsequently emphasized (18, 30). The rationale for including CMJ performance testing within rugby league physical testing batteries is in-part based on previous research that has shown it to be correlated to faster 5-, 10- and 30 m sprint performances ($r = 0.56\text{-}0.62$, $p < 0.05$) (2) and better tackling ability ($r = 0.38$, $p < 0.05$) (4) in high-level rugby league players. In terms of the latter attribute, playing experience (number of top-flight competitive rugby league games) and vertical jump height were the only variables that contributed significantly ($r^2 = 0.60$, $p < 0.01$) to a multiple-regression model applied to predict tackling ability (4). Additionally, changes in CMJ peak power and tackling ability, following an 8-week pre-season strength and power training block, shared a small correlation ($r = 0.38$) and discriminated between the tackling ability of semi-professional rugby league players who demonstrated the highest and lowest change in CMJ peak power (Cohen's *d* = 0.56) (28). As rugby league is an intermittent team sport, that is comprised of several bouts of high-intensity running, collisions and tackling (5), a simple non-fatiguing test such as the CMJ, that seemingly distinguishes between better performances in these important competitive match-based tasks, is an appealing option for sports scientists to further explore in this cohort.

In England, the highest tier of competitive rugby league is the Super League (SL), which is comprised of 12 full-time professional teams. A change to the English rugby league competition structure in 2015, means that SL teams now regularly compete against teams from the second highest tier of the English game, the Rugby League Championship (RLC), which is comprised of 12, mostly semi-professional, teams. To the authors' knowledge, only two studies to date, have compared physical characteristics between English senior-aged SL and RLC players (7, 10). Glenohumeral internal rotation peak torque and cycle ergometry-derived absolute and relative peak power were significantly higher for SL vs. RLC players (7). Additionally, no differences in age, stature or body mass were observed between SL and RLC players (10), but the former possessed significantly greater lean mass. The greater upper and lower body force and power characteristics, along with greater lean body mass, noted for SL players may be due to this cohort being part of a full-time professional structure, thus allowing them to dedicate more time to both rugby training and strength and conditioning. It is, however, currently unknown how performance differs between senior-aged SL and RLC players in other athletic tests of relevance to rugby league such as the CMJ, from which a glut of useful information can be generated when this test is conducted using a force platform (6). Furthering one's understanding of differences (or lack of) in CMJ performance between SL and RLC players may, therefore, help to better direct the training foci of these cohorts.

Recently, CMJ height and RSI_{mod} (calculated as jump height divided by time to take-off) were shown to discriminate between professional senior and academy (u19s, the final academy age group before senior-level) rugby league players competing in the RLC (20). The time to take-off was similar between the groups (Cohen's *d* [*d*]=0.04), but senior players jumped higher (*d*=0.91) which led to them achieving a higher RSI_{mod} (*d*=0.58) (20). Thus, between these two levels of RLC players, jump height was the main discriminator of CMJ performance (20). In a recent study, researchers compared CMJ height and propulsion power (mean and peak values) attained between senior SL players and two groups of academy players (including u19s) (9). Although the senior players achieved higher mean values for each of these variables, statistically speaking, they amounted to just a trivial difference in jump height (*d*=0.12), a small difference in peak propulsion power (*d*=0.37), but a moderate difference in mean propulsion power (*d*=0.94) when compared to the u19s' scores. Thus, although senior players demonstrated a similar jump height (which is determined by propulsion work) to the u19s, their rate of propulsion work (i.e. mean power) was greater. This was likely due to the senior players performing the CMJ with a shorter propulsion phase time (i.e. similar work done in a shorter time would increase mean power), although phase times were not included in the study by Ireton et al. (9). Overall, these results indicate that senior SL players performed the CMJ within a shorter time than the u19s, which would have resulted in them achieving a higher RSI_{mod} owing to jump height being similar (albeit, we do not know if RSI_{mod} would have been significantly/meaningfully higher for the senior players).

The results of the two studies above indicate that 1) CMJ height alone may not always discriminate between rugby league cohorts, emphasizing the requirement for the associated underpinning force-time variables [to indicate jump 'strategy'], or RSI_{mod} at the very least, to be reported alongside jump height, and 2) the precise CMJ force-time variable that distinguishes between rugby league cohorts competing within the SL and RLC playing tiers may differ. McMahon et al. (19) reported that a group of combined professional senior SL and RLC rugby league players who performed the CMJ with a higher RSI_{mod} demonstrated higher force, velocity and thus power outputs. The appeal of RSI_{mod} is that it is easy to understand (compared to force, velocity and power) and report to coaches (e.g., the athlete jumped higher and with a shorter time to take-off), despite it not relating very well to the traditional RSI metric in senior-level SL rugby league players (24). Also, time-constrained force production, which in the case of the CMJ translates to a shorter time to take-off, is said to be an important ability of athletes (31). From a coaching perspective, it is impossible to "see" time to take-off, but one can see countermovement displacement (i.e. squat depth) and it might be that if an athlete or group of athletes perform the CMJ with a longer time to take-off and thus a reduced RSI_{mod}, this is due to them performing a larger countermovement displacement (i.e., squatting deeper) (19). Information about the relationship between countermovement displacement and time to take-off in the CMJ may highlight potential jump exercise coaching strategies designed to improve RSI_{mod}.

The primary purpose of this study was to compare CMJ-derived RSI_{mod} and the underpinning force-time variables recorded during the different phases of CMJ between rugby league players competing in the English SL and RLC. It was hypothesized that SL players would demonstrate a higher RSI_{mod} by jumping higher with a shorter time to take-off and resultantly, force, velocity (if any reduction in time to take-off is not offset by a reduction in countermovement displacement) and power values would be larger for this group. A secondary purpose of this study was to explore the relationship between time to take-off and both relative countermovement and propulsion displacement in the CMJ for the combined data recorded for both groups. It was hypothesized that these variables would share a large positive relationship based on previous cross-sectional studies conducted with both rugby league and union players (11, 19).

METHODS

Experimental Approach to the Problem

This study employed a within-session repeated measures design whereby subjects performed three CMJs on a force platform, enabling comparisons of RSI_{mod} and underpinning force-time variables between SL and RLC players to be made.

Subjects

Sixty rugby league players from the English SL (n=30) and RLC (n=30), comprised of thirteen backs in each group, attended a single testing session at the start of the preseason training period. A comparison of their physical characteristics can be seen in Table 1. All subjects had previous experience of performing CMJs in line with the protocols discussed in the procedures section. Written informed consent was provided prior to testing, the study was pre-approved by the institutional review board and it conformed to the World Medical Association’s Declaration of Helsinki.

Procedures

Following a brief (approximately 10 min) warm-up consisting of dynamic stretching and sub-maximal jumping (five sets of single effort and two sets of five repeated CMJs), the subjects performed three recorded maximal-effort CMJs to a self-selected depth with arms akimbo (12). All sub-maximal jumps that were completed in the warm-up were also executed to the subjects’ self-selected depth (thus, the repeated CMJs were not performed with the intention of minimizing ground contact time), however they were not performed to a maximal jump height. The recorded maximal-effort CMJs were performed approximately three minutes after the completion of the warm-up and each of the three trials were separated by one minute of rest.

Maximal-effort CMJ ground reaction forces were recorded at 1000 Hz using a previously zeroed Kistler type 9286AA force platform and Bioware 5.11 software (Kistler Instruments Inc., Amherst, NY, USA). The subjects were instructed to stand still for the initial one second of data collection (25, 26) to enable the subsequent determination of their body weight (vertical force averaged over the first 1 s). The subjects were then instructed to perform the maximal-effort CMJs as fast and as high as possible, whilst keeping their arms akimbo. Any jumps that were inadvertently performed with the inclusion of arm swing or leg tucking during the flight phase (tester observation) were omitted and additional jumps were performed after one minute of rest.

Raw vertical force-time data only were exported as text files and analyzed using a customized Microsoft Excel spreadsheet (version 2016, Microsoft Corp., Redmond, WA, USA). Center of mass velocity was determined by dividing force (minus body weight) by body mass and then integrating the product using the trapezoid rule (25). Instantaneous power was calculated by multiplying force and velocity at each time point and instantaneous center of mass displacement was determined by twice integrating force data at each time point (25).

Onset of movement was identified in line with current recommendations (26). In brief, the first 1 s of vertical force was averaged, and the standard deviation (SD) calculated. This SD was then multiplied by 5 and the first force value +/- this value was identified. Finally, the point 30 ms before this value was identified and marked the onset of movement. Take-off and touchdown were identified when the force fell below and exceeded five times the SD of the flight phase force, respectively (20, 21). The flight phase force was identified as the force during the middle of the flight phase (i.e., when the force platform was unloaded) as described by Lake et al. (15, 16).

The CMJ phases were identified using the terminology explained recently by McMahon et al. (23). Specifically, the unweighting phase was defined as occurring between the onset of movement and the instant of peak negative velocity, the braking phase was defined as occurring between the instants of peak negative velocity (plus one sample) and zero velocity and the propulsion phase was deemed to have started when velocity exceeded $0.01\ \text{m}\cdot\text{s}^{-1}$ (this usually occurred one sample after zero velocity) and finished at take-off (20, 21).

Braking and propulsion peak force, power, velocity and displacement were defined as the maximum values attained during the braking and propulsion phases, respectively. All kinetic data were normalized by dividing them by body mass to enable between-group comparison. Similarly, countermovement (combined displacement during the unweighting and braking phases) and propulsion displacement (i.e. the displacement between the end of the braking phase and the instant of take-off) were expressed as a percentage of standing center of mass height which, in turn, was calculated as 57% of standing height (17), to enable fairer between-group comparison. Jump height was derived from vertical velocity at take-off (25). The RSI_{mod} was calculated as jump height divided by time to take-off (3), with the latter calculated as the time between the onset of movement and take-off.

Statistical Analyses

A two-way mixed-effects model (average measures) intraclass correlation coefficient (ICC), along with the upper and lower 95% confidence interval (CI), was used to determine the relative between-trial reliability of each variable. Based on the 95% CI of the ICC estimate, values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.90, and greater than 0.90 were indicative of poor, moderate, good, and excellent relative reliability, respectively (14). Absolute between-trial reliability of each variable was calculated using the coefficient of variation percentage (CV%, calculated in this study as the standard deviation divided by the mean which was then expressed as a percentage), along with the upper and lower 95% CI. A CV of ≤10% and ≤5% has been used as an indicator of reliability in previous similar studies (1, 27). Due to a lack of consistency across studies, <5% and 5-10% thresholds (based on the 95% CI of the CV% estimate) were considered to represent good and excellent reliability, respectively, in the present study.

For each variable, the average recorded across the three maximal-effort CMJs was taken forward for further analyses. A Shapiro-Wilks test was conducted to assess normality of data distribution. The RLC players' braking and propulsion phase times, the SL players' age, and both the RLC and SL players' braking peak power were not normally distributed; thus, these were compared between groups via the non-parametric Mann-Whitney U test. All other variables were compared between groups via the independent t-test. A Levene's test was used to assess the assumption of the equality of variances and that adjusted t statistic and degrees of freedom was adopted with variances that were not assumed to be equal. The effect size calculations (Cohen's *d*) provided a measure of the magnitude of the differences in each variable between groups and they were interpreted as trivial (<0.19), small (0.20-0.49), moderate (0.50-0.79), or large (>0.80). For pooled data (n=60), time to take-off was not normally distributed thus its relationships with both relative countermovement and propulsion displacement were assessed via a one-tailed Spearman's test. Correlation coefficients were interpreted as trivial (0.0-0.1), small (0.1-0.3), moderate (0.3-0.5), large (0.5-0.7), very large (0.7-0.9), and nearly perfect (0.9-1.0) (8). All statistical analyses, apart from the CV% and effect size calculations, were performed using SPSS software (version 23; SPSS Inc., Chicago, IL, USA) with the alpha level set at $P \leq 0.05$.

RESULTS

As shown in Table 1, the SL players were significantly (moderate effects) younger (p=0.018, *d*=0.58) and shorter (p=0.028, *d*=0.58), but there was no significant (small effect) between-group difference in body mass (p=0.276, *d*=0.28), with RLC players being just slightly heavier.

** INSERT TABLE 1 ABOUT HERE **

The between-trial relative reliability was excellent (i.e., ICC lower 95% CI ≥0.9) for all variables (0.913-0.991) except eccentric time, which was good-excellent 0.896-0.957. The between-trial absolute reliability was excellent (i.e., CV% upper 95% CI <5%) for propulsion peak velocity (1.00-1.62%), propulsion peak power (1.77-2.88%), propulsion peak force (2.22-3.69%), jump height (2.37-3.80%), braking peak force (2.98-4.35%), propulsion displacement (2.55-4.40%), and propulsion time (2.60-4.41%). The between-trial absolute reliability was good-excellent (i.e., CV% upper 95% CI between <5 and 10%) for time to take-off (3.37-6.05%), braking phase peak velocity (3.41-6.15%), countermovement displacement (3.61-

6.66%), and RSI_{mod} (4.54-7.09%). The between-trial absolute reliability was good (i.e., CV% upper 95% CI between 5 and 10%) for braking time (5.49-9.86%) but excellent to poor (i.e., CV% upper 95% CI between <5 and >10%) for braking peak power (3.82-10.08%).

The distribution of individual RSI_{mod} scores for SL and RLC players can be seen in Figure 1. When considering mean data comparisons, the SL players achieved a significantly (large effect) higher RSI_{mod} by performing the CMJ with a significantly (large effect) shorter time to take-off, as achieved by significantly (large effects) shorter braking and propulsion phase times (Table 2). The SL players also demonstrated significantly (large effects) reduced relative displacement during both the countermovement (combined unweighting and braking displacement) and propulsion phases, but significantly higher (moderate effects) propulsion peak force and power (Table 2). There were non-significant (trivial-small effects) between-group differences in jump height, braking peak force, power and velocity, and propulsion peak velocity (Table 2).

** INSERT FIGURE 1 ABOUT HERE **

** INSERT TABLE 2 ABOUT HERE **

There were very large positive relationships between time to take-off and both relative countermovement ($r=0.719$, $p<0.001$) and propulsion ($r=0.771$, $p<0.001$) displacement (Figure 2).

** INSERT FIGURE 2 ABOUT HERE **

DISCUSSION

The primary aim of this study was to compare CMJ-derived RSI_{mod} and underpinning force-time variables between English SL and RLC players. A secondary purpose of this study was to explore the relationship between time to take-off and both relative countermovement and propulsion displacement in the CMJ (for pooled data). In relation to the primary aim, there was a large difference in RSI_{mod} between groups, with SL players achieving a higher mean value (Table 2). Interestingly, there was a larger spread of RSI_{mod} scores for the RLC players with the highest individual RSI_{mod} score produced by an RLC player (Figure 1). The lack of homogeneity among RLC players' RSI_{mod} scores might be due to this cohort being largely comprised of semi-professional players (some of whom had previously played at a professional level in the SL and some of whom have only ever competed in the RLC) who likely undertake more variable training programs. The SL players achieved a higher RSI_{mod} by performing the CMJ with a shorter time to take-off (large effect) but not a statistically higher jump height (small effect). This contrasts with the original hypothesis; thus, it was rejected. The latter result highlights the limitations of considering jump height alone when conducting CMJ force-time assessments with rugby league players (this is a point that has been discussed previously (18)), as it does not describe the underpinning jump strategy which, in this case, better discriminated between SL and RLC groups.

Propulsion time was the largest discriminator (based on the effect size) between SL and RLC players (Table 1). Large between-group differences were also found (in order) for propulsion displacement, countermovement displacement, time to take-off, RSI_{mod}, and braking time (Table 1). These results reveal that SL players can perform the CMJ with a shorter time to take-off because they do not squat as deep during the countermovement phase (i.e., reduced displacement during the combined unweighting and braking phases) which means that they do not have to push as far before take-off (i.e., reduced displacement in the propulsion phase), thus reducing the braking and propulsion times that comprise the majority of the total time to take-off calculation. The very large association of both countermovement and propulsion displacement with time to take-off, as hypothesized, can be seen in Figure 2. These results suggest that the RLC players rely on a larger propulsion displacement and, thus, a longer propulsion time to attain their jump height (13). Relying on propulsion net impulse comprised of a longer time rather than a larger force to attain a given jump height is, however, an impractical solution given that there is limited time available to produce force during many sporting tasks (31). The relationship shown in Figure 2 implies that one strategy to reduce the RLC players' time to take-off could be to coach them to reduce their countermovement and propulsion displacement (these displacements can be visually gauged from the hip and knee flexion angles (e.g. squat depth) attained during the CMJ). This approach would likely increase force production but reduce jump height (22), the reasons for which are discussed below.

The consequence of SL players demonstrating a reduced propulsion displacement and time is that their jump height scores were similar, from a statistical perspective (small effect size), to the RLC players'. This occurs when propulsion displacement and time are reduced by a greater proportion than propulsion force is increased, owing to the work-energy and impulse-momentum theorems, respectively. The fact that propulsion peak force was only moderately greater for the SL players somewhat supports the previous statement, although it should be noted that it is the propulsion mean force that governs the force component of work and impulse calculations. Nevertheless, the similar work done but over a shorter time in the propulsion phase resulted in SL players' attaining a moderately larger propulsion peak power (Table 2). In contrast to the hypothesis, however, the SL players achieved almost an identical but slightly lower (trivial effect size) propulsion peak velocity to the RLC players. The fact that the jump height, which was estimated from take-off velocity, was slightly higher for the SL players despite this group showing a slightly lower propulsion peak velocity, was probably due to the SL players being lighter (Table 1). As stated in a recent article (23), propulsion peak velocity occurs when subjects' center of mass height is momentarily identical to what it was when they stood still immediately prior to commencing the jump, after which they plantarflex the ankles and thus 'pick up' the weight of their shanks and feet. It stands to reason that those with a larger body mass will likely possess heavier shanks and feet, thus creating a greater deceleration effect prior to take-off. This finding illustrates a potential limitation of comparing propulsion peak velocity between groups of athletes of differing body mass and echoes previous suggestions that this method will overestimate jump height (23). To contextualize the 'level of performance' in the CMJ displayed by the subjects tested in the present study, it is useful to compare the descriptive statistics collated for RSI_{mod} and its constituent parts to those reported for rugby league players in previous studies. The mean RSI_{mod} value reported here for the SL players is higher (~11%) than values previously reported for a cohort of 21 SL players, due to the currently reported jump height and time to take-off being higher (~9%) and lower (~2%), respectively (24). The SL players' mean RSI_{mod} result is, however, comparable to what has been reported for a 'high scoring' RSI_{mod} group of rugby league players comprised of a mix of those from the SL and RLC (19). The RSI_{mod} jump height and time to take-off values attained by the RLC players tested in this study are also very similar to those previously reported for an equivalent group (20). It should be noted that the current and previous methods of calculating RSI_{mod} from SL and RLC players' CMJ force-time records are identical. This is important, as variations in force platform sampling frequency, onset of movement and take-off force thresholds, and jump height calculations affect RSI_{mod} values which would compromise the efficacy of any comparisons made across studies. To the authors' knowledge, there are no other published studies that have calculated RSI_{mod} from rugby league players' force-time records, thus it is recommended that any future studies that do should adopt the same procedures reported both here and in previous work (19, 20, 24).

PRACTICAL APPLICATIONS

The CMJ-derived RSI_{mod} distinguished between SL and RLC players because the former group were able to perform the CMJ with a much shorter time to take-off while attaining a similar jump height. Within the sport of rugby league, therefore, it is recommended that practitioners should consider reporting RSI_{mod} and time to take-off, alongside jump height, following CMJ force-time testing. The very large correlation between both countermovement and propulsion displacement and time to take-off, along with large between-group differences in these displacements, suggests that rugby league players who produce lower RSI_{mod} scores would benefit from being trained to produce larger CMJ propulsion forces over a shallower range of hip, knee and ankle extension. Acutely reducing countermovement displacement in the CMJ would likely result in an initial reduction in jump height but this should recover, and eventually improve, with augmented rapid force production capability. Both maximal strength and ballistic training can help subjects achieve this, thus these 'resistance training types' should be advocated with the precise weighting of maximal strength to ballistic training for a given individual determined based on their maximal strength capacity and, ideally, their dynamic strength index score. Training intervention studies are, however, required within the sport of rugby league to determine the best methods of improving RSI_{mod} scores.

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Figures Legends:

Figure 1: Distribution of individual reactive strength index modified scores for Super League (SL) and Rugby League Championship (RLC) players (open circles). Black horizontal lines represent the mean value attained by each group.

Figure 2: Scatter plots illustrating the relationships between both countermovement displacement (top) and propulsion displacement (bottom) and time to take-off for pooled mean data.

Table 1: Comparison of physical characteristics.

Variables	Superleague		Championship	
	Mean	SD	Mean	SD
Age (years)*	22.9	3.8	25.0	3.4
Height (m)*	1.82	0.06	1.85	0.06
Body Mass (kg)	95.2	10.9	98.2	10.7

*SD = Standard Deviation; * = significantly larger values for championship players (p<0.05).*

Table 2: Comparison of gross countermovement jump variables between levels of rugby league competition.

Jump Variables	Superleague		Championship		*P*	*d*	ES Interpretation
	Mean	SD	Mean	SD			
RSI_{mod} (ratio)	0.52	0.05	0.44	0.08	<0.001	1.11	Large
Jump Height (cm)	36.56	3.99	35.57	3.99	0.354	0.25	Small
Time to Take-Off (s)	0.712	0.074	0.822	0.099	<0.001	1.26	Large
Braking Phase Time (s)	0.150	0.024	0.179	0.039	0.006	0.89	Large
Propulsion Phase Time (s)	0.232	0.025	0.279	0.032	<0.001	1.62	Large
Countermovement COM Displacement (%)	28.02	4.23	33.29	4.10	<0.001	1.26	Large
Propulsion COM Displacement (%)	37.57	4.76	43.89	3.80	<0.001	1.47	Large
Braking Peak Force (N·kg^{-1})	25.05	2.12	23.76	3.12	0.068	0.48	Small
Propulsion Peak Force (N·kg^{-1})	25.99	2.10	24.32	2.59	0.008	0.71	Moderate
Braking Peak Power (W·kg^{-1})	14.64	11.90	19.01	6.18	0.549	0.46	Small
Propulsion Peak Power (W·kg^{-1})	55.02	4.91	52.30	5.02	0.038	0.55	Moderate
Braking Peak Velocity (m·s^{-1})	1.27	0.13	1.33	0.23	0.227	0.31	Small
Propulsion Peak Velocity (m·s^{-1})	2.79	0.15	2.81	0.14	0.768	0.08	Trivial

SD = Standard Deviation; ES = Effect Size; COM = Center of Mass

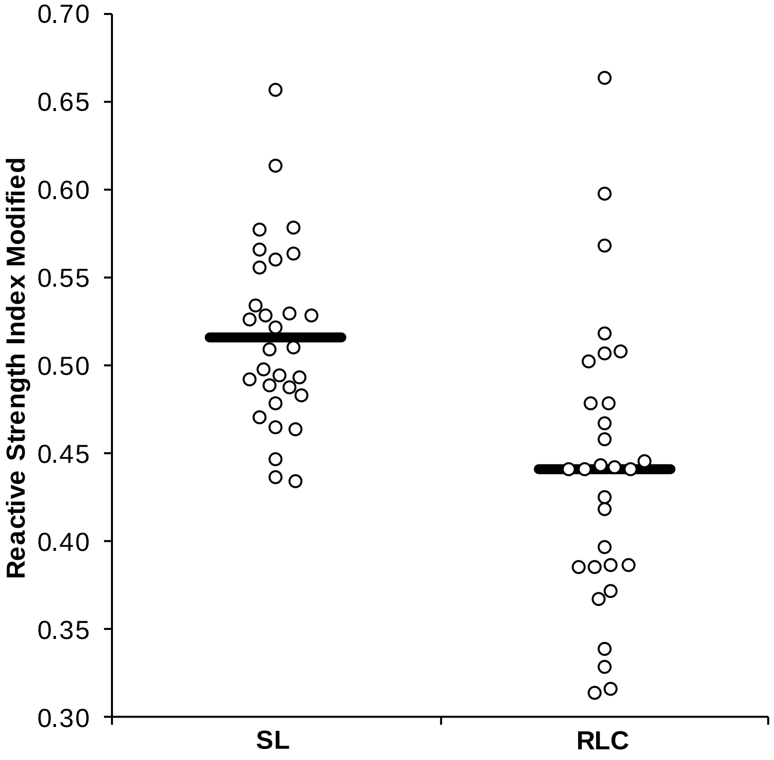
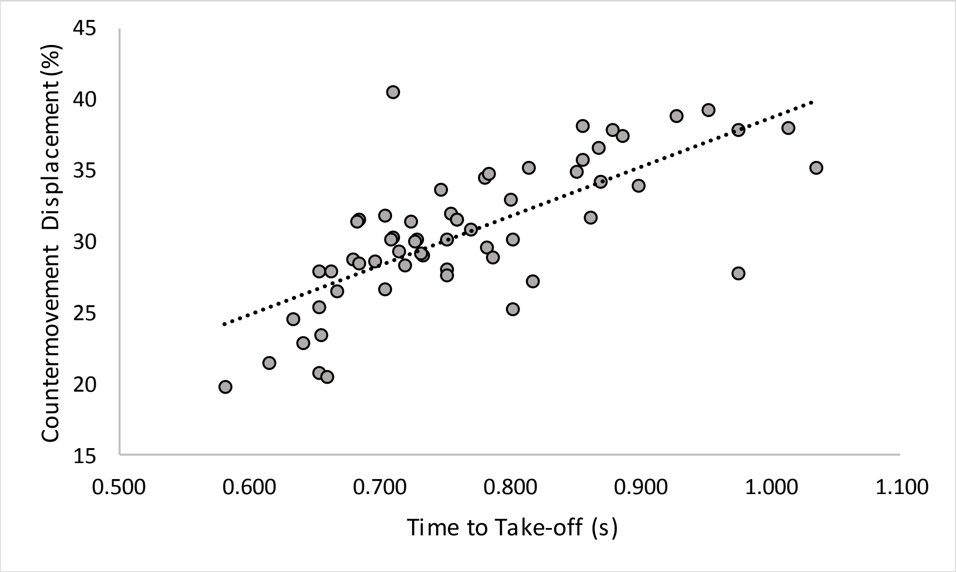


Figure 1: Distribution of individual reactive strength index modified scores for Super League (SL) and Rugby League Championship (RLC) players (open circles). Black horizontal lines represent the mean value attained by each group.



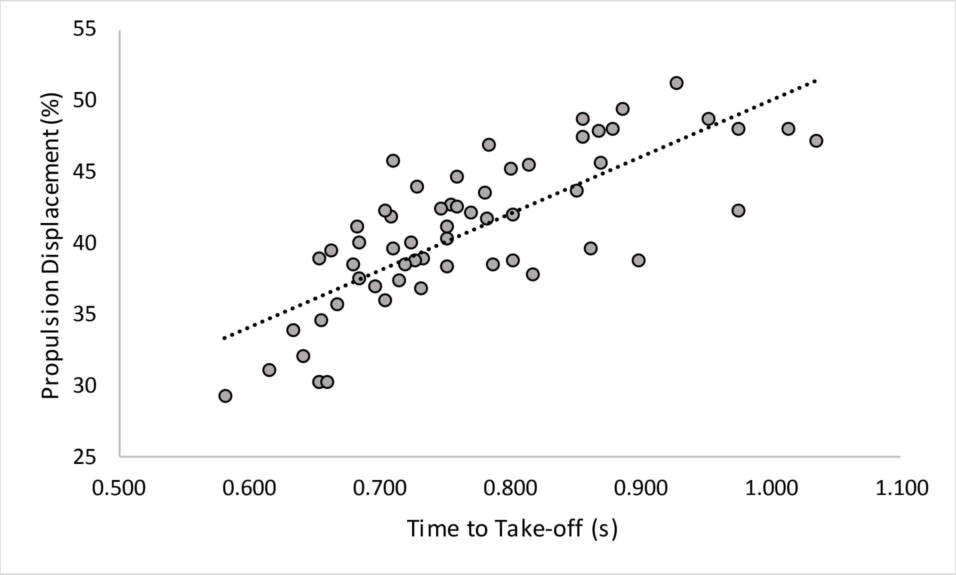


Figure 2: Scatter plots illustrating the relationships between both countermovement displacement (top) and propulsion displacement (bottom) and time to take-off for pooled mean data.