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Reliability and variability of step mechanics in Rugby Union: A comparison between forwards and backs

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ABSTRACT
The aim of this study was to explore differences in 10 m, 20 m and 40 m sprint times (STs) and initial acceleration kinematic and spatiotemporal step mechanics between Rugby Union (RU) forwards and backs. Nineteen elite male academy RU players (12 forwards; 7 backs; age: 18.0 ± 0.5 years, height: 1.83 ± 0.07 m, mass: 90.3 ± 10.0 kg) were recruited from an English academy club. Subjects completed 3 maximum effort 40 m sprint trials. STs were taken at 10 m, 20 m, and 40 m. Step length (SL), step duration (SD), ground contact time (GCT), flight time, step frequency (SF), step velocity, trunk angle at take-off (T_AT_O), hip flexion at take-off (HF_AT_O), leg extension angle at take-off, shoulder extension angle at take-off (SE_AT_O), and touchdown distance (TD) were collected during the initial acceleration of the sprint via video analysis. Coefficients of variation (CV) were calculated to quantify movement variability. To explore differences independent t-tests were performed with hedges' g effect sizes calculated. CVs for the whole group displayed mixed variability (CV 4.06–18.9%) where HF_AT_O and SE_AT_O were the most varied and SD and SV were the least varied. Backs demonstrated significantly ($p < 0.05$) lower STs, SL, SD, GCT, T_AT_O, TD (moderate–extremely large effect) and significantly higher SFs than forwards. To conclude, differences in spatiotemporal and kinematic step characteristics between forwards and backs were evident, which should be acknowledged when coaching/monitoring sprint technique in RU.

1. Introduction

Rugby union (RU) is an 80–minute, 15 player a side, fast–paced, collision team sport. Players are separated into 2 positional groups, forwards and backs. Forwards are typically heavier than backs and complete more force–based actions such as scrummaging, rucking and mauling where backs are usually more athletic in stature and complete higher velocity-based tasks including change of direction (CoD) and sprinting to evade opponents (Deutsch, Kearney, & Rehrer, 2007).

Sprinting is important for all positions in RU, particularly over short distances (Barr, Sheppard, Gabbett, & Newton, 2014) to gain territorial advantage and penetrate defensive lines. During match time motion analysis players have been reported to complete sprints in bursts between 0–40 m (Sayers, 2000). Therefore, the ability to accelerate is an important factor (Bangsbo, Norregaard, & Thorsoe, 1991) and thus developing sprinting speed in RU seems to be of fundamental importance.

In research, sprinting gait is often divided into sub–phases consisting of stance phase, terminal swing, mid swing, initial swing, and touchdown (Dicharry, 2010). In order to achieve effective sprint gait kinematics and kinetics (McFarlane, 1984), coaches tend to cue athletes to accelerate with: a forward leant torso angle, big arm drive, long stride length with full triple extension of the rear leg, ball of the foot plant and dorsiflexion as this has been found to be the most efficient way to accelerate according to research (Hoffman & Graham, 2011). However, although this is deemed the fastest way to accelerate based on 'the fastest of all-time athletes' (Wild, Bezodis, North, & Bezodis, 2018) there are many demands that can interfere with the

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fundamental mechanics of sprinting alone in RU such as contact collisions (Bradshaw, Maulder, & Keogh, 2007; Coh, Jost, Skof, Tomazin, & Dolenec, 1998; Dick, 1989; Hay, 1993; Jeffreys & Goodwin, 2016; Ryan & Harrison, 2003; Seagrave et al., 2009). Alongside this, due to the differing within position demands and anthropometrics in RU, there are likely intra-athlete variability between forwards and backs. Forwards are likely to show varying sprint mechanics to not only the traditional track and field sprinters, but also their co-players, backs (and vice versa). However, research is lacking in this area.

Current research has shown that maximal velocity is usually attained between 65–75 m in track sprinters (Mackala & Mero, 2013) however research shows differently within RU. Barr et al. (2014) found that RU players attain maximum velocity (MV) between 30–40 m, due to player adaptations to the game. Wingers were found to produce the greatest MV at 39 m where some positions produced MV as early as 33 m showing intra-athlete variability in MV attainment. (Nagahara, Takai, Kanehisa, & Fukunaga, 2018). Whilst this is the case, due to the constant intercepting actions during sprint burst in RU, players will rarely sprint for longer than 30 m. Therefore, MV is very rarely met, highlighting the importance of acceleration in RU (Cross et al., 2015).

According to the deterministic model the key kinematic parameters for acceleration include: step velocity (SV), step frequency (SF), ground contact time (GCT), flight time (FT) and step length (SL) (Fletcher, 2009). Such variables have been deemed to be key due to the formula: Running speed = SL x SF (Fletcher, 2009), where an enhancement in variables such as GCT and FT can further improve SL and/or SF thus overall sprint performance (Lockie, Murphy, Schultz, Jeffriess, & Callaghan, 2013). Lockie et al. (2013) found SL to correlate to initial accelerative sprint performance of 10 m sprints in team sport athletes (0–5 m: $r = 0.502$, $p \leq 0.011$). Lockie et al. found that FT showed the highest correlation to 0-5 m acceleration performance ($r = 0.522$, $p \leq 0.007$). Although, authors failed to present the magnitude of the differences (i.e., effect size) or reliability measures (i.e., intraclass correlation coefficient) for the testing variables. But interestingly, upon calculating the CV% for SL, GCT and FT it was evident that FT was the least varied (SL = 9.15%; SF = 12.9%; GCT = 9.69%; FT = 6.53%). Due to the high correlation and low variability of FT it could be suggested that a longer FT may produce ideal step mechanics for acceleration performance. However, the testing sample included subjects from RU, rugby league, Australian rules football, soccer, and field hockey (Lockie et al., 2013). This range of sports is likely to have created large variation in results meaning calculated CV% may be inaccurate. The heterogeneous sample used, also does not represent specific RU sprinting characteristics so it is likely that differences may not be practically meaningful and may not show relevant findings to any specific sport.

Despite the importance of sprinting in RU, limited studies have assessed the reliability and variability of step mechanics between forwards and backs. The only study to have researched this area is Wild et al. (2018). Wild et al. (2018) compared mechanics between forwards and backs and found differing touchdown and toe off positions during the sprinting action between the two positional groups. Backs had a more posterior touchdown and toe off position (i.e., greater leg extension to maximise propulsion) compared to forwards. Backs also displayed shorter GCTs producing large effect size differences across steps 2 and 3 of sprint performances compared to forwards (Wild et al., 2018). In contrast, only trivial and small effect size differences were shown between contact lengths (horizontal distance the centre of mass travelled during stance). Touchdown placement for RU players relative to centre of mass has been shown to be further forward compared to track and field athletes, showing ‘very large’ effect sizes (sprinters vs forwards) (Wild et al., 2018). Such effect size differences have been suggested to be due to the forward orientation of the ground reaction force vector. Anthropometrical factors like range of motion at the hip, rate of force development and body mass are likely reasons for these variances (Wild et al., 2018). Due to forwards being heavier than backs, forwards have to produce larger forces to overcome inertia suggesting reason for the greater touchdown distance (TD). Intraclass correlation coefficient (ICC) and confidence limits were almost perfect between first and second digitising periods of the study (ICC > 0.90; Confidence Limits 0.85-0.99) (Wild et al., 2018). However, Wild et al. (2018) failed to present reliability and variability measures between forwards and backs for each of the variables tested in the study.

There is limited research in the background of STs and acceleration kinematics and spatiotemporal step mechanics in RU players. Previous research has assessed initial step mechanics in track and field athletes but there is limited research assessing the reliability and intra-athlete variability of step mechanics in RU. Evaluating sprint technique in the field is time consuming and requires the need for expert training to use digitisation techniques. This has potentially led to neglecting the evaluation of spatiotemporal step mechanics in team sports. Thus, there is a need to develop a practitioner friendly approach to measure spatiotemporal mechanics for team sport strength and conditioning coaches to use in practice. Furthermore, to the authors’ knowledge no study has evaluated the variability of sprint times or step mechanics between RU positions. Therefore, the aim of this study is to explore differences in 10 m, 20 m and 40 m STs and initial acceleration kinematic and spatiotemporal step mechanics between RU forwards and backs. To achieve this aim, the study has the following objectives; 1) quantify the variability of SL, step duration (SD), GCT, FT, SF, SV, trunk angle at take-off (T_AT_O), hip flexion angle at take-off (HF_AT_O), leg extension angle at take-off (LE_AT_O), shoulder extension angle at take-off angle at take-off (SE_AT_O), TD in forward and backs; and 2) explore differences between forwards and backs in the abovementioned technique variables. It was hypothesised that forwards would have more variability (CV) compared to backs across all variables. In particular backs would produce more varied STs (<CV) than forwards. In terms of step mechanics, it was hypothesised that backs would have a higher SF with a shorter SL compared to forwards.

2. Methods

2.1. Participants

Nineteen semi-professional elite male academy RU players (forwards, n = 12; age: 18.0 ± 0.5 years, height: 1.84 ± 0.08 m, mass: 92.8 ± 10.5 kg; backs, n = 7; age: 18.0 ± 0.5 years, height:

1.82 ± 0.05 m, mass: 86.0 ± 7.91 kg) were recruited from a professional English academy to take part in the study. A minimum of 14 (n = 7 each group) participants was determined from an *a priori* power analysis using G*Power (Version 3.1.9.2, University of Dusseldorf, Germany) (Dos'Santos, McBurnie, Thomas, Comfort, & Jones, 2020). This was based upon a previously reported Cohen's *d* effect size of 1.69 (step 3 contact time) (Wild et al., 2018), a power of 0.8, and type 1 error or alpha level 0.05. All subjects wore studded rugby boots and regularly completed a two and a half hour training session three times a week. Each session includes: rugby training, strength and conditioning training, plyometric training and sprint training. Subjects were currently in-season training and were in a speed-strength meso-cycle. Ethical approval was obtained from the University of Salford ethics board, and all subjects provided written informed consent to participate in the study. All subjects completed a physical activity readiness questionnaire to check eligibility and ensure safety. At the time of the study all subjects were injury free and were familiar with sprint training/testing as part of their rugby programme across 10–100 m.

2.2. Apparatus and Task

Testing took place in a single session at one site. The test was selected as it has been shown to be highly reliable (Darrall-Jones, Jones, Roe, & Till, 2016). In addition, the 40 m sprint is the maximum sprint distance likely to be covered during RU (Sayers, 2000). Subjects completed 3 maximal effort trials on a synthetic 3G AstroTurf surface with STs taken at 10 m, 20 m and 40 m using a single beam photocell timing gate system. A video camera was placed in the acceleration portion down the track in order to evaluate early acceleration sprinting technique similar to previous research (Wild et al., 2018). Several kinematic parameters were determined from video analysis and within session reliability and variation was quantified using ICCs with 95 % Confidence intervals (CI) and CV for the group as a whole and positional sub-group (forwards n = 12, backs n = 7). Furthermore, positional group comparisons were made for all abovementioned variables and Hedges' *g* effect sizes calculated.

2.3. Procedures

The data collection used an experimental quantitative approach (between subjects, cross sectional design) to assess the reliability and variability of the 10 m ST, 20 m ST and 40 m. The study also assessed SL, SD, GCT, FT, SF, SV, T_AT_O, HF_AT_O, LE_AT_O, SE_AT_O, TD of the acceleration (0–5 m) portion of 40 m maximal effort sprint. Subjects undertook a standardized warm up consisting of dynamic stretching and three sub maximal 40 m running efforts (50% effort; 75% effort; 95% + effort) from a standing start in line with successful previous research (Dos'Santos, Thomas, Jones, & Comfort, 2017). Testing took place on a 3G AstroTurf pitch. Using a measuring tape, a 40 m track was marked out in a straight line along the AstroTurf. A Panasonic Lumix DMC-FZ200 camera (Panasonic corporation, Kadoma, OSA, JP) sampling at 100 Hz set on a manual focus setting was placed at 3 m down the track, 5 m away from the track perpendicular to the sagittal plane of motion of the subject during the trial. The resolution of the camera was set to 1280 x 720p. This enabled evaluation of initial acceleration steps (first 3 steps) of each trial. The camera was placed on a rigid tripod 0.98 m off the floor with 1 pair of Draper flood lights (WL28, Draper, UT, USA) (1500 watts) on a 3 m tall tripod. The flood lights were placed 5 m down the track, 45° from the plane of motion to enhance lighting for the field of view of the camera in the acceleration phase. The field of view of the camera was 7 m where measurements were only taken in the central 5 m of the field of view in order to reduce parallax error. A 1.22 m calibration frame was set directly in front of the camera frame in the centre of the track. Brower photocell timing gates (BRO001; Brower, Draper, UT, USA) were placed at 0 m, 10 m, 20 m and 40 m along the track, timing to the nearest 0.001 s (Figure 1). Timing gates were set up to approximately hip height

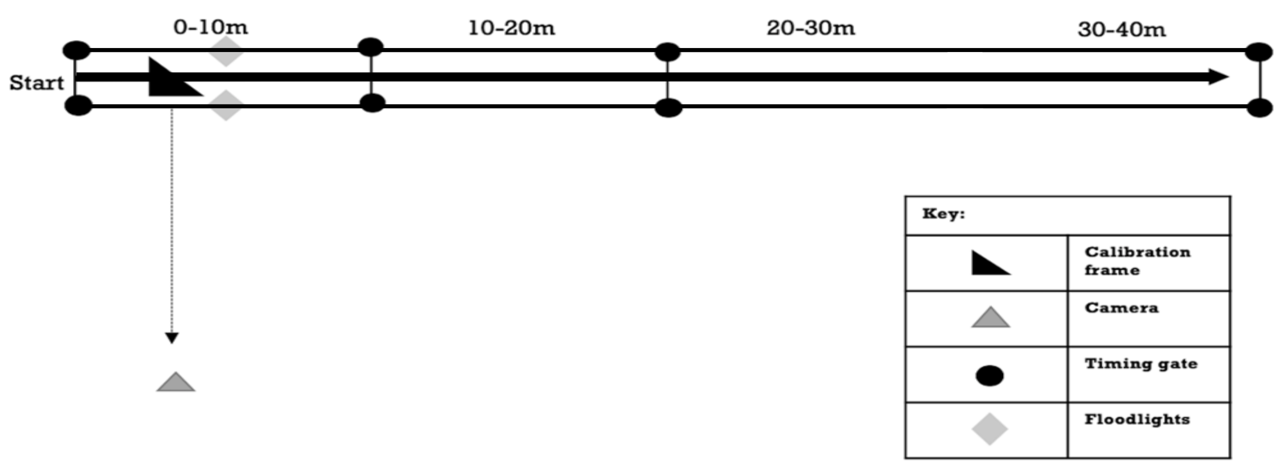

Figure 1: Diagram of 40 m sprint testing set up

Table 1: Acquisition/definition of step mechanic variables (Hunter et al., 2004; Seagrave et al., 2009)

Step mechanics	Process of acquisition/definition
Step length (m)	Toe to toe horizontal distance between consecutive foot contacts
Step duration (s)	Number of frames from take-off to take-off of consecutive steps × 1/100
Ground contact time (s)	Number of frames from touchdown to take-off of one-foot contact × 1/100
Flight time (s)	Number of frames from take-off to touchdown of during one step × 1/100
Step frequency	1/ step duration
Step velocity (m/s)	Step length × step frequency
Trunk Angle at Take-Off (°)	Angle of trunk relative to the vertical at take-0.508-. Where a lower trunk would be a more upright and vertical posture.
Leg Extension Angle at Take-Off (°)	Angle of rear leg at full extension relative to vertical at take-off.
Hip Flexion Angle at Take-Off (°)	Angle of forward leg relative to centre of knee to the centre of hip joint during take-off of swing leg. A lower hip flexion angle would have greater knee lift.
Shoulder Extension Angle at Take-Off (°)	Angle formed between upper arm and trunk at take-off to TD (m) (horizontal distance of toe to centre of hip of support leg at touchdown). Where a greater shoulder extension angle would result in a greater backward arm drive
Touchdown distance (m)	Horizontal distance of toe to centre of hip of support leg at touchdown. A foot landing further forwards relative to the centre of hip of support leg would result in a greater touchdown distance.

of each subject to ensure the lower torso broke the beam to ensure reliable results in line with previous research (Yeadon, Kato, & Kerwin, 1999). Subjects started 0.5 m behind the first timing gate in a 2-point staggered athletic start and were told not to rock back in order to prevent the timing beam from breaking prematurely (Woolford, Polgaze, Rowsell, & Spencer, 2013). Each subject then completed 3 maximal effort trials of the 40 m sprint. Subjects were signaled to start with synchronization of the camera recording for each trial to *"run as fast as possible and to not decelerate until they passed the final timing gate"* (Woolford et al., 2013). Subjects were encouraged throughout the trial and given rest periods of 3–4 minutes between trials (Wild et al., 2018). Split times were recorded for each trial for each subject. A step was defined as *one consecutive movement of right foot contact to left foot contact* similar to that used by Wild et al. (2018). The point of touchdown was identified as *the first frame the foot was visibly in contact with the ground* and toe off was identified as *the first frame the foot had visibly left the ground* (Wild et al., 2018).

Times were taken and averaged in a Microsoft excel spreadsheet (Microsoft Corp., Redmond, WA, USA) for each subject for further data and statistical analysis. Videos were imported into Quintic Biomechanics software (v31, Solihull, UK) and calibrated ready for further analysis. Using the 'angle drawing', 'shapes' and 'marker' functions in Quintic, several variables were determined from the first three consecutive steps (these values were then averaged across steps then reported) with the aim to allow these variables to be easily measured by coaches using video analysis. Definitions for each variable acquired from trials are presented in Table 1. Technique variables were determined for the first 3 steps of each trial and then averaged across the three steps. The data was then separated into two groups, forwards and backs.

2.4 Statistical Approach

Test-retest intra-rater reliability of manual digitization for all step mechanics were determined using ICC (ICC 3,1) with 95 % CI (Shrout & Fleiss, 1979; Wild et al., 2018). The data of 10 participants, of whom were selected at random from the testing sample was digitized on two separate occasions 2 weeks apart similar to work done by Wild et al. (2018). All statistical analysis was conducted in SPSS for windows (Version 23; SPSS Inc., Chicago, IL, USA). ICCs with 95% CI were used to test rank order consistency between trials (two-way mixed effects, average measures, absolute agreement) for the whole group and positional sub-groups. ICCs were interpreted as poor reliability (< 0.5), moderate reliability (0.5-0.75), good reliability (0.76-0.9) and excellent reliability (> 0.9) in line with Koo and Li (2016) where ICC ≥ 0.7 was deemed acceptable (Baumgartner & Chung, 2001). Intra-rater reliability with 95% CI were calculated using (two-way random effects, average measures, absolute agreement).

Percentage within subject CV was calculated to determine the variability across 3 trials for each variable using SD/mean x 100. Average CV and 95% CIs were calculated and reported where acceptable CV was <15% (Baumgartner & Chung, 2001). Normality was inspected using a Shapiro-Wilks test. Normality ($p > 0.05$) was confirmed for 10 m, 20 m, 40 m, SL, SV, T_AT_O, LE_AT_O, HF_AT_O and SE_AT_O; thus, to explore differences between positional groups a parametric independent samples T-Test was performed. A Levene's test was used to test the assumption of equality of variances, with degrees of freedom adjusted for 'variances not assumed' for violations of this assumption. SD, GCT, FT, SF and TD were not normally distributed ($p < 0.05$); thus, a Mann-Whitney U test was used to explore positional differences. Effect sizes were determined and corrected using Hedges' *g* due to uneven sample sizes, with values interpreted as follows: trivial (≤ 0.19), small (0.20–0.59), moderate (0.60–1.19), large (1.20–1.99) and very large (2.0–4.0) extremely large ≥ 4.0 (Hopkins, 2002).

3. Results

ICCs between the first and second digitizing occasions indicated excellent intra-rater reliability for all step characteristics (ICC = 0.993 – 1.00, 95% CI = 0.972 – 1.00). Mixed reliability and variability (ICC=0.508–0.892, moderate-good; CV = 4.06–18.9%) was found for all step characteristics in grouped data. CVs for forwards and backs individually are presented in Table 2. Step mechanics demonstrated varied results (forwards ICC = 0.023–0.847, poor-good, CV ≤ 11.02%; backs ICC = -0.003–0.643, poor-moderate; CV = 2.73–9.91%). Backs demonstrated significantly ($p < 0.05$) lower STs, SL, SD, GCT, T_AT_O, TD and SE_AT_O (moderate–extremely large effect) compared to forwards (Table 2 and Figures 2 and 3). Backs also demonstrated significantly higher ($p < 0.05$) SF (small effect) compared to forwards (Table 2 and Figure 3).

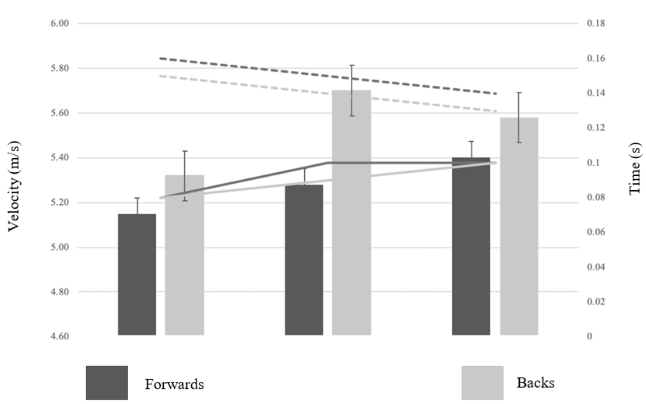

Figure 2: Comparison between forwards and backs for velocity, ground contact time and flight time over the first three steps of sprint performance. Bar chart = Velocity (m/s); Solid lines = Flight time (s); Dashed lines = Ground contact time (s)

4. Discussion

The aim of this study was to explore differences in 10 m, 20 m and 40 m STs and initial acceleration kinematic and spatiotemporal step mechanics between RU forwards and backs. The results of forwards alone and backs alone showed that both positional groups produced acceptable CVs on all occasions. SL showed the least variability (CV = 3.89%) in backs and SD showed the least variability in forwards (CV = 1.37%). The hypothesis was partially accepted as backs displayed less varied STs compared to forwards (ST forwards CV ≤ 4.83%, ST backs CV ≤ 4.01%). Backs displayed higher SF with shorter SL compared to forwards which also accepts the hypothesis. Although this was evident, forwards displayed less varied step mechanics in a higher number of variables compared to backs, rejecting the hypothesis.

Joint angle variables HF_AT_O and SE_AT_O displayed the greatest CV scores for both forwards and backs but were still acceptable. Bradshaw et al. (2007) agreed with our findings and found greater variability involving the measurement of joint angles. Findings showed that T_AT_O displayed the greatest CV (CV = 8.31%). Although Bradshaws CV for T_AT_O was acceptable, it was still Bradshaws' most varied variable. This suggests joint angle variables are problematic variables to obtain consistent data from and stricter guidelines should be followed to enhance the likelihood of consistency. However, in Bradshaw's study subjects were male track and field sprinters therefore direct comparisons cannot be made.

On the other hand, the high variability exhibited for HF_AT_O and SE_AT_O could be due to the need for a higher degree of 'flexibility' in shoulders and hips in order to execute these variables efficiently. Both SE_AT_O (arm drive) and HF_AT_O (knee lift) vary from sprint to sprint in order to adapt to differing game circumstances on field, e.g., pushing off an opponent or acceleration into different directions. Thus, the adaption of co-ordination within these variables during a given situation on field shows another potential area for variability.

TD displayed a large effect where backs produced significantly shorter TDs (g =1.53, $p < 0.001$) substantiating previous findings (Wild et al., 2018). Backs also had increased T_AT_O (large effect) and arm drive/SE_AT_O (small effect) compared to forwards. The combination of an increased trunk lean (T_AT_O), decreased TD and increased arm drive (SE_AT_O) in backs theoretically may enable players to increase horizontal force production which in turn increases horizontal velocity, as the centre of mass is ahead of the base of support during the majority of the ground contact phase reducing initial braking impulse leading to a great net horizontal impulse. The adoption of this more efficient running technique in backs confirms conclusions by Wild et al. (2018). Sayers (2000) also found similar results in field sport players, demonstrating smaller arm actions/reduced SE_AT_O resulted in a detriment to the biomechanical characteristics required for good running technique.

It was clear that backs had faster absolute STs (CV ≤ 4.01%) showing moderate differences. This was also confirmed when looking at individual steps as backs displayed higher SVs at all three steps (Figure 2). Forwards in the current study had higher average SLs where backs had greater average SFs. When comparing individual steps for SF it was evident that backs had a

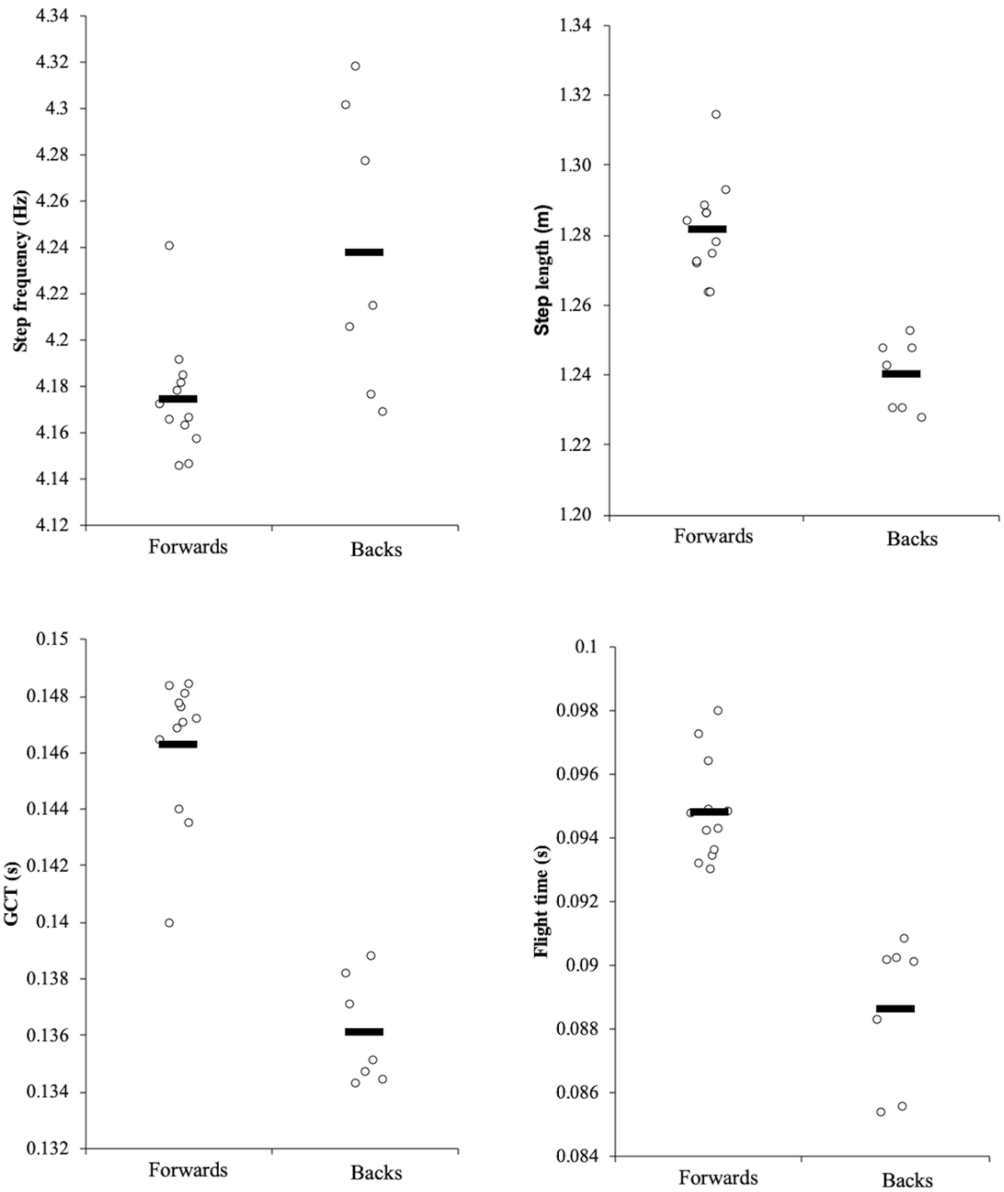

Figure 3: Dot Plots for step frequency, step length, ground contact time (average of first 3 steps) and flight time of forwards versus backs

much higher SF for steps 1, 2 and 3 compared to forwards confirming average results. Although less, on average backs also showed less varied SLs (g = 1.00) compared to forwards displaying a more consistent running style. Our SL findings agree with findings by La Monica et al. (2016) who also found forwards had longer SLs and backs had higher SFs. Due to the fastest subjects in current the study (backs) displaying less varied SLs and (g = 1.00) and higher SFs our results suggest that for the fastest SV subjects should display higher SFs. Previous research has found similar, but stated that for enhanced results, the highest SF that can be maintained with the highest possible SL would result in superior results (Hunter, Marshall, & McNair, 2004). CV for isolated forwards and backs SV, SL and SF in the current study were acceptable (CV ≤ 4.42%) on all occasions however it still cannot be concluded that a high SF with a lower SL is optimal as only small-moderate differences were evident and correlations between SV-SF and SV-SL were not measured.

Results from the current study also suggest that taller/longer limbed subjects find it much more challenging to reach higher SFs. In contrast to this, although La Monica et al. (2016) agreed with our findings, forwards and backs in La Monica's study were both of the same average height thus suggesting height does not explain differences. Although such findings were evident, our results agree with findings by Wild et al. (2018) who also found taller subjects had lower SF (forwards vs track and field athletes). But

Table 2: Descriptive statistics, reliability measures and effect sizes for average of first three steps for 40 m sprint

Step Mechanics	*p*	Forwards Mean and ± SD	CV %	95 % LB	95 % UB	Backs Mean and ± SD	CV %	95 % LB	95 % UB	*g*	± 95 % CI
10 m sprint time (s)	0.044	1.90 ± 0.09	4.83	2.90	6.76	1.83 ± 0.07	4.01	1.91	6.11	0.74	0.96
20 m sprint time (s)	0.017	3.20 ± 0.13	4.01	2.40	5.61	3.08 ± 0.08	2.73	1.30	4.17	1.08	0.99
40 m sprint time (s)	0.045	5.58 ± 0.24	4.30	2.58	6.01	5.39 ± 0.15	2.77	1.32	4.22	0.91	0.98
Step length (m)	<0.001	1.28 ± 0.03	2.25	1.35	3.15	1.24 ± 0.05	3.89	1.85	5.93	1.00	0.98
Step duration (s)	<0.001	0.24 ± 0.00	1.37	0.82	1.92	0.22 ± 0.01	3.98	1.90	6.07	2.32	1.19
Ground Contact time (s)	0.001	0.15 ± 0.00	2.41	1.45	3.39	0.14 ± 0.01	5.28	2.51	8.04	1.72	1.08
Flight time (s)	0.161	0.09 ± 0.00	2.25	1.35	3.16	0.09 ± 0.00	4.40	2.10	6.71	1.88	1.11
Step Frequency (Hz)	0.010	4.17 ± 0.06	1.44	0.87	2.02	4.24 ± 0.19	4.42	2.10	6.73	-0.43	0.94
Step Velocity (m/s)	0.068	5.34 ± 0.08	1.48	0.89	2.07	5.39 ± 0.23	4.18	1.99	6.37	-0.28	0.94
Trunk angle at take-off (°)	<0.001	34 ± 2	4.94	2.96	6.92	31 ± 2	7.41	3.53	11.30	1.40	1.03
Leg extension angle at take-off (°)	0.163	43 ± 1	2.27	1.36	3.18	42 ± 2	4.29	2.04	6.53	0.21	0.93
Hip flexion angle at take-off (°)	0.448	27 ± 3	11.02	6.61	15.44	28 ± 3	9.91	4.72	15.10	-0.12	0.93
Shoulder angle extension at take-off (°)	0.058	49 ± 3	6.58	3.95	9.21	50 ± 4	7.80	3.71	11.88	-0.42	0.94
Touch down distance (m)	<0.001	0.27 ± 0.02	6.21	3.73	8.69	0.24 ± 0.02	7.46	3.55	11.37	1.53	1.05

Trivial ES	Small ES	Moderate ES	Large ES	Very Large ES	Extremely Large ES

Note: SD = Standard deviation; CV % = Coefficient of variation; 95 % CI LB = 95 % Confidence interval lower bound; 95 % CI UB = 95 % Confidence interval upper bound similar to La Monica et al., Wild et al. also found that backs vs track and field athletes were of similar height (± 0.01 m) but backs produced higher SF than track and field athletes (small effect). This was likely due to the nature the track and field athletes sport being based completely around running alone. The majority of a track and field athletes training is built solely around linear step mechanics and does not involve skills such as CoD or passing. Track and field athletes also have a greater focus on developing and maintaining MV thus signifying sprinters were more familiar and developed with the action of sprinting.

A large effect was found for GCT and FT (Table 2 and Figure 2). This supports findings by Barr et al. (2014) who found that faster RU players had shorter GCTs. Shorter GCTs are important to establish higher SF, thus explaining the lower GCTs and higher SF in backs compared to forwards, who were more SL dependent (Figure 2 and 3). When comparing individual steps, it was clear that backs had shorter GCT and longer FT for each of the three steps confirming the accuracy of average results (Figure 2 and 3). The fact that there were no significant differences observed between positional groups for LE_AT_o and HF_AT_o suggests there are no differences in the leg extension angle in order to maximise propulsion force and amount of knee lift during sprinting.

When assessing the usefulness of the 40 m sprint as a testing battery, it may not be deemed as the best method. Backs cover higher sprint distances than forwards during game play (Cahill, Lamb, Worsfold, Headey, & Murray, 2013) and therefore it may not be appropriate for forwards to carry out 40 m sprints as part of their training programme. Shorter sprints may be a better replacement allowing a better transfer to RU. The high effect size differences in step mechanics between positions also suggest it may be difficult to teach the same technique. Differences in anthropometrics propose it may be beneficial if positions had different sprinting technical models. Practitioners should take this into consideration.

In conclusion, acceptable CVs can be derived from all variables for both forwards and backs (Baumgartner & Chung, 2001). HF_AT_O and SE_AT_O displayed the lowest CVs for both groups. Forwards had lower CVs in a higher number of variables than backs, rejecting the hypothesis. The hypothesis was accepted in terms of step mechanics, where backs displayed higher SF, shorter SL and faster STs than forwards.

Backs had faster absolute GCT and it was evident that forwards were more SL dependent thus, the development of separate technical models for positions individually may improve coaching prescription to enhance sprint performance, but future research is needed in this area. An increase in SF with a greater LE_AT_O (Hunter et al., 2004) should be adhered to for faster SVs. Increased T_AT_O, SE_AT_O and decreased TD should also be a focus for practitioners. But it should be noted that shorter sprints for forwards may allow a better transfer to RU. Overall, due to SL and SD having lower variability suggests that these variables could be used to monitor the development of step mechanics in periodized training programs. Future research should also consider the comparison step mechanics of specific steps rather than an average of steps when analyzing sprint performance for even more accurate results.

Assessing spatiotemporal kinematics in RU players may be a tool to monitor sprint performance. Differences in kinematics and spatiotemporal characteristics were evident between forwards and backs which may indicate that there will be position specific technical models. Therefore, from a practical standpoint coaches may want to separate players into positions when carrying out sprint training in order to address differing weaknesses. Coaches should also consider having forwards carry out shorter sprints as part of their training programme. Coaching RU players to have an optimal combination of a higher SF, shorter SD and longer SL may display enhancements in step mechanics. Coaches may consider using external cues to achieve desired outcomes, as it has been found, external cues allow subjects to better responding to instructions (better quality of movement and higher successful frequency of responses to instructions) (Wulf, McNevin, & Shea, 2001). Cues such as “the floor is lava” in order to improve SF whilst encouraging players to “maximally drive/push the floor away” to achieve longer SLs (Wulf, McNevin, & Shea, 2001). Coaches may also consider implementing fast stretch-shortening cycle plyometrics such as pogos, rope jumps, travelling pogos or hurdle jumps with a focus on minimizing GCT and maximizing jump height, therefore maximizing SF and SL and exhibiting greater RU sprint performances.

Conflict of Interest

The authors declare no conflict of interests.

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