Vertical jump testing in rugby league: a rationale for calculating take-off momentum

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Abstract

The purpose of this study was to determine the usefulness of calculating jump take-off momentum in rugby league (RL), by exploring its relationship with sprint momentum, due to the latter being an important attribute to this sport. Twenty-five male RL players performed three maximal-effort countermovement jumps (CMJs) on a force platform and three maximal effort 20 m sprints (with split times recorded). Jump take-off momentum and sprint momentum (between 0-5 m, 5-10 m and 10-20 m) were calculated (mass multiplied by velocity) and their relationship determined. There was a very large positive relationship between both jump take-off and 0-5 m sprint momentum (r = 0.781, $p < .001$) and jump take-off and 5-10 m sprint momentum (r = 0.878, $p < .001$). There was a nearly perfect positive relationship between jump take-off and 10-20 m sprint momentum (r = 0.920, $p < .001$). Jump take-off and sprint momentum demonstrated good-excellent reliability and very large-near perfect associations (61-85% common variance) in a RL cohort, enabling prediction equations to be created. Thus, it may be practically useful to calculate jump take-off momentum as part of routine CMJ testing of RL players, and other collision-sport athletes, to enable indirect monitoring of sprint momentum.

Keywords: Countermovement Jump, Impulse, Sprinting, Velocity, Body Mass, Collision

Introduction

The countermovement jump (CMJ) has been suggested to be an important test in rugby league.[21] The support for including the CMJ as part of rugby league physical testing batteries is largely based on studies that have reported greater CMJ heights to be related to faster 5-, 10- and 30 m sprint performances (r = 0.56-0.62, $p < .05$)[4] and better tackling ability (r = 0.38, $p < .05$)[7] in high-level players. These attributes are considered important because rugby league match play is comprised of many high-intensity running, collisions and tackling actions.[8] Sprint momentum (body mass × velocity) has been suggested to be more important than sprint velocity in collision-oriented sports.[2] These suggestions are due to research showing that higher-level rugby league players attain similar sprint velocity to lower-level counterparts, but greater momentum because of greater body mass.[2] In American footballers, however, CMJ height was related to sprint velocity, but unrelated to sprint momentum, even across multiple distances.[10] The same authors also reported that body mass was positively correlated to sprint momentum but negatively related to sprint velocity.[10] This highlights that being heavier impedes sprint velocity but can augment sprint momentum, with the latter being a more important attribute for many collision sport athletes.[2] In rugby league, sprinting with greater momentum should help to drive the opposition's defenders backwards and thereby facilitate their own team's progression down field.[2]

Jump height attained from vertical jumping (not just the CMJ) depends on the velocity with which the athlete leaves the ground (termed take-off velocity) and so, as when sprinting, being heavier impedes jump take-off velocity. Indeed, any heavier athlete must push harder (i.e. they must apply a larger net impulse) during the propulsion phase of a jump to attain the same take-off velocity as a lighter athlete. Even if a heavier athlete does not attain the same take-off velocity as a lighter athlete, they may have greater take-off momentum. Equally, a heavier athlete could attain the same jump take-off momentum as a lighter athlete by producing a lower take-off velocity (i.e. not jumping as high), providing that their mass is sufficiently greater. For example, an athlete who weighs 110 kg and jumps 0.30 m would take-off with an almost identical momentum to an athlete who weighs 90 kg and jumps 0.45 m (i.e. 267 kg·m/s). It is important to note that change in momentum is equal to net impulse, thus the example momentum values presented above would be identical to the jump propulsion net impulse applied, although the unit of measurement is different (i.e. 267 Ns).

Given that the heavier body mass of collision sport athletes may be considered an asset, it may be prudent to include body mass in rugby league players' CMJ metrics. This is something that jump take-off momentum does but jump height and take-off velocity do not. Unfortunately, in most previous rugby league studies, researchers have assessed CMJ performance via field-based methods and reported jump height alone, although it has been recommended recently that CMJ testing of this cohort should ideally be performed using a force platform.[15, 22] A shift towards testing rugby league player CMJ performance on force platforms has been noted in more recently published studies, although the reported metrics have still been biased towards lighter athletes/tasks that require acceleration of the athlete's body mass alone.[16, 18] Because force platform assessment of CMJs is being more routinely conducted in rugby league, propulsion net impulse (and, therefore, take-off momentum) can be readily calculated. The CMJ propulsion net impulse attained by rugby league players has, indeed, been reported by McMahon et al.[18] and was shown to be much larger for senior players (d = 1.56) than for academy players owing to the heavier body mass of the former. However, no researchers, to the authors' knowledge, have explored and reported the relationship between CMJ propulsion net impulse/take-off momentum and sprint momentum in any athletic cohort, not least rugby league players.

The purpose of this study was to explore the efficacy of calculating the CMJ propulsion net impulse/take-off momentum from rugby league players by exploring its relationship with sprint momentum across multiple distances. Based on previous research that showed the CMJ height (which is determined by take-off velocity) of collision-sport athletes to be positively associated with sprint velocity but unrelated to sprint momentum,[10] it was hypothesized that jump take-off momentum would be positively related to sprint momentum as body mass is included in its calculation. As sprint momentum is considered to be important to rugby league match performance,[2] identifying positive associations with jump take-off momentum would be of interest to rugby league practitioners and researchers alike and provide a rationale for its inclusion in vertical jump testing batteries. Despite jump take-off momentum being identical to jump propulsion net impulse, it could be argued that momentum is a more widely understood term among athletes and coaches within collision-sports. Therefore, if positive results emerge from this study, it would be worthwhile adopting the former term (take-off momentum) going forward to promote clearer understanding when reporting CMJ performance data to rugby league athletes and coaches which could facilitate practitioners maximizing the use of their CMJ force platform data.

Methods

Twenty-five rugby league players (age = 24.8±3.1 years, height = 1.86±0.06 m, body mass = 98.1±10.0 kg) who, at the time of testing, were competing in the English Rugby League Championship agreed to participate in this study. Fourteen of the subjects regularly competed in the global ‘forwards’ positional group (age = 25.8±3.3 years, height = 1.85±0.05 m, body mass = 101.9±10.4 kg) with the remainder regularly competing in the global ‘backs’ positional group (age = 23.9±2.8 years, height = 1.86±0.07 m, body mass = 94.8±8.6 kg). All subjects were free from injury and engaged in a full-time strength and conditioning programme at the time of testing (the start of the pre-season). Written informed consent was provided prior to testing, the study was pre-approved by the institutional review board and conformed to the World Medical Association's Declaration of Helsinki.

A within-session repeated measures design was adopted in this study, whereby subjects performed multiple CMJs on a force platform and multiple 20 m sprints (with 5, 10 and 20 m split times recorded) on an indoor running track, enabling jump take-off momentum and sprint momentum to be calculated and their relationship to be determined.

Following a brief (~10 minutes) warm-up comprised of dynamic stretching and sub-maximal jumping (5×1 sets of single effort and 2×5 repeated CMJs), subjects performed three recorded maximal effort CMJs to their preferred countermovement depth, each interspersed by ~1 minute.[11] The jumps were performed with the subjects instructed to "jump as fast and as high as possible", whilst keeping hands on hips.

Ground reaction forces during the maximal effort CMJs were sampled at 1000 Hz using a Kistler type 9286AA force platform and Bioware 5.11 software (Kistler Instruments Inc., Amherst, NY, USA). Subjects stood still for the first second of data collection[19, 20] to enable body weight (N, calculated as vertical force averaged over 1 s) and body mass (kg, calculated as body weight divided by gravitational acceleration) to be subsequently calculated. Raw vertical force-time data 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 net force by body mass on a sample-by-sample basis and then integrating the product using the trapezoid rule.[19] The instant of take-off was identified when force fell below a threshold equal to five times the standard deviation of the flight phase force.[13, 14] The standard deviation of the flight phase force was calculated across the middle 50% of the flight phase duration (i.e., force during the mid-portion of when the force platform was unloaded and the subjects were airborne).[13, 14] Take-off velocity was calculated as the center of mass velocity at the instant of take-off. Jump take-off momentum was calculated by multiplying take-off velocity by the subject's body mass. The authors would like to note that this method of calculating jump take-off momentum yielded identical values to the propulsion net impulse attained based on the impulse-momentum relation.

Approximately five minutes after completing the CMJs, two 20 m practice sprints at 50 and 75% of perceived maximum intensity were performed followed by three maximum effort trials of the 20 m sprint, interspersed by two minutes of rest.[3, 5, 17] Subjects initiated the sprint from a stationary two point, split start[3] and were instructed to sprint as fast as possible through the full 20 m course marked out on the running track. Any sprint trials that were initiated with a countermovement or included deceleration before completing the 20 m course were discarded and supplementary sprint trials were recorded after two minutes of rest.

Brower single-photocell electronic timing gates (ETGs) (Draper, Utah, USA) were placed at 0-, 5-, 10-, and 20 m increments along an indoor running track, with each emitter and reflector spaced 2 m apart[6] at approximately hip height.[23] Specifically, the average hip height (taken as the highest point of the iliac crest when in a standing position) of the subjects was used to set the timing gate height (~1 m) and this was not adjusted for the smallest or tallest subjects tested.[17] Although the initial pair of ETGs were placed at 0 m, the subjects started 0.3 m behind this point in line with previous recommendations.[1]

Sprint times for each distance (5-, 10-, and 20 m) and trial were automatically recorded via a handheld computer and manually entered into a Microsoft Excel spreadsheet (version

2016, Microsoft Corp., Redmond, WA, USA) for further analysis. The 5-10 m and 10-20 m split times for each trial were calculated by subtracting the 10 m time from the 5 time and the 20 m time from the 10 m time, respectively. Momentum was then calculated by firstly calculating the average velocity (horizontal displacement divided by time) between each timing gate (e.g. between 0-5 m, 5-10 m and 10-20 m) and then multiplying this by the subject's body mass.[2]

A two-way mixed-effects model (average measures) intraclass correlation coefficient (ICC), along with the upper and lower 95% confidence interval (CI_{95}), was used to determine the relative between-trial reliability of each variable. Based on the CI_{95} of the ICC estimate, values between 0.75 and 0.90 and greater than 0.90 were indicative of good and excellent relative reliability, respectively.[12] 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 CI_{95}. A CV of ≤10% and ≤5% (based on the CI_{95} of the CV% estimate) was considered to represent good and excellent reliability, respectively.[16]

All momentum calculations met parametric assumptions, therefore, relationships between sprint momentum (at all distances) and jump take-off momentum were explored using the Pearson correlation coefficient and CI_{95} via SPSS software (version 25; SPSS Inc., Chicago, IL, USA) with the alpha level set at $p \leq .05$. Correlation coefficients were interpreted as very large (0.7-0.9) and nearly perfect (0.9-1.0).[9] Linear regression equations were subsequently produced to enable the prediction of sprint momentum (for each distance) from jump take-off momentum in future work and in applied practice.

Results

The jump take-off momentum (ICC = 0.988 [CI_{95} = 0.977-0.994], CV% 1.7 [CI_{95} = 1.3-2.2]) 0-5 m sprint momentum (ICC = 0.953 [CI_{95} = 0.908-0.977], CV% 2.7 [CI_{95} = 1.5-3.8]), and 5-10 m sprint momentum (ICC = 0.964 [CI_{95} = 0.930-0.983], CV% 3.0 [CI_{95} = 2.1-3.9]) demonstrated excellent reliability. The 10-20 m sprint momentum demonstrated good-excellent reliability (ICC = 0.897 [CI_{95} = 0.795-0.952], CV% 4.0 [CI_{95} = 2.6-5.3]).

There was a very large positive relationship between both jump take-off and 0-5 m sprint momentum (r = 0.781, p < .001) and jump take-off and 5-10 m sprint momentum (r = 0.878, p < .001). There was a nearly perfect positive relationship between jump take-off and 10-20 m sprint momentum (r = 0.920, p < .001). The scatter plots that illustrate these associations, including the corresponding CI_{95}, coefficient of determination (R^2), and linear regression equation, are presented in Figures 1-3.

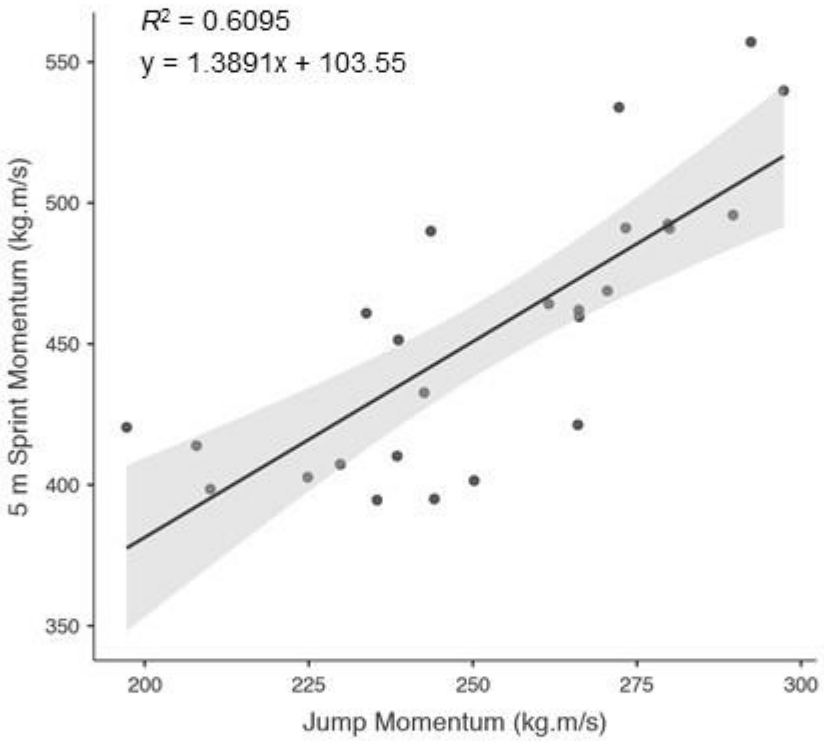

Figure 1: Relationship between jump take-off momentum and 0-5 m sprint momentum. The grey shaded area represents the 95% confidence interval.

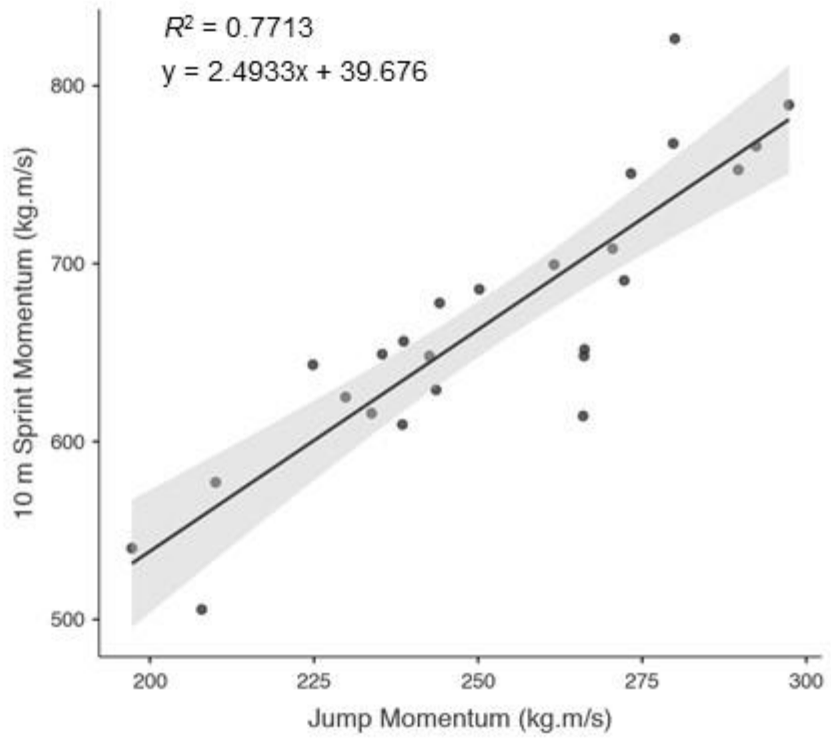

Figure 2: Relationship between jump take-off momentum and 5-10 m sprint momentum. The grey shaded area represents the 95% confidence interval.

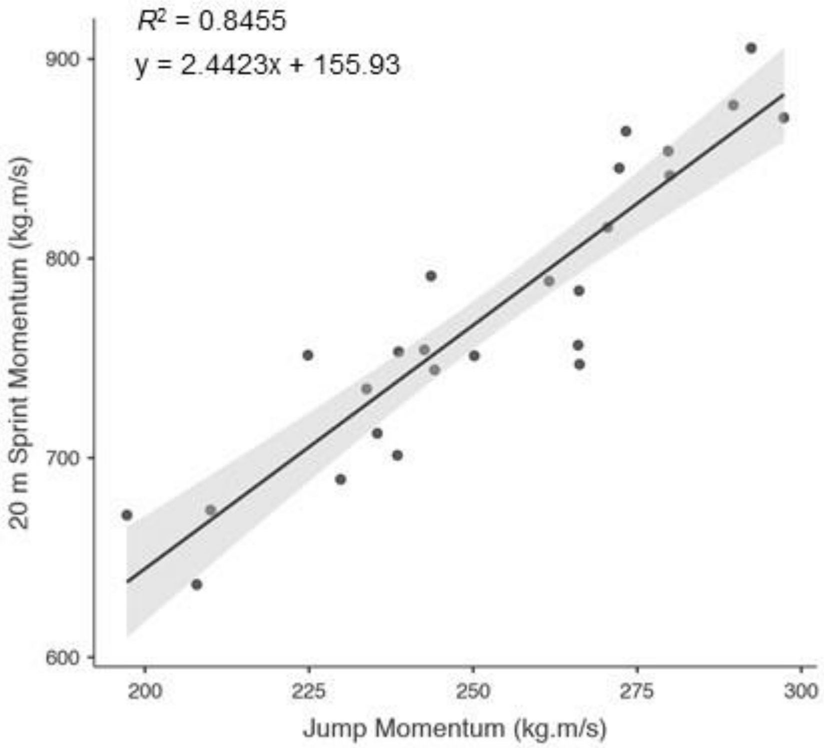

Figure 3: Relationship between jump take-off momentum and 10-20 m sprint momentum. The grey shaded area represents the 95% confidence interval.

Discussion

The purpose of this study was to explore the efficacy of calculating the jump take-off momentum (via CMJ testing) of rugby league players by exploring its relationship with sprint momentum across multiple distances (0-5 m, 5-10 m and 10-20 m). The results of this study show that jump take-off momentum is positively correlated with sprint momentum, as shown by the very large-nearly perfect correlation coefficients, with the strength of the relationship being largest with longer sprint distances (Figures 1-3). These high associations enabled prediction equations to be produced. The hypothesis of the study was, therefore, accepted.

This is the first study, to the authors' knowledge, to explore relationships between jump take-off momentum and sprint momentum in any collision sport athletes. The strength of the relationships shown in Figures 1-3, illustrate that 61-85% of the variance in 5-20 m sprint momentum can be explained by jump take-off momentum. The magnitude of these relationships is much larger than those reported for the CMJ height and 5-30 m sprint velocities (~32-38% common variance) attained by rugby league athletes.[4] As explained earlier, possessing a larger body mass will impede jump height and sprint velocity attainment. Indeed, a previous study involving American footballers, who, like rugby league players, present with a large range of body masses, reported body mass to be negatively related to sprint velocity.[10] Thus, the much lower relationships between jump height and sprint velocity reported for a sample of rugby league players of varying body masses[4] is unsurprising. However, momentum is the product of velocity and body mass and so the very large to nearly perfect associations between the jump take-off and sprint momentum are likely due to body mass being accounted for by momentum. The previously discussed study involving American footballers also reported that body mass alone was positively correlated to sprint momentum.[10] However, the finding that jump take-off momentum became a stronger correlate of sprint momentum at longer sprint distances illustrates the positive influence of being able to sprint at a higher velocity on the associations reported in the present study (Figures 1-3).

The rationale for exploring the efficacy of calculating the jump take-off momentum of rugby league players by exploring its relationship with sprint momentum is due to the former already being established as an important attribute in collision-oriented sports.[2] As there were such high associations between the two momentum variables (Figures 1-3), it is reasonable to state that calculating jump take-off momentum, following a CMJ test, provides insight into rugby players' sprint momentum capabilities. Therefore, even though the CMJ is not a movement that is readily performed in rugby league or in other collision sports, jump take-off momentum appears to be a valuable metric that would likely be of interest to rugby league researchers and practitioners due to its ability to indirectly inform sprint momentum. It is also very useful to learn that jump take-off momentum yielded a very low typical error between trials (CV% 1.7 [CI_{95} = 1.3-2.2]), meaning that it should demonstrate suitable sensitivity to change with respect to rugby league training. This, of course, needs to be verified by future research. For example, future research into the test-retest reliability of the jump take-off momentum of rugby league players is encouraged to inform the typical error of this metric between days. Work is also required to determine whether training induced changes in both jump and sprint momentum are related, as we explored these associations in a cross-sectional manner alone.

Anecdotally, sprint testing is less likely to be performed early in the rugby league preseason due to perceived potential risk of injury which may be associated with detraining over the off-season. It may be possible, therefore, that jump take-off momentum could be calculated during early preseason instead, due to it posing a reduced injury risk, and used to indirectly inform the sprint momentum capability of players via the prediction equations presented in Figures 1-3. It is also not essential for researchers and practitioners to have access to the force platform, as jump take-off momentum can be estimated from CMJ height values that have been recorded via alternative means, such as from mobile phone applications, contact mats or optoelectronic systems, by calculating the square root of jump height (in meters) multiplied by 19.62 (which represents two times gravitational acceleration) and then multiplying this answer by body mass. For example, if an athlete's body mass is 90 kg and they jump 0.42 m their take-off momentum is 258 kg·m/s. It is important to note, however, that athletes should be coached to avoid tucking their legs during flight when assessing the CMJ via alternative means, otherwise the estimated jump height, and, therefore, take-off momentum, will be inaccurate. Based on the above example of an athlete attaining a jump take-off momentum of 258 kg·m/s, their predicted sprint momentum over 0-5 m, 5-10 m and 10-20 m is 462 kg·m/s, 683 kg·m/s and 786 kg·m/s, respectively.

We would like to emphasize that being able to accelerate body mass alone is still an important attribute in rugby league.[2] For example, a higher absolute sprint velocity is required to beat an opponent to the ball or to accelerate away from them when carrying the ball. We merely suggest that jump take-off momentum may be of interest to rugby league (and other collision sports) researchers and practitioners for the reasons discussed above and do not want to devalue the importance of absolute sprint velocity. Based on the results of this study, the potential utility of calculating the jump take-off momentum of collision sport athletes, with respect to within-athlete monitoring and talent identification, is promising but does require the research avenues mentioned earlier to be explored fully.

In conclusion, jump take-off and sprint momentum (calculated between 0-5 m, 5-10 m and 10-20 m) demonstrated good-excellent reliability and very large-near perfect associations (r = 0.781-0.920, P <0.001) in a rugby league cohort. It seems, therefore, to be efficacious to calculate jump take-off momentum as part of routine CMJ testing of rugby league players. Sprint momentum is deemed to be an important attribute within rugby league as it should facilitate a backwards drive of the opposition's defenders thus facilitating a team's progression down field.[2] The calculation of jump take-off momentum following routine CMJ testing of rugby league players is, therefore, recommended because it could enable prediction of sprint momentum (see equations in Figures 1-3) without the potential risks associated with maximum sprint testing, particularly at the beginning of new seasons.

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