Manchester Metropolitan University

e-space

Manchester Metropolitan University's Research Repository

Please cite the Published Version

Dobbin, Nicholas (2022) Sprint mechanical properties of professional rugby league players according to playing standard, age and position, and the association with key physical characteristics. The Journal of Sports Medicine and Physical Fitness, 62 (4). pp. 467-475. ISSN 0022-4707

DOI: https://doi.org/10.23736/S0022-4707.21.12859-2

Publisher: Edizioni Minerva Medica

Version: Accepted Version

Downloaded from: https://e-space.mmu.ac.uk/628517/

Additional Information: This is a postprint version of the article published in The Journal of Sports Medicine and Physical Fitness. This version is free to view and download to private research and study only. Not for redistribution or re-use. ©Edizioni Minerva Medica. The final published article is available online on Minerva Medica website at https:doi.org 10.23736/S0022-4707.21.12859-2. Cite this article as Dobbin, N; Sprint mechanical properties of professional rugby league players according to playing standard, age and position, and the association with key physical characteristics. The Journal of Sports Medicine and Physical Fitness 2021; Oct 15.

Enquiries:
If you have questions about this document, contact openresearch@mmu.ac.uk. Please include the URL of the record in e-space. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from https://www.mmu.ac.uk/library/using-the-library/policies-and-guidelines)

Manuscript Title: Sprint mechanical properties of professional rugby league players according to playing standard, age and position, and the association with key physical characteristics.

Submission Type: Original Investigation

Author: Nick Dobbin[1]

Affiliation:
[1]Department of Health Professions, Manchester Metropolitan University, Manchester, UK

Corresponding Author: Dr Nick Dobbin, Department of Health Professions, Manchester Metropolitan University, Manchester, UK, M15 6GX.
Work Tel: 0161 247 2887
Work Email: N.Dobbin@mmu.ac.uk

ORCID: https://orcid.org/0000-0001-7508-1683

Brief Running Head: Sprint mechanical properties of rugby league players.

COI: The author reports no conflicts of interest
Funding: No funding is associated with this research.

Abstract Word Count: 278
Manuscript Word Count: 3971
Number of References: 35

Tables: 3
Figures: 1

ABSTRACT

BACKGROUND: This study determined the influence of playing standard, age, and position on the horizontal force-velocity (FV) properties of rugby league players, and the association with other characteristics.

METHODS: This observational study used a cross-sectional design with a range of physical characteristics recorded from 132 players from 5 Super League clubs. Sprint data was used to derived theoretical maximal force (F_0) and velocity (V_0), power (P_{max}), maximal rate of force (RF_{max}) and the rate of decrease in RF_{max} (D_{RF}). Differences between playing standard, age groups and playing positions were determined (P value and standardised mean difference (SMD) along with correlational analysis to assess the relationship between FV properties and key physical characteristics.

RESULTS: Senior players reported lower split time (SMD = -0.26--0.59, *P* =0.002-0.017), absolute F_0, P_{max} and V_0 (SMD = 0.47-0.78, *P* <0.001-0.010). Players aged <21 years reported higher split times and lower absolute F_0 compared to 21-26 years (SMD = -0.84--0.56, *P* <0.001-0.04) and a lower V_0 than >26 years (SMD = -0.40, *P*=0.002). Hit-up forwards were slower than outside backs (SMD = -0.30--0.89, *P* <0.001-0.042), though produced the highest absolute F_0 and P_{max}. Split times F_0, V_0, P_{max} and RF_{max} were associated with change of direction and countermovement jump performance, whilst FV_{slope} and D_{RF} were associated with countermovement jump performance. F_0 and P_{max} were associated with medicine ball throw distance (*r* = 0.302-0371, *P* = ≤0.001). There was no association with prone Yo-Yo IR1 distance (*r* = -0.16-0.09, *P* =0.060-0.615).

CONCLUSIONS: These results provide insight into the horizontal FV properties with reference to key sub-groups, and highlights several associations with other characteristics across large sample of rugby league players. The result of this study should be used when

interpreting the sprint ability of rugby league players, planning the long-term development of youth players, and inform programme design for all.

Keywords: Sprint mechanics; collision sport; power; team sport; training implications.

Introduction

Rugby league match-play requires players to perform 35 ± 2 maximal accelerations and sprints,[1] with many occurring in combination with sport-specific actions (e.g. passing) during crucial passages of play such as scoring or conceding a try.[2] Sprint performance is also important given its association with final league position in rugby league[3] as well as potential moderating effect for injury risk.[4] Accordingly, there has been a large focus on developing and understanding the changes in the sprint capability of rugby league players[3] as well as the magnitude of difference between playing standards such as academy and senior players,[5] playing positions[3,6] and selected/non-selected groups.[7] These results suggest that all rugby league players are required to possess a high level of sprinting ability, with this characteristic being particularly important for those at higher standards; competing in the backs position; and who are selected into talent identification programmes.

One potential factor that has received less consideration when assessing and interpreting sprint performance in rugby league is the chronological and training age of an individual. As noted in Haugen et al.'s[8] review on the training and development of sprint performance, the sprint capacity of an athlete evolves and devolves due to growth, maturation, training, and ageing. They noted how peak sprint performance typically occurs around 25-26 years,[8] though is likely influenced by the age at which specialised training was introduced. In rugby league, the age and training age of an athlete is rarely considered when interpreting the sprint capability of players, but differences between those with two or three years of training within an academy have been noted for 10 m sprint times.[3] In contrast, Till et al.[9] reported minimal difference in 10 and 20 m sprint performance between academy players with 0, 1 and 2 years of training experience. The influence of chronological age was recently explored across a large sample of soccer players, where those with greater age (>28 years) reporting inferior split times compared to their younger (<24 years) counterparts.[10] However, no such information is available for rugby league athletes when considering both chronological and training age across a large sample, but warrants investigation given its importance when assessing and interpreting players results that inform selection, long-term development and/or return to play decisions.

Despite interest in the acceleration and sprint capabilities of rugby league athletes, research is largely limited to split times, total sprint time or velocity using electronic timing gates or a radar gun, respectively. Over recent years, there has been an emergence of research that has reported the mechanical properties of sprinting using a field-based method introduced by Samozino et al.[11] that provides a macroscopic insight using inverse dynamics applied to the centre of mass, estimating the step-average ground reaction forces. Researchers have used this method to assess the change in mechanical properties of sprinting[12] as well as compare the horizontal force-velocity (FV) profiles of drafted and non-drafted football players[13] basketball and handball players,[14] soccer and futsal players,[15] rugby union,[16] rugby union and rugby league players[17] and multiple sporting populations.[18,19] The application of this model in these populations has provided insight into the mechanical effectiveness of force application in a horizontal direction (i.e., maximum ratio of horizontal-to-resultant force [RF_{max}], the decrease in horizontal-to-resultant force [D_{RF}]) and enabled the evaluation of the maximal theoretical force (F_0), theoretical velocity (V_0), FV_{slope}, and maximal power (P_{max}). Whilst this information builds on what is known, there is a lack of understanding regarding the factors that may affect the FV profile of rugby league players despite the widespread assessment on sprint ability in these athletes. Cross et al.[17] demonstrated positional difference in F_0 (standardised mean difference (SMD) = 0.18), V_0 (SMD = 1.02) and P_{max} (SMD = 0.88) in a small sample of elite players limited to forward and backs. Whether the FV profile is different between specific positional grouping (e.g., hit-up forwards, outside backs and adjustables), playing standards (e.g., academy or senior) or is influence by chronological and training age is unknown in rugby league. It is also currently unknown if the mechanical outputs associated with the FV profile are related to other key physical characteristics. Dobbin et al.[3] recently reported that 20 m sprint time was associated with change of direction time, whole-body power, and intermittent running ability, though as noted earlier, this was limited to sprint time and does not consider the mechanical properties. This information will support practitioners in understanding the sprint capabilities and expectations of players with reference to specific sub-groups, and allow them to understand how influencing outputs from the FV profile might affect other physical characteristics important in rugby league. Attempts have been made to explore the differences in the FV profile across playing standards, position, chronological age and sex in soccer players.[10,20] However, given the difference in the development pathway and position-specific demands, such information in rugby league will provide representative data for strength and conditioning coaches, sport scientists and physiotherapist to support the long-term development of athletes, the physical preparation for competition, and return-to-play procedures following injury (e.g., hamstring strain).

Therefore, this study aimed to determine the influence of playing standard, age and playing position on sprint properties and mechanical determinants in rugby league players. It was hypothesised that senior players, outsides backs, and older players with greater training experience would report lower split times and superior FV properties.

Materials and Methods

Study Design

This observational study used a cross-sectional design as it allows for comparisons in sprint split times and the FV properties of professional rugby league players considering sub-groups based on playing standard, age and playing position. This design also allows for the association between a variety of physical characteristic to be assessed. All participants were assessed during the final two weeks of preseason after a period of 10-14 weeks of structured training by the same researcher under identical conditions.

Participants

One hundred and thirty-two rugby league players from 5 Super League clubs (~27% of the pooled league cohort) participated in this study and were categorised based on their playing standard, age and playing position. An a-priori power calculation based on a moderate difference between groups[10,20] was used with alpha and power set at 0.05 and 0.80, respectively. The minimum estimated sample was estimated using G*Power, with a sample of 90 participants required. Academy player (n = 67) were defined as those contracted to a Super League academy and who were yet to complete an entire Super League season. Senior players (n = 65) were contracted to a club and had completed at least one entire competitive Super League season. Hit-up forwards (n = 58) included props, second row and loose forwards; outside backs (n = 40) included wingers, fullbacks, and centres; and adjustables (n = 34) included hooker, halfbacks, and stand-off. Age groups were categorised as ≤ 21 years (n = 76), 21-26 years (n = 33) and ≥ 26 years (n = 23). Participants were free of any injury that would prevent them from completing a thorough warm-up and all components testing battery. Participants who didn't provide playing position, age, or information when they started rugby league were excluded. Ethics approval for this study was granted by the Faculty of Medicine, Dentistry and Life Science Research Ethics Committee at the University of Chester (1493/18/ND/SES). All participants provided informed consent.

Procedures

Participants completed a standardised warm up as part of an overall standardised testing battery conducted indoors on artificial (3G) turf and taking about 75 minutes for the entire squad to complete. This warm-up was led by the lead researcher based on the raise, activate, mobilise, and potentiate principles, and involved a series of short jogging bouts, dynamic stretches and high-speed work building to a single maximal sprint. A period of 5-7 minutes was then given before the assessment of physical characteristics.

The sprint test was completed indoors on artificial surface, with participants wearing their full training kit and playing boots. All participants were familiar with the testing procedures and were required to adopt a two-point athletic stance 0.3 m behind the starting timing gate. In their own time, players performed two maximal sprints down a 30 m channel with single-beam timing gates positioned at 0, 5, 10, 15, 20 and 30 m at a height of 90 cm and 150 cm apart (running channel width) (Brower, Speedtrap 2, Brower, Timing Systems, Draper, UT, USA). All split times were recorded to the nearest 0.01 s, with the lowest of two 30 m sprint times and corresponding splits used for analysis. Sprints were completed one at a time, and participants given a 3-minute passive recovery period between efforts.

The horizontal FV profile for each participant was determined using a validated method based on the sprint velocity-time curve which was fitted by a monoexponential function using least-squares regression.[11] Due to the difference in the initiation of the sprint and the triggering of the first timing gate, a time shift method was applied based on the work of Stenroth et al.[21] Temperature, humidity, stature, body mass, and split times were included in the calculation of the acceleration of the centre of mass and net horizontal force. An individual FV profile was derived with F_0 and V_0 identified and used to calculate P_{max} ($F_0 * V_0 / 4$).[11] RF_{max} was determined to represent the maximum ratio of force whilst D_{RF} was the rate of decrease in the ratio of force.

Values derived from the model were expressed in absolute and relative terms, with the reliability previously reported as excellent when using timing gates.[22]

In addition to the sprint test, all players completed a standardised testing battery which include a countermovement jump with arms akimbo, a medicine ball throw, a change of direction test and a rugby-specific Yo-Yo Intermittent Recovery Test. All procedures have been described previously[23] and can be found in Supplement 1, with the outcomes deemed reliable (coefficient of variation = 2.5 – 9.9%) and not subject to a learning effect.[23] The mean and standard deviation for temperature, humidity, pressure was 8.7 ± 2.5°C, 82.3± 3.9% and 1004 ± 16 mbar, respectively.

Statistical Analyses

Data are presented and mean ± SD. All data met the assumptions of normality. Intraclass correlation between the repeated sprints was determined using a mixed model. Between-group comparisons for playing level was assessed with an independent sample *t*-test, whilst playing position and training age were assessed using a one-way ANOVA. Where a main effect was found, a follow-up post-hoc test was completed with a Bonferroni adjustment applied. The between-group comparisons were also supplemented with Hedges g (SMD) and 95% confidence limits (95%CL) interpreted as: 0.00 to 0.20 (trivial), 0.21 to 0.60 (small), 0.61 to 1.20 (moderate), 1.21 to 2.00 (large), and >2.00 (very large)[24] When assessing the relationship between sprint times and FV properties with the other physical characteristics, Pearson's correlations were derived with 95%CL. Correlations were interpreted as: <0.1, trivial; 0.10-0.30, small; 0.31-0.50, moderate; 0.51-0.70, large, 0.71-0.90, very large; and > 0.90, nearly perfect. The compatibility of the data with the hypothesis was inferred from the P values that were calculated using SPSS for Macintosh (Versions 26, Armonk, USA).

Results

The intra-trial reliability for the two repeated sprints was 0.729 to 0.816. Results for the independent sample *t*-test indicated a difference between academy and senior players for age ($t = 13.584$, $P < 0.001$), training age ($t = 12.969$, $P < 0.001$), stature ($t = -4.091$, $P < 0.001$) and body mass ($t = 5.608$, $P < 0.001$). Differences were also evident across all split times ($t = 2.413$ to 3.221; $P = 0.002$ to 0.017), absolute F_0 ($t = -2.958$; $P = 0.010$), V_0 ($t = -2.886$, $P < 0.005$) and absolute P_{max} ($t = -4.613$, $P < 0.001$). Minimal difference was observed between playing groups for relative F_0 ($t = 0.702$, $P = 0.484$), P_{max} ($t = -0.586$, $P = 0.559$) or FV_{slope} ($t = -1.542$, $P = 0.125$), RF_{max} ($t = -0.209$, $P = 0.834$) and D_{RF} ($t = -1.717$, $P = 0.088$). When considering the magnitude of difference, results revealed small differences in split times and trivial to moderate difference in mechanical properties (Table 1).

****INSERT TABLE 1 ABOUT HERE****

There was a main effect of age group for stature (F = 8.682, $P < 0.001$), body mass (F = 10.792, $P < 0.001$) and training age (F = 190.103, $P < 0.001$). Differences were apparent across age groups for all split times (F = 3.821 to 9.435, $P = 0.024$ to < 0.001) and for absolute F_0 (F = 3.841, $P = 0.024$), V_0 (F = 6.460, $P = 0.002$) and P_{max} (F = 9.756, $P < 0.001$). No main effect of age group was observed relative F_0 (F = 1.091, $P = 0.339$) or P_{max} (F = 1.388, $P = 0.253$), FV_{slope} (F = 1.881, $P = 0.157$), RF_{max} (F = 1.243, $P = 0.292$) and D_{RF} (F = 1.960, $P = 0.145$). Pairwise comparisons between groups as well as the magnitude of difference are presented in Table 2.

****INSERT TABLE 2 ABOUT HERE****

There was no main effect of playing positions for age (F = 0.623, $P = 0.538$), stature (F = 2.666, $P = 0.073$) or training age (F = 0.461, $P = 0.632$). There was, however, a main effect of position for body mass (F = 35.600, $P < 0.001$), with post-hoc analysis indicating that all positions differed to each other. There was a main effect of position for split times at 10 m (F = 3.257, $P = 0.042$), 15 m (F = 3.174, $P = 0.045$), 20 m (F = 5.843, $P = 0.004$) and 30 m (F = 9.620, $P < 0.001$), but not 5 m (F = 0.716, $P = 0.491$). Post-hoc analysis indicated lower split times for outside backs compared to hit-up forwards at 10 to 30 meters. Outside backs also reported a lower split time at 30 m compared to adjustables (Table 3). A main effect of playing position was evident for absolute F_0 (F = 13.860, $P < 0.001$), V_0 (F = 3.565, $P = 0.031$) and absolute P_{max} (F = 13.211, $P < 0.001$), with adjustables producing the least (moderate to large effect) F_0 and P_{max} of all groups and outside backs reporting a lower (small effect) F_0 and P_{max} than hit-up forwards. Outside backs reported a higher V_0 than hit-up forwards. No significant effect of playing position was observed for relative F_0 (F = 0.096, $P = 0.908$), relative P_{max} (F = 1.708, $P = 0.185$), FV slope (F = 0.359, $P = 0.699$), RF_{max} (F = 1.724, $P = 0.182$) or D_{RF} (F = 0.509, $P = 0.602$), though trivial to small differences were observed.

****INSERT TABLE 3 ABOUT HERE****

Trivial correlations were observed between all split times and most FV properties with medicine ball throw distance (r = -0.12 to 0.15, P = 0.100 to 0.960), except for absolute F_0 and P_{max} (r = 0.320 to 0.371, both ≤ 0.001). Trivial correlations were observed for all variables with prone Yo-Yo IR1 test (r = -0.16 to 0.09, P = 0.06 to 0.62) (Figure 1). A negative correlation was observed between 10-30 m split times and CMJ height (r = -0.25 to -0.51, all $P < 0.01$), whilst V_0, P_{max}, FV_{slope}, RF_{max} and D_{RF} were positively associated with CMJ height (r = 0.17 to 0.47, P = < 0.001 to 0.049) (Figure 1). All split times were positively correlated with change of direction time (r = 0.33 to 0.52, all P < 0.001). Absolute F_0 and P_{max} were positively associated with change of direction time (r = 0.184 to 0.256, P = 0.004 to 0.04). Small negative associations were evident for change of direction time and velocity and RF_{max} (r = -0.178 to -0.192, P = 0.032 to 0.046).

****INSERT FIGURE 31 ABOUT HERE****

Discussion

The results of this study indicated distinct FV profiles for specific sub-groups, with senior players reporting lower split times and higher absolute F_0, V_0 and P_{max} compared to academy players. Further, those age between 21 and 26 years generally demonstrated superior split times and FV properties than those < 21 years and > 26 years. Finally, the results highlighted outside backs generally reported superior split times and FV profile, with adjustables being inferior to outside backs and hit-up forwards for F_0 and P_{max}.

Several studies have used a large sample of soccer and rugby union players to provide insight into the influence of playing standard to aid practitioners' interpretation of the FV profile and support the development of players of lesser standards.[10,16,20,25] However, no studies have reported the difference in the FV profile between academy and senior rugby league players, which is important given most academy players progress straight to the Super League due to limited use of development squads (reserves/U23s). Senior players reported lower split times, with the magnitude of difference increasing sightly over the distance covered, which is consistent with Cross et al.[17] and Edwards et al.,[13] both of whom observed similar results when comparing rugby union and rugby league players and drafted and non-drafted Australian footballers, respectively. This finding, combined with the greater V_0, suggests that senior players have a greater ability to apply force at higher velocities potentially due to greater fatigue resistance, greater gluteal and hamstring strength, backward movement speed of the limb throughout a sprint and superior sprint mechanics (e.g. application and force orientation).[28] Further, the higher horizontal absolute F_0 and V_0 in senior players resulted in a moderate between-group difference in P_{max}, indicating that senior players can generate greater net horizontal ground reaction force during the sprint start (%RF_{max}) and at high velocity. The stepped increase in horizontal absolute F_0, V_0, P_{max} and sprint performance as playing standard increased agrees with previous work in soccer players.[10,20,25,26] The greater absolute difference might explain the small difference in D_{RF} between academy and senior players, where a slightly steeper negative slope was observed for academy players. There are several explanatory factors associated with these findings such as morphological, neural, and mechanical properties of the skeletal muscle that result in a greater absolute force output, greater backward movement of the limb during the stance and late swing phase and reduced influence of fatigue over a 30 m course.[27,28] Of particular interest for sprinting, is a greater knee flexor strength which is known to be associated with horizontal force application[28] and often a higher standard athletes.[29] However, the lack of difference in relative F_0 and P_{max} suggest much of the different is explained by the greater body mass, in part, due to > 7 years greater training exposure consisting of exposure of lifting heavier maximal loads, engaging in more frequent force-dominant actions and more specialised programmes compared to academy players.

The influence of the participants' age should be considered when evaluating the mechanical properties of rugby league sub-groups given the difference in split times previously reported.[6] When considering the mechanical properties in soccer players, Haugen et al.[10] noted minimal difference between those ages 24 to 28 years but an inferior profile in those over 28 years compared to the 24–28-year-olds. The results in this study demonstrate that players aged 21-

26 years reported superior split times compared to < 21 years. However, considering the SMDs, a moderate difference was also observed between those 21-26 years and > 26 years, thus potentially indicating an that 21-26 year reflects a period of optimal training adaptation and minimal influence of age-related changes in muscle morphology caused by greater recovery time needed and reduced training volumes often see in senior players. Whilst the participants in this study are likely to be younger than that where alteration in size of fast-twitch muscles fibres and a change in the myosin heavy chain isoform profile[30] are observed (~ 40 years), the range of ages in the > 26-year group was 27 to 35 years. In the older athletes, it is anticipated that these may require greater time-course recovery following exercise that elicits symptoms associated with exercise-induced muscle damage[31,32] which will ultimately reduce training frequency, intensity, and volume across a season. These findings suggest that age and training age are important considerations when interpreting sprint and FV data, and that specific age groups might require a more targeted approach in developing these characteristics to off-set the decline in these performance variables.

A factor that has received consideration in other sports is playing position, which due to sport-specific roles, cannot be expanded to rugby league. However, recent multi-club research indicates minimal difference between outside backs and adjustables, though hit-up forwards were slightly slower at the academy standard over 10 and 20 m.[5] Dobbin et al.'s[5] research indicated there was no difference in mean 10 and 20 m sprint times between hit-up forwards and adjustables, with the outside backs being quicker.[5] The results of the present study provide some insight into the mechanical properties associated with achieving the given split times. Split times revealed differences between hit-up forwards and outside backs, and a difference in 30 m split times between outside backs and adjustables. To overcome the greater inertia, the hit-up forwards produced a larger absolute F_0 and P_{max} during the sprint and achieved a similar

V_0 to adjustables, but lower than outside backs. The inferior F_0, V_0 and P_{max} found for adjustables reflects position-specific needs, whereby greater intermittent running ability is likely to be more important to ensure they are available during the 'play-the-ball' rather than their sprinting ability. This finding concurs with Haugen et al.[10] who observed a similar profile for midfielders in soccer; a position that historically resulted in greater distance being covered[33] and on-ball activity.[34] Outside backs reported the lowest split times, highest V_0 and P_{max} compared to the other positions. This finding agrees with Cross et al.[17] who compared rugby league forwards and backs; Haugen et al.[10] who reported data on forwards/strikers; and Watkins et al.[16] reported across rugby union position. Collectively, these results indicated that players involved in decisive high-speed moments and who have the greatest space on the field to reach higher sprint speeds display a superior FV profile than others.

The association between physical characteristics is important for programme effective and efficient programme design. In this study, the results indicate that a lower split time at almost at all distances were associated with superior countermovement jump and change of direction ability. This is consistent with the work of Dobbin et al.[3] using the same tests. The relationship between squat jump, countermovement jump, and change of direction ability with sprint split times support the results of this study.[19,35,36] When considering the mechanical properties, V_0 and RF_{max} were negatively associated with change of direction time (faster), whilst F_0 and P_{max} were positively associated (slower). Similar correlations were found between the 505 test and V_0,[37] but not F_0, where a negative association was observed. However, comparing these results is difficult given the variety of team-sport athletes used and differences in change of direction test. FV_{slope}, RF_{max} and D_{RF} were positively associated with countermovement jump performance, whilst for no association was observed for any sprint properties with prone Yo-Yo IR1 running distance. F_0 and P_{max} was associated with medicine ball throw distance and is likely explained by the greater distance achieved by hit-up forward[3] who also report greater absolute F_0 and P_{max}. Practitioners in rugby league can use this information to design strength and conditioning programmes considering the degree of covariance between physical characteristics. This is likely to be particularly important when working with youth and academy athletes as the development of some characteristics may translate to a positive or negative changes elsewhere that could impact on coach's perceptions or match performance.

Limitations, Practical Implications and Conclusions

Whilst this is the largest dataset available in rugby league and was collected under identical conditions by the same researcher, it's important to note that the results reflect ~30% of the available population in the UK at each playing level. As such, there is a need for centrally governed research by the sport's governing body to capture truly reflective normative data across the league if deemed necessary. Also, it is important to highlight that the assessment was conducted during the final two weeks of preseason, thus some individual might have arrived in a less than optimal condition due to residual fatigue from a period of high training volume.

This study provides the magnitude and probability of the differences between key sub-groups in rugby league; that is, academy and senior players; three age groups, and positional groups. This data can support practitioners evaluating athletes' athletic ability, supporting their return to play following injury, and considering developmental opportunities. Also, the inclusion of other key physical characteristics enables researchers and practitioners to understand the degree of covariance between the horizontal FV properties and key physical characteristics, particularly change of direction and jump performance, thus supporting overall programme design for rugby league athletes.

Author Contribution

This study was designed by Nick Dobbin. Data was collected and analysed by Nick Dobbin. The manuscript was prepared by Nick Dobbin. The author declares no conflict of interest.

Acknowledgments

I would like to thank all participants and Super League clubs who took part in the study. I would also like to thank Professor Craig Twist who supported access to clubs and for his valuable guidance at the time this data was collected. The authors have no funding or conflicts of interest to disclose.

References

1. Gabbett TJ. Sprinting patterns of national rugby league competition. J Strength Cond Res 2012;26(1):121-30.
2. Gabbett TJ, Gahan CW. Repeated high-intensity effort activity in relation to tries scored and conceded during rugby league match-play. Int J Sports Physiol Perform 2015;11(4):530-4.
3. Dobbin N, Highton J, Moss SL, Twist C. Factors affecting the anthropometric and physical characteristics of elite academy rugby league players: a multi-club study. Int J Sports Physiol Perform 2019;14(7):958-65.
4. Malone S, Roe M, Doran DA, Gabbett TJ, Collins K. High chronic training loads and exposure to bouts of maximal velocity running reduce injury risk in elite Gaelic football. J Sci Med Sport 2017;20(3):250-4.
5. Dobbin N, Highton J, Moss SL, Twist C. The discriminative validity of a standardised testing battery and its ability to differentiate anthropometric and physical characteristics between youth, academy, and senior professional rugby league players. Int J Sports Physiol Perform 2019;14(8):1110-6.
6. Gabbett TJ. Physiological characteristics of junior and senior rugby league players. Br J Sports Med 2002;36(5):334-9.
7. Tredrea M, Dascombe B, Sanctuary CE, Scanlan AT. The role of anthropometric, performance and psychological attributes in predicting selection into an elite development programme in older adolescent rugby league players. J Sports Sci 2017;35(19):1897-1903.
8. Haugen T, Seiler S, Sandbakk Ø, Tønnessen E. The training and development of elite sprint performance: an integration of scientific and best practice literature. Sports Med Open 2019;5(1):44.
9. Till K, Darrall-Jones J, Weakley JJ, Roe GA, Jones BL. The influence of training age on the annual development of physical qualities within academy rugby league players. J Strength Cond Res 2017;31(8):2110-18.
10. Haugen TA, Breitschädel F, Seiler S. Sprint mechanical properties in soccer players according to playing standard, position, and age and sex. J Sports Sci 2020;38(9):1070-76.
11. Samozino P, Rabita G, Dorel S, Slawinski J, Peyrot N, Saez de Villarreal E, Morin JB. A simple method for measuring power, force, velocity properties, and mechanical effectiveness in sprint running. Scand J Med Sci Sport 2015;26(6):648-58.
12. Dobbin N, Clarke J, Cushman S. The effects of an 8-week off-season period on the mechanical properties of sprinting in professional rugby league players: implication for training recommendations. J Trainology. 2020;9:15-9.
13. Edwards T, Piggott B, Banyard HG, Haff G, Joyce C. Sprint acceleration force-velocity-power characteristics in drafted vs non-drafted junior Australian football players: preliminary results. Sci Med Football. 2020;5(3):204-7.
14. Haugen TA, Breitschädel F, Seiler S. Sprint mechanical properties in handball and basketball players. Int J Sports Physiol Perform. 2019;14:1388-94.
15. Jiménez-Reyes P, García-Ramos A, Chaudrado-Peñafiel V, Párraga-Montilla JA, Morcillo-Losa JA, Samozino P, Morin JB. Differences in sprint mechanical force-velocity profile between trained soccer and futsal players. Int J Sports Physiol Perform. 2019;14(4):478-85.

16. Watkns C, Storey A, McGuigan MR, Downes P, Gill ND. Horizontal force-velocity-power profiling of rugby players a cross-sectional analysis of competition level and position-specific movement demands. J Strength Cond Res. 2021;36(6):1576-85.
17. Cross MR, Brughelli M, Brown SR, Samozino P, Gill N, Cronin JB, Morin JB. Mechanical properties of sprinting in elite rugby union and rugby league. Int J Sports Physiol Perform. 2015;10(6):695-702.
18. Haugen TA, Breitschädel F, Seiler S. Sprint mechanical variables in elite athletes: are force-velocity profiles sport specific or individual? PLoS ONE. 2019;e0215551.
19. Jiménez-Reyes P, Samozino P, García-Ramos A, Chaudrado-Peñafiel V, Brughelli M, Morin JB. Relationship between vertical and horizontal force-velocity-power profiles in various sports and levels of practice. PeerJ 2018;6:e5937.
20. Devismes M, Aeles J, Philips J, Vanwanseele B. Sprint force-velocity profiles in soccer players: impact of sex and playing level. Sports Biomech 2019; doi: 10.1080/14763141.2019.1618900.
21. Stenroth L, Vartiainen P. Kajalainen PA. Force-velocity profiling in ice hockey skating: reliability and validity of a simple, low-cost field method. Sports Biomech. 2020;17:1-16.
22. Haugen TA, Breitchadel F, Samozino P. Power-force-velocity profiling of sprinting athletes: methodological and practical considerations when using timing gates. J Strength Cond Res. 2020;34(6):1769-73.
23. Dobbin N, Hunwicks R, Highton J, Twist C. A reliable testing better for assessing physical qualities of elite academy rugby league players. J Strength Cond Res. 2018;32(11):3232-38.
24. Hopkins WG. A scale of magnitudes for effect statistics. Sportscience, 2002; Retrieved from: https://www.sportsci.org/resources/stats/effectmag.html.
25. Jiménez-Reyes P, Samozino P, García-Ramos A, Chaudrado-Peñafiel V, Brughelli M, Morin JB. Relationship between vertical and horizontal force-velocity-power profiles in various sports and levels of practice. PeerJ. 2018;6:e5937.
26. Haugen TA, Breitschädel F, Seiler S. Sprint mechanical variables in elite athletes: are force-velocity profiles sport specific or individual? PLoS ONE. 2019;e0215551.
27. Cross MR, Bughelli M, Samozino P, Morin JB. Methods of power-force-velocity profiling during sprint running: a narrative review. Sports Med. 2017;47(7):1255-69.
28. Morin JB, Edouard. P, Samozino P. Technical ability of force application as a determinant factor of sprint performance. Med Sci Sport Exerc. 2011;43(9):1680-88.
29. Eustace SJ, Page RM, Greig M. Isokinetic strength differences between elite senior and youth female soccer players identified training requirements. Phys Ther Sport. 2019;39:45-51.
30. Korhonen MT, Cristea A, Alén M, Häkkinen K, Sipilä S, Mero A, Viitasalo, JT, et al. Aging, muscle fibre type, and contractile function in sprint-trained athletes. J Appl Physiol. 2006;101(3):906-17.
31. Fell J, Williams AD. The effects of aging on skeletal-muscle recovery from exercise: possible implications for aging athletes. J Aging Phys Act. 2018;16(1):97-115.
32. Fernandez JFT, Lamb KL, Twist C. Exercise-induced muscle damage and recovery in young and middle-aged males with different resistance training experience. Sports. 2019;7(6):132.
33. Rampinini E, Coutts AJ, Castagna C, Sassi R, Impellizzeri FM. Variation in top level soccer match performance. Int J Sports Med. 2007;28(12):1018-24.
34. Bloomfield J, Polman R, O'Donoghue P. Physical demands of different positions in FA Premier League soccer. J Sports Sci Med. 2007;6(1):63-70.

35. Cunningham DJ, West DJ, Owen NJ, Shearer DA, Bracken RM, Crewther BT, et al. Strength and power predictors of sprinting performance in professional rugby players. J Sports Med Phys Fit. 2013;53(2):105-11.
36. Gabbett TJ, Kelly JN, Sheppard JM. Speed, change of direction speed, and reactive agility of rugby league players. J Strength Cond Res. 2008;22(1):174-81.
37. Baena-Raya A, Soriano-Maldonado A, Conceição F, Jiménez-Reyes P, Rodríguez-Pérez MA. Association of the vertical and horizontal force-velocity profile and acceleration with change of direction ability in various sports. Eur J Sport Sci 2021; https://doi.org/10.1080/17461391.2020.1856934.

Table 1. Comparison in FV profile between academy and senior rugby league players.

	Playing Standard		SMD ± 95%CL
	Academy (n = 67)	Senior (n = 65)	
Age (y)	17.4 ± 1.02	24.5 ± 4.3*	2.27 ± 0.94
Stature (cm)	179.7 ± 6.1	183.0 ± 6.5*	0.52 ± 0.64
Body mass (kg)	85.2 ± 10.7	94.9 ± 10.9*	0.89 ± 0.73
Training age (y)	1.4 ± 1.0	8.5 ± 4.0*	2.43 ± 0.96
Recorded split times			
5 m (s)	1.11 ± 0.07	1.09 ± 0.06*	-0.30 ± 0.58
10 m (s)	1.86 ± 0.07	1.84 ± 0.08*	-0.26 ± 0.57
15 m (s)	2.52 ± 0.08	2.48 ± 0.09*	-0.47 ± 0.63
20 m (s)	3.15 ± 0.10	3.10 ± 0.11*	-0.47 ± 0.63
30 m (s)	4.36 ± 0.14	4.28 ± 0.13*	-0.59 ± 0.66
Time-shifted FV data			
F_0 (N)	661 ± 126	727 ± 134*	0.50 ± 0.64
F_0 ($N \cdot kg^{-1}$)	7.8 ± 1.2	7.7 ± 1.3	-0.08 ± 0.52
V_0 ($m \cdot s^{-1}$)	8.93 ± 0.59	9.22 ± 0.64*	0.47 ± 0.63
P_{max} (W)	1465 ± 233	1667 ± 280*	0.78 ± 0.71
P_{max} ($W \cdot kg^{-1}$)	17.3 ± 2.4	17.6 ± 2.5	0.12 ± 0.53
FV_{slope}	-0.88 ± 0.18	-0.84 ± 0.17	-0.22 ± 0.56
RF_{max} (%)	44.7 ± 2.6	45.0 ± 2.9	0.11 ± 0.53
D_{RF} (%)	-8.2 ± 1.7	-7.8 ± 1.6	-0.24 ± 0.57

*Note: F_0 = theoretical maximum force, V_0 = theoretical maximum velocity, Pmax = mechanical power output, FV = force-velocity, RF_{max} = maximum rate of force, D_{RF} = rate of decrease in the rate of force with increasing speed. SMD = standardised mean difference. 95%CL = 95% confidence limits. * Significantly different to academy players.*

Table 2. Comparisons in the anthropometric characteristics, split times, and force-velocity properties according to age group

	Age groups			SMD ± 95%CL (*P* value)		
	< 21 year (1) (*n* = 76)	21-26 years (2) (*n* = 33)	>26 years (3) (*n* = 23)	2 *vs.* 1	3 *vs.* 1	3 *vs.* 2
Age (y)	17.7 ± 1.3	23.6 ± 1.9*	30.0 ± 2.0*†	4.00 ± 0.99	4.44 ± 0.99	1.88 ± 0.91
Stature (cm)	179.8 ± 6.5	183.4 ± 5.7*	184.9 ± 5.7*	0.57 ± 0.66	0.56 ± 0.66	0.26 ± 0.57
Body mass (kg)	86.0 ± 10.9	95.2 ± 9.7*	98.3 ± 10.4*	0.86 ± 0.73	1.13 ± 0.79	0.30 ± 0.59
Training age (y)	1.9 ± 1.7	7.6 ± 1.9*	12.9 ± 2.5*†	3.23 ± 0.98	5.72 ± 0.99	2.82 ± 0.98
Recorded split times						
5 m (s)	1.11 ± 0.07	1.07 ± 0.05*	1.10 ± 0.05	-0.61 ± 0.60	-0.15 ± 0.55	0.59 ± 0.66
10 m (s)	1.86 ± 0.07	1.81 ± 0.08*	1.86 ± 0.06	-0.68 ± 0.66	-0.01 ± 0.50	0.69 ± 0.69
15 m (s)	2.52 ± 0.08	2.45 ± 0.09*	2.50 ± 0.08	-0.84 ± 0.72	-0.25 ± 0.57	0.58 ± 0.66
20 m (s)	3.14 ± 0.10	3.07 ± 0.11*	3.13 ± 0.11	-0.68 ± 0.66	-0.09 ± 0.53	0.54 ± 0.65
30 m (s)	4.35 ± 0.14	4.26 ± 0.14*	4.28 ± 0.13*	-0.64 ± 0.60	-0.50 ± 0.64	0.15 ± 0.54
Time-shifted FV data						
F_0 (N)	669 ± 126	744 ± 148*	717 ± 114	0.56 ± 0.55	0.39 ± 0.61	-0.19 ± 0.56
F_0 (N·kg^{-1})	7.8 ± 1.3	7.8 ± 1.2	7.3 ± 0.9	0.01 ± 0.50	-0.40 ± 0.62	-0.46 ± 0.63
V_0 (m·s^{-1})	8.9 ± 0.6	9.2 ± 0.4	9.5 ± 0.8*	0.54 ± 0.66	0.92 ± 0.73	0.48 ± 0.63
P_{max} (W)	1485 ± 237	1697 ± 315	1687 ± 233	0.81 ± 0.70	0.85 ± 0.73	-0.03 ± 0.51
P_{max} (W·kg^{-1})	17.3 ± 2.4	17.9 ± 2.8	17.2 ± 1.9	0.24 ± 0.56	-0.04 ± 0.51	-0.28 ± 0.58
FV slope	-0.88 ± 0.19	-0.86 ± 0.15	-0.78 ± 0.15	-0.11 ± 0.53	-0.55 ± 0.66	-0.53 ± 0.64
RF_{max} (%)	44.7 ± 2.7	45.3 ± 3.1	44.4 ± 2.4	0.21 ± 0.56	-0.11 ± 0.53	-0.31 ± 0.59
D_{RF} (%)	-8.2 ± 1.7	-8.0 ± 1.3	-7.2 ± 1.4	-0.12 ± 0.54	-0.61 ± 0.67	-0.58 ± 0.66

*Note: F_0 = theoretical maximum force, V_0 = theoretical maximum velocity, Pmax = mechanical power output, FV = force-velocity, RF_{max} = maximum rate of force, D_{RF} = rate of decrease in the rate of force with increasing speed. SMD = standardised mean difference. 95%CL = 95% confidence limits. * difference to < 21 years.* † different to 21-26 years.

Table 3. Comparisons in the anthropometric characteristics, split times, and force-velocity properties according to playing position.

	Positional grouping			SMD ± 95%CL (P value)		
	Hit-up Forward (1) (*n* = 58)	Outside Back (2) (*n* = 40)	Adjustable (3) (*n* = 34)	2 *cf.* 1	3 *cf.* 1	3 *cf.* 2
Age (y)	21.1 ± 4.7	21.3 ± 5.1	20.2 ± 4.5	0.04 ± 0.51	0.19 ± 0.56	-0.22 ± 0.56
Stature (cm)	184.7 ± 5.4	181.3 ± 5.2	175.7 ± 6.0	-0.63 ± 0.67	-1.59 ± 0.87	-0.99 ± 0.76
Body mass (kg)	97.3 ± 9.9	87.6 ± 9.4*	80.4 ± 8.9*†	0.99 ± 0.76	-1.76 ± 0.89	0.78 ± 0.72
Training age (y)	5.3 ± 4.7	5.1 ± 4.8	4.2 ± 4.5	-0.04 ± 0.51	-0.24 ± 0.57	-0.19 ± 0.55
Recorded split times						
5 m (s)	1.11 ± 0.07	1.09 ± 0.06	1.10 ± 0.07	-0.30 ± 0.59	-0.14 ± 0.54	0.15 ± 0.54
10 m (s)	1.87 ± 0.07	1.83 ± 0.08*	1.85 ± 0.07	-0.53 ± 0.65	-0.28 ± 0.58	0.26 ± 0.57
15 m (s)	2.51 ± 0.09	2.47 ± 0.09*	2.50 ± 0.08	-0.44 ± 0.62	-0.11 ± 0.53	0.35 ± 0.60
20 m (s)	3.15 ± 0.10	3.08 ± 0.11*	3.13 ± 0.10	-0.66 ± 0.68	-0.20 ± 0.56	0.47 ± 0.63
30 m (s)	4.36 ± 0.12	4.24 ± 0.15*	4.33 ± 0.13†	-0.89 ± 0.73	-0.24 ± 0.57	0.63 ± 0.67
Time-shifted FV data						
F_0 (N)	750 ± 138	683 ± 119*	612 ± 94*†	-0.51 ± 0.64	-1.10 ± 0.79	-0.64 ± 0.68
F_0 ($N\cdot kg^{-1}$)	7.7 ± 1.3	7.8 ± 1.1	7.7 ± 1.3	0.08 ± 0.52	-0.01 ± 0.50	-0.08 ± 0.52
V_0 ($m\cdot s^{-1}$)	8.93 ± 0.63	9.27 ± 0.55*	9.08 ± 0.65	0.56 ± 0.66	0.23 ± 0.57	-0.31 ± 0.59
P_{max} (W)	1666 ± 278	1577 ± 262	1385 ± 191*†	-0.33 ± 0.59	-1.12 ± 0.79	-0.81 ± 0.72
P_{max} ($W\cdot kg^{-1}$)	17.1 ± 2.4	18.0 ± 2.5	17.3 ± 2.3	0.37 ± 0.60	0.08 ± 0.52	-0.29 ± 0.58
FV slope	-0.88 ± 0.19	-0.85 ± 0.14	-0.85 ± 0.19	-0.17 ± 0.55	-0.16 ± 0.54	-0.01 ± 0.50
RF_{max} (%)	44.5 ± 2.8	45.5 ± 2.8	44.6 ± 2.5	0.35 ± 0.60	0.03 ± 0.51	-0.33 ± 0.59
D_{RF} (%)	-8.1 ± 1.8	-7.8 ± 1.3	-7.9 ± 1.7	-0.18 ± 0.55	-0.11 ± 0.53	0.07 ± 0.51

*Note: F_0 = theoretical maximum force, V_0 = theoretical maximum velocity, Pmax = mechanical power output, FV = force-velocity, RF_{max} = maximum rate of force, D_{RF} = rate of decrease in the rate of force with increasing speed. P values are Bonferroni corrected. SMD = standardised mean difference. 95%CL = 95% confidence limits. * significantly different to hit-up forwards. † significantly different to outside backs.*

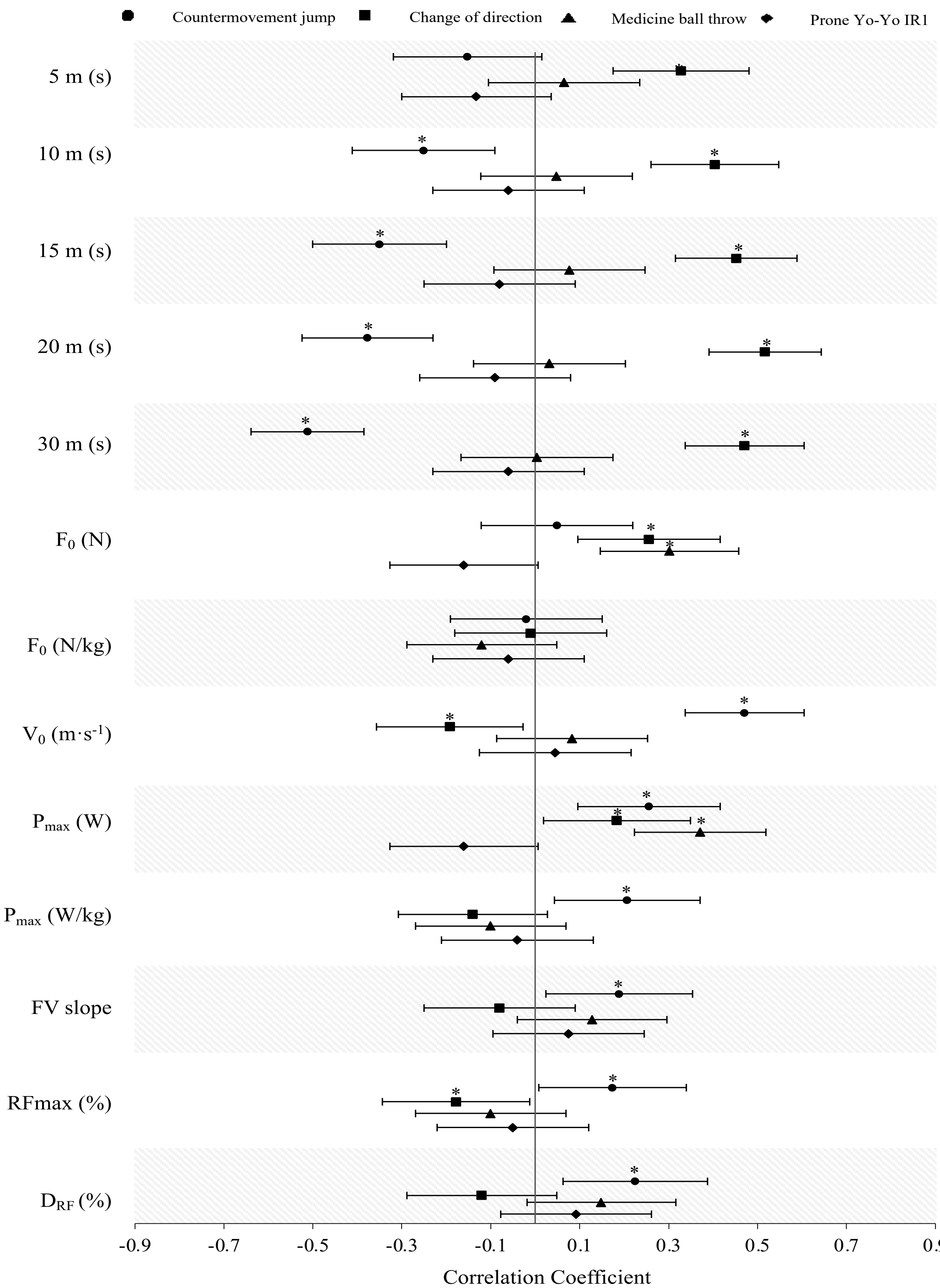

Figure 1. Pearson's correlation (± 95% CL) between sprint split times and mechanical properties with countermovement jump height (circles), change of direction time (squares), medicine ball throw distance (triangles) and prone Yo-Yo IR1 distance (diamonds). * significant correlation.