

A comparison of match demands between elite and semi-elite rugby league competition

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Abstract

The purpose of this study was to examine differences in physical performance and game-specific skills between elite and semi-elite rugby league players during match-play. Time-motion analysis was used to determine physical and game-specific skill match demands in 17 elite and 22 semi-elite rugby league players. Physical performance (time, intensity of exercise, frequency, repeated-sprint ability, and speed measures) and game-specific skill measures (ball carries, supports, ball touches, play-the-balls, and tackles) were recorded per minute of playing time. The main findings were that total intensity (elite: $108.9 \pm 10.6 \text{ m} \cdot \text{min}^{-1}$; semi-elite: $102.3 \pm 9.7 \text{ m} \cdot \text{min}^{-1}$), high-intensity exercise (elite: $36.7 \pm 9.8 \text{ m} \cdot \text{min}^{-1}$; semi-elite: $29.6 \pm 7.8 \text{ m} \cdot \text{min}^{-1}$), mean playing speed (elite: $6.6 \pm 0.6 \text{ km} \cdot \text{h}^{-1}$; semi-elite: $6.2 \pm 0.6 \text{ km} \cdot \text{h}^{-1}$), and support play (elite: $0.29 \pm 0.16 \cdot \text{min}^{-1}$; semi-elite: $0.15 \pm 0.09 \cdot \text{min}^{-1}$) were all higher during first-half match-play in the elite than semi-elite players ($P < 0.01$). The elite players experienced decrements in most physical performance measures during the second-half of match-play ($P < 0.01$), which was not evident in the semi-elite players ($P > 0.01$). There were no differences in most physical performance and game-specific skill measures for the match between the two playing standards. These results show that while the two standards of competition have similar game-specific skills and physical demands during a match, there is variation within a match according to standard. Specifically, the higher physical demands placed on elite players during the first half could result in the earlier onset of physical fatigue towards the end of a match.

Keywords: Match analysis, physical movement patterns, game-specific skills, repeated-sprint bouts

Introduction

Rugby league is an international sport played at many standards, ranging from amateur to elite. In Australia, the National Rugby League (NRL) is the highest standard of competition, while the New South Wales Premier League (NSWPL) forms a “feeder” competition to the NRL. The NSWPL is an important competition, providing a pathway for players to develop physical and game-specific skill attributes in preparation for NRL competition. During a season, NSWPL players might be required to play in the NRL because of injury, match suspension or representative playing commitments of elite players. Accordingly, these semi-elite players are expected to cope with the physical and game-specific skill demands of the higher standard of competition. However, the extent to which match demands of the NSWPL competition prepare semi-elite players physically and technically

to make a successful transition to match-play in the NRL is not clear. Thus, differences in match demands between the two standards need to be assessed so that specific training programmes can be developed.

Time-motion analysis is used to quantify physical and technical movement patterns of team sports and so provide important guidelines for training in a chosen sport (Duthie, Pyne, & Hooper, 2005). This approach has been used in a wide range of team sports, including soccer, rugby union, hockey, and Australian rules football (Dawson, Hopkinson, Appleby, Stewart, & Roberts, 2004; Duthie et al., 2005; Mohr, Krstrup, & Bangsbo, 2003; Spencer et al., 2004). Time-motion analysis can also provide specific information for the physical and technical preparation of players at each competitive standard in rugby league. Such preparation could improve weaknesses in physical performance and game-specific skills for each standard of competition,

making a more successful transition between playing standards.

To date, only two time-motion studies of rugby league have been published (Meir, Arthur, & Forrest, 1993; Meir, Colla, & Milligan, 2001). These studies, which examined the physical and technical match demands of elite rugby league, had limitations, including low sample size (i.e. four players) and investigation of the requirements of several players in one position rather than one player in a position during a match. Furthermore, this research was conducted before the introduction of the 12-man limited interchange rule in 2001. There is no detailed information on the differences in physical and game-specific skill demands between NRL and NSWPL competitions. Such information could identify development requirements needed to meet current top-standard rugby league match demands. Therefore, the aims of this study were to: (1) quantify physical performance and game-specific skill demands in elite rugby league players competing in the NRL and semi-elite players partaking in the NSWPL; and (2) determine the extent to which differences occur both in physical performance and game-specific skill in these two standards of competition.

Methods

Participants

Seventeen elite rugby league players from the NRL (mean $\pm$ s: age 24.8 ± 3.1 years, body mass 95.7 ± 8.1 kg, stature 1.84 ± 0.05 m) and 22 semi-elite players from the NSWPL (age 22.1 ± 2.4 years, body mass 93.8 ± 8.8 kg, stature 1.83 ± 0.05 m) participated in the study. All players were from the same professional NRL club (Parramatta Eels) and were video monitored over two rugby league seasons (2004–2005). Each playing position was filmed on one or more occasion(s) during 16 NRL and 14 NSWPL official matches for a total of 39 NRL and 35 NSWPL match samples analysed. Data collection was “single blind” so that players were unaware they were being video monitored during a match. Voluntary informed consent was obtained from all players before the study commenced. Ethics approval for all experimental procedures was granted by the University Human Research Ethics Committee.

Video procedures

Each player was filmed throughout matches, including all stoppages in play (i.e. injury time, video referee, etc.), at the club’s home ground according to the methods of Sirotic and Coutts (submitted). If a player being filmed was replaced during the match

because of injury or sent from the field by the referee for rule infringement, that player’s match was not analysed. If a player selected to be video monitored was interchanged because of the team’s normal player-substitution routine, the camera continued filming this player on the interchange bench until he returned to the field.

Match-analysis procedure

The match-analysis procedure used has been described elsewhere (Burgess, Naughton, & Norton, 2006; Edgecomb & Norton, 2006). Match-analysis was performed by a trained operator, using a computer-based tracking system (Trak Performance version 2.2, SportsTec Pty Ltd., Sydney, Australia) together with a drawing tablet (intuos2, Wacom Company Ltd., Tokyo, Japan) containing scaled dimensions of a rugby league field. A stylus pen (intuos2 Grip Pen, Wacom Company Ltd., Tokyo, Japan) was used by the trained operator to follow or “track” players around the scaled field continuously from video playback of recorded matches. Rugby league field markings (i.e. 10-m lines and sidelines) were used to establish players’ locations, replicating as closely as possible speed of movement and actual distance covered during all movement activities.

Physical match-analysis data

Analysis of physical match-play activities was determined using the following movement categories based on previous time-motion data (Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007): (a) standing ($0\text{--}1.0 \text{ km} \cdot \text{h}^{-1}$); (b) walking ($1.1\text{--}7.0 \text{ km} \cdot \text{h}^{-1}$); (c) jogging ($7.1\text{--}13.0 \text{ km} \cdot \text{h}^{-1}$); (d) running ($13.1\text{--}18.5 \text{ km} \cdot \text{h}^{-1}$); (e) fast running ($18.6\text{--}24.0 \text{ km} \cdot \text{h}^{-1}$); (f) sprinting ($> 24.0 \text{ km} \cdot \text{h}^{-1}$); (g) low-intensity running (activity below a running speed of $13.1 \text{ km} \cdot \text{h}^{-1}$), (h) high-intensity running (activity above a running speed of $13.1 \text{ km} \cdot \text{h}^{-1}$); and (j) very high-intensity running (activity above a running speed of $18.6 \text{ km} \cdot \text{h}^{-1}$). To analyse backward movements, a computer keyboard stroke was applied on each occasion a player started (keystroke “A”) and completed (keystroke “B”) any movement in a backward direction. Trak Performance software was programmed to recognize these keystrokes and recorded the time that the event occurred.

Distance, speed, and backward movement were collected at a user-selected rate of 20 Hz and reduced to 1-s means by the Trak Performance software, when exported to Microsoft Excel[®] (Microsoft, Redmond, USA). Relative time, intensity of exercise, and frequency of each movement and total(s) were calculated for the first half, second half,

and complete match. Mean recovery time between sprints, mean playing speed, repeated-sprint ability, and changes in speed (acceleration and deceleration) were also determined. Repeated-sprint ability was determined according to the methods of Spencer et al. (2004). Changes in speed were divided into two categories: moderate and rapid. A moderate acceleration or deceleration action was defined as an increase or decrease in speed of between 4 and $8 \text{ km} \cdot \text{h}^{-1}$. A rapid acceleration or deceleration action was defined as an increase or decrease in speed of greater than $8 \text{ km} \cdot \text{h}^{-1}$. Because of variations in playing time due to player interchanges, measures of intensity, frequency, and changes in speed were expressed per minute of playing time.

Game-specific skill match-analysis data

Game-specific skill data from each NRL and NSWPL match were manually coded by the trained operator from video replay of recorded matches. Game-specific skill data were analysed separately from those for physical performance data. Frequency of involvements for the following skills were collected for the first half, second half, and match and expressed per minute of playing time:

- *Ball-carries*: number of times a player travelled a distance of more than two steps in any direction while in possession of the ball.
- *Support-runs*: number of times a player performed a genuine offensive movement close to a ball runner with the intention of receiving the ball or drawing a defender away from the ball runner in an effort to advance the ball towards the opposition's goal line.
- *Touches of the ball*: number of times a player was in contact with the ball; if the player touched the ball more than once after making initial contact with the ball before releasing it, this was recorded as one involvement.
- *Play-the-balls*: number of times a tackled player rose to his feet and played the ball backwards with a striking action.
- *Tackle-made*: number of times a player engaged in physical contact with an opponent while defending, in an effort to stop the opponent from advancing the ball towards the player's goal line.

Reliability

Reliability of the physical match-analysis method is described elsewhere (Sirotic & Coutts, submitted). To assess intra-rater reliability of the game-specific skill analysis method, the first halves of nine rugby league matches were analysed twice. Retest trials

were conducted one month apart to decrease retention of information on selected video footage (Duthie, Pyne, & Hooper, 2003). Student's paired *t*-test revealed no differences between trial 1 and trial 2 for any game-specific skill variable ($P > 0.05$). Precision of the game-specific skill analysis method was assessed using the technical error of measurement (TEM) and intraclass correlation coefficients (ICC) (Table I) (Hopkins, 2000). To identify "real" differences (i.e. greater than error in measurement) in physical and game-specific skill measures between playing standards, the absolute technical error of measurement with 95% confidence intervals (TEM 95% CI) was calculated for all physical and game-specific skill variables for 18 and 9 players respectively during one half of a match.

Statistical analyses

Data were tested for violations of the assumption of normality and homogeneity of variances using the Shapiro-Wilks statistic and Levene's Test for equality in variances respectively. Differences in physical performance and game-specific skill measures between the two standards of competition (i.e. NRL vs. NSWPL) for the first half, second half, and entire match were determined using Student's unpaired *t*-test. Differences in physical performance and game-specific skill measures between the first and second half for elite and semi-elite players were also determined using Student's paired *t*-test. To control for type I error, a pseudo-Bonferroni adjustment was applied by dividing the *P*-value by the number of dependent variable groups (Rampinini et al., 2007): (1) time, (2) intensity of exercise, (3) frequency, (4) speed, and (5) game-specific skill measures. Thus, statistical significance was set at an alpha of 0.01 ($P < 0.05/5$). Relationships between physical performance and game-specific skill measures were determined using Pearson's product-moment correlation coefficient. Statistical significance was set at $P < 0.05$ for all correlation analysis. Analyses were performed using SPSS (Version 15.0, Chicago, IL, USA). All data are reported as means ($\pm s$) unless otherwise stated.

Results

Match time measures

There were no differences in playing times between the two standards of competition for the first half (NRL vs. NSWPL: 2409 ± 545 vs. 2339 ± 406 s), second half (NRL vs. NSWPL: 2412 ± 560 vs. 2214 ± 582 s) or total playing time (NRL vs. NSWPL: 4821 ± 966 vs. 4553 ± 899 s)

($P > 0.01$). Elite players spent 433.7 ± 180.6 , 1041.2 ± 278.7 , 639.8 ± 163.0 , and 2114.7 ± 507.4 s of total match time standing, walking, jogging, and performing low-intensity running respectively. These times were similar to those spent standing (420.1 ± 120.9 s), walking (1076.0 ± 227.0 s), jogging (606.4 ± 125.2 s), and performing low-intensity running (2102.4 ± 372.8 s) by the semi-elite players throughout a match ($P > 0.01$). Elite players performed more high-intensity running and very high-intensity running during the first half and entire match than semi-elite players ($P < 0.01$) (Table II). Elite players spent 3.9 ± 1.6 min between each sprinting bout for the match, which was similar to that for semi-elite players (4.2 ± 1.9 min) ($P > 0.01$). Additionally, time between repeated sprints was 7.7 ± 5.0 and 9.3 ± 5.5 s for elite and semi-elite players,

with sprint durations of 2.1 ± 1.2 and 2.0 ± 0.9 s respectively.

Match intensity of exercise

The elite players ran at higher intensities for the first half than semi-elite players ($P < 0.01$) (Table II). Elite players also showed a greater intensity for high-intensity running and very high-intensity running during the first half than semi-elite players ($P < 0.01$) (Table II). The elite players showed match intensities of 30.0 ± 4.1 , 41.6 ± 5.4 , and 71.7 ± 5.0 m $\cdot$ min $^{-1}$ for walking, jogging, and low-intensity running respectively, which was similar to those for walking (31.7 ± 3.3 m $\cdot$ min $^{-1}$), jogging (41.2 ± 4.4 m $\cdot$ min $^{-1}$), and low-intensity running (72.9 ± 4.7 m $\cdot$ min $^{-1}$) for semi-elite players ($P > 0.01$). Elite and semi-elite players had similar

Table I. Reliability data for intra-rater analysis of game-specific skills, expressed as the number of occurrences per minute between two trials of one half of rugby league time-motion analysis ($n = 9$).

	Ball carries	Support runs	Touches of the ball	Play-the-balls	Tackles made
Mean value ($\pm$ s)	0.195 ± 0.110	0.239 ± 0.088	0.493 ± 0.358	0.164 ± 0.119	0.318 ± 0.173
Mean difference ($\pm$ s)	-0.005 ± 0.010	-0.003 ± 0.015	0.020 ± 0.026	-0.005 ± 0.010	-0.004 ± 0.023
TEM	0.008	0.010	0.022	0.008	0.015
ICC	0.996	0.986	0.997	0.997	0.991

Note: TEM = technical error of measurement; ICC = intraclass correlation coefficient.

Table II. Differences in physical performance among National Rugby League and NSW Premier League players during the first half of rugby league matches.

Variables	National Rugby League ($n = 39$)	NSW Premier League ($n = 35$)	Difference mean value	TEM 95% CI	P-value
Intensity of exercise (m $\cdot$ min^{-1})					
Total intensity of exercise	108.9 ± 10.6^c	102.2 ± 9.8	6.7^d	2.15 to 4.30	0.007^a
High-intensity running exercise	36.7 ± 9.8^c	29.6 ± 7.8	7.1^d	1.89 to 3.77	0.001^a
Very high-intensity running exercise	14.4 ± 5.1^c	11.5 ± 3.8	2.9^d	0.92 to 1.83	0.007^a
Running exercise	22.3 ± 5.7^c	18.1 ± 5.1	4.2^d	1.42 to 2.83	0.001^a
Fast running exercise	9.0 ± 3.5	7.1 ± 2.4	1.9^d	0.78 to 1.57	0.007^a
Sprinting exercise	5.4 ± 2.3^c	4.5 ± 2.0	0.9^d	0.43 to 0.85	0.058
Time variables (s)					
Time spent at high-intensity running	294.0 ± 77.3^c	236.6 ± 72.3	57.4^d	15.65 to 31.26	0.002^a
Time spent at very high-intensity running	87.2 ± 29.2^c	70.8 ± 28.0	16.4^d	6.15 to 12.29	0.010^a
Time spent running	206.8 ± 55.7	165.8 ± 49.8	41.0^d	14.20 to 28.36	0.001^a
Time spent fast running	59.7 ± 19.8	48.3 ± 19.1	11.4^d	5.54 to 11.06	0.010^a
Time spent sprinting	27.5 ± 12.3^c	22.5 ± 11.3	5.0^d	2.33 to 4.66	0.071
Frequency (n $\cdot$ min^{-1})					
Total frequency	18.3 ± 1.9	17.5 ± 1.7	0.8	0.49 to 0.97	0.074
Running frequency	2.9 ± 0.7^c	2.4 ± 0.5	0.5^d	0.14 to 0.29	0.001^a
Fast running frequency	1.0 ± 0.4	0.8 ± 0.2	0.2^d	0.08 to 0.16	0.006^a
Sprinting frequency	0.31 ± 0.13^c	0.25 ± 0.11	0.06^d	0.02 to 0.04	0.054
Changes of speed (n $\cdot$ min^{-1})					
Total accelerations	3.8 ± 0.8^c	3.3 ± 0.7	0.5^d	0.17 to 0.33	0.008^a
Total decelerations	3.7 ± 0.8^c	3.2 ± 0.7	0.5^d	0.16 to 0.31	0.003^a

Notes: ^aSignificant difference ($P < 0.01$; with pseudo-Bonferroni adjustment) between the two groups of players. ^bSignificant difference ($P < 0.05$) between the two groups of players. ^cSignificant difference ($P < 0.01$) between the first and second half variable. TEM = technical error of measurement; CI = confidence interval; ^dAbove the upper level of TEM 95% CI.

exercise intensities during backward movement for the first half (8.3 ± 5.5 vs. 7.1 ± 4.8 m · min⁻¹), second half (8.2 ± 6.2 vs. 6.8 ± 4.5 m · min⁻¹), and entire match (8.3 ± 5.7 vs. 6.9 ± 4.5 m · min⁻¹) respectively ($P > 0.01$).

Match frequency measures

During the first half, run- and fast-run rates were higher in elite players than semi-elite players ($P < 0.01$) (Table II). While there was no difference in second-half run- or fast-run rates between the two standards of competition ($P > 0.01$) (Table III), elite players had a higher run-rate for the match than semi-elite players ($P < 0.01$) (Table IV). The range in the number of repeated-sprint bouts performed during elite and semi-elite rugby league matches was 0–3 and 0–1, with 3.0 ± 0.3 and 3.0 ± 0.4 sprints completed during a repeated-sprint bout, respectively.

Match speed measures

Figure 1 shows playing speed for the two standards of competition for the first half, second half, and entire match. In terms of total playing time, elite players performed 3.2 ± 0.6 and 0.5 ± 0.2 moderate and rapid accelerations per minute respectively, and 3.1 ± 0.6 and 0.5 ± 0.2 moderate and rapid decelerations per minute respectively. This was similar to

the number of moderate and rapid accelerations (2.9 ± 0.5 and 0.4 ± 0.2 respectively), and moderate and rapid decelerations (2.8 ± 0.5 and 0.4 ± 0.2 respectively), completed per minute of match time for semi-elite players ($P > 0.01$). Elite players performed more total accelerations and decelerations per minute during the first half than semi-elite players ($P < 0.01$) (Table II). Elite players also completed more moderate decelerations per minute during the first half than semi-elite players (3.2 ± 0.7 vs. 2.8 ± 0.7) ($P < 0.01$).

Match game-specific skill measures

Elite players completed more support runs per minute than semi-elite players during the first half, second half, and entire match ($P < 0.01$) (Table V). There were no differences in any other game-specific skill measures for the first half, second half or match between the two standards of competition ($P > 0.01$). The NRL match data demonstrated a moderate relationship between the number of supports performed per minute of total playing time and intensity of exercise for very high-intensity running ($r = 0.59$), fast run ($r = 0.60$) and sprint ($r = 0.65$) bouts completed per minute, relative time spent at very high-intensity running ($r = 0.59$), and number of rapid accelerations completed per minute of total playing time ($r = 0.48$) (all $P < 0.001$; $n = 39$).

Table III. Differences in physical performance among National Rugby League and NSW Premier League players during the second half of rugby league matches.

Variables	National Rugby League ($n = 39$)	NSW Premier League ($n = 35$)	Difference mean value	TEM 95% CI	P-value
Intensity of exercise (m · min⁻¹)					
Total intensity of exercise	103.6 ± 10.8^c	104.4 ± 8.9	-0.8	2.15 to 4.30	0.714
High-intensity running exercise	32.5 ± 8.4^c	30.9 ± 8.5	1.6	1.89 to 3.77	0.410
Very high-intensity running exercise	12.2 ± 4.8^c	11.6 ± 4.6	0.6	0.92 to 1.83	0.608
Running exercise	20.3 ± 5.6^c	19.2 ± 5.2	1.1	1.42 to 2.83	0.396
Fast running exercise	7.8 ± 3.0	7.2 ± 2.9	0.6	0.78 to 1.57	0.428
Sprinting exercise	4.4 ± 2.6^c	4.4 ± 2.1	0.0	0.43 to 0.85	0.976
Time variables (s)					
Time spent at high-intensity running	269.3 ± 86.3^c	229.0 ± 67.7	40.3^d	15.65 to 31.26	0.028^b
Time spent at very high-intensity running	76.8 ± 33.0^c	65.7 ± 28.8	11.1	6.15 to 12.29	0.128
Time spent running	192.5 ± 65.8	163.3 ± 45.7	29.2^d	14.20 to 28.36	0.029^b
Time spent fast running	54.2 ± 22.3	45.0 ± 19.1	9.2	5.54 to 11.06	0.060
Time spent sprinting	22.6 ± 14.6^c	20.7 ± 11.6	1.9	2.33 to 4.66	0.546
Frequency (n · min⁻¹)					
Total frequency	17.9 ± 1.8	18.0 ± 1.4	-0.1	0.49 to 0.97	0.876
Running frequency	2.6 ± 0.6^c	2.5 ± 0.6	0.1	0.14 to 0.29	0.274
Fast running frequency	0.9 ± 0.3	0.8 ± 0.3	0.1	0.08 to 0.16	0.185
Sprinting frequency	0.25 ± 0.13^c	0.25 ± 0.12	0.0	0.02 to 0.04	0.892
Changes of speed (n · min⁻¹)					
Total accelerations	3.5 ± 0.8^c	3.4 ± 0.7	0.1	0.17 to 0.33	0.480
Total decelerations	3.4 ± 0.6^c	3.3 ± 0.7	0.1	0.16 to 0.31	0.778

Notes: ^aSignificant difference ($P < 0.01$; with pseudo-Bonferroni adjustment) between the two groups of players. ^bSignificant difference ($P < 0.05$) between the two groups of players. ^cSignificant difference ($P < 0.01$) between the first and second half variable. TEM = technical error of measurement; CI = confidence interval; ^dAbove the upper level of TEM 95% CI.

Discussion

This study is the first to examine differences in physical performance and game-specific skills between elite and semi-elite rugby league competition. Results show that differences exist in physical and game-specific skills within a match between the two standards of competition. However, overall physical match demands and game-specific skills were similar between the two playing standards. Specifically, elite

players engaged in more high-intensity activity in the first half most likely due to increases in support play. These higher physical demands placed on elite players during the first half could result in an earlier onset of physical fatigue towards the end of a match.

Results show that elite players perform at higher exercise intensities during the first half of a match than semi-elite players, primarily because of the increased intensity for high-intensity running and very high-intensity running. This is in line with

Table IV. Differences in physical performance among National Rugby League and NSW Premier League players for the entire duration of rugby league matches.

Variables	National Rugby League ($n = 39$)	NSW Premier League ($n = 35$)	Difference mean value	TEM 95% CI	<i>P</i> -value
Intensity of exercise ($\text{m} \cdot \text{min}^{-1}$)					
Total intensity of exercise	106.0 ± 9.3	103.0 ± 8.1	3.0^c	2.15 to 4.30	0.139
High-intensity running exercise	34.3 ± 7.9	30.1 ± 7.5	4.2^d	1.89 to 3.77	0.019^b
Very high-intensity running exercise	13.1 ± 4.2	11.5 ± 3.7	1.6^c	0.92 to 1.83	0.088
Running exercise	21.2 ± 5.1	18.6 ± 4.7	2.6^c	1.42 to 2.83	0.021^b
Fast running exercise	8.2 ± 2.6	7.1 ± 2.4	1.1^c	0.78 to 1.57	0.047^b
Sprinting exercise	4.9 ± 2.2	4.4 ± 1.6	0.5^c	0.43 to 0.85	0.333
Time variables (s)					
Time spent at high-intensity running	563.3 ± 146.4	465.6 ± 129.1	97.7^d	15.65 to 31.26	0.003^a
Time spent at very high-intensity running	164.0 ± 58.7	136.5 ± 52.7	27.5^{cd}	6.15 to 12.29	0.037^b
Time spent running	399.3 ± 106.6	329.1 ± 86.7	70.2^{cd}	14.20 to 28.36	0.003^a
Time spent fast running	113.8 ± 38.5	93.3 ± 36.1	20.5^{cd}	5.54 to 11.06	0.020^b
Time spent sprinting	50.1 ± 25.0	43.3 ± 18.9	6.8^{cd}	2.33 to 4.66	0.184
Frequency ($\text{n} \cdot \text{min}^{-1}$)					
Total frequency	18.1 ± 1.7	17.1 ± 1.4	1.0^d	0.49 to 0.97	0.303
Running frequency	2.7 ± 0.6	2.4 ± 0.5	0.3^d	0.14 to 0.29	0.009^a
Fast running frequency	0.9 ± 0.3	0.8 ± 0.3	0.1^c	0.08 to 0.16	0.028^b
Sprinting frequency	0.3 ± 0.1	0.3 ± 0.1	0.0^c	0.02 to 0.04	0.321
Changes of speed ($\text{n} \cdot \text{min}^{-1}$)					
Total accelerations	3.7 ± 0.7	3.4 ± 0.6	0.3^c	0.17 to 0.33	0.060
Total decelerations	3.5 ± 0.6	3.2 ± 0.6	0.3^c	0.16 to 0.31	0.038^b

Notes: ^aSignificant difference ($P < 0.01$; with pseudo-Bonferroni adjustment) between the two groups of players. ^bSignificant difference ($P < 0.05$) between the two groups of players. ^cSignificant difference ($P < 0.01$) between the first and second half variable. TEM = technical error of measurement; CI = confidence interval; ^dAbove the upper level of TEM 95% CI.

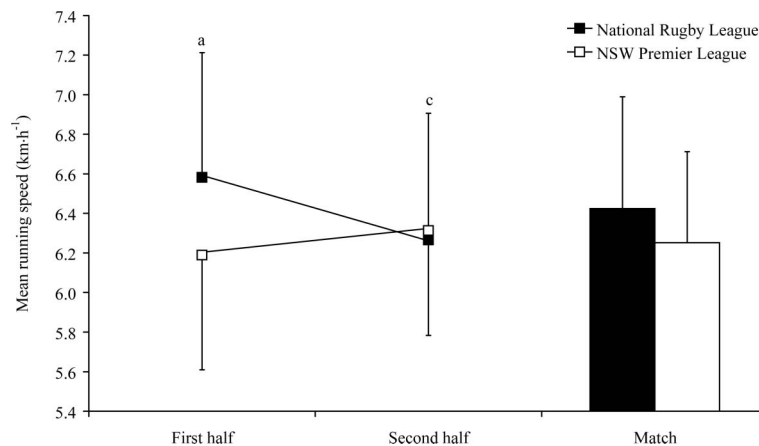


Figure 1. Mean running speed for National Rugby League (NRL; $n = 39$) and NSW Premier League ($n = 35$) players for the first half, second half, and entire match. ^aSignificant difference between the two playing standards ($P < 0.01$; with pseudo-Bonferroni adjustment). ^cSignificantly different from the first half for the elite players competing in the NRL ($P < 0.01$; with pseudo-Bonferroni adjustment).

Table V. Differences in game-specific skill involvement among National Rugby League and NSW Premier League players during the first half, second half and entire duration of rugby league matches.

Variables ($n \cdot \text{min}^{-1}$)	National Rugby League ($n = 39$)	NSW Premier League ($n = 35$)	Difference mean value	TEM 95% CI	P-value
First half					
Carries	0.16 ± 0.09	0.16 ± 0.08	0.00	0.00 to 0.01	0.860
Support runs	0.29 ± 0.16	0.15 ± 0.09	0.14^d	0.01 to 0.02	0.000 ^a
Touches of the ball	0.44 ± 0.35	0.45 ± 0.39	-0.01	0.01 to 0.03	0.904
Play-the-ball	0.12 ± 0.07	0.12 ± 0.09	0.00	0.00 to 0.01	0.968
Tackles made	0.26 ± 0.18	0.30 ± 0.17	-0.04^d	0.01 to 0.03	0.393
Second half					
Carries	0.15 ± 0.09	0.15 ± 0.10	0.00	0.00 to 0.01	0.693
Support runs	0.25 ± 0.16	0.15 ± 0.08	0.10^d	0.01 to 0.02	0.001 ^a
Touches of the ball	0.42 ± 0.35	0.41 ± 0.34	0.01	0.01 to 0.03	0.820
Play-the-ball	0.11 ± 0.07	0.11 ± 0.10	0.00	0.00 to 0.01	0.872
Tackles made	0.23 ± 0.16	0.27 ± 0.16	-0.04^d	0.01 to 0.03	0.332
Entire match					
Carries	0.15 ± 0.08	0.15 ± 0.08	0.00	0.00 to 0.01	0.928
Support runs	0.27 ± 0.14	0.15 ± 0.07	0.12^d	0.01 to 0.02	0.000 ^a
Touches of the ball	0.43 ± 0.34	0.43 ± 0.35	0.00	0.01 to 0.03	0.981
Play-the-ball	0.12 ± 0.06	0.12 ± 0.08	0.00	0.00 to 0.01	0.798
Tackles made	0.25 ± 0.16	0.28 ± 0.16	-0.03	0.01 to 0.03	0.368

Notes: ^aSignificant difference ($P < 0.01$; with pseudo-Bonferroni adjustment) between the two groups of players. ^bSignificant difference ($P < 0.05$) between the two groups of players. ^cSignificant difference ($P < 0.01$) between the first and second half variable. TEM = technical error of measurement; CI = confidence interval; ^dAbove the upper level of TEM 95% CI.

previous research reporting greater total (~ 0.5 km) and high-intensity running distances travelled by 18 top-class than 24 moderate professional soccer players (Mohr et al., 2003). In this study, the higher intensity for high-intensity running during the first half might be related to the higher number of supports completed by the elite than semi-elite players. The increased number of support runs might also explain the increase in high-intensity running bouts, as well as accelerations and decelerations performed by elite players. This is supported by the moderate relationship observed between high-intensity activity indices and support runs performed during the first half, second half, and throughout the entire match. Overall, these results demonstrate that there is a greater physical demand placed on elite than semi-elite players during the first half of a match.

While the elite players performed more high-intensity activities during the first half, the total amount of high-intensity activities performed during a match was similar between the two standards of competition. Moreover, most physical performance measures during the second half and throughout the entire match showed no difference between the two playing standards. This similarity in physical match demands might have resulted from the reductions in total intensity of exercise, high-intensity activities, and accelerations of elite players during the second compared with the first half. In contrast, no differences in physical performance were shown for semi-elite players between the two halves. Although

not statistically significant, semi-elite players increased their total intensity of exercise, performed more high-intensity activities, and completed more total movement bouts during the second than the first half. This is consistent with previous research showing total distance and high-intensity bouts to decrease during the second half of matches in 18 top-class soccer players, while 24 moderate soccer players showed no decrease in the same physical performance measures during the second half (Mohr et al., 2003). Thus, the greater high-intensity demands placed on elite players during the first half might cause an earlier onset of physical fatigue and decrease performance during the second half. This could be related to factors such as dehydration, muscle glycogen depletion, inadequate resynthesis of ATP and phosphocreatine, and lowered pH and muscle lactate accumulation (Bangsbo, Iaia, & Krustrup, 2007).

There is an increased awareness of the importance of players being able to repeat brief duration sprints in a short period of time in team-sports (Dawson, Fitzsimons, & Ward, 1993; Spencer et al., 2004). This is the first study to show that repeated-sprint bouts rarely occur during high-standard rugby league competition, with between 0 and 3 repeated-sprint bouts being observed during a match. This is similar to previous research reporting 0–4 repeated-sprint bouts, depending on playing position, during an international field hockey game for 14 Australian representative male field hockey players (Spencer et al., 2004). The rarity of repeated-sprint bouts

during high-standard rugby league match-play could be because of the nature of the game or team tactics, which can restrict the amount of pitch area that a player has to accelerate before coming into contact with or being slowed down by an opposing player. However, despite the low occurrence of repeated-sprint bouts in rugby league, these events might occur at critical times during a match (Spencer et al., 2004). For example, when defending, repeated-sprint efforts might occur between successive tackles or collisions, increasing the physical cost. Therefore, we recommend that rugby league players train for repeated high-intensity efforts involving game-specific skills such as hit-ups, support runs or tackling to prepare physically for the worst-case scenario during a rugby league match at all competitive standards.

While high physical effort is likely to contribute to a successful match performance, overall performance is also determined by game-specific skills and the abilities of players (Gabbett, Kelly, & Pezet, 2007). The present results show that elite players support the ball carrier on more occasions than semi-elite players during a match. This is most likely because of the higher match speed and greater game-specific skill ability of NRL players, which might require these players to provide more decoy runners and ball movement to try to break the defensive line. Although no studies have examined differences in game-specific skill abilities between the two playing standards, previous research has reported that with the introduction of the 10-m defensive rule, elite players started running more in support of the ball carrier because of greater space and ball movement within an attacking team (Meir et al., 2001). Conversely, different styles of coaching or team tactics between the two standards of competition could also explain the difference in the number of support runs performed. However, no differences were observed in any other game-specific skills during match-play between the two standards of competition. These results demonstrate that very little variation exists in the amount of game-specific involvement during a match between the two playing standards. Therefore, we recommend that semi-elite players train to increase their ability to support the ball carrier, according to the team's style of play.

An understanding of the limitations of time-motion studies would help to minimize the incorrect use of physical and technical match data in a practical setting (Dobson & Keogh, 2007). A limitation of this study was that all rugby league players analysed were from the same NRL club. Inherently, training structures and coaching styles might vary between clubs, which could affect the physical and skill activities performed during a

match. Thus, the results of this study might not be indicative of all NRL clubs. However, the results do serve the purpose of adding to the knowledge accrued nearly a decade ago (Meir et al., 1993, 2001). In addition, the bias associated with one player being analysed per game and differences between individual matches, possibly because of varying team tactics, also needs to be acknowledged as a potential limitation (Dobson & Keogh, 2007; Meir et al., 1993). However, the use of 39 NRL and 35 NSWPL match samples should provide an acceptable representation of elite and semi-elite rugby league competition, respectively (O'Donoghue, 2004). Another limitation is the systematic error associated with computer-based tracking (Burgess et al., 2006). It has been suggested that time-motion results need to be interpreted in conjunction with the error of measurement to identify "real" differences (Sirotic & Coutts, 2008). We have reported the measurement error of all physical and game-specific skill measures so that "real" differences, independent of systematic error, can be determined.

Conclusion

This study is the first to describe the physical performance and game-specific skills of elite and semi-elite rugby league competition. Results show that while the two standards of competition have similar physical and game-specific skill demands placed on them during matches, variations do exist within a match between the two playing standards. The higher physical demands placed on elite players during the first half could cause a reduction in physical performance during the second half. Future studies need to investigate the effect of first-half high-intensity activity on subsequent second-half physical performance among elite rugby league players. Given the likely crucial time when repeated-sprint bouts occur, we suggest that rugby league players train repeated-sprint ability involving game-specific skills, such as hit-ups, support runs or tackling, to prepare physically for the worst-case scenario during a match.

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