EARLY PRE-SEASON CHANGES IN THE COUNTERMOVEMENT JUMP OUTCOME AND STRATEGY VARIABLES OF ENGLISH SUPER LEAGUE RUGBY PLAYERS

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The aim of this study was to quantify changes in typical (i.e., jump height) and alternative (i.e., jump momentum) countermovement jump (CMJ) outcome and strategy variables, alongside maximal strength, during the early English Super League pre-season period. Twenty professional senior male rugby league players from an English Super League club performed CMJ and isometric mid-thigh pull (IMTP) testing (3 trials of each) on portable dual force plates on the first and last day of pre-season training held prior to a short Christmas break (December 2021). Select CMJ outcome and strategy variables and both absolute and relative (to body mass) peak force for the IMTP trials were automatically calculated via proprietary software. IMTP peak force significantly increased in both absolute and relative terms (moderate effects; g = 0.69) reflecting the aims of the pre-season training programme. Countermovement depth moderately reduced (r = 0.76) but time to take-off and reactive strength index modified remained unchanged. A small but non-significant increase in body mass was noted, which, along with increased jump height (small effect; g = 0.46), contributed to a significant, moderate increase in jump momentum (g = 0.59). Quantifying concomitant changes in CMJ outcome and strategy variables, alongside body mass, during pre-season training may offer richer insight into rugby league players' future physical development requirements beyond jump height alone.

KEYWORDS: vertical jump, force plate, collision sports, momentum.

INTRODUCTION: Commercial force plate systems are now commonplace in professional sport (Weldon et al., 2021) and are often used daily to assess athletes' function. Various jump tests, such as the countermovement jump (CMJ), are commonly conducted on force plates to provide insight into both neuromuscular and stretch-shortening cycle function and fatigue. The inferences drawn from CMJ force-time variables are broadly applied across professional rugby codes for benchmarking athletes' performance, evaluating exercise intervention effectiveness, monitoring neuromuscular function, and guiding injured athletes' return to play.

Jump height is mostly reported following CMJ tests, but it may mask subtle acute and chronic alterations in neuromuscular strategies which force plates can illuminate. Key phases can be obtained from the CMJ force-time record to provide comprehensive insight into athletes' neuromuscular strategies (McMahon et al., 2018). Such neuromuscular strategies during the CMJ have been explored in relation to level of play within professional rugby league (RL) (McMahon et al., 2022). Also, within RL, force plate-derived CMJ performance standards for the main outcome variables were compiled in a multi-club (n=104) study (McMahon et al., In-Press). Recently, a rationale for calculating CMJ momentum for RL cohorts alongside jump height (McMahon et al., 2020) was provided due to the requirement for certain players to utilise their heavier body mass effectively at speed to resist or make tackles during match play.

To date, there is limited research on how CMJ outcome and strategy variables change during the professional RL pre-season training period, whereby gaining lower body strength and hypertrophy prior to the commencement of the competitive season are typical priorities. Therefore, the purpose of this study was to quantify changes in typical (i.e., jump height) and alternative (i.e., jump momentum) outcome and select strategy variables during the CMJ, as assessed via a commercial force plate system during the English Super League pre-season.

METHODS: Twenty professional senior male RL players from an English Super League club participated in the study (age = 27 ± 3 years, height = 1.83 ± 0.05 m, body mass = 100 ± 9 kg). All players were injury free and engaged in a full-time programme comprised of skills training and at least three structured strength and conditioning sessions per week. Data were collected during the first day of pre-season training (Friday 5th November 2021) and the last day of pre-season training held prior to a short Christmas break (Friday 17th December 2021). Testing was conducted at the same location and time of day on each occasion and on each testing occasion the participants had avoided strenuous physical activity in the previous 48 hours. Informed consent was gained by each participant prior to testing and the study was pre-approved by the authors' institutional ethics committee.

Following a brief (~10 minutes) warm-up comprised of ~5 minutes of cycling on an ergometer and self-selected dynamic stretching, participants performed three recorded maximal effort CMJs to their preferred countermovement depth, each interspersed by ~30 seconds of rest. They were instructed to "jump as fast and as high as possible", whilst always keeping their hands on their hips. Following the CMJs, participants performed three recorded maximal effort isometric mid-thigh pull (IMTP) trials to allow training-induced changes in maximal lower body strength to be monitored between testing occasions. Participants were instructed to maximally push their feet into the force plates for ~3-5 seconds whilst simultaneously pulling on a cold-rolled steel bar set at mid-thigh height and embedded within a portable IMTP rig.

The vertical ground reaction forces (GRFs) during the maximal effort CMJs and IMTPs were sampled at 1000 Hz using a wireless dual force plate system via proprietary software (Hawkin Dynamics Inc., Maine, USA). The force plates were zeroed before each trial. The Hawkin Dynamics software operates via an android tablet that connects with the force plate system via Bluetooth. The GRFs were automatically low pass filtered with a 50 Hz cut-off frequency. After each trial, data were exported from the android tablet via Wi-Fi to the Hawkin Dynamics cloud server and later downloaded as a .csv file for data management in Microsoft Excel.

The participants stood upright and still for the CMJs or in the "second pull" position for the IMTPs during the first second of data collection (Owen et al., 2014) to enable subsequent calculation of body weight (N, vertical force averaged over 1 s) and body mass (kg, body weight divided by gravitational acceleration). Peak force during the IMTP trials was simply calculated as the highest force produced during the trials. It was also divided by body mass to provide a relative value. For the CMJs, net force was calculated by subtracting body weight from every force sample. Centre of mass velocity was then determined by dividing net force by body mass on a sample-by-sample basis and then integrating the product using the trapezoid rule (Moir, 2008). Instantaneous centre of mass displacement was determined by integrating the velocity data at each time point, again using the trapezoid rule (Moir, 2008). The onset of movement was identified in line with current recommendations (Owen et al., 2014). The instant of take-off was identified when force fell below a threshold equal to 25 N. The countermovement phase comprised of the unweighting and braking phases and was defined as occurring between the onset of movement and zero velocity and the propulsion phase was deemed to have started when vertical velocity became positive and finished at take-off (McMahon et al., 2022).

Two CMJ 'strategy' variables were calculated to help explain how the outcome variables changed over time. Specifically, time to take-off was calculated as the time interval between the onset of movement and take-off. Also, countermovement depth was calculated as the change in vertical centre of mass position between the onset of movement and its peak negative value prior to take-off and end of each phase. Three CMJ outcome variables were calculated. Jump height was derived from vertical velocity at take-off, as it represents the main outcome variable (Moir, 2008). Jump momentum was calculated by multiplying take-off velocity by the participant's body mass, owing to its relevance to RL cohorts (McMahon et al., 2020). Reactive strength index modified (RSImod) was calculated by dividing jump height by time to take-off as it best reflected the verbal cues provided to the participants.

A Shapiro-Wilk test revealed that time to take-off (pre-test) and countermovement depth (post-test) were the only variables that were not normally distributed. Dependent T-tests and or Wilcoxon signed-rank tests (for time to take-off and countermovement depth only) were performed to explore the significance of mean differences between pre- and post-testing (alpha level = 0.05). Effect sizes were calculated (Hedge's *g* for parametric data and Rosenthal's *r* for non-parametric data) to establish the magnitude of mean differences between pre- and post-testing and were interpreted as trivial (≤0.19), small (0.20-0.49), or moderate (0.50-0.79). A quadrant scatter chart was produced to illustrate the cause-effect relationship (Pearson's R^2) between changes in jump momentum and jump height. The standard error of measurement expressed as a percentage coefficient of variation (CV%) was calculated with 0-5%, 5-10% and 10-15% interpreted as excellent, good, and moderate absolute reliability, respectively.

RESULTS: Bodyweight and jump momentum showed excellent reliability (CV = 0.2-3.0%), IMPT peak force, jump height and RSImod showed good reliability (CV = 5.7-6.0%), and time to take-off and countermovement depth showed moderate reliability (CV = 12.3-14.0%). The IMTP peak force significantly increased by 529 N (P = 0.008, g = 0.69) and 5.7 N/kg (P = 0.013, g = 0.64) in absolute and relative terms (moderate effects), respectively. Countermovement depth moderately reduced at post-testing (P <0.001, r = 0.76) but time to take-off remained unchanged (P = 0.296, r = 0.23). Jump height increased by a small magnitude (P = 0.049, g = 0.46). However, RSImod remained unchanged at post-testing (P = 0.645, g = 0.10). A small (g = 0.33) but non-significant (P = 0.151) increase in body weight was noted too, however, this, along with improvements to jump height, contributed to a significant and moderate post-test increase in jump momentum (P = 0.015, g = 0.59), as shown in Figure 1.

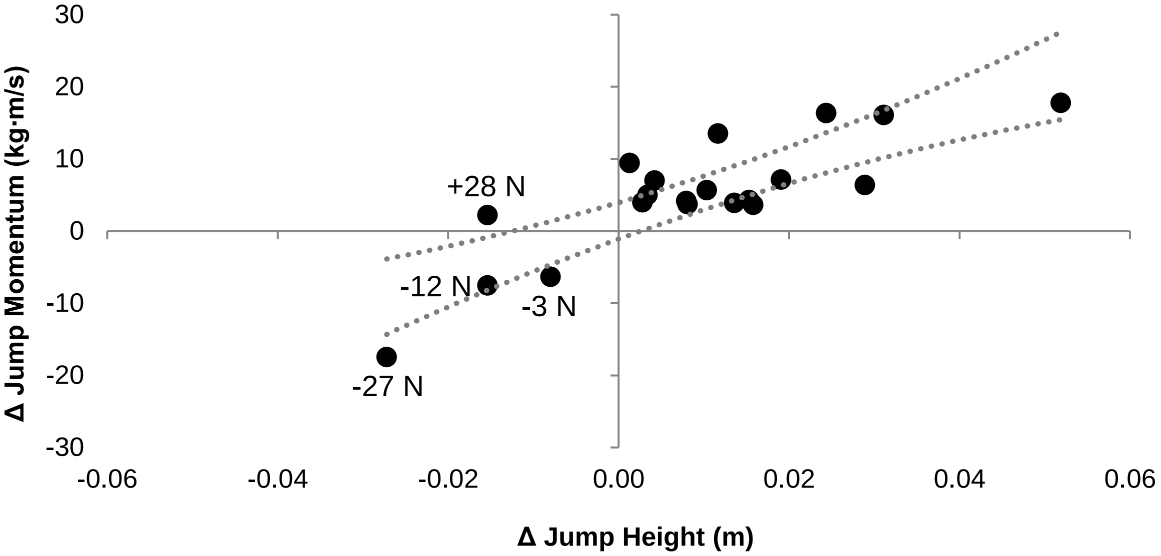

Figure 1: A quadrant scatter plot of changes in jump momentum and height (R^2 = 0.69) Dotted lines show 95% confidence intervals. Changes in bodyweight are shown for select participants.

DISCUSSION: The aim of this study was to quantify changes in typical (i.e., jump height) and alternative (i.e., jump momentum) outcome and select strategy variables during the CMJ and maximal strength that occurred during the early English Super League pre-season period. The pre-season training programme was hypertrophy and strength focussed which was reflected by moderate increases in both absolute and relative IMTP peak force over this period.

With respect to CMJ outcome variables, the results of the study show that while both jump height and momentum increased, the latter increased by a larger magnitude. The greater increases in jump momentum are attributable to slight increases in body weight. However, Figure 1 shows that all 14 participants who improved their jump height scores also increased their jump momentum, which at face value questions the efficacy of reporting each of these outcome metrics. Nevertheless, the authors believe that the reporting of jump height and momentum alongside body weight changes for any unexpected changes between tests can be helpful to RL practitioners. For example, all but four participants showed a desirable post-testing increase in both jump momentum and height (Figure 1). All three participants that fell into the reduced jump momentum and height quadrant were forwards who demonstrated a reduction in body weight. A reduction of jump momentum may be considered undesirable for RL forwards, especially if also shown in their sprint momentum as may be expected (McMahon et al., 2020), as they are involved in more collisions during matches (Glassbrook et al., 2019).

Alternatively, the only participant in the increased jump momentum but reduced jump height quadrant was a scrum half (back position), who gained body weight. This is perhaps unsurprising, as an increase in body weight can reduce jump height owing to its hinderance to take-off velocity, however, backs cover more sprints over a larger distance during match play (Glassbrook et al., 2019) and so one would hope that eventually this participant would improve their jump height (increased velocity) with further training during the final stages of pre-season held post the short Christmas break.
Post-test reductions in countermovement depth, as shown in this study, might be expected to coincide with shorter times to take-off, owing to the reduced distance through which the participants have pushed their centre of mass. However, the small, albeit non-significant, increases in body mass illustrated in this study may explain the unchanged time to take-off scores. Specifically, the participants' slightly heavier body mass may have impeded their capacity to move quicker over a shorter distance during post-testing. This supposition may only be applicable to the countermovement phase rather than the propulsion phase duration, however, as the increased jump heights seen post testing suggest that shorter propulsion times must have been applied to a allow a greater jump height to be attained from a shallower countermovement depth. This, however, may be an interim adaptation and reflective of the training programme focus. As the participants progress through the latter stages of their pre-season training one would hope that they would be able to accelerate their heavier body mass in a shorter time than what they achieved in this study, particularly if their training programmes become more ballistic in nature. Such adaptations may then also lead to concomitant improvements in RSImod, but future longitudinal studies are required to attest this theory.

CONCLUSION: Both CMJ outcome (increased jump height and momentum) and strategy (decreased countermovement depth) variables changed during the early RL pre-season training period that focussed mostly on lower limb hypertrophy and strength development. Quantifying concomitant changes in CMJ outcome and strategy variables alongside changes in body mass following different training programmes may be beneficial to RL practitioners as it may be offering richer insight into players' physical development and requirements compared with reporting jump height alone.

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