Manuscript Title: Match demands of Senior and Junior players during International Rugby League.

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Authors:

Gary M Dempsey[1,2], Neil V Gibson[3], Dave Sykes[3], Brad Pryjmachuk[2], Anthony P Turner[4],

Affiliations:

[1]The English Institute of Sport, Sheffield, United Kingdom.

[2]The Rugby Football League, Leeds, United Kingdom.

[3]Oriam: Scotland's sports performance centre, Edinburgh, United Kingdom.

[4]University of Edinburgh, Edinburgh, United Kingdom

Corresponding Author:

Gary Dempsey, English Institute of Sport, Coleridge Road, Sheffield, S9 5DA, England

Work Tel: +448707590547

Work email: gary.dempsey@eis2win.co.uk

Running Head: International rugby league match demands

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ABSTRACT

This study aims to quantify and compare the positional game demands of international junior and senior rugby league competition for the first time. Global Positioning System (GPS) and video analysis were used to track 118 elite male rugby league players (57 seniors aged 28.7 ± 4.4 y; 61 juniors aged $17.2 \pm .5$ y) over 10 international matches (6 senior; 4 junior) characterized as either forwards ($n = 67$) or backs ($n = 51$). There were significant increases in the offensive carries (0.18 cf. 0.09 $n.\text{min}^{-1}$; r = .56) and defensive tackles (0.36 cf. 0.23 $n.\text{min}^{-1}$; r = .3) between senior and junior players, as well as forwards and backs (0.16 cf. 0.09; r = .34 and 0.41 cf. 0.14; r = .52) respectively. Running demands were significantly greater in backs than forwards (independent of playing level) for total distance (6962 ± 1263 m cf. 4879 ± 1824 m; r = .55), individualized high speed distances (310 ± 158 m cf. 250 ± 171 m; r = .2), high-intensity accelerations (28.7 ± 12.1 m·s^{-1} cf. 21.9 ± 11.7 m·s^{-1}; r = .27) and decelerations (57.2 ± 18.3 m·s^{-1} cf. 43.0 ± 17.8 m·s^{-1}; r = .38). Positional differences were eliminated when reported relative to minutes played. From a practical perspective, whilst running demands relative to time on the pitch may prepare junior players for senior competition, it is not representative of the increased body mass and contact frequency within the senior game. Coaches should therefore reflect these differences within their physical preparation programmes to prepare junior athletes accordingly for progression to the senior level.

Key Words

Movement demands, team sports, position, high-intensity running, playing level.

INTRODUCTION

Success in Rugby League match play is characterized by the need for repeated high-intensity efforts including accelerations, directional changes, high-velocity running, and tackling (28). Empirical research has developed our understanding of the movement demands associated with competitive match play by delineating playing level based on running activities (22, 24). However, repeated sprinting when combined with contact has been shown to drive higher rates of perceived exertion and heart rate than repeated sprinting in isolation (15). Considering match running performance does not appear to underpin the prospective selection policy on elite youth players (32), assessment of in-game running activities alone may not be representative of successful performance at the senior level.

In a comparison of senior State-of-Origin and regular National Rugby League (NRL) fixtures, activity profiles were greater during State-of-Origin match play when characterised by a greater proportion of ball in play (11), suggesting higher levels of competition drive greater playing intensities over longer periods. Furthermore, whilst senior elite players have been shown to cover a greater overall distance and perform more contacts than junior elite players during domestic competitions (12, 22), there has been no comparative investigation into international match play. Therefore, it appears a better understanding is required of the activity profiles associated with elite, international match play at both junior and senior level. Indeed, this would allow coaching staff to identify and develop key performance characteristics in junior elite

players that may facilitate their progression to the senior level. Moreover, it would aid long-term player development by allowing coaching staff to compare junior international performance data to the existing body of data collected from the senior domestic leagues, and identify readiness to progress into the senior ranks.

Consequently, the aim of this study was to describe the positional game demands of international rugby league and establish whether differences exist between senior and junior matches. We hypothesized that data would show that the demands of senior matches are greater than that of junior matches, and secondly that the absolute demands would be greater for backs when compared to forwards.

METHODS

Experimental approach to the problem

This study used a prospective cohort observational design. Global positioning system (GPS) and video data were recorded during 10 international matches (6 senior and 4 junior matches). Total distance, high-intensity distance, high-intensity accelerations and decelerations, and completed tackles were compared by position (forwards vs. backs) and playing level (junior vs. senior). Whilst all of the senior games were recorded in England during the Four Nations 2011 tournament and Summer Tests in June 2012, the four junior match locations were split equally between England and Australia, although conditions at specific locations and time of year were similar (temperature, humidity and precipitation ranges: senior – 1-15 °C, 85-98 %, 0 mm; junior – 4-13 °C, 53-95 %, 0-0.4 mm).

Subjects

Fifty-seven senior international male rugby league players (age 28.7 ± 4.4 y, stature 185.7 ± 6.3 cm, mass 99.0 ± 8.3 kg) and sixty-one junior (under-18) international male rugby league players (age 17.2 ± 0.5 y, stature 182.4 ± 6.4 cm, mass 91.9 ± 7.6 kg) participated in the study. Players were further divided into forwards and backs playing positions for analysis (see table 1). All players were contracted to professional rugby league clubs (115 UK-based and 3 senior NRL-based) training on a full-time basis and represented England at international level. All participants were informed and agreed to the research protocols. Parents provided written consent, and players under 18 provided assent, players 18 years and older provided written consent. Ethics approval for all experimental procedures was granted by the School of Education Research Ethics Committee of the University of Edinburgh.

Procedures

Players were asked to wear an individual GPS unit (Pro-X, GPSports, Canberra, Australia) positioned in the centre of the upper back slightly superior to the shoulder blades at the level of approximately thoracic vertebrae 2 (T2) in a purpose-designed vest (GPSports, Canberra, Australia). The SPI Pro X units measure GPS at 10Hz and contain a 100Hz tri-axial accelerometer. The validity and reliability of the units have been confirmed previously (5,16, 18, 22). GPS units had been worn in every international training session for one season prior to the study. GPS data were assessed through the Team AMS software (Version R1 2012.4, GPSports, Canberra, Australia) and exported to Excel (Microsoft Office 2010, Microsoft Corporation, Redmond, USA) for data management.

All units were switched on and placed in the vest in each player's changing area approximately 20 minutes before arrival at the stadium to minimise disruption to pre-game routines (90 – 110 minutes before kick-off). Only the players' time on the field was collected for analysis (2).

Thus time spent on the bench through injury, substitution, or sin-bin, was removed from data analysis. A stop-watch was synchronized with the software for accurate determination of the start and end of each half of match play. Player interchanges were recorded to the nearest second to allow for accurate 'time on the field' measures. Stoppages (such as video referee or injury time) were included in the study as this represented 'real playing time' resulting in game time exceeding 80 minutes. Players in the position of scrum-half, stand off and hooker were omitted from the analysis due to poor player compliance with the GPS units.

Total distance, high-intensity distance, high intensity accelerations and decelerations were quantified in absolute terms and relative to minutes played. High-intensity running was defined as >65% player's maximum velocity, established using a 40 m maximal sprint performed from 0.5m behind the first timing gate (Brower Timing Systems) during the training period preceding international matches. High-intensity accelerations and decelerations were defined as movements > 3 m·s^{-1} (33). A high speed running threshold of 65% maximum threshold was set to compliment that of the performance analysis system being used by the governing body to monitor games (ProZone 3, ProZone®, Leeds, England). This velocity band falls in similar ranges reported in a recent review by Johnston et al (16).

Video footage for each of the matches were obtained from an elevated location at the half way position. The match was filmed using a high definition video camera (Sony HDR-HC9E Mini DV Handycam, Minato, Tokyo, Japan) and captured in real-time to a laptop (MacBook White, Apple Inc., California, USA) into a video editing software package (iMovie '11, Apple Inc., California, USA) via a logical control bus system (LANC) cable. Following the match, footage was exported as a movie file (.mp4) and was subsequently analysed retrospectively using the bespoke video analysis software. Coded tackles included 1st, 2nd and 3rd man into the tackle

and were only recorded as a tackle if completed. A tackle was complete if the players were in contact and forced a play-the-ball. A play-the-ball resulted in the tackled player rising to his feet and playing the ball backwards with a striking action (2). If the offensive player offloaded the ball this was not recorded as a completed tackle.

Statistical Analysis

The data was tested for normal distribution using the Kolmogorov-Smirnov test for normality, and sphericity was checked using Mauchly's test of sphericity. All variables were presented as means ± standard deviations. A 2x2 (position [forwards vs. backs] x playing level [junior vs. senior]) between-subjects analysis of variance (ANOVA) was used to determine any differences across level and position, using main effects. Statistical significance was set as $P <$ 0.05. Effect sizes were assessed using partial eta squared (partial η2) values which were square-rooted to give correlation coefficients (r) that were compared with the effect sizes given by Hopkins et al. (14); 0-0.1 as trivial, 0.1-0.3 small, 0.3-0.5 moderate, 0.5-0.7 large and 0.7-0.9 as very large. All statistical analysis was conducted using a computer software package (SPSS for Windows, version 17.0; SPSS Inc., Chicago, USA).

RESULTS

The junior and senior activity profiles for forwards and backs positional groups are shown in Table 1. There were significant main effects of player level for contact data (detailed below) but not for running demands (range $F_{(1,114)} < .001$ to 1.902, $P = .171$ to .988, r = .03 to .13) and no significant level*position interaction effects for any variables, with trivial to small effect

sizes (r: 0 to .17). There were significant main effects of position for absolute variables that were accounted for by greater time on pitch in the backs, except for contacts, as detailed below.

Anthropometric data

As expected, a significant main effect of level (independent of position, here and throughout) showed that senior players were significantly heavier than juniors with a moderate effect size $(F_{(1,114)} = 25.33, P <.001, r = .43)$. Additionally, a significant main effect of position (independent of level, here and throughout) showed that forwards were also heavier than the backs with a large effect size $(F_{(1,114)} = 104.442, P <.001, r = .69)$; there was no significant interaction effect $(F_{(1,114)} = 0.587, P = .445, r = .07)$. The same pattern emerged when comparing heights as senior players were significantly taller than juniors with a small effect size $(F_{(1,114)} = 4.781, P = .031, r = 0.2)$, and forwards significantly taller than backs with a large effect size $(F_{(1,114)} = 41.724, P <.001, r = .52)$.

Time on the field

There was a significant main effect of position with a corresponding large effect size $(F_{(1,114)} = 55.6, P < .001, r = .57)$ for playing time between backs and forwards (Table 1).

Contact data

Senior players completed significantly more defensive tackles than junior players both in absolute terms $(F_{(1,114)} = 8.8, P <.01, r = .3)$ and relative to playing time $(F_{(1,114)} = 7.9, P <.01, r = .25)$ with moderate to small effect sizes (Table 1). Senior players also made significantly more absolute offensive carries into contact $(F_{(1,114)} = 53.1, P <.001, r = .56)$, and when expressed relative to playing time $(F_{(1,114)} = 32.2, P <.001, r = .47)$ with large to moderate effect sizes (Table 1).

Forwards completed significantly more tackles than backs both in absolute terms ($F_{(1,114)}$ = 43.3, P <.001, r = .52) and when expressed relative to playing time ($F_{(1,114)}$ = 82.3, P <.001, r = .65) with large effect sizes (Table 1). There was no effect of position on offensive carries ($F_{(1,114)}$ = 0.003, P = 0.95, r = 0) in absolute terms, however, relative to playing time forwards made significantly more offensive carries than backs ($F_{(1,114)}$ = 15.2, P <.001, r = .34) with a moderate effect size (Table 1).

Distance and speed variables

For total distance there was a significant main effect of position and a corresponding large effect size ($F_{(1,114)}$ = 49.0, P <= .001, r = .55), with backs covering greater distances than forwards (Table 1, Figure 1A). When distances covered were analysed relative to playing duration ("relative distance" in m·min^{-1} – Table 1 and Figure 1B) non-significant differences of a trivial nature were observed ($F_{(1,114)}$ = .504, P = .479, r = .06).

Figure 1 near here

For distance at individualised high-intensity speeds, there was a significant main effect of position and corresponding small effect size ($F_{(1,114)}$ = 4.966, P = .028, r = .2) with backs covering greater distances than forwards at high speeds (Table 1). Similar to total distance, when individualised high-intensity distance was normalised relative to playing time ("relative individualised high-intensity distance", Table 1), no main effect of position was evident with a corresponding small effect size ($F_{(1,114)}$ =.573, P = .450, r = 0.22) .

High-intensity accelerations and decelerations

For high-intensity accelerations and decelerations there was a significant main effect of position with small to moderate effect sizes ($F_{(1,114)} = 8.77$, $P = .004$, r = .27 and $F_{(1,114)} = 19.5$, $P < .001$, r = .38 respectively), with backs exposed to more high-intensity accelerations and decelerations than forwards (Table 1). When the high-intensity accelerations and decelerations were analysed relative to playing time ("relative high-intensity accelerations and decelerations", Table 1), there were no main effects of position with small effect sizes ($F_{(1,114)} = 2.446$, $P = .121$, r = .14 and $F_{(1,114)} = 2.185$, $P = .142$, r = .14 respectively).

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

DISCUSSION

This study characterised and contrasted the positional locomotor and contact demands of junior and senior international rugby league players and is the first to conduct such a comparison. In conflict with our initial hypothesis, running demands were independent of playing level, however, there were significant differences between the junior and senior cohorts in defensive and offensive contacts. In support of our second hypothesis, backs had significantly greater total running distances, individualised high-intensity running distances, accelerations, and decelerations, independent of playing level. However, when expressed relative to time on the pitch there were no significant differences between positional running demands. Conversely, forwards had significantly more defensive contacts in both absolute and relative terms, and offensive carries into contact relative to playing time.

A major finding of this study were the moderate to large differences in physical contact demands between playing levels. Senior players made more defensive tackles and offensive carries into contact than their junior counterparts. These findings are supported by Gabbett in

national level rugby league (12), where contact demands were higher during senior NRL compared to junior, under-20 level match play. Additionally, the pooled frequency of defensive tackles (0.29 $n \cdot min^{-1}$) and offensive carries into contact (0.13 $n \cdot min^{-1}$) were similar to those reported by Sirotic et al. (23, 26) (0.25 and 0.15 $n \cdot min^{-1}$ for tackles and play-the-balls, respectively).

Another major finding of this study was there were no significant differences in the running demands of senior and junior international matches, independent of position. A difference between senior and junior levels was hypothesized as it was expected that senior players may obtain higher absolute values in some speed variables due to increased maturation, standard of play, and augmented physical capacity (4, 9, 26). However, locomotor data shows little difference between age group when the information is compared relative to time on the pitch, which corresponds with the aforementioned research by Gabbett (12). In contrast to our findings, McLellan & Lovell (22) showed running demands to be higher in the Australian semi-professional and professional competition than that of the junior level (under-20s). This difference may be attributed to the notably lower distances covered during those junior games (4646 ± 978 m; 78 $m \cdot min^{-1}$). As a result of our findings, junior international competition would appear to provide an effective pathway for preparing players for the running demands of the senior international game.

The largest effect sizes in the current study were for the positional differences in contacts (independent of playing level), emphasising the importance of position-specific conditioning to prepare for international matches. In line with previous research (1, 19, 20) forwards completed more tackles than backs, with the positional effect increasing when expressed relative to minutes played. In contrast to defensive tackles, there was no significant difference

in the number of times forwards and backs carried the ball into contact. However, given the reduced time on the field for forwards, their offensive carries per minute were significantly greater. Moreover, as momentum is the product of mass and velocity, the significantly higher body mass of senior players will lead to increased physical contact demands that may exacerbate the high frequency of contacts found in forward playing positions (25). These findings have clear implications on preparing junior players for senior-level international competition regarding both body mass and resilience.

In the present study, the mean total distances covered in match-play were significantly greater for backs than forwards (Table 1, Figure 1A) which is consistent with previous research (2,6,20,21). While the absolute distances (Table 1) are slightly lower than those reported for senior elite Australian rugby league club matches by Austin and Kelly (2), they are higher than those reported by McLellan et al. (21) for a different NRL team. Therefore, it is difficult to conclude whether the running demands of international rugby league matches are higher than those in the NRL. As research is often based on a single team (19, 20, 30) the comparison of results is difficult due to a range of factors including geographical and environmental influences; differences in fitness level; tactical set-up; and the competitive nature of matches. Indeed, research shows running demands differ when playing a top four ranked team compared to a bottom four ranked team (13). An additional consideration when comparing studies is the influence of data analysis software. The current study aligned with similar research (2, 21) using GPS units from the same manufacturer to minimise this effect. Despite this, Buchheit et al. (3) have demonstrated that software updates can significantly affect the reported data.

The present study found that significantly longer times spent on the pitch accounted for the greater absolute distances covered by backs during match play, as there were no significant

positional differences in relative distance (Table 1 and Figure 1B). Waldron et al. (31) reported slightly higher relative distances of 89 ± 4 m.min^{-1} for forwards and 95 ± 7 m.min^{-1} for backs in their study of 12 Super league players over 12 games. Austin and Kelly (2) studied 28 games throughout an entire season in the NRL and reported similar findings to the current study of 85 ± 4 m.min^{-1} for forwards but a significantly higher rate of 86.5 ± 5 m.min^{-1} for backs. There may therefore be similarities in relative distance demands of senior national level and both junior and senior international matches. This adds support to the assertion that junior international competition is an effective pathway to prepare junior players for the running demands at the elite senior level.

An important finding of the current study is that backs cover a significantly greater distance at high-intensity (Table 1). This may be attributed to field position, as line breaks are more common on the fringes where defence is less compact (7, 30), therefore allowing the attainment of greater running velocities. This is supported in similar research (21, 23), however, the total running distances varied considerably. An important contributing factor to this difference is the thresholds used to define 'high-intensity'. Whilst previous studies have used fixed velocities >18 km.h^{-1} (2, 6, 21, 22), we elected to use velocities normalised to the individual's maximum velocity to help compare relative intensities. Accordingly, the mean thresholds for our data were 19.4 and 21.5 km.h^{-1} for forwards and backs, respectively.

Collectively, the findings of this study suggest that international junior match-play is an effective preparatory step in developing young players for the demands of the senior game. Of note are the non-significant differences between junior and senior match play running demands, which presents the junior international game as an important step in an athlete's long-term progression. Moreover, the significantly greater contact demands and body mass at the senior

level may be insightful for coaches involved in the physical preparation of junior athletes, in order to develop appropriate levels of resilience and mass. It is recommended that coaches monitor successful contact frequency during junior games as a key performance indicator for assessing readiness to progress. This study also provides insight into the position specific demands of international rugby league. Importantly, as forwards are involved in a significantly higher frequency of defensive tackles and backs accumulate significantly greater absolute running demands due to increased time on the pitch, the physical preparation of international rugby league players must reflect the specific needs of the position.

A limitation to the current study is that the data presented reflects movement patterns and contact data recorded during matches, and as such, does not take into account the technical or tactical information, nor the quality of physical performance and final outcome of the match. An interesting area for future research will be to combine the running and contact data with key performance indicators from video analysis, such as movements and contacts associated with scoring points or preventing points being conceded. Nonetheless, the novel movement and contact data presented here are useful for developing conditioning sessions, establishing return-to-play targets and also as simulation models for research studies.

PRACTICAL APPLICATIONS

There are several findings from this study that are relevant to the applied sports scientist and physical preparation coach. First, junior international rugby league competition provides running demands representative of the senior international match play. However, the same running frequency and intensity must be completed with a significantly greater body mass at the senior level. Furthermore, junior international rugby league matches do not present the same overall physical demands of senior international matches, where the contacts experienced

occur with a greater frequency. In turn, this information could be used to ensure players are given appropriate preparation for the increased mass and physicality of senior international rugby league.

Secondly, the greater overall distances covered by back positions, principally as a result of longer time spent on the pitch, may offer support for the increased emphasis on the development of aerobic capacity. Considering the high-intensity nature of many of the running and contact demands outlined in this study, this may be best attained through frequent high intensity running bouts combined with contact efforts and incomplete recovery (16). Finally, due to the more intermittent nature of their involvement (7), forwards may benefit from conditioning which incorporates shorter efforts requiring high intensity accelerations and decelerations, while incorporating higher frequencies of both offensive carries and defensive tackles. It is recommended this be bolstered by appropriate hypertrophy development to reflect the increased positional contact demands.

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Figures and Tables

Figure 1: Comparison of the mean (SD) (A) total distance (m) and (B) relative distance (m.min^{-1}) covered by Senior and Junior back and forward international rugby players. * Significantly different from forwards (p < 0.01) independent of playing level (no interaction).

Table 1: The mean (SD) Anthropometrical, locomotor, and contact variables of forwards and backs across both levels (senior and junior).

Note: $^\wedge$ forwards significantly greater than backs and seniors significantly greater than juniors < .01), * backs significantly greater than forwards ($P < .01$), ** backs significantly greater than forwards ($P < .05$), † forwards significantly greater than backs ($P < .01$), ‡ seniors significantly greater than juniors ($P < .01$).