Whole, half and peak running demands during club and international youth rugby league match-play

Running Head: Running demands of youth rugby league

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Abstract

This study quantified, and compared, the whole- half- and peak-match running demands of professional club and international under-16 rugby league match-play. Four professional Club (*n* = 30) and two International (*n* = 23) under-16 matches were analysed using 10-Hz micro-technology units, with players analysed according to positional groups. Absolute (m) and relative (RD; $m.min^{-1}$) total, high speed (>5 $m \cdot s^{-1}$; HSR) and sprint (>7 $m \cdot s^{-1}$) distance were analysed for whole- and half-match alongside maximum velocity (V_{MAX}; $m.s^{-1}$). Peak running demands were determined via moving averages of RD for 10, 30, and 60- to 600-seconds. International forwards had *most likely* higher whole match relative sprint and V_{MAX}, and 1st half RD than club level, and had *very likely* higher peak running demands at 60-, 180- and 600-second durations. For backs, whole game RD was *most likely* higher and total and sprint distance was *likely* higher at club level matches. Peak RD was also *very likely* higher for club backs at 10- and 60-seconds. The running demand differences between club and international level at the under-16 age group are position dependent, with greater running demands at club level match play for backs, but at the international level of forwards.

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Introduction

Rugby league is an intermittent contact sport, involving frequent bouts of high intensity activity (e.g., high speed running and tackling), interspersed with periods of low intensity activity (e.g., walking and repositioning) (Cummins and Orr 2015; Gabbett 2015; McLellan and Lovell 2013). The sport is played both domestically and internationally, at amateur, semi-professional, and professional standards across junior and senior levels (Johnston, Gabbett and Jenkins 2014), with the two major competitions being the Australasian National Rugby League (NRL) and the European Super League (ESL). Knowledge of the locomotive (e.g., walking, running, sprinting) demands of rugby league match play at these different levels is required for practitioners to optimally prepare players for their current standard (i.e., age and level) and for playing level progressions (i.e., older age groups, and higher standards). To date, extensive research exists evaluating the running demands of rugby league match play using global positioning systems (GPS) across senior levels (Austin and Kelly 2013; Delaney et al. 2015; Gabbett 2013; Hulin et al. 2015; McLellan et al. 2011; Waldron et al. 2011), but is limited within youth elite levels (Waldron et al. 2014).

In the United Kingdom (UK), the first opportunity young players have to train and play within an elite (i.e., professional) team is when they are recruited by a professional rugby league club from the amateur game at the under 16 (U16) age category (Till et al. 2015). Players identified as having the potential to play professionally progress to senior (U19) academy squads; where the primary aim is to develop players for Super League (Till et al. 2017). The physical qualities of players at different age groups and playing level are well established (Ireton et al. 2017; Till et al. 2011; Till et al. 2014), yet within the youth age group (i.e., U16), the match demands have received little attention to date. Waldron et al. (2014) previously investigated the differences in locomotive demands between playing standards (i.e., players who progressed to the next age group *vs.* those who were released) within a ESL club team, showing the higher standard players covered a greater total (5181 ± 1064 *vs.* 3943 ± 1109 m) and high-intensity (>75% individualized maximal aerobic velocity) running distance (1809 ± 369 *vs.* 1281 ± 368 m) during a match, compared to lower standard players.

While the most commonly reported locomotive variable is 'total distance' covered (Hausler et al. 2015), the usefulness of this information may be limited, given the numerous ways (e.g., walking, jogging, sprinting) in which total distance can be accumulated. Expressing total distance relative to time provides 'relative distance' (the distance travelled per minute; $m \cdot min^{-1}$), which is considered a reflection of match 'intensity' (Cummins et al. 2013). However, when considering how total distance is calculated (average velocity x duration), then relative distance is calculated by dividing the total distance covered by total playing time, it is likely important intense periods of activity are missed (e.g., line breaks). Therefore, the identification of 'peak' running demands is required (Hulin et al. 2015; Furlan et al. 2015). Current research on differences in locomotive match demands between playing standard focuses on whole- and half-game values (Gabbett 2013; McLellan and Lovel 2013), thus comparing the peak demands is a novel approach, and may be more sensitive at identifying differences in match demands between playing standards across sports.

The peak running demands can be calculated through a moving averages approach (Varley et al. 2012) for pre-determined duration specific periods. This approach takes a moving average, of a specified duration, of the instantaneous speed ($m \cdot s^{-1}$) which is sampled at a given rate (i.e., 10Hz GPS, 10 instantaneous velocity samples per second). For example, to identify the peak relative distance for a 5-minute period, a moving average of 3000 data points (300-seconds with 10 samples per second) would be calculated from the start to the end of a match. The highest relative distance identified would be deemed the 'peak' 5-minute running demands. This analysis will likely provide more useful information for the practitioners, as these periods are typically what players should be physically prepared for. Using this method of analysis, the peak demands of NRL match play have been identified (Delaney et al. 2015; Delaney et al. 2016). Peak 1-minute periods range from ~163 to 179 $m \cdot min^{-1}$, and peak 10-minute periods range from ~98 to 109 $m \cdot min^{-1}$, dependent upon position (Delaney et al. 2016), which are greater than previously reported whole-match demands (~ 82 to 105 $m \cdot min^{-1}$) (Austin and Kelly 2014; Gabbett 2013; Kempton et al. 2015; Twist et al. 2014). Current research has focused on peak demands from 1- to 10-minutes in duration (Delaney et al. 2015; Delaney et al.2016); however, considering changes in the physiological (Buchheit and Laursen, 2013) and technical-tactical demands as the duration increases, the quantification of both shorter- (i.e., 10- and 30-seconds), and longer- (i.e., 10-minutes) peak running demands are required.

The quantification of running demands is required to provide practitioners with data, which can be useful in practice (Jones et al. 2017). Practitioners are then in a position to use these data to prescribe specific running drills and monitor the intensity of coach led rugby drills. Therefore, the aim of this study was to quantify and compare the whole- half- and peak-running demands of club and international under-16 rugby league match-play.

Methods

Experimental approach

A prospective observational study design was used to establish the locomotive demands of club and international rugby league match play. GPS data were collected during match play of a professional club's Scholarship team competing in the Super League under16s competition, and a representative International Youth (U16s) team (i.e., players recruited from the Super League under16s competition) during the 2017 season. Whole-, half- and peak-running demands were quantified for positional groups at each playing level. The differences between playing levels for positional groups were compared.

Subjects

Forty-eight male rugby league players participated in the study. Thirty players participated in professional club Scholarship matches (Club; mean ± standard deviation [SD] age 15.5 ± 0.7 years, stature 178.0 ± 5.9 cm, body mass 81.9 ± 12.8 kg) and twenty-three participated in England International (International; mean ± SD age 15.8 ± 0.5 years, stature 178.0 ± 5.9 cm, body mass 81.1 ± 5.0 kg) matches. Five players were included in both groups, which was dealt with by the analysis technique used. The study was approved by the university ethics committee. Prior to the commencement of the study, all participants were informed on the purpose, benefits and requirements of the study, and written consent was obtained from players and a parent or guardian.

The number of observations for each player ranged from 1 to 4 (2.3 ± 1.1) and 1 to 2 (1.5 ± 0.5), during Club and International matches, respectively. Based on positional differences observed at the senior level, players were classified into the two commonly used positional groups: forwards (Club, n = 16; International, n = 13) and backs (Club, n = 14; International,

n = 10) (Austin and Kelly 2013; McLellan et al. 2011; McLellan and Lovell 2013). Each match was 70-minutes in duration, with 35-minute halves. The mean ± SD playing time was 54 ± 19 and 58 ± 18 minutes during Club and International matches, respectively. Players were excluded from analysis if their match time was less than 10 minutes per half, due to the analysis of moving averages being up to 10-minutes. The Club won three and drew one match with a mean score difference of 31 ± 25 points, and the International side won two out of two matches with a score difference of 21 ± 15 points.

Methodology

The match demands were evaluated using micro-technology units (Optimeye S5, Catapult Innovations, Melbourne, Victoria) with a GPS receiver sampling at 10-Hz (firmware version 5.27). The use of 10Hz GPS units to quantify distance and speed measurements has been determined as valid and reliable (Scott et al. 2016). Players were familiarised with wearing the units prior to study commencement. The GPS units were worn in tight fitted garments and positioned in the centre of their back between their scapulae. Players wore the same units for repeated observations and the devices were switched on 30 minutes prior to match play to ensure adequate satellite connection and data quality (Malone et al. 2017). The number of satellites and HDOP during match play was 15.1 ± 2.2 (range: 11 - 19) and 0.8 ± 0.2 (range: 0.5 - 1.2) respectively for the Club and 14.7 ± 1.8 (range: 12 - 17) and 0.8 ± 0.2 (range: 0.6 - 1.2) for the International fixtures.

Data analysis

The start and end time for each half was recorded and used to truncate the GPS file. Following each match, data were extracted and analysed using propriety software Openfield (v1.14, Catapult Innovatons, Melbourne, Victoria). Speed was calculated via the Dopler shift method. The minimum effort duration was set at one second (Varley et al. 2012). Locomotor variables analysed for whole-, and half-match, demands were: relative distance covered ($m \cdot min^{-1}$), total distance covered (m), which was further differentiated into the distance covered at high speed running (HSR, m) (> 5 $m \cdot s^{-1}$) and sprinting (m) (> 7 $m \cdot s^{-1}$), relative distance covered at HSR (rHSR, $m \cdot min^{-1}$) and sprinting ($m \cdot min^{-1}$), and maximum velocity (V_{MAX}, $m \cdot s^{-1}$).

To establish peak running demands a file of each sampled instantaneous speed value (i.e., 10-Hz GPS, 10 speed samples per second) were exported. This was then analysed using customized software (R, v R-3.1.3) to compute the moving averages for the distance covered per unit of time (relative distance; $m \cdot min^{-1}$) for duration specific periods (Varley et al. 2012). Peak demand durations of 10- and 30-seconds, and 60- to 600-seconds were calculated. For example, for the 10-second duration, a moving average was calculated every 100 data points (10 samples per second, for 10-seconds), e.g., 0 – 100, 1 – 101, 2 – 102, for the duration of the file. The peak running demands were determined as the highest value for each duration during the total game time for an individual player, then averaged for positional groups.

Statistical Analyses

Prior to analyses, data were log-transformed to reduce bias and non-uniform error (Hopkins et al. 2009). Total and relative sprint distance were analysed as raw data due to the inclusion of zeros, thus cannot be log-transformed. Descriptive data are presented as mean ± SD. Linear mixed-effects models were carried out in SAS Studio Software (4.2, SAS Institute Inc., Cary, NC, USA) to assess differences in the whole and half game locomotor variables, and duration specific peak periods, between Club and International matches. Individual athletes were specified as random effects to account for error associated with repeated measurements, allowing different within-subject SD (Delaney et al. 2016). To account for the variability between matches (Kempton et al. 2013), match identification was also included as a random effect. Level of play, positional group and the interaction of level and positional group, were included as fixed effects to describe their relationships with the dependent variable. Pairwise comparisons between levels of play and positions were assessed using the Least Squares mean test. Differences of Least Squares means were back-transformed to percentage differences, with 90% confidence intervals (CI). Standardized effect sizes (ES) were quantified (reported as ES with 90% CI), and the magnitude-based inference network was used to determine the practical importance of the derived percentage difference (Hopkins 2007). The smallest worthwhile difference (SWD) was calculated as 0.2 x the between-subject SD and assessed qualitatively as follows: <0.5%, *most unlikely*; 0.5 – 5%, *very unlikely*; 5 – 25%, *unlikely*; 25-75%, *possibly*; 75-95% *likely*, 95- 99.5%, *very likely* and >99.5%, *most likely* (Hopkins 2007). If the 90% CI over-lapped positive and negative values of the SWD the magnitude was deemed *unclear*.

Results

Whole- and Half- match demands

The differences in whole- and half- Club and International match running demands for all variables are displayed in Table 1 for backs and Table 2 for forwards.

***** Table 1 near here*****

***** Table 2 near here*****

Peak match demands

Figure 1 presents the peak relative distance for forwards and backs, for 10- and 30-second periods, with the percentage differences between levels and the inference of the differences. During a Club match, backs have *very likely* higher relative distance than during an International match for the 10-second duration (International: 350.3 ± 8.3 ± *vs.* Club: 392.7 ±16.5 $m \cdot min^{-1}$; ES: -0.74 [-1.2 to -0.2]). The difference for forwards at 10-seconds was *unclear* (International: 315.7 ± 17.4 *vs.* Club: 326.1 ± 15.2 $m \cdot min^{-1}$, ES: 0.2 [-0.3 to 6.2]). For 30-seconds, during the International match, forwards *likely* covered greater relative distance than during a Club match (International: 205.0 ± 10.6 *vs.* Club: 194.1 ± 11.9 $m \cdot min^{-1}$; ES: 0.6 [0.1 to 1.1]). The difference between levels for backs at this duration was *unclear* (International: 210.3 ± 6.3 *vs.* Club: 220.8 ± 11.7 $m \cdot min^{-1}$; ES: 0.5 [-0.2 to 1.1]).

***** Figure 1 near here*****

Figures 2 and 3 present the peak relative distance for backs and forwards, for duration specific periods of 60- to 600-seconds, with percentage differences and inferences. For backs, the differences between levels were *unclear* at all durations, except 60-seconds where International was *very likely* lower (International: 157.5 ± 5.6 *vs.* Club: 168.0 ± 5.8 $m \cdot min^{-1}$, ES: -0.7 [-1.0 to -0.3]). The average peak 600-second period during International and Club matches for backs were 101.3 ± 9.5 and 102.5 ± 7.2 $m \cdot min^{-1}$ respectively. Forwards had *very likely* higher peak relative distance at 60-seconds during International compared to Club matches (163.2 ± 10.1 *vs.* 158.5 ± 10.5 $m \cdot min^{-1}$, ES: 0.8 [0.4 to 1.2]). The average peak 600-second duration was also *very likely* higher during the International matches compared to Club matches for forwards (103.7 ± 8.8 *vs.* 99.3 ± 7.6 $m \cdot min^{-1}$; ES: 0.8 [0.2 to 1.3]).

***** Figure 2 near here*****

***** Figure 3 near here*****

Discussion

This study aimed to quantify and compare the the whole- half- and peak-match running demands of Club and International under-16 rugby league match-play. It is the first study to evaluate the peak running demands within youth elite rugby league, and to compare the demands between playing standards. Findings revealed similar peak running demands to those previously reported in professional senior NRL match play (Delaney et al. 2015; Delaney et al. 2016). Contrasting findings between positional groups were found for the comparison between playing standard, with running demands for backs being greater during professional club level matches, but greater for forwards during international level matches.

The differences between the International and Club standard at the youth level show meaningful differences between the two levels, dependent upon position. For backs, there was a difference in whole-game relative distance, and total and relative sprint distance covered between levels, with the largest percentage difference being in the second half for all three parameters, perhaps due to changes in technical-tactical focus in the second half of match-play **(Table 1).** In contrast, for forwards the whole game relative sprint distance was greater during the International compared to Club matches **(Table 2).** Such findings suggest that the whole- and half-match running demands are harder at the international level for forwards but club level for backs, highlighting the position-specific nature of rugby league. However, the differences could also be attributed to differences in the technical-tactical demands and playing style of international *vs.* club level matches, which may have a large impact on due to the small sample size.

The contrasting findings for the whole- and half-match demands between positional groups are also present in the peak running demands. For backs, most of the differences between International and Club matches were *unclear,* except 10- and 60-second durations where relative distance is 10.1 and 3.9% lower respectively, during International compared to a Club matches **(Figures 1 and 2).** During International matches, forwards have greater peak relative distances at several duration specific periods (30-, 60-, 120-, 180-, 300- and 600-seconds) compared to club matches, with the greatest differences at the 60- and 600-second periods **(Figures 1 and 3).** The differences in the running demands between levels observed could be attributed to the closer games (i.e., lower score difference) during International compared to Club matches. For the backs, the closer score-line could lead to more defensive involvements, and consequently more collisions and less running (Roe et al. 2017), as well as fewer chances for line breaks. The higher running demands observed for forwards during international matches are consistent with other studies in which the higher standard of competition encounters higher running demands (Johnston et al. 2015; McLellan and Lovell 2013). In the higher standard of competition with the tighter score lines, the teams could be competing more for field position and spend more time defending. The role forwards play in making attacking meters and preventing meters gained by the opposition in defense, means they are likely to be involved in the game more and perhaps have higher running demands, especially during defensive play (Gabbett et al. 2014; Sykes et al. 2009).

In addition to progressing players through the playing pathway (e.g., amateur to international) at the youth level, the progression of players to senior competition is of equal importance. Therefore, a comparison of the peak running demands of match-play between youth and senior levels is of interest. Both the forwards and backs during Club and International matches in the current study covered less total distance than their respective positional group reported in the NRL (Austin and Kelly 2013; Gabbett 2013; Kempton et al. 2015; Twist et al. 2014) and ESL (Twist et al. 2014; Waldron et al. 2011); likely due to the longer game time in senior NRL and ESL *vs.* youth level (80-minute *vs.* 70-minute). When comparing relative distance, the average match intensities found in this study are within the ranges reported from NRL (~82 to 102 $m \cdot min^{-1}$) (Austin and Kelly 2014; Gabbett 2013) and ESL match play (~94 to 104 $m \cdot min^{-1}$) (Twist et al. 2014; Waldron et al. 2011). The peak running demands are comparable to those reported for NRL matches (Delaney et al. 2015; Delaney et al. 2016). For both playing levels, and positional groups, the duration-specific peak running demands are within ranges reported for respective positions in the NRL studies. For example, NRL 'forwards' peak relative distances for 10- minutes were ~90 to 108 $m \cdot min^{-1}$ (Delaney et al. 2015; Delaney et al. 2016), compared to 103.7 ± 8.8 and 99.3 ± 7.6 $m \cdot min^{-1}$ during International and Club U16 matches in the current study. Similarly, for 'backs' the peak 10-minutes of 101.3 ± 9.5 and 102.5 ± 7.2 $m \cdot min^{-1}$ during International and Club matches are within the range of ~93 to 109 $m \cdot min^{-1}$ reported in the NRL (Delaney et al. 2015; Delaney et al. 2016). Thus, suggesting that the peak running demands are similar to that of NRL match play.

It is however important to acknowledge that this study only quantified the running demands, which does not represent all the physical demands of match play. For example, it is unlikely that U16 players could cope with the physical demands (i.e., contact) of senior NRL or ESL match play, despite the similarity in running demands. Furthermore, the junior players are likely to have a lower body mass than senior players (Ireton et al. 2017) thus it is unlikely that junior players would be able to maintain that running intensity whilst competing against bigger and stronger players (Darrall-Jones et al. 2016; Scott et al. 2017).

The findings demonstrate the running demands are greater during Club and International matches for backs and forwards respectively. However, considering the contact nature of rugby league, these findings are not representative of the overall match-demands. Further research is needed including the collisions encountered during the peak running demands. Additionally, to provide context to the different findings, and determine technical, tactical and skill differences video analysis and game statistics (e.g., completed sets, missed tackles) are necessary. A limitation presented by the current study is the small sample size for matches, particularly at the International level. This was limited by the structure of the season and that there were only two games for the International youth squad throughout the season. The small sample size likely leads to the large confidence intervals observed, thus leading to many *unclear* findings. However, considering minimal matches are played at that level of competition, this study does provide a reference of the demands during different levels of match play, which until now was unknown.

In conclusion, based on the limited sample available, the difference in whole-, half- and peak-match running demands between Club and International match-play is position dependent; for backs they are greater during Club matches, whereas for forwards they are greater during International matches. These findings should be considered when preparing players for progression through the playing pathway. This study also provides duration specific peak running intensities, which can be used to aid in preparing players for intensified periods of match play.

Practical applications

The differences between levels of play highlighted provide coaches and practitioners with indicators of how the running demands change when progressing players to higher levels. For example, forwards competing at the lower levels require an exposure to a higher intensity of locomotor activity during training to prepare for the increased demands at International level. When coaches are selecting or preparing players for International match-play, in addition to the physical fitness of players, other factors (technical, tactical, decision making) should be considered, given the observed higher running demands at the lower level. The short-duration (i.e., 10- and 30-seconds) peak running demands provide duration specific running intensities for running conditioning drills with repeated exposure, and the longer durations (i.e., 10 minutes) can be used to monitor the intensity of coach led rugby drills to replicate match-intensity whilst focusing on technical-tactical ability.

References

Austin DJ, Kelly SJ. 2013. Positional differences in professional rugby league match play through the use of global positioning systems. J Strength Cond Res. 27(1):14-19.

Batterham AM, Hopkins WG. 2006. Making meaningful inferences about magnitudes. Int J Sports Physiol Perform, 1(1):50-57.

Buchheit M, Laursen PB. 2013. High-intensity interval training, solutions to the programming puzzle. Sports Med. 43(5):313-38.

Cummins C, Orr R. 2015. Analysis of physical collisions in elite national rugby league match play. Int J Sports Physiol Perform, 10(6):732-739.

Cummins C, Orr R, O'Connor H, West C. 2013. Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. Sports Med. 43(10):1025-1042.

Darrall-Jones J, Roe G, Carney S, Clayton R, Phibbs P, Read D, Till K, Jones B. 2016. The effect of body mass on the 30-15 intermittent fitness test in rugby union players. Int J Sports Physiol Perform, 11(3):400-403.

Delaney JA, Scott TJ, Thornton HR, Bennett KJ, Gay D, Duthie GM, Dascombe BJ. 2015. Establishing duration-specific running intensities from match-play analysis in rugby league. Int J Sports Physiol Perform, 10(6):725-731.

Delaney JA, Duthie GM, Thornton HR, Scott TJ, Gay D, Dascombe BJ. 2016. Acceleration-based running intensities of professional rugby league match play. Int J Sports Physiol Perform. 11(6):802-809.

Furlan N, Waldron M, Shorter K, Gabbett TJ, Mitchell J, Fitzgerald E, Osborne MA, Gray AJ. 2015. Running-intensity fluctuations in elite rugby sevens performance. Int J Sports Physiol Perform. 10(6):802-807.

Gabbett TJ. 2013. Influence of playing standard on the physical demands of professional rugby league. J Sports Sci. 31(10):1125-1138.

Gabbett TJ. 2015. Relationship between accelerometer load, collisions, and repeated high-intensity effort activity in rugby league players. J Strength Cond Res, 29(12):3424-3431.

Gabbett TJ. 2016. The training-injury prevention paradox: should athletes be training smarter and harder? Br J Sports Med, bjsports-2015.

Gabbett TJ, Gahan CW. 2016. Repeated high-intensity-effort activity in relation to tries scored and conceded during rugby league match play. Int J Sports Physiol Perform. 11(4):530-534.

Gabbett TJ, Jenkins DG, Abernethy B. 2012. Physical demands of professional rugby league training and competition using microtechnology. J Sci Med Sport, 15(1):80-86.

Gabbett TJ, Polley C, Dwyer DB, Kearney S, Corvo A. 2014. Influence of field position and phase of play on the physical demands of match-play in professional rugby league forwards. J Sci Med Sport ,17(5):556-561.

Hopkins WG. 2007. A spreadsheet for deriving a confidence interval, mechanistic inference and clinical inference from a P value. Sport Science. 11:16-21.

Hopkins W, Marshall S, Batterham A, Hanin J. 2009. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 41(1):3.

Hulin BT, Gabbett TJ, Kearney S, Corvo A. 2015. Physical demands of match play in successful and less-successful elite rugby league teams. Int J Sports Physiol Perform. 10(6):703-710.

Hausler J, Halaki M, Orr R. 2016. Application of global positioning system and microsensor technology in competitive rugby league match-play: A systematic review and meta-analysis. Sports Med. 46(4):559-588.

Ireton MR, Till K, Weaving D, Jones B. 2017. Differences in the movement skills and physical qualities of elite senior & academy rugby league players. J Strength Cond Res.

Johnston RD, Gabbett TJ, Jenkins DG. 2014. Applied sport science of rugby league. Sports Med. 44(8):1087-1100.

Johnston RD, Gabbett TJ, Jenkins DG. 2015. Influence of playing standard and physical fitness on activity profiles and post-match fatigue during intensified junior rugby league competition. Sports Med- Open. 1:18.

Jones B, Till K, Emmonds S, Hendricks S, Mackreth P, Darrall-Jones J, Roe G, McGeechan I, Mayhew R, Hunwicks R, Potts N, Clarkson M, Rock A. 2017. Accessing off-field brains in sport; an applied research model to develop practice. Br J Sports M, Epub ahead of print. Doi:10.1136/bjsports-2016-097082.

Kempton T, Sirotic AC, Coutts AJ. 2014. Between match variation in professional rugby league competition. J Sci Med Sport. 17(4):404-407.

Kempton T, Sirotic AC, Rampinini E, Coutts AJ. 2015. Metabolic power demands of rugby league match play. Int J Sports Physiol Perform. 10(1): 23-28.

Malone JJ, Lovell R, Varley MC, Coutts AJ. 2017. Unpacking the black box: applications and considerations for using GPS devices in sport. Int J Sports Physiol Perform. 12:S2-18.

McLellan CP, Lovell DI. 2013. Performance analysis of professional, semi-professional, and junior elite rugby league match-play using global positioning systems. J Strength Cond Res. 27(12):3266-3274.

McLellan CP, Lovell DI, Gass GC. 2011. Performance analysis of elite rugby league match play using global positioning systems. J Strength Cond Res. 25(6):1703-1710.

Roe G, Darrall-Jones J, Till K, Phibbs P, Read D, Weakley J, Rock A, Jones B. 2017. The effect of physical contact on changes in fatigue markers following rugby union field-based training. Eur J Sport Sci. 17(6):647-655.

Scott TJ, Black CR, Quinn J, Coutts AJ. 2013. Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. J Strength Cond Res. 27(1):270-276.

Scott TJ, Duthie GM, Delaney JA, Sanctuary CE, Ballard DA, Hickmans JA, Dascombe BJ. 2017. The validity and contributing physiological factors to 30-15 intermittent fitness test performance in rugby league. J Strength Cond Res. 31(9):2409-2416.

Sykes D, Twist C, Hall S, Nicholas C, Lamb K. 2009. Semi-automated time-motion analysis of senior elite rugby league. Int J Perform Anal Sport. 9(1):47-59.

Till K, Tester E, Jones B, Emmonds S, Fahey J, Cooke C. 2014. Anthropometric and physical characteristics of English academy rugby league players. J Strength Cond Res. 28(2):319-327.

Till K, Cobley S, Morley D, Cupples B, O'Connor D. 2015. Talent Identification and Development in Rugby. Chapter 10. In Till, K. & Jones, B. (Eds.) The Science of Sport: Rugby. Crowood Press.

Till K, Cobley S, O'Hara J, Brightmore A, Cooke C, Chapman C. 2011. Using anthropometric and performance characteristics to predict selection in junior UK Rugby League players. J Sci Med Sport. 14(3):264-269.

Till K, Scantlebury S, Jones B. 2017. Anthropometric and Physical Qualities of Elite Male Youth Rugby League Players. Sports Med. 1-16.

Varley MC, Elias GP, Aughey RJ. 2012. Current match-analysis techniques' underestimation of intense periods of high-velocity running. Int J Sports Physiol Perform. 7(2):183-185.

Varley MC, Jaspers A, Helsen WF, Malone JJ. 2017. Methodological Considerations When Quantifying High-Intensity Efforts in Team Sport Using Global Positioning System Technology. Int J Sports Physiol Perform. 1-25.

Waldron M, Twist C, Highton J, Worsfold P, Daniels M. 2011. Movement and physiological match demands of elite rugby league using portable global positioning systems. J Sports Sci. 29(11):1223-1230.

Waldron M, Worsfold PR, Twist C, Lamb K. 2014. A three-season comparison of match performances among selected and unselected elite youth rugby league players. J Sports Sci, 32(12):1110-1119.

Figure 1. Peak relative distance ($m \cdot min^{-1}$) of temporal durations of 10- and 30- seconds during International and Professional Club match play for A) backs and B) forwards. Differences presented as percentages, standardized effect with 90% confidence limits and magnitude based inferences.

Figure 2. Peak relative distance ($m \cdot min^{-1}$) of temporal durations from 60 to 600 seconds for backs during International and Professional Club match play. Differences presented as percentages, standardized effect with 90% confidence limits and magnitude based inferences.

Figure 3. Peak relative distance ($m \cdot min^{-1}$) of temporal durations from 60 to 600 seconds for forwards during International and Professional Club match play. Differences presented as percentages, standardized effect with 90% confidence limits and magnitude based inferences.

Table 1. Mean (± standard deviation) differences in running based parameters for U16 rugby league backs during club and international matches.

		Club	International	% Differences	Standardized effect	Inference
Relative distance (m·min^{-1})	1st half	89.9 ± 8.7	89.2 ± 9.0	-1.6 (-6.6 to 3.6)	-0.3 (-1.1 to 0.49)	*Unclear*
	2nd half	90.3 ± 8.9	77.8 ± 10.3	-14.4 (-19.4 to -9.1)	-2.2 (-3.1 to -1.3)	*Most likely* ↓
	Full game	89.9 ± 7.3	83.4 ± 9.3	-7.5 (-11.9 to -2.8)	-1.5 (-2.3 to 0.72)	*Most likely* ↓
Total distance covered (m)	1st half	3235.4 ± 366.7	3264.9 ± 263.5	1.3 (-18.9 to 26.8)	0.0 (-0.0 to 0.1)	*Most likely* ↔
	2nd half	3144.4 ± 454.3	3058.8 ± 451.0	-0.3 (-21.0 to 25.9)	-0.0 (-0.6 to 0.6)	*Unclear*
	Full game	5706.7 ± 1566.9	6321.7 ± 635.2	16.5 (-7.9 to 47.3)	0.4 (-0.1 to 1.0)	*Likely* ↑
High speed running distance (m)	1st half	203.6 ± 80.5	207.4 ± 54.9	10.5 (-23.1 to 58.7)	0.2 (-0.3 to 0.6)	*Unclear*
	2nd half	206.3 ± 65.6	190.9 ± 64.5	-1.1 (-32.8 to 45.4)	-0.0 (-0.6 to 0.5)	*Unclear*
	Full game	367.3 ± 155.2	398.3 ± 83.7	23.4 (-13.0 to 74.8)	0.4 (-0.2 to 1.0)	*Possibly* ↑
Relative high speed running distance (m·min^{-1})	1st half	5.7 ± 2.2	5.7 ± 1.5	7.4 (-21.9 to 47.6)	0.1 (-0.4 to 0.6)	*Unclear*
	2nd half	5.9 ± 1.6	4.9 ± 1.6	-16.0 (-36.7 to 11.3)	0.4 (-0.1 to 1.0)	*Possibly* ↑
	Full game	5.7 ± 1.6	5.3 ± 1.1	-1.8 (-23.0 to 25.3)	-0.0 (-0.5 to 0.4)	*Unclear*
Maximum velocity (m·s^{-1})	1st half	7.7 ± 0.8	8.2 ± 0.8	6.8 (-0.4 to 14.4)	0.7 (0.1 to 1.3)	*Likely* ↑
	2nd half	8.1 ± 0.8	7.6 ± 0.7	-6.0 (-12.3 to 0.8)	-0.7 (-1.4 to -0.0)	*Likely* ↓
	Full game	8.1 ± 0.8	8.2 ± 0.8	0.3 (-5.6 to 6.6)	0.6 (0.1 to 1.1)	*Likely* ↑
Sprint distance (m)	1st half	47.7 ± 49.2	43.7 ± 31.9	-5.2 (-28.1 to 17.7)	-0.2 (-0.7 to 0.4)	*Unclear*
	2nd half	66.5 ± 46.8	18.9 ± 24.7	-46.0 (-69.5 to -22.6)	-1.3 (-1.9 to -0.8)	*Most likely* ↓
	Full game	102.3 ± 86.8	62.5 ± 51.0	-38.7 (-77.6 to 0.1)	-0.6 (-1.0 to -0.1)	*Likely* ↓
Relative sprint distance (m·min^{-1})	1st half	1.3 ± 1.4	1.2 ± 0.9	-0.2 (-1.0 to 0.5)	-0.2 (-0.9 to 0.4)	*Unclear*
	2nd half	1.9 ± 1.34	0.5 ± 0.6	-1.4 (-2.1 to -0.7)	-1.4 (-2.0 to -0.8)	*Most likely* ↓
	Full game	1.5 ± 1.2	0.8 ± 0.7	-0.6 (-1.2 to -0.1)	0.0 (-0.6 to 0.7)	*Unclear*

Differences presented as percentages, standardized effect with 90% confidence limits and magnitude based inferences.

Table 2. Mean (± standard deviation) differences in running based parameters for U16 rugby league forwards during club and international matches.

		Club	International	% Differences	Standardized effect	Inference
Relative distance (m·min^{-1})	1st half	85.6 ± 10.4	96.2 ± 8.0	6.6 (1.5 to 11.9)	1.2 (0.4 to 1.9)	*Very likely* ↑
	2nd half	89.5 ± 9.8	86.7 ± 8.9	-3.4 (-8.5 to 2.0)	0.5 (-0.2 to 1.1)	*Likely* ↑
	Full game	88.7 ± 8.8	91.1 ± 7.9	0.8 (-3.5 to 5.2)	0.2 (-0.6 to 0.9)	*Unclear*
Total distance covered (m)	1st half	2403.6 ± 858.1	2535.1 ± 967.5	4.5 (-15.4 to 29.0)	0.1 (-0.1 to 0.4)	*Possibly* ↔
	2nd half	2288.4 ± 866.6	2121.0 ± 850.8	-12.4 (-28.9 to 8.0)	0.4 (-0.1 to 1.0)	*Likely* ↑
	Full game	4063.4 ± 1380.8	4167.9 ± 1651.7	-0.8 (-19.2 to 21.8)	-0.0 (-0.52 to 0.47)	*Unclear*
High speed running distance (m)	1st half	122.7 ± 72.4	138.1 ± 68.6	18.1 (-16.5 to 67.0)	0.3 (-1.1 to 1.2)	*Unclear*
	2nd half	128.5 ± 60.0	103.9 ± 68.3	-37.3 (-55.6 to -11.4)	-0.3 (-0.49 to -0.12)	*Likely* ↓
	Full game	217.9 ± 102.7	217.8 ± 122.3	-11.3 (-34.9 to 20.9)	-0.2 (-0.7 to 0.3)	*Unclear*
Relative high speed running distance (m·min^{-1})	1st half	4.6 ± 2.3	5.3 ± 1.9	26.8 (-6.8 to 72.4)	0.4 (-0.0 to 0.86)	*Likely* ↑
	2nd half	5.2 ± 1.9	4.0 ± 1.8	-27.0(-43.5 to -5.8)	0.7 (0.2 to 1.2)	*Very likely* ↓
	Full game	5.0 ± 1.7	4.6 ± 1.4	-10.2 (-27.8 to 11.6)	0.3 (-0.2 to 0.9)	*Unclear*
Maximum velocity (m·s^{-1})	1st half	7.1 ± 0.8	7.6 ± 0.7	7.6 (0.7 to 14.9)	0.8 (0.2 to 1.4)	*Likely* ↑
	2nd half	7.1 ± 0.7	7.4 ± 0.8	1.1 (-5.0 to 7.6)	0.1 (-0.5 to 0.8)	*Unclear*
	Full game	7.4 ± 0.7	7.9 ± 0.5	7.1 (1.6 to 13.0)	0.9 (0.3 to 1.5)	*Very likely* ↑
Sprint distance (m)	1st half	7.6 ± 13.1	25.6 ± 23.8	16.0 (-6.0 to 38.0)	0.5 (-0.0 to 1.0)	*Likely* ↑
	2nd half	13.3 ± 27.8	21.4 ± 23.2	6.0 (-15.1 to 27.0)	0.2 (-0.3 to 0.7)	*Unclear*
	Full game	18.8 ± 31.4	44.4 ± 34.1	23.3 (-11.0 to 57.5)	0.4 (-0.1 to 0.8)	*Possibly* ↑
Relative sprint distance (m·min^{-1})	1st half	0.4 ± 1.0	0.8 ± 0.7	0.4 (-0.31 to 1.12)	0.5 (-0.2 to 1.2)	*Unclear*
	2nd half	0.6 ± 1.0	0.8 ± 0.8	0.2 (-0.42 to 0.88)	0.2 (-0.3 to 0.8)	*Unclear*
	Full game	0.4 ± 0.6	1.0 ± 0.6	0.6 (0.09 to 1.07)	0.8 (0.5 to 1.1)	*Most likely* ↑

Differences presented as percentages, standardized effect with 90% confidence limits and magnitude based inferences.