SESNZ
SPORT & EXERCISE SCIENCE
NEW ZEALAND

The Journal of Sport and Exercise Science, Vol. 10, Issue 1, 71-77 (2026)

www.jses.net

JSES
ISSN: 2703-240X

Unilateral isometric force development; A determinant of acceleration in adolescent female Rugby Union players

Jack Davies[1*], Anya Small[1], Dr. Claire Mills[2], Fiona Ware[1]

[1] *South Gloucestershire and Stroud College, England, UK*
[2] *University of Gloucestershire, England, UK*

ARTICLE INFO

Received: 28.11.2025
Accepted: 06.05.2026
Online: 14.08.2026

Keywords:
Female athletes
Rugby union
Isometric force
Sprint acceleration
Adolescent

ABSTRACT

Despite the growth in female participation within rugby union, research surrounding the assessment of force and acceleration remains underdeveloped. This study aimed to investigate the relationship between rate of force development and 5-metre sprint times in female rugby union players. Nine female athletes (age = 17 ± 0.5 years; height = 164.8 ± 4.24 cm; weight = 67.2 ± 13.16 kg) performed three maximal isometric pushes, followed by three maximal effort 5-metre sprints. Rate of force development at epochs of 30, 50, 75 and 100 milliseconds were correlated with sprint times. Statistical analysis included Pearson Correlation Coefficient, coefficient of variance and regression models. Rate of force development the coefficient of variance (32.6–51.0%) data indicated poor reliability compared to 5-metre sprint data (6.8%). No significant relationship was discovered between variables (p = 0.428 – 0.902). However, rate of force development at 30ms had a moderate positive correlation with 5-metre sprint times (r = 0.303), compared to small, or less than, reported at 50ms (r = 0.075), 75ms (r = 0.048) and 100ms (r = 0.127). A regression model revealed results with a high variance inflation factor (30ms = 60.55) to have no statistical significance (30ms p = 0.428). This study demonstrates that rate of force development could not be used to predict sprint times. Future research should aim to improve run-specific ankle isometric push protocols and use alternative metrics, such as peak force, in female youth rugby union athletes at a college level. Subsequently, more female rugby union athletes can gain experience in force expressing practices, aiding academically informed athletic programming for power and acceleration improvements specific to female populations.

1. Introduction

The growth in female participation in rugby union (RU) in recent years has prompted research to focus on an athlete's physical characteristics to provide practitioners with evidence-based insights (Atack et al., 2023). Yet despite this growth research remains limited, with female focused investigations accounting for ~13% of studies (Cowley et al., 2021; Devries & Jakobi, 2021; Hutchins et al., 2021; Smith et al., 2022), assessing an array of physical performance attributes, including reactive strength, metabolic function, and the expression of force (Dubois et al., 2020; Zabaloy et al., 2022).

With advancing technology there has been a shift to investigate the expression of force via isometric contraction modalities (James et al., 2017). Specifically, force expressed against an immovable apparatus while adhering to specific joint angles and postures (Stolz et al., 2022). Lum et al.'s (2020) systematic review investigated correlations between isometric strength testing modalities, force-time metrics, and dynamic performance. Their findings demonstrated that isometric strength testing interventions such as the isometric bench press, isometric squat test, and isometric mid-thigh-pull (IMTP) align with primary force-time metrics (peak force, impulse, and epochs of rate of force development) (RFD). These underlying metric values

*Corresponding Author: Jack Davies, South Gloucestershire and Stroud College, England, UK, jack.davies@sgscol.ac.uk

correlated with assessed athletic movements (jumping, sprinting, change of direction, and throwing tasks), collectively yielding small-to-very large meaningful correlations (r ≈ 0.20 - 0.87). This data reinforces the use of isometric strength testing as a measure of expressing force in athletic populations. Due to the likes of the IMTP's high test-retest reliability (Intraclass correlation coefficient (ICC) = 0.94; Grover et al., 2024), minimal injury risk and reduced resulting fatigue (Comfort et al., 2019) isometric strength testing has steadily emerged within sports research applications (Moeskops et al., 2018). The IMTP has grown over several sporting disciplines, and substantially more so in RU (Martin & Beckham, 2020). Understanding an athlete's capacity for maximal and rapid force generation is of paramount significance within RU, considering the athletic skills where these qualities are of value (e.g. tackle, maul) (Martin & Beckham, 2020; Wang et al., 2016).

Alongside bilateral testing of IMTP, Dos 'Santos et al. (2017) highlight the reliability of unilateral IMTP. Though unilateral testing is more apparent in injury pathways and asymmetry testing for imbalances, single-leg force-time metrics from isometric testing share metrics relevant to sprint assessments (Bishop et al., 2018). Kuki et al. (2019) similarly emphasise a discrepancy between IMTP and sprinting; as force is generated unilaterally during sprinting, an alternative method with unilateral IMTP and sprinting was challenged. The results suggested this method was harder to perform for athletes with less experience in strength training, but effective as a predictor of strength for sprinting (Kuki et al., 2019). As Watkins et al. (2021) accentuate speed and acceleration as pivotal qualities for success in RU, employing a test more replicable of these skills used for performance would outline data holding more practical significance to RU.

Dobbs et al. (2018) assessed speed and unilateral isometric force in collegiate RU players (*n* = 19; age = 22.4; height = 178.3; weight = 94). The investigation demonstrated the importance of measuring unilateral leg strength when attempting to match the demands of RU, due to the positive influence unilateral horizontal strength had on sprint times. Taking the value isometric testing instils in athletic development, in conjunction with sprinting, would start to compare these performance parameters to advise towards athletic performance in RU athletes (Brady et al., 2019; Ferguson et al., 2024; Wang et al., 2016). Although Hicks et al. (2020) outlined ground reaction force and horizontal force as imperative features for understanding sprint ability, Haugen et al. (2019) indicate a level of vertical force that is required to overcome gravity when sprinting. As the acceleration phase at the start of the sprint relies heavily on both horizontal and vertical force to increase ground reaction time, measuring one of these variables outlines an element practitioners can target during an athlete's training sessions (Moiroux-Sahraoui et al., 2024; Wilkau et al., 2020). Although Brady et al. (2019) identified isometric strength measures to account for 33 – 37% variance in 0–5-metre sprint performance, more research is required to understand why this relationship differs for female athletes. Despite Brady et al. (2019) highlighting this need for more female-driven research, the importance of 5-metre sprint testing is linked similarly with a study by Wannouch et al. (2024), who conducted a comprehensive analysis of sprint test reliability in male and female youth athletes. Good coefficient of variation percentage (CV%) and ICC data concluded that the 0 – 9.14-metre (0 – 10 yards) sprint is a reliable assessment of youth athletes (females: CV = 8.9%, ICC = 0.76; males: CV = 9.8%, ICC = 0.80). Although not specific to sex, Freitas et al. (2022) illustrated that female RU players demonstrate greater sprint speed and velocity in 5-metre sprints than handball and football players. Encompassing Brady et al. (2019), Wannouch et al. (2024) and Freitas et al. (2022) results and reliability, 5-metre sprint distances prevail as a relevant choice for sprint testing female college RU athletes.

Despite RFD remaining a well-established force-time metric for athletic performance, literature highlights the unknown relationship isometric RFD holds for female athletes (Blazevich et al., 2020; Brady et al., 2019; Martin & Beckham, 2020). Haff et al. (2015) explored isometric RFD reliability in female collegiate volleyball players, with significant RFD results demonstrating relevance towards pioneering academically informed research investigations towards female athletic populations. This presents an opportunity to gather further insight into the correlations between force-time metric values and a key athletic determinant of success (acceleration) in the sport of female RU to better support training prescription and thus adaptation in force generating capacity. With this, there is scope to examine this relationship through a novel unilateral isometric testing means (the run specific ankle isometric push test) to more appropriately correspond force generating capacity with linear sprint performance in female RU athletes. This potentially offers an opportunity to assess the expression of force across wider female populations, across playing levels, and sports. This investigation therefore through a modern unilateral testing format sort to assess the correlation between RFD force-time metrics and sprint accelerative performance in adolescent female rugby union populations.

2. Methods

2.1. Participant recruitment

A cross-sectional experimental study design was adopted using female RU players (age = 17 ± 0.5 years; height = 164.8 ± 4.24cm; weight = 67.2 ± 13.16kg). Sample size was calculated using G*Power software, version 3.1 where, population correlation: 0.8 effect size, alpha: 0.05, power analysis: 0.8, and null hypothesis correlation: 0 (Kang, 2021). Participants (*n* = 9) were recruited from a college programme in England and were part of the same female college RU team. Ethics were approved by SGS Higher Education University Centre.

Informed consent was obtained from the participants and the participant's parents and/or guardians, and they were informed of their right to withdraw at any stage of the study. Data was collected and stored on a password-protected laptop and transferred to a secure OneDrive database where it would be stored in alignment with local data protection guidelines.

2.2. Data Collection

Testing consisted of a run specific ankle isometric push (RSAIP) test protocol conducted on a flat, solid surface using the VALD ForceDecks (FD Lite-0308, ForceDecks, VALD Performance, Australia). No administrative protocol has been registered within academic literature for the RSAIP protocol therefore the VALD performance practitioner's run-specific ankle ISO-push guide (VALD, n.d.) was largely adopted to facilitate delivery of testing. This was followed by a 5-metre linear sprint test on a flat indoor third generation artificial surface, using Brower TCi speed gates (TCi, Brower Timing Systems, Utah, USA).

2.3. RSAIP testing

Participants completed a standardised warm up comprised of a 2-minute cycle at a moderate pace of 60 revolutions per minute (McCormick et al., 2022) followed by a series of preparatory exercises consisting of a dynamic kneeling quadricep stretch, a banded sprint hold, and three maximal effort countermovement jumps (two sets of six repetitions on each exercise). Each participant was then familiarised and guided to position themselves under the barbell, chest up, with their dominant limb extended in contact with the corresponding force plate, with the active foot slightly plantar-flexed. The participant then lifted their inactive limb off the plate raising their flexed knee to hip height, dorsi-flexing at the ankle (replicating a high knee sprint position typically adopted during accelerative phases of a sprint start), and maintained this position throughout the duration of a given recorded push. This was followed by a specific warmup on the force plates of a 1 x 4-second effort at 70%, 80%, and 90% of a perceived one repetition max push, with a 10-second recovery period between efforts (Healy et al., 2019). For official push recordings, on the call "3, 2, 1, push", the participants performed a 4-second maximal voluntary contraction (MVC) isometric push (Travis et al., 2018). A 60-second rest was permitted between efforts to maximise recovery (Davies et al., 2025).

2.4. 5-metre linear sprint testing

Sprint performance was evaluated using a 5-metre marked distance with timing speed gates set up on the third-generation artificial grass surface. Participants completed a short (2-3 efforts) series of gradual increase in sprint efforts to prepare (Healy et al., 2019). Participants were instructed to place their RSAIP dominant limb on the starting line, thus, adopting a two-point stance. The participants were instructed to initiate each sprint at their own volition (Darrall-Jones et al., 2016). Each participant completed three maximal effort sprints, with a one-minute rest between bouts. The results were recorded to the nearest 0.01 seconds, with the average from all three logged.

2.5. Data analysis

Pearson Correlation Coefficient was used to ascertain the extent of the linear relationship between RFD and sprint times. Correlations were evaluated as: small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), nearly perfect (0.90–0.99) and perfect (1.0). To establish reliability throughout the statistical process, hypothesis testing was used to reduce systematic bias and help avoid Type I and Type II errors (Ferguson et al., 2024; Streib & Dehmer, 2019). The criterion for statistical significance was set at an alpha level of p-value (p) $\leq$ 0.05. The reliability of the data sets was measured from the CV% of the data and its variance (Bailey, 2023). Regression analysis models interpreted the data to reveal the magnitude of the effect and investigated whether the variables could be used as predictors for one another (Gratton & Jones, 2010).

3. Results

Results indicated poor RFD reliability from high degrees of variability (32.6 – 51.0%) compared to the 5-metre sprint (CV = 6.8%) (Table 1).

Table 1. Descriptive values for RSAIP, RFD and spring times (M ± SD) and coefficient of variation.

	M ± SD	CV%
Sprint	1.1 ± 0.08*	6.8%
RFD 30m	771.56 ± 251.58**	32.6%
RFD 50ms	1016.22 ± 437.59**	43.1%
RFD 75ms	1285.11 ± 654.94**	51.0%
RFD 100ms	1470.67 ± 691.13**	47.0%

No significant relationship was observed between targeted epochs of RFD and 5-metre sprint times (p = 0.428 – 0.902) (Table 2).

Table 2. Correlations and statistical significance between 5-metre sprint times and epochs of RFD.

	Mean Sprint Times (s)	
	r	p
RFD 30m	0.30 (moderate)	0.428
RFD 50ms	0.07 (<small)	0.847
RFD 75ms	0.04 (<small)	0.902
RFD 100ms	0.12 (small)	0.745

RFD at 30ms had a moderate positive correlation with 5-metre sprint times (r = 0.30) (Figure 1), compared to small or less reported at 50ms (r = 0.07) (Figure 2), 75ms (r = 0.04) (Figure 3), and 100ms (r = 0.12) (Figure 4).

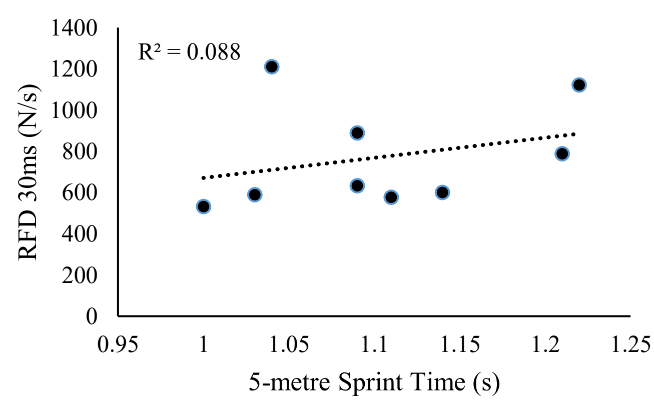

Figure 1. Scatter plot of association between 5-metre sprint time and RFD at 30ms.

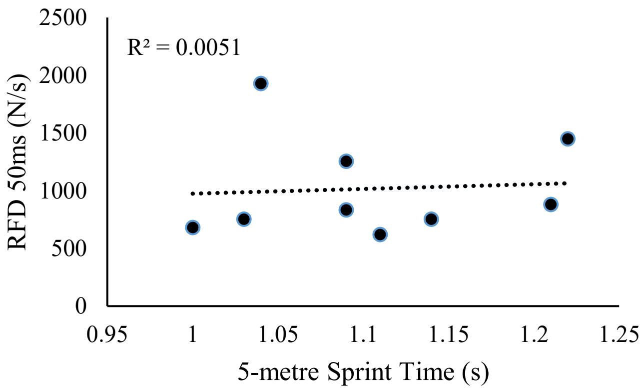

Figure 2. Scatter plot of association between 5-metre sprint time and RFD at 50ms.

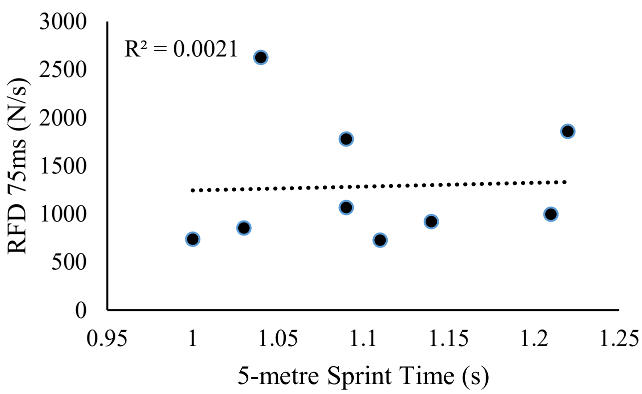

Figure 3. Scatter plot of association between 5-metre sprint time and RFD at 75ms.

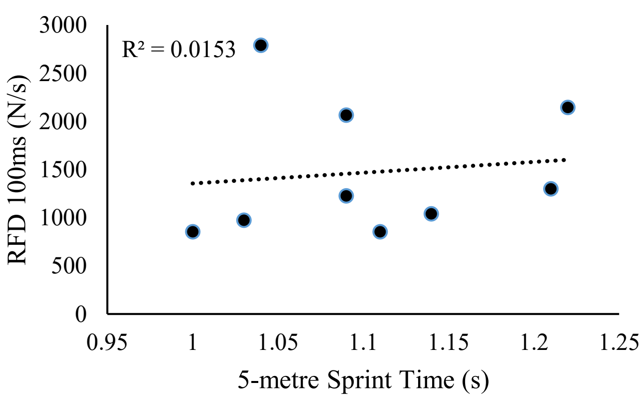

Figure 4. Scatter plot of association between 5-metre sprint time and RFD at 100ms.

A multiple linear regression model explained the proportion of variance in sprint performance ($R^2 = 0.841$), reporting no statistical significance ($p = 0.061$) (Table 3).

Table 3. Multiple liner regression results of the proportion of variation in sprint performance.

	SE	Lower 95%	Upper 95%	*p*
RFD 30ms	0.00045	-0.00006	0.00245	0.057
RFD 50ms	0.00055	-0.00242	0.00062	0.177
RFD 75ms	0.00053	-0.00126	0.00168	0.708
RFD 100ms	0.00036	-0.00104	0.00095	0.904

4. Discussion

This investigation sought to assess the correlation between RFD force-time metrics and sprint accelerative performance in adolescent female rugby union populations. This study demonstrated no significant positive correlations between isometric strength and 5-metre sprint time (Table 2). This is contrast with Thomas et al. (2015) and Tillin et al. (2013) who reported moderate to strong negative correlations between isometric strength and 5-metre sprint time in male rugby players (r = -0.58 - 0.63), likely because sprint performance was assessed alongside maximal force and RFD metrics, which may be more sensitive to short-distance acceleration. Aligning similarly to the results of this study, Wang et al. (2016) presented the first 5-metre sprint to significantly correlate with RFD between 30ms and 50ms (30ms r = -0.570; 50ms r = -0.527). The results suggest that during acceleration, where ground contact times during the concentric phase average around 50ms, observing RFD and 5-metre sprint relationships is more beneficial if the RFD metric does not exceed 50ms or higher due to no significant correlations observed (Wang et al., 2016).

While Wang et al. (2016) used male university rugby athletes, which opposes the female sample from this study, Martinopoulou et al. (2022) investigated RFD in twenty-three male and female basketball and volleyball players. The study comparably explored RFD at 50ms and showed similarities between the male and female athletes' ability to exert rapid force isometrically (Martinopoulou et al., 2022). However, Martinopoulou et al. (2022) highlight how this may result from both sexes in the sample being well-trained athletes. Nevertheless, the maximum lower limb strength to overcome the inertia of body weight in accelerating affiliates with the practical application of understanding 5-metre sprint times and force expression from these studies (Martinopoulou et al., 2022; O'Driscoll et al., 2024; Thomas et al., 2015; Tillin et al., 2013; Wang et al., 2016).

Throughout the literature, sprint distances vary for RU athletes, with no set sprint distance exceeding the importance of another (Darrall-Jones et al., 2016). However, when paired with RFD correlations, as previously mentioned, Wang et al. (2016) identified that 5-metre sprints significantly correlate with RFD at 30ms and 50ms. The correlation discrepancy between this study and Wang et al. (2016) may be related to the use of university participants (20.67 ± 1.23 years) with greater experience in expressing force and a higher sample size (n = 15). However, although RFD at 75ms was not used by Wang et al. (2018), the correlation between a 5-metre sprint and RFD at 100ms (100ms r = -0.163), similar to this study, revealed no significant correlation

*Corresponding Author: Jack Davies, South Gloucestershire and Stroud College, Bristol, BS34 8LP, England, UK

(100ms r = 0.127). Nonetheless, the results from the 5-metre sprint show greater reliability than the RSAIP RFD results, proposing the practical significance potential this study could present if reliability measures were improved in the RSAIP test (Ferguson et al., 2024).

During this investigation, the multiple linear regression established an R^2 value of 0.850, explaining an 85% variance in sprint time, with the overall model p-value reporting no statistical significance at 0.061. RFD at 30ms was the most statistically promising predictor of 5-metre sprint with a p-value of 0.057. Despite this, all RFD variables were highly correlated, resulting in multicollinearity that compromised the stability of the regression model, an issue similarly observed in a study by Weaving et al. (2019) on youth rugby league players. In this study's analysis, RFD at 30ms presented the variance inflation factor at 60.55, well above the recommended threshold of 10, confirming severe multicollinearity across predictors (Akinwande et al., 2015). When the singular regression model of RFD at 30ms and 5-metre sprint times was calculated, the R^2 value dropped to 0.092, and the p-value increased to 0.428. This suggests that, while RFD at 30ms had the strongest relationship with 5-metre sprint performance, none of the single RFD time points could significantly predict 5-sprint times. These results are likely influenced by the small sample size (n = 9), the multicollinearity observed in the full regression model and wider biomechanical and neuromuscular factors of sprint performance that were not measured in this study (Akinwande et al., 2015; Oleksy et al., 2024).

The lack of significance across Pearson's correlation coefficient and multiple linear regression models suggests that RFD at 30ms, 50ms, 75ms, and 100ms do not significantly correlate with 5-metre sprint times in this sample of 16–18-year-old female RU players. Contrastingly, a study by Brady et al. (2019) demonstrated isometric tests to be reliable tests that correlate with and predict early acceleration (r = -0.517 to -0.714; P<0.05). The results displayed the high statistical significance of 5-metre sprint prediction in IMTP and isometric squat (IMTP p = 0.023; isometric squat p = 0.017). Despite Brady et al. (2019) highlighting that isometric strength accounts for 33-37% of the variance in 5-metre sprint performances, the IMTP was based on impulse, and the isometric squat was based on relative-peak force, neither of which both were included in this investigation. Although Wang et al. (2016) do show RFD contributions to sprint acceleration, this study demonstrated that an isolated use of RFD in correlations with and predictive measures of 5-metre sprint times is somewhat limited.

The high CV% across all the RFD time points indicated poor within-session reliability of the RSAIP test. These findings correspond with previous research by Dos 'Santos et al. (2017), demonstrating RFD at different time points during an IMTP showed lower reliability in 16-year-old male athletes. Similarly, while studying female youth athletes, Moeskops et al. (2018) reported high typical errors in RFD values despite showing good reliability for absolute and relative peak force. Although Haff et al. (2015) observed higher reliability for time-specific RFD (CV = 2.3-2.7%) in trained female volleyball players, the overall evidence suggests that RFD is a less stable measure in younger or less experienced athletes. This inherent variability in RFD measurement could help explain the weak correlations and lack of significant predictive value observed in this study. Given that RFD values may fluctuate, especially in adolescent populations, the low reliability likely contributed to the inconsistency and instability of the regression models and the poor correlation between RFD time points and 5-metre sprint performance (Moeskops et al., 2018).

Dos 'Santos et al. (2017) and Moeskops et al. (2018) highlighted that athletes' ability to express force improves with maturation and training experience, suggesting that future studies may see more apparent relationships in older or more physically developed populations. While Moeskops et al. (2018) highlight isometric tests, such as the IMTP, as reliable for evaluating peak force in adolescent female athletes, a further emphasis explains the unreliability seen when testing RFD across the ages 6-17 years. This unreliability can be seen in the high variability of all RFD time points: RFD at 30ms (CV = 32.6%), 50ms (CV = 43.1%), 75ms (CV = 51%) and 100ms (CV = 47%). Studies by Focke et al. (2013) and Merrigan et al. (2020) similarly documented RFD as inherently less reliable across adult, adolescent and child athletes in multi-joint movements with more degrees of freedom (Moeskops et al., 2018).

These results may have been mitigated if pre-tension levels were set to avoid countermovement within the push phase of the RSAIP testing (Comfort et al., 2019). However, due to time limitations of the VALD ForceDecks' availability, the pre-tension was only prompted by verbal cues to push into the bar when counting down before the MVC testing. Furthermore, Merrigan et al. (2020) explain a limitation of minimal familiarisation that also impacted the testing protocols. Similar limitations within this study highlight a need for extensive familiarisation when asking mixed-ability RU athletes to complete a new, complex multi-joint isometric test such as the RSAIP (Merrigan et al., 2020; Moeskops et al., 2018).

For future recommendations, researchers should plan to have more than one familiarisation day when a population of youth athletes, who may be inexperienced in force expression, is used. Allocating time for the female athletes to practice would improve the data sets' accuracy and provide a better understanding of the testing procedures (Martin & Beckham, 2020; Merrigan et al., 2020). Throughout these sessions and the testing day, protocols around the bar pre-tension should also be considered and implemented. Comfort et al. (2019) suggest that a pre-tension that does not exceed 50 N should remove slack from the body before MVC testing. Due to the inherent unreliability of RFD in adolescent athletes, researchers could also investigate athletes' peak force alongside RFD (Moeskops et al., 2018). McCormick et al. (2022) explain that within-session performances for peak force are highly reliable (CV = 3.4 – 5.1%) in youth athletes, while similarly emphasising verbal cues to help participants achieve their best testing results. Encompassing these recommendations in future research would aim to improve the overall value of the data, from greater understanding and implementation by the participants, and broader research applications in female RU settings (Martin & Beckham, 2020; McCormick et al., 2022; Moeskops et al., 2018). Beyond these adjustments, a study exploring the reliability of RSAIP testing protocols in female adolescent RU athletes may contribute to standardised procedures for future research, similarly to studies by Darrall-Jones et al. (2016), Dos'Santos, Thomas, Comfort, et al. (2019) and Ferguson et al. (2024). The findings from this investigation may serve as a benchmark for kinetic performance assessment in female adolescent populations, within the emerging RU game as RFD is a valued derivative of explosive strength. Under the unilateral testing construct there is scope to further investigate as to the degree of relation between kinetic performance and other key dynamic performance parameters such as vertical jump, change of direction, and throwing performance.

The findings of this study add further knowledge to the field of unilateral kinetic assessment and its insights relating to 5-metre sprint performance in female RU players. Understanding optimal metrics and their alignment to early sprint performance, in adolescent female RU players, can determine appropriate kinetic metric selection to better profile athletes and therefore more accurately prescribe for them. At present the current study suggests that RFD at selected early time points (30-100ms) in isolation may not sufficiently predict 5-metre sprint performance. As a result, grassroots academies may benefit in understanding their female athletic populations further through reliable isometric force-time metric outputs, under reasonable time frames.

Conflict of Interest

The authors declare no conflict of interests.

Acknowledgment

The authors thank all participants for their involvement in this study.

References

Akinwande, M. O., Dikko, H. G., & Samson, A. (2015). Variance inflation factor: As a condition for the inclusion of suppressor variable(s) in regression analysis. *Open Journal of Statistics*, *5*(7), 754–767.

Atack, A. C., Lineham, J., & Bezodis, N. E. (2023). Biomechanical analysis of elite female rugby place kickers. *International Society of Biomechanics in Sports Conference*, *41*(1), 1–4.

Bishop, C., Read, P., Lake, J., Chavda, S., & Turner, A. (2018). Interlimb asymmetries: Understanding how to calculate differences from bilateral and unilateral tests. *Strength and Conditioning Journal*, *40*(4), 1–6.

Blazevich, A. J., Wilson, C. J., Alcaraz, P. E., & Rubio-Arias, J. A. (2020). Effects of resistance training movement pattern and velocity on isometric muscular rate of force development: A systematic review with meta-analysis and meta-regression. *Sports Medicine*, *50*(5), 943–963.

Brady, C. J., Harrison, A. J., Flanagan, E. P., Haff, G. G., & Comyns, T. M. (2019). The relationship between isometric strength and sprint acceleration in sprinters. *International Journal of Sports Physiology and Performance*, *15*(1), 1–25.

Comfort, P., Dos'Santos, T., Beckham, G. K., Stone, M. H., Guppy, S. N., & Haff, G. G. (2019). Standardization and methodological considerations for the isometric midthigh pull. *Strength and Conditioning Journal*, *41*(2), 57–79.

Cowley, E. S., Olenick, A. A., McNulty, K. L., & Ross, E. Z. (2021). "Invisible sportswomen": The sex data gap in sport and exercise science research. *Women in Sport and Physical Activity Journal*, *29*(2), 146–151.

Darrall-Jones, J. D., Jones, B., Roe, G., & Till, K. (2016). Reliability and usefulness of linear sprint testing in adolescent rugby union and league players. *Journal of Strength and Conditioning Research*, *30*(5), 1359–1364.

Davies, J., Cooper, M., Hughes, J., & Barden, C. (2025). The Correlation between Net Impulse and Phases of Linear Sprint Performance in University American Football Players. *The Global Journal of Sport and Exercise Science*, *1*(1), 26-38.

Devries, M. C., & Jakobi, J. M. (2021). Importance of considering sex and gender in exercise and nutrition research. *Applied Physiology, Nutrition, and Metabolism*, *46*(6), 1–5.

Dobbs, I. J., Wong, M. A., Watkins, C. M., Barillas, S. R., Rivera, M., Coburn, J. W., Costa, P. B., & Brown, L. E. (2018). Correlation between isometric horizontal push force and sprint times in collegiate rugby union players. *Journal of Australian Strength and Conditioning*, *26*(4), 16–23.

Dubois, R., Bru, N., Paillard, T., Le Cunuder, A., Lyons, M., Maurelli, O., Philippe, K., & Prioux, J. (2020). Rugby game performances and weekly workload: Using of data mining process to enter in the complexity. *PLOS One*, *15*(1), 1–21.

Ferguson, J., Gibson, N. V., Weston, M., & McCunn, R. (2024). Reliability of measures of lower-body strength and speed in academy male adolescent soccer players. *Journal of Strength and Conditioning Research*, *38*(3), 96–103.

Focke, A., Strutzenberger, G., Jekauc, D., Worth, A., Woll, A., & Schwameder, H. (2013). Effects of age, sex and activity level on countermovement jump performance in children and adolescents. *European Journal of Sport Science*, *13*(5), 518–526.

Freitas, T. T., Pereira, L. A., Alcaráz, P. E., Comyns, T. M., Azevedo, P., & Loturco, I. (2022). Change-of-Direction ability, linear sprint speed, and sprint momentum in elite female athletes: Differences between three different team sports. *Journal of Strength and Conditioning Research*, *36*(1), 262–267.

Gratton, C., & Jones, I. (2010). *Research methods for sports studies* (2nd ed.). Routledge.

Grover, Z., McCormack, J., Cooper, J., & Fisher, J. P. (2024). Test-retest reliability of a single isometric mid-thigh pull protocol to assess peak force and strength-endurance. *PeerJ*, *12*, e17951.

Haff, G. G., Ruben, R. P., Lider, J., Twine, C., & Cormie, P. (2015). A comparison of methods for determining the rate of force development during isometric midthigh clean pulls. *Journal of Strength and Conditioning Research*, *29*(2), 386–395.

Haugen, T. A., Breitschädel, F., & Seiler, S. (2019). Sprint mechanical variables in elite athletes: Are force-velocity profiles sport specific or individual? *PLOS One*, *14*(7), 1–14.

Healy, R., Smyth, C., Kenny, I. C., & Harrison, A. J. (2019). Influence of reactive and maximum strength indicators on sprint performance. *Journal of Strength and Conditioning Research*, *33*(11), 3039–3048.

Hicks, D. S., Schuster, J. G., Samozino, P., & Morin, J-B. (2020). Improving mechanical effectiveness during sprint acceleration: Practical recommendations and guidelines. *Strength and Conditioning Journal*, *42*(2), 45–62.

Hutchins, K. P., Borg, D. N., Bach, A. J. E., Bon, J. J., Minett, G. M., & Stewart, I. B. (2021). Female (under) representation in exercise thermoregulation research. *Sports Medicine - Open*, *7*(43), 1–9.

James, L. P., Roberts, L. A., Haff, G. G., Kelly, V. G., & Beckman, E. M. (2017). Validity and reliability of a portable isometric mid-thigh clean pull. *Journal of Strength and Conditioning Research*, *31*(5), 1378–1386.

Kang, H. (2021). Sample size determination and power analysis using the G*Power software. *Journal of Educational Evaluation for Health Professions*, *18*, 17. https://doi.org/10.3352/jeehp.2021.18.17

Kuikman, M. A., Smith, E. S., McKay, A. K. A., Ackerman, K. E., Harris, R., Elliott-Sale, K. J., Stellingwerff, T., & Burke, L. M. (2022). Fuelling the female athlete: Auditing her representation in studies of acute carbohydrate intake for exercise. *Medicine & Science in Sports & Exercise*, *55*(3), 569–580.

Kuki, S., Konishi, Y., Yoshida, T., & Tanigawa, S. (2019). Relationship among unilateral stance isometric mid-thigh pull variables, sprint times, and jump performance in collegiate football players. *International Journal of Sport and Health Science*, *17*, 227–234.

Lum, D., Haff, G. G., & Barbosa, T. M. (2020). The relationship between isometric force-time characteristics and dynamic performance: A systematic review. *Sports*, *8*(5), 1–32.

Martin, E. A., & Beckham, G. K. (2020). Isometric mid-thigh pull performance in rugby players: A systematic literature review. *Journal of Functional Morphology and Kinesiology*, *5*(4), 1–18.

Martinopoulou, K., Donti, O., Sands, W. A., Terzis, G., & Bogdanis, G. C. (2022). Evaluation of the isometric and dynamic rates of force development in multi-joint muscle actions. *Journal of Human Kinetics*, *81*(1), 135–148.

McCormick, B., Talpey, S., James, L., & MacMahon, C. (2022). The influence of instruction on isometric mid-thigh pull force-time variables. *International Journal of Strength and Conditioning*, *2*(1), 1–9.

Merrigan, J. J., Stone, J. D., Hornsby, W. G., & Hagen, J. A. (2020). Identifying reliable and relatable force–time metrics in athletes—considerations for the isometric mid-thigh pull and countermovement jump. *Sports*, *9*(1), 1–13.

Moeskops, S., Oliver, J. L., Read, P. J., Cronin, J. B., Myer, G. D., Haff, G. G., & Lloyd, R. S. (2018). Within- and between-session reliability of the isometric midthigh pull in young female athletes. *Journal of Strength and Conditioning Research*, *32*(7), 1892–1901.

Moiroux-Sahraoui, A., Mazeas, J., Jhingoor, J. M., Douryang, M., Bouzerkraoui Alaoui, I., & Forelli, F. (2024). Relationship between force-velocity characteristics and sprint performance in elite sprinters: A pilot study. *Cureus*, *16*(8), 1–8.

O'Driscoll, M. B., Mooney, T. J., & Sweeney, L. (2024). The relationship between maximum lower limb strength & power, and GPS acceleration speed in elite U20 Gaelic football athletes. *International Journal of Strength and Conditioning*, *4*(1), 1–9.

Oleksy, L., Mika, A., Kuchciak, M., Stolarczyk, A., Adamska, O., Szczudło, M., Kielnar, R., Wolański, P., Deszczyński, J. M., & Reichert, P. (2024). Relationship between countermovement jump and sprint performance in professional football players. *Journal of Clinical Medicine*, *13*(15), 1–14.

Smith, E. S., McKay, A. K. A., Kuikman, M., Ackerman, K. E., Harris, R., Elliott-Sale, K. J., Stellingwerff, T., & Burke, L. M. (2022). Auditing the representation of female versus male athletes in sports science and sports medicine research: Evidence-Based performance supplements. *Nutrients*, *14*(5), 1–16.

Stotz, A., Maghames, E., Mason, J., Groll, A., & Zech, A. (2022). Maximum isometric torque at individually-adjusted joint angles exceeds eccentric and concentric torque in lower extremity joint actions. *BMC Sports Science, Medicine and Rehabilitation*, *14*(1), 13.

Streib, F. E., & Dehmer, M. (2019). Understanding statistical hypothesis testing: The logic of statistical inference. *Machine Learning and Knowledge Extraction*, *1*(3), 945–961.

Thomas, C., Comfort, P., Chiang, C.-Y., & A. Jones, P. (2015). Relationship between isometric mid-thigh pull variables and sprint and change of direction performance in collegiate athletes. *Journal of Trainology*, *4*(1), 6–10.

Tillin, N. A., Pain, M. T. G., & Folland, J. (2013). Explosive force production during isometric squats correlates with athletic performance in rugby union players. *Journal of Sports Sciences*, *31*(1), 66–76.

Travis, S. K., Goodin, J. R., Beckham, G. K., & Bazyler, C. D. (2018). Identifying a test to monitor weightlifting performance in competitive male and female weightlifters. *Sports*, *6*(2), 1–12.

VALD Performance. (n.d.). *ForceDecks test protocol: Run-specific ankle iso-push*. VALD Knowledge Base. https://support.vald.com/hc/en-au/articles/30764798489625-ForceDecks-Test-Protocol-Run-Specific-Ankle-Iso-Push

Wang, R., Hoffman, J. R., Tanigawa, S., Miramonti, A. A., La Monica, M. B., Beyer, K. S., Church, D. D., Fukuda, D. H., & Stout, J. R. (2016). Isometric mid-thigh pull correlates with strength, sprint, and agility performance in collegiate rugby union players. *Journal of Strength and Conditioning Research*, *30*(11), 3051–3056.

Wannouch, Y. J., Leahey, S. R., Whitworth-Turner, C. M., Oliver, J. L., YH, K. C., Laffer, J. C., & Leicht, A. S. (2024). A comprehensive analysis of 10-yard sprint reliability in male and female youth athletes. *Journal of Strength & Conditioning Research*, *38*(9), 477–488.

Watkins, C. M., Storey, A., McGuigan, M. R., Downes, P., & Gill, N. D. (2021). Horizontal force-velocity-power profiling of rugby players: A cross-sectional analysis of competition-level and position-specific movement demands. *Journal of Strength and Conditioning Research*, *35*(6), 1576–1585.

Weaving, D., Jones, B., Ireton, M., Whitehead, S., Till, K., & Beggs, C. B. (2019). Overcoming the problem of multicollinearity in sports performance data: A novel application of partial least squares correlation analysis. *PLOS One*, *14*(2), 1–16.

Wilkau, H. C. V. L. U., Bezodis, N. E., Morin, J.-B., Irwin, G., Simpson, S., & Bezodis, I. N. (2020). The importance of duration and magnitude of force application to sprint performance during the initial acceleration, transition and maximal velocity phases. *Journal of Sports Sciences*, *38*(20), 2359–2366.

Zabaloy, S., Tondelli, E., Pereira, L. A., Freitas, T. T., & Loturco, I. (2022). Training and testing practices of strength and conditioning coaches in Argentinian rugby union. *International Journal of Sports Science and Coaching*, *17*(6), 1331–1344.