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ORIGINAL ARTICLE

Fluctuations in running and skill-related performance in elite rugby union match-play

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Abstract
This study investigated end-game and transient changes in running activities and whether these were concomitantly associated with reductions in skill-related performance in senior international rugby union match-play. Altogether, 18 official matches were analysed (322 individual observations) using computerised video-based tracking and event coding (Amisco Pro®, SUP, Nice, France). In forwards and backs, trivial to small reductions (% difference: −2.1, ±1.3 to −10.0, ±4.0%) in total distance and that covered at high speeds (>18.0 km h^{-1}) occurred in the second- versus the first-half while there were trivial differences in skill-related performance measures (−2.3, ±4.5 to 7.5, ±14.0%). In both positions, small to moderate declines (−42, ±10 to −21, ±7%) occurred in high-speed running in the final 10-min and 5-min periods versus mean values for all other 10-min and 5-min periods throughout the game while only small changes (−18, ±51 to 13, ±41%) in skill-related performance were observed. Trivial changes in running and skill-related performance (−11, ±74 to 7, ±39%) were observed in the 5-min period immediately following the most intense 5-minute periods of play compared to mean performance over the other 5-min periods. These findings suggest that international rugby union players were generally able to maintain skill-related performance over the course of match-play even when declines in running performance occurred.

Keywords: *Performance; fatigue; team sport; skill*

Introduction

In elite rugby union match-play, a large body of literature has described the physical demands using time-motion analyses of running activities, such as the total distance covered and that travelled at high-speeds. In comparison, patterns of fatigue represented by declines in distances covered have received less attention. Investigations have nevertheless reported that running activity (e.g. total distance, high-speed running) was frequently unaffected across match halves, quarters and 10-minute intervals (Cunniffe, Proctor, Baker, & Davies, 2009; Duthie, Pyne, & Hooper, 2005; Lacome, Piscione, Hager, & Bourdin, 2014; Roberts, Trewartha, Higgitt, El-Abd, & Stokes, 2008). Thus, it would seem that elite players generally do not experience accumulated 'fatigue' manifested by a progressive drop in running activity over the course of play although further research particularly at international standards and using a larger number of match observations is warranted. Studies notably in elite rugby league (Kempton, Sirotic, & Coutts, 2014) and soccer (Bradley & Noakes, 2013; Carling & Dupont, 2011) have also examined running performance in the very latter stages of match-play (e.g. final 5-minute period). Kempton et al. (2014) reported that overall distance covered in the final 5 minutes of rugby league matches declined significantly (~14% decrease) in comparison to the first 5-minute period suggesting that players were possibly fatigued in the closing stages of play. A similar temporal analysis of running performance is warranted in elite rugby union as previous analyses of 10-minute intervals did not demonstrate any reductions in activity. This information has the potential to

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identify whether fatigue represented by a decline in distance run occurs at the very end of play thereby informing coach decision-making (e.g. substitutions, tactics) particularly if the match result is still undecided.

To our knowledge, there is no information on the existence of transient fatigue represented by temporary reductions in running activity in elite rugby union competition. Research in elite soccer and rugby league has shown that high-speed distance in the 5-minute period immediately following the most intense 5-minute period of activity was reduced in comparison to the mean value for all the other 5-minute match periods (Bradley & Noakes, 2013; Kempton, Sirotic, Cameron, & Coutts, 2013). However, conflicting results exist in rugby league (Hulin & Gabbett, 2015; Hulin, Gabbett, Kearney, & Corvo, 2015) as sub-elite and elite players maintained performance following the peak 5-min activity period. Research into these aforementioned areas is warranted in an attempt to determine whether transient changes also occur in elite rugby union match-play. Data could inform prescription of physical conditioning regimens in order to help prepare players cope with the most intense running demands that arise during short periods of play (Jones, West, Crewther, Cook, & Kilduff, 2015).

Up to now, no study has examined the potential association between fatigue indirectly determined by time-motion analyses and skill-related performance in elite rugby union match-play. In other team sports contrasting findings have been reported (Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2009; Sirotic, Coutts, Knowles, & Catterick, 2009). In elite soccer, moderate declines occurred in high-speed running following short intense phases and at the end of match-play (effect sizes: ~−0.7) whereas only small reductions (effect sizes: ~−0.4) in the frequency of and success rates in technical actions such as passing (Carling & Dupont, 2011) were concomitantly observed. In contrast, total distance covered, the 'quality' of skill performance, and the number of ball involvements were all reduced both transiently and in the very final stages of matches in rugby league players with these drops possibly linked to glycogen depletion in individual muscle fibres, dehydration arising from hyperthermia and declines in cognitive function (Kempton et al., 2013). Similar information would be pertinent for elite rugby union training settings to determine, for example, whether there is a need for players to practice game skills under 'fatigued' conditions. Consequently, the aim of this study in elite rugby union match-play was to examine end-game and transient changes in running performance using time-motion analyses and determine whether these were accompanied by altered skill-related performance.

Method

In this study, male player performance in official international rugby union competition was examined. A total of 18 matches of which 7 test (autumn tours) and 11 Six Nations tournament matches played between 2005 and 2011 were analysed. All players were either members of the French national team or their direct opponents (nine different teams) and completed all matches in their entirety. Players either substituted or replaced were not included. Altogether, 322 match performance observations for 188 different players were collected. In order to conduct interpositional comparisons, players were subdivided into forwards (match observations: $n = 154$) and backs (match observations: $n = 168$). Further breakdown of playing positions was not feasible due to insufficient numbers of match observations. To ensure player confidentiality, all performance data were anonymised before the analysis. Approval for the study was obtained from the Fédération Française de Rugby.

Study design

An optical computerised player tracking system (Amisco Pro®, Sport Universal Process, Nice, France) was used to analyse performance in international rugby union match-play at the Stade de France stadium (St Denis, France). This system passively tracked the movements of every player over the entire course of play. Simultaneously, trained operators coded post-match each technical action involving the ball. The workings and quality control of AMISCO Pro® have been described elsewhere (Carling, Bloomfield, Nelsen, & Reilly, 2008; Carling, Williams, & Reilly, 2005; Lacome et al., 2014; Randers, Mujika, & Hewitt, 2010).

Two categories of performance measures were employed:

(1) Running performance: total distance run and that covered in high-speed running. The latter was also categorised according to team ball possession: running during own team and opponent possession. Movements recorded at speeds above 18.0 km h^{-1} were considered high-speed running actions (Roberts et al., 2008).
(2) Measures of skill-related performance defined in the and coded internally by AMISCO Pro®-trained company match analysts included the total number of passes and tackles and

success rates in these events. Passes were deemed unsuccessful when a player attempted a pass to a team mate but the ball did not go to hand. Tackles were coded as unsuccessful if the tackling player attempted to tackle but was unable to stop an opponent moving with the ball in hand.

The effective playing time (total time the ball was in play) was also determined as this affects time-related changes in running and skill-related performance (Carling & Dupont, 2011).

Data collection procedures

To investigate accumulated and transient changes in match performance in forwards and backs, running and skill-related performance measures were compared between match halves and across 5- and 10-min intervals. Performance data collected during stoppage time were not included in the analysis to facilitate comparisons.

Accumulated changes in match performance were investigated by comparing the above running and skill-related performance measures across first- and second-half halves. Performance was also examined for the first 10- and 5-min intervals versus both the final 10- and 5-min intervals and the mean for all other 10- and 5-min intervals (minus first and final 10- and 5-min periods).

To analyse transient changes in running and skill-related performance, data were compared between the peak 5-min period of high-speed running activity, the following 5-min period, and the mean of all other 5-min periods (minus the peak and the following 5-min periods) (Carling & Dupont, 2011). Data for players performing their peak 5-min period at the end of a half were removed. The peak 5-min period of running activity was considered to represent the most intense match-play interval in terms of high-speed running output (Bradley et al., 2009).

Statistical analysis

Statistical analyses were performed using R statistical software (R. 3.1.0, R Foundation for Statistical Computing) using the *lme4* and *psychometric* package. Means and standard deviations for each group or playing time were derived from a *generalised linear model*, with the distribution and link function contingent upon the nature of the dependent variable. The overdispersed Poisson distribution was chosen for modelling the data from the notational analysis, and the normal distribution was chosen for distances from the time-motion analysis. For each analysis, the playing time (halves, 10-min and 5-min periods) was included as a fixed effect while players and teams were included as random effects. The % differences between mean values with 90% confidence intervals (CI) are reported.

A magnitude-based inferential approach to statistics was adopted based on recent recommendations (Batterham & Hopkins, 2006; Winter, Abt, & Nevill, 2014). Effect sizes (ES) were quantified to indicate the practical meaningfulness of the differences in mean values. Standardisation was performed with the estimated marginal means and associated variance provided by the *generalised linear model*. The ES was classified as trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0) and very large (>2.0–4.0) based on the guidelines of Batterham and Hopkins (Batterham & Hopkins, 2006). If the 90% CI over-lapped positive and negative values, the magnitude was deemed unclear. The chances that the changes in running or technical performance were greater for a group (i.e. greater than the smallest worthwhile change, SWC (0.2 multiplied by the between-subject standard deviation, based on Cohen's d principle)), similar or smaller than the other group, were calculated. Quantitative chances of greater or smaller changes in performance variables were assessed qualitatively as follows: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, probably not; 25–75%, possibly; 75–97.5%, likely; 97.5–99%, very likely; >99%, almost certain (Hopkins, Marshall, Batterham, & Hanin, 2009). In order to ease reading of the results, inferences and effect magnitudes were collated in the text section by calculating the likelihood of having the appropriate effect.

Results

First- versus second-half performance

Table I reports a possible small decline in total distance covered by forwards in the second- compared to the first-half (% difference: −2.1, ±1.3%; % chance of having greater/trivial/lower performance: 0/36/64). Backs experienced very likely small reductions in total distance covered during the second- versus the first-half (−3.8, ±1.1%; 0/1/99) as well as a likely small reduction in distance covered at high speeds (−10.0, ±4.0%; 0/15/85). Regarding high-speed distance covered while in possession of the ball or not and skill-related performance in forwards and backs, only trivial differences were observed between match halves (ES: −0.19, ±0.10 to 0.09, ±0.17).

Trivial effect size differences were observed for the frequency and success rates in skill-related performance measures across halves in backs and forwards.

Table I. Comparisons of running and skill-related performance for back and forwards across the first- and second-halves of match-play.

	First half	Second half	Diff% (90% CI)	ES (90% CI)	% chances
Performance for forwards (n = 154)					
TD (m)	3122 ± 248	3056 ± 260	−2.1, ±1.3	−0.23, ±0.14	0/36/64
HS (m)	249 ± 131	228 ± 123	−8.4, ±5.6	−0.13, ±0.09	0/91/9
HS (%)	7.8 ± 3.8	7.3 ± 3.7	−6.8, ±5.2	−0.11, ±0.085	0/95/5
HS in posses (m)	130 ± 68	119 ± 70	−8.1, ±6.6	−0.12, ±0.10	0/92/8
HS out of posses (m)	107 ± 73	101 ± 72	−5.6, ±9.4	−0.07, ±0.12	0/96/4
Passes (n)	1.64 ± 1.87	1.76 ± 1.96	7.5, ±14.0	0.05, ±0.09	0/100/0
Tackles (n)	3.81 ± 2.34	4.05 ± 2.72	6.3, ±12.0	0.09, ±0.17	14/86/0
Successful passes (%)	92 ± 19	92 ± 24	−0.77, ±4.7	−0.04, ±0.22	4/85/11
Successful tackles (%)	87 ± 20	85 ± 18	−2.3, ±4.5	−0.10, ±0.20	1/79/21
Effective playing time (s)	900 ± 77	957 ± 103	6.2, ±1.8	0.62, ±0.18	100/0/0
TD (m min of effective time)	209.8 ± 28.1	193.7 ± 32.0	−7.7, ±1.7	−0.64, ±0.14	0/32/68
HS (m min of effective time)	16.9 ± 10.1	14.4 ± 8.7	−15.0, ±5.7	−0.23, ±0.09	0/30/70
Performance for backs (n = 168)					
TD (m)	3515 ± 289	3381 ± 322	−3.8, ±1.1	−0.35, ±0.10	0/1/99
HS (m)	432 ± 132	389 ± 126	−10.0, ±4.0	−0.26, ±0.10	0/15/85
HS (%)	12.2 ± 3.3	11.4 ± 3.3	−6.6, ±3.5	−0.19, ±0.10	0/57/43
HS in posses (m)	228 ± 86	211 ± 90	−7.8, ±5.9	−0.17, ±0.13	0/65/35
HS out of posses (m)	165 ± 70	151 ± 74	−8.6, ±7.0	−0.18, ±0.14	0/60/40
Passes (n)	5.19 ± 9.26	5.50 ± 8.59	6, ±11	0.03, ±0.045	0/100/0
Tackles (n)	2.81 ± 2.38	2.81 ± 2.17	0, ±13	−0.00, ±0.14	1/98/1
Successful passes (%)	92 ± 16	94 ± 10	2.6, ±4.1	0.12, ±0.19	24/75/0
Successful tackles (%)	82 ± 27	83 ± 27	1.0, ±6.4	0.04, ±0.24	13/82/5
Effective playing time (s)	897 ± 75	952 ± 108	6.2, ±1.8	0.60, ±0.17	100/0/0
TD (m min of effective time)	237 ± 29	215 ± 38	−8.9, ±1.6	−0.72, ±0.13	0/7/93
HS (m min of effective time)	29 ± 10	25 ± 8	−16.0, ±3.7	−0.43, ±0.10	0/0/100

Notes: ES, effect size; % chances, % chances that the true difference is +ive/trivial/ −ive; TD, total distance; HS, high-speed distance; HS (%), high-speed distance relative to total distance.

When normalised to effective playing time, there was a possibly moderate decline in total distance covered by forwards in the second- versus the first-half (−7.7, ±1.7%; 0/32/68) as well as a possibly small decline in high-speed distance (−15.0, ±5.7%; 0/30/70). In backs, there was a likely moderate decline in total distance covered (−8.9, ±1.6%; 0/7/93) and a most likely small decline in high-speed distance (−16.0, ±3.7%; 0/0/100) in the second-half. Unclear or trivial effect size differences were observed for the frequency of passes and tackles when normalised to effective playing time in forwards and backs.

End-game performance

Final 10-min interval. In backs and forwards, possibly moderate to likely large declines (% difference range: −17, ±4% to −47, ±20%) in measures of running performance were observed for the first 10-min versus the 70–80-min period (Table II). Regarding the 70–80-min period versus the mean for other 10-min periods, there were most likely to possible small declines (−28, ±18 to −7.1, ±2.1%) in measures of running performance for both positional roles. When normalised to effective playing time, there were possibly small declines in distance covered at high speeds in forwards (−18, ±13%; 0/48/52) and likely small declines in backs (−16, ±8%; 0/10/90).

Regarding skill-related performance in backs and forwards, trivial or unclear effect size differences in the frequency and success rates of skill-related performance measures were observed between the first 10-min versus the 70–80-min period. Similarly, there were trivial or unclear effect size differences in the frequency and success rates of skill-related performance measures between the 70–80-min period versus the mean for all 10-min periods.

Final 5-min interval. In Table III, likely moderate to likely large declines (−24, ±6.6% to −68, ±33) in running performance are reported for backs and forwards for the first 5-min versus the 75–80-min period. In comparison to the mean for 5-min periods, backs experienced very likely small to likely moderate declines in running performance in the 75–80-min period (−10.2, ±2.9 to −42, ±10%) while forwards showed possibly to very likely small reductions (−8.9, ±3.5 to −42, ±23%).

When results were expressed relative to effective playing time, very likely small to possibly large declines (−11, ±5% to −65, ±24%) in running performance were observed for forwards and backs

Table II. Running and skill-related performance in back and forwards during the first 10-min period, the last 10-min period and the mean 10-min period of match-play.

	End-game fluctuations											
	Observed values			Last 10 min vs First 10 min			First 10 min vs Mean 10 min			Last 10 min vs Mean 10 min		
	First 10 min	Last 10 min	Mean 10 min	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances
Performance for forwards (n = 154)												
TD (m)	863 ± 100	712 ± 102	766 ± 57	−18.0, ±5.2	−1.60, ±0.47	0/0/100	13.0, ±3.7	1.0, ±0.3	100/0/0	−7.1, ±2.1	−0.57, ±0.17	0/0/100
HS (m)	84 ± 52	44 ± 36	58 ± 31	−47, ±20	−0.82, ±0.34	0/0/100	45, ±19	0.54, ±0.22	99/1/0	−24, ±11	−0.28, ±0.13	0/15/85
HS (%)	9.4 ± 5.3	5.9 ± 4.5	7.4 ± 3.7	−37, ±15	−0.66, ±0.27	0/0/100	28, ±11	0.38, ±0.16	97/3/0	−20.0, ±9.6	−0.27, ±0.13	0/18/82
HS in posses (m)	45 ± 30	24 ± 22	30 ± 16	−46, ±23	−0.72, ±0.36	0/1/99	49, ±24	0.52, ±0.26	98/2/0	−19, ±14	−0.20, ±0.15	0/48/52
HS out of posses (m)	35 ± 31	18 ± 23	25 ± 17	−48, ±24	−0.65, ±0.32	0/1/99	40, ±20	0.38, ±0.19	94/6/0	−28, ±18	−0.27, ±0.17	0/26/74
Passes (n)	0.46 ± 0.78	0.38 ± 0.62	0.43 ± 0.43	−16, ±32	−0.09, ±0.19	1/82/17	6, ±73	0.03, ±0.40	25/58/17	−11, ±46	−0.06, ±0.25	5/78/18
Tackles (n)	1.26 ± 1.28	1.05 ± 1.30	0.90 ± 0.93	−17, ±22	−0.19, ±0.25	0/51/49	36, ±25	0.30, ±0.21	78/22/0	13, ±41	0.11, ±0.35	33/60/7
Successful passes (%)	85 ± 32	82 ± 40	87 ± 16	−3, ±196	−0.02, ±1.40	39/19/41	−3, ±184	−0.025, ±1.4	39/20/41	−6, ±96	−0.05, ±0.72	27/37/36
Successful tackles (%)	92 ± 24	91 ± 22	86 ± 16	1.0 ± 60	−0.02, ±1.70	41/16/43	7, ±10	0.17, ±0.26	43/56/1	6, ±10	0.15, ±0.27	39/60/2
Effective playing time (s)	243 ± 64	225 ± 46	232 ± 14	−7.4, ±3.9	−0.39, ±0.20	0/6/94	5.1, ±4.5	0.26, ±0.23	66/34/0	−2.7, ±6.1	−0.13, ±0.31	4/60/36
TD (m min of effective time)	222 ± 42	198 ± 47	199 ± 18	−11, ±3.9	−0.62, ±0.23	0/0/100	11, ±4.1	0.58, ±0.21	100/0/0	−0.8, ±15	−0.04, ±0.78	30/33/37
HS (m min of effective time)	22 ± 14	12 ± 10	15 ± 8	−43, ±21	−0.73, ±0.36	0/1/99	45, ±22	0.52, ±0.26	98/2/0	−18, ±13	−0.21, ±0.15	0/48/52
Performance for backs (n = 168)												
TD (m)	960 ± 111	795 ± 104	859 ± 70	−17.0, ±4.1	−1.50, ±0.36	0/0/100	11.8, ±2.8	0.93, ±0.22	100/0/0	−7.4, ±1.8	−0.59, ±0.14	0/0/100
HS (m)	131 ± 56	80 ± 44	102 ± 28	−39, ±13	−1.0, ±0.34	0/0/100	29.4, ±9.6	0.60, ±0.20	100/0/0	−21.3, ±6.9	−0.44, ±0.14	0/0/100
HS (%)	13.5 ± 5.2	9.8 ± 4.8	11.7 ± 2.9	−27, ±11	−0.76, ±0.31	0/0/100	14.9, ±6.2	0.36, ±0.15	96/4/0	−16.5, ±6.9	−0.40, ±0.16	0/2/98
HS in posses (m)	68 ± 39	42 ± 32	55 ± 18	−38, ±16	−0.79, ±0.33	0/0/100	23.5, ±9.8	0.39, ±0.16	97/3/0	−23.9, ±9.9	−0.40, ±0.17	0/2/98
HS out of posses (m)	51 ± 34	32 ± 29	38 ± 15	−37, ±18	−0.67, ±0.33	0/1/99	33, ±16	0.45, ±0.22	97/3/0	−16, ±15	−0.22, ±0.20	0/44/56

(*Continued*)

Table II. Continued.

	Observed values			End-game fluctuations								
				Last 10 min vs First 10 min			First 10 min vs Mean 10 min			Last 10 min vs Mean 10 min		
	First 10 min	Last 10 min	Mean 10 min	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances
Passes (n)	1.4 ± 2.6	1.3 ± 2.5	1.4 ± 2.3	−3, ±110	−0.01, ±0.47	23/51/26	−2, ±160	−0.01, ±0.72	32/35/33	−4, ±65	−0.02, ±0.29	11/74/15
Tackles (n)	0.64 ± 1.00	0.70 ± 1.01	0.70 ± 0.50	10, ±53	0.075, ±0.39	30/58/12	−10, ±46	−0.08, ±0.37	11/60/30	−1, ±740	−0.00, ±6.00	48/4/48
Successful passes (%)	96 ± 12	89 ± 22	95 ± 6	−6.4, ±8.2	−0.20, ±0.25	1/51/49	0, ±90	0.01, ±2.7	45/10/45	−6.0, ±8.5	−0.18, ±0.26	1/53/46
Successful tackles (%)	83 ± 35	68 ± 42	77 ± 21	−17, ±25	−0.18, ±0.26	1/53/46	8, ±48	0.08, ±0.47	33/51/16	−11, ±37	−0.11, ±0.36	8/59/33
Effective playing time (s)	241 ± 60	224 ± 48	231 ± 14	−7.0, ±3.6	−0.36, ±0.19	92/8/0	4.2, ±4.4	0.23, ±0.24	57/43/0	−3.1, ±5.1	−0.17, ±0.27	1/47/52
TD (m min of effective time)	248 ± 48	223 ± 53	224 ± 20	−10, ±3.8	−0.59, ±0.21	0/0/100	11, ±4	0.57, ±0.21	100/0/0	−0.44, ±22	−0.0, ±1.1	37/23/40
HS (m min of effective time)	34 ± 16	22 ± 12	26 ± 7	−36, ±15	−0.9, ±0.37	0/0/100	30, ±12	0.58, ±0.24	100/0/0	−16, ±8	−0.32, ±0.15	0/10/90

between the first 5-min and the 75–80-min period. Differences in running performance in the 75–80-min period compared to the mean 5-min period were possibly to very likely small (−5.4, ±6.3 to −40, ±15%) in forwards while in backs, likely moderate differences in the distance covered at high speed (−45, ±13%; 0/0/100) were observed.

Regarding skill-related performance in backs and forwards, only possibly small to trivial declines in the frequency of tackles and passes performed were observed between the first 5-min and the 75–80-min period. Similarly, only trivial or unclear differences were observed between the final 5-min period and the mean 5-min period for the number of passes and tackles performed. Differences in success rates in skill-related actions were not examined due to insufficient numbers. When expressed relative to effective playing time, unclear to trivial differences were reported for the frequency of passes and tackles.

In-game performance

In backs and forwards, very likely small to possible very large declines in running performance (−25, ±12 to −51, ±19%) between the 5-min peak period of activity and the following 5-min period were observed, whereas there were only unclear to possible trivial differences in the frequency of skill-related measures (Table IV). Only unclear to likely trivial differences in high-speed running performance and the frequency of skill-related measures were reported between the 5-min period following the 5-min peak period and the mean 5-min period of the game. Differences in success rates in skill-related actions once again were not examined due to insufficient numbers. When expressed relative to effective playing time, there were only unclear to very likely small differences in the majority of the variables.

Discussion

To our knowledge, this is the first study to investigate fluctuations in physical and skill-related performance during international 15-a-side rugby union competition. The main findings were: 1. A small drop in total distance covered in the second-half was observed but generally this was not accompanied by declines in high-speed running distance or in the frequency of or success in skill-related performance. 2. Players experienced substantial decrements in high-speed running distance towards the end in comparison to the start of play but were able to maintain skill-related action frequency and success rates. 3. There was no clear performance decrement in high-speed running performance and the

Table III. Running and skill-related performance in back and forwards during the first 5-min period, the last 5-min period and the mean 5-min period of match-play.

	End-game fluctuations											
	Observed values			Last 5 min vs First 5 min			First 5 min vs Mean 5 min			Last 5 min vs Mean 5 min		
	First 5 min	Last 5 min	Mean 5 min	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances
Performance for forwards (n = 154)												
TD (m)	463 ± 67	349 ± 95	383 ± 28	−24.7, ±8.9	−1.65, ±0.60	0/0/100	21.0, ±7.6	1.16, ±0.42	100/0/0	−8.9, ±3.5	−0.49, ±0.19	0/1/99
HS (m)	53 ± 37	18 ± 20	29 ± 15	−66, ±24	−1.22, ±0.44	0/0/100	87, ±31	0.86, ±0.31	100/0/0	−36, ±15	−0.36, ±0.15	0/4/96
HS (%)	11.3 ± 6.7	4.7 ± 4.8	7.1 ± 8.3	−59, ±19	−1.11, ±0.36	0/0/100	59, ±19	0.70, ±0.23	100/0/0	−34, ±12	−0.41, ±0.14	0/1/99
HS in posses (m)	29 ± 23	11 ± 14	15 ± 8	−64, ±32	−1.06, ±0.52	0/0/100	99, ±49	0.82, ±0.41	99/1/0	−29, ±22	−0.24, ±0.18	0/37/63
HS out of posses (m)	23 ± 22	7 ± 12	13 ± 8	−68, ±33	−0.91, ±0.45	0/0/100	79, ±39	0.59, ±0.29	99/1/0	−42, ±23	−0.32, ±0.17	0/13/87
Passes (n)	0.22 ± 0.49	0.19 ± 0.41	0.21 ± 0.22	−15, ±60	−0.07, ±0.29	6/70/24	6.8, ±130	0.03, ±0.6	32/42/26	−9, ±100	−0.04, ±0.46	19/52/28
Tackles (n)	0.70 ± 0.98	0.50 ± 0.92	0.48 ± 0.24	−29, ±25	−0.26, ±0.23	0/34/66	45, ±36	0.28, ±0.22	72/28/0	3, ±250	0.02, ±1.57	42/17/41
Effective playing time (s)	131 ± 33	120 ± 38	114 ± 7	−8.8, ±4.5	−0.39, ±0.20	0/6/94	15.1, ±7.5	0.59, ±0.29	99/1/0	5.0, ±6.5	0.20, ±0.25	49/50/0
TD (m min of effective time)	221 ± 51	190 ± 72	201 ± 18	−14, ±6.9	−0.59, ±0.29	0/1/99	9.8, ±5.3	0.38, ±0.21	93/7/0	−5.4, ±6.3	−0.21, ±0.24	0/47/53
HS (m min of effective time)	26 ± 18	9 ± 10	15 ± 8	−65, ±24	−1.16, ±0.42	0/0/100	72, ±26	0.75, ±0.27	100/0/0	−40, ±15	−0.41, ±0.15	0/1/99
Performance for backs (n = 168)												
TD (m)	507 ± 82	385 ± 90	429 ± 35	−24.0, ±6.6	−1.60, ±0.44	0/0/100	18.3, ±5.0	1.03, ±0.28	100/0/0	−10.2, ±2.9	−0.57, ±0.16	0/0/100
HS (m)	73 ± 42	30 ± 28	51 ± 14	−59, ±14	−1.34, ±0.32	0/0/100	43, ±10	0.68, ±0.16	100/0/0	−42, ±10	−0.66, ±0.16	0/0/100
HS (%)	13.9 ± 6.7	7.0 ± 4.8	11.3 ± 8.3	−49, ±20	−1.19, ±0.49	0/0/100	22.3, ±9.2	0.44, ±0.18	98/2/0	−38, ±16	−0.75, ±0.31	0/0/100
HS in posses (m)	39 ± 26	16 ± 20	27 ± 9	−59, ±17	−1.09, ±0.32	0/0/100	43, ±13	0.56, ±0.17	100/0/0	−41, ±13	−0.53, ±0.17	0/0/100
HS out of posses (m)	29 ± 25	12 ± 17	20 ± 7	−59, ±22	−0.93, ±0.34	0/0/100	48, ±17	0.51, ±0.18	100/0/0	−40, ±16	−0.42, ±0.17	0/2/98
Passes (n)	0.72 ± 1.54	0.63 ± 1.61	0.68 ± 1.10	−12, ±49	−0.05, ±0.20	2/88/10	5, ±110	0.02, ±0.43	24/56/20	−8, ±79	−0.03, ±0.30	10/72/17
Tackles (n)	0.37 ± 0.77	0.29 ± 0.64	0.35 ± 0.23	−22, ±41	−0.14, ±0.25	1/65/33	6, ±130	0.03, ±0.73	35/35/30	−18, ±51	−0.10, ±0.30	5/66/29

(*Continued*)

Table III. Continued.

	End-game fluctuations											
	Observed values			Last 5 min vs First 5 min			First 5 min vs Mean 5 min			Last 5 min vs Mean 5 min		
	First 5 min	Last 5 min	Mean 5 min	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances
Effective playing time (s)	131 ± 33	118 ± 39	114 ± 7	−9.9, ±4.4	−0.43, ±0.19	0/2/98	15.0, ±6.2	0.57, ±0.24	99/1/0	3.6, ±7.5	0.14, ±0.28	35/62/3
TD (m min of effective time)	243 ± 62	217 ± 86	225 ± 21	−11, ±5.4	−0.4, ±0.2	0/5/95	7.9, ±5.5	0.27, ±0.19	73/27/0	−3.8, ±7.4	−0.13, ±0.25	2/65/33
HS (m min of effective time)	34 ± 19	15 ± 14	27 ± 7	−57, ±17	−1.2, ±0.37	0/0/100	28, ±8.8	0.48, ±0.15	100/0/0	−45, ±13	−0.76, ±0.23	0/0/100

frequency of skill-related measures following the most intense periods of play.

First- versus second-half performance. Rugby union is considered to be one of the most physically demanding team games (Mashiko, Umeda, Nakaji, & Sugawara, 2004) but limited information exists on the occurrence of fluctuations in match-play running performance at international standards. Here, analyses showed a *possibly small* reduction in total distance covered during the second- versus the first-half in both forwards and backs (−2.1 and −3.8%; ES: −0.23 and −0.35, respectively). These results differ slightly to those observed by Roberts et al. (2008) who reported a smaller difference for total distance covered between match halves in elite players (ES: 0.1). One explanation for this finding could be the substantially larger sample size used in the present study potentially allowing clearer identification of differences across halves. It is noteworthy that when the total distance covered was normalised to effective playing time, the difference between the relative distance covered per minute of effective time was substantially larger (−7.7%, ES: −0.64, and −8.9%, ES: −0.72, respectively) suggesting that overall running performance was more affected when the ball was in play. However, only *trivial* to *small* reductions in high-speed distance covered, both overall and according to team ball possession, were reported across halves in both backs and forwards. These results are generally in accordance with previous findings (Cunniffe et al., 2009; Duthie et al., 2005; Lacome et al., 2014; Roberts et al., 2008) and suggest that potential accumulation of 'fatigue' and its effects on intense running activities globally in the second-half of games is minor at elite levels.

The analysis of frequency and success in skill-related actions showed no substantial fluctuations in the first- versus the second-half of play suggesting that skill-related performance in the players was maintained. A reasonable suggestion for this lack of decline in skill-related performance and aforementioned high-speed running activity could be that players adopted a pacing strategy aimed at reducing low-intensity activity progressively during the game (hence the aforementioned drop in overall distance covered across halves) in order to maintain their ability to participate in and perform key game actions (Abbiss & Laursen, 2008).

End-match performance. Here, *moderate* to *large* declines (ES range: ranging from −0.6 to −1.6; % change: −17% to −47%) in the various measures of running performance were observed in backs and forwards in the first 10-min versus the 70–80-min

Table IV. Running and skill-related performance in back and forwards during the peak 5-min period, the following 5-min period and the mean 5-min period of match-play.

	In-game fluctuations										
	Observed values			Following 5 min vs Peak 5 min			Peak 5 min vs Mean 5 min			Following 5 min vs Mean 5 min		
	Peak 5 min	Following 5 min	Mean 5 min	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances
Performance for forwards (n = 133)												
TD (m)	522 ± 49	391 ± 66	377 ± 26	−25, ±12	−2.4, ±1.2	0/0/100	39, ±19	2.7, ±1.3	100/0/0	3.8, ±2.8	0.26, ±0.19	70/30/0
HS (m)	59 ± 39	30 ± 27	28 ± 15	−50, ±21	−0.90, ±0.37	0/0/100	110, ±47	0.96, ±0.40	100/0/0	7, ±39	0.06, ±0.33	24/66/9
HS (%)	11.1 ± 6.7	7.4 ± 6.4	7.0 ± 8.8	−33, ±14	−0.57, ±0.23	0/1/99	58, ±24	0.63, ±0.26	100/0/0	6, ±29	0.06, ±0.32	23/68/9
HS in posses (m)	30 ± 25	15 ± 15	15 ± 8	−50, ±16	−0.78, ±0.25	0/0/100	100, ±34	0.80, ±0.26	100/0/0	2, ±240	0.01, ±1.9	43/14/43
HS out of posses (m)	27 ± 24	13 ± 18	12 ± 7	−51, ±21	−0.70, ±0.29	0/0/100	130, ±54	0.78, ±0.32	100/0/0	13, ±54	0.08, ±0.32	27/66/7
Passes (n)	0.27 ± 0.51	0.18 ± 0.42	0.21 ± 0.21	−32, ±27	−0.18, ±0.15	0/57/43	31, ±40	0.13, ±0.17	26/74/0	−11, ±74	−0.05, ±0.32	10/68/22
Tackles (n)	0.48 ± 0.66	0.44 ± 0.73	0.49 ± 0.25	−10, ±49	−0.075, ±0.38	11/60/29	−1, ±280	0.0, ±2.2	44/12/44	−11, ±43	−0.09, ±0.34	8/63/29
Effective playing time (s)	156 ± 32	106 ± 37	114 ± 8	−31, ±13	−1.68, ±0.70	0/0/100	39, ±16	1.52, ±0.63	100/0/0	−4.0, ±7.3	−0.16, ±0.28	2/58/40
TD (m min of effective time)	205.6 ± 43	233.7 ± 69	200.2 ± 20	14, ±5.7	0.57, ±0.24	99/1/0	2.7, ±8.4	0.11, ±0.34	34/60/7	17, ±6.9	0.69, ±0.28	69/31/0
HS (m min of effective time)	23.6 ± 16	18.9 ± 19	14.8 ± 8	−20, ±12	−0.27, ±0.16	0/23/77	59, ±29	0.51, ±0.25	98/2/0	28, ±19	0.24, ±0.16	67/33/0
Performance for backs (n = 146)												
TD (m)	567 ± 57	428 ± 72	422 ± 33	−24, ±10	−1.90, ±0.79	0/0/100	35, ±14	1.02, ±0.42	100/0/0	2.6, ±2.8	0.15, ±0.16	31/69/0
HS (m)	95 ± 40	47 ± 31	47 ± 13	−49, ±16	−1.37, ±0.45	0/0/100	99, ±32	0.69, ±0.23	100/0/0	1, ±96	0.01, ±1.35	41/19/40
HS (%)	16 ± 6.1	10 ± 6.4	11 ± 2.7	−36, ±13	−1.00, ±0.36	0/0/100	54, ±19	0.48, ±0.17	100/0/0	−2, ±29	−0.04, ±0.53	23/47/31
HS in posses (m)	51 ± 30	26 ± 24	25 ± 8	−50, ±18	−1.09, ±0.39	0/0/100	110, ±39	0.56, ±0.20	100/0/0	4, ±60	0.04, ±0.63	34/40/26
HS out of posses (m)	36 ± 24	17 ± 19	19 ± 7	−51, ±19	−0.98, ±0.35	0/0/100	94, ±34	0.46, ±0.17	99/1/0	−5, ±51	−0.05, ±0.5	20/49/31
Passes (n)	0.9 ± 1.6	0.6 ± 1.2	0.6 ± 1.1	−31, ±18	−0.16, ±0.09	0/76/24	33, ±25	0.07, ±0.05	0/100/0	−8, ±58	−0.03, ±0.23	5/84/11
Tackles (n)	0.4 ± 0.7	0.3 ± 0.6	0.4 ± 0.2	−20, ±39	−0.13, ±0.26	2/64/34	13, ±63	0.04, ±0.19	8/90/2	−9, ±82	−0.06, ±0.49	20/49/32

(*Continued*)

Table IV. Continued.

	Observed values			In-game fluctuations								
				Following 5 min vs Peak 5 min			Peak 5 min vs Mean 5 min			Following 5 min vs Mean 5 min		
	Peak 5 min	Following 5 min	Mean 5 min	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances	Diff % (90% CI)	ES (90% CI)	% Chances
Effective playing time (s)	153 ± 36	107 ± 33	114 ± 8	−29, ±12	−1.51, ±0.63	0/0/100	36, ±15	0.70, ±0.29	100/0/0	−2.9, ±8.4	−0.11, ±0.32	6/62/32
TD (m min of effective time)	231 ± 52	255 ± 80	224 ± 23	10, ±4.7	0.42, ±0.19	97/3/0	3, ±7.9	0.06, ±0.15	7/93/0	14, ±5.7	0.54, ±0.22	99/1/0
HS (m min of effective time)	39.2 ± 18	27.9 ± 21	25.7 ± 7	−29, ±12	−0.63, ±0.26	0/0/100	53, ±22	0.37, ±0.16	97/3/0	8.9, ±17	0.13, ±0.24	31/68/1

period. Roberts et al. (2008) observed a reduction in total distance covered during the final 10-min compared to the first 10-min of elite rugby union games (−14.2%, ES = 1.3) but no concomitant reduction in high-speed activity. In elite rugby league players (Sykes, Twist, Nicholas, & Lamb, 2011; Waldron, Highton, Daniels, & Twist, 2013) reductions of 20–30% occurred in high-speed running distance in the first versus the final quartile of play. However, it has been deemed unreasonable to compare running performance in team sports between the first and final game periods owing to the recognised frantic nature of play in the former when teams attempt to ‘engage’ and ‘register their presence’ with the opposition (Carling, 2013). A comparison with distance covered averaged over other 10-min periods enables a more objective evaluation of changes in running activity. Indeed, when regarding the 70–80-min period versus the mean for other 10-min periods, only *small* reductions in high-speed activity overall and on and off the ball (ranging from >−15%, ES: −0.3 to ~−7%, ES: −0.7 for total distance) were observed for both positional roles. While these declines are less pronounced than for the first versus the final 10-min period, they nevertheless suggest that the present players might have experienced accumulated fatigue towards the end of play and disagree with Jones et al. (2015) who only reported a ~−2% decline in high-speed activity in elite rugby union players for the final versus the mean 10-min match period. Interestingly, the additional analysis of end-game fatigue patterns showed that high-speed running performance in both forwards and backs during the final 5-min of the game respectively, declined by 36% and 42% (ES: −0.4 and −0.7) compared to the mean performance across 5-min periods. It seems therefore that fatigue towards the very end of match-play is even more manifest. It is noteworthy that when the total distance covered was normalised relative to effective playing time, there were only unclear to small differences between mean 10- or 5-min period and the final 10- or 5-min period, respectively. However, declines in distance covered at high speeds in relation to effective time remained substantial (−16 to −18%) confirming that fatigue occurring in the latter period of the game affected high-speed activity in these elite rugby union players. This result has implications for conditioning interventions to aid players in maintaining high-speed running activity towards the end of match-play. It also strengthens the need for real-time monitoring of activity to identify players most at risk of *moderate*-to-*large* reductions in running performance towards the end of play and inform the need for substitutions and tactical changes particularly if the match result is yet to be decided. Future

work using both GPS and heart-rate monitoring would be pertinent to analyse whether time-related changes also occur for accelerations, collisions and forces exerted, repeated high-intensity activity and physiological responses.

It is noteworthy that no clear differences were reported for the frequency of and success rates in skill-related events for the 70–80-min interval versus the mean for 10-min periods suggesting skill-related performance was maintained until the end of play. These results are in accordance with those observed in elite soccer (Carling & Dupont, 2011). A reasonable explanation could be that the players adopted pacing strategies in order to maintain their ability to perform key actions such as tackles and passes by decreasing running activities notably low-intensity output (Jones et al., 2015). These results could also testify a change in collective strategy towards the end of the game. Indeed, irrespective of score, teams might aim to conserve ball possession using short passes close to the rucking zone rather than opting for a kicking or expansive game thereby leading to an increased frequency of actions such as tackles. Further studies are necessary to investigate whether changes in playing strategy impacts running and other elements of skill-related performance.

In-match performance. Research in team-sport match-play has shown that high-speed running distance and/or skill-related performance can be deleteriously affected immediately following the most intense (peak) period of high-speed activity (Carling & Dupont, 2011; Kempton et al., 2014). Here, the analysis of the 5-minute period following the peak 5-minute period showed *large* to *very large* decreases in high-speed distance covered. Yet whether players actually experienced transient fatigue is unclear as running and skill-related performance during the 5-min period immediately following the intense 5-min period was not clearly affected when compared to performance for the mean across other 5-min periods. In addition, it is noteworthy that the most intense period of high-speed activity was accompanied by a *very large* increase in effective playing time (time the ball was in play). Thus any subsequent declines in relation to the following 5-min period might simply be linked to a reduction in the time the ball was in play rather than to transient fatigue with the natural ebb and flow of the game allowing players sufficient time to recover (Carling & Dupont, 2011). This suggestion was confirmed when running activity was normalised to effective playing time. Indeed, though fluctuations were observed between the peak 5-min period and the following 5-min period, running performance remained higher in both periods compared to the mean 5-min period, in forwards and backs. These findings suggest that players were comfortable with performing game skills in situations of fatigue due to their current training regimens and/or raise doubts on the real-world need for players to actually practice executing game skills under 'fatigued' conditions. Research is nevertheless warranted to analyse running and skill-related performance following intense prolonged continual attacking/defending sequences where the ball is continually in play (e.g. up to 2-min) and whether individual physical fitness is related to decrements in running activity.

Limitations. A limitation here was that player positions were broken down into forward and back positional groups only. Larger scale studies are therefore warranted to provide more detailed inter-positional comparisons. In addition, the distance run at high speeds was assessed using an absolute speed threshold and not tailored to individual physiological capacity potentially leading to under- or over-estimations in running performance (Reardon, Tobin, & Delahunt, 2015). Finally, recent evidence has demonstrated that pre-defined periods do not accurately represent peak running demands compared to rolling periods (Varley, Elias, & Aughey, 2012). As such peak activity periods reported here should be interpreted with caution.

Conclusion. This study investigated fluctuations in running and skill-related performance in international 15-a-side rugby union competition. The distance covered overall and at high speed during the second- versus the first-half did not decrease substantially in either forwards and backs while frequency of and success in skill-related actions were unaffected suggesting that players were able to maintain performance. While no clear decrement in high-speed activity was observed immediately following the most intense periods of the game, a clear reduction occurred towards the end of play. However, skill-related performance remained unchanged suggesting that the present international rugby union players employed pacing strategies to maintain their ability to perform key actions throughout play.

Disclosure statement

No potential conflict of interest was reported by the authors.

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