

Title: “Transient fatigue is not influenced by ball-in-play time during elite rugby league matches”

Authors and affiliations

Waldron, M.^{1,3*}, Thomson, E.², Highton, J.², & Twist, C.²

¹ School of Sport, Health and Applied Science, St Mary’s University, Twickenham, London, UK

² Department of Sport and Exercise Sciences, University of Chester, Chester, UK

³ School of Science and Technology, University of New England, Armidale, NSW, Australia

*Corresponding author

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ABSTRACT

The capacity to sustain high-speed running is important for rugby league players. Transient fatigue, described as a reduction in high-speed running in the 5-min after a peak 5-min period, is a phenomenon observed during rugby league matches. This concept has recently been questioned based on the proposed confounding influence of ball-in-play time during these periods. Therefore, this study examined the changes in high-speed running ($> 14 \text{ km}\cdot\text{h}^{-1}$) of elite rugby league players, as well as ball-in-play time, during the peak, subsequent and mean 5-min periods of five competitive matches using 5 Hz GPS devices. The suitability of ball-in-play time as a covariate was also evaluated. The high-speed running and ball-in-play time was different between peak ($26.7 \pm 5.5 \text{ m}\cdot\text{min}^{-1}$ and $177 \pm 37 \text{ s}$) and subsequent ($12.1 \pm 6.2 \text{ m}\cdot\text{min}^{-1}$ and $147 \pm 37 \text{ s}$) 5-min periods ($P < 0.05$; *most likely* ↓). However, there was no relationship ($r = 0.01$ to -0.13 ; $P > 0.05$) between ball-in-play time and high-speed running and ball-in-play time was not independent of the match period. This study has reaffirmed the presence of transient fatigue during elite rugby league matches but questioned the influence of ball-in-play time as a confounding factor. These observations have implications for the design of appropriate training practices and informing tactical strategies employed by coaches. Most importantly, any practitioner wishing to measure transient fatigue could follow a similar statistical approach taken herein and, based on the current findings would not need to account for ball-in-play time as a confounding variable.

INTRODUCTION

Rugby league is a high-speed, intermittent team sport, played over a period of 80 min, with players covering between 3,000 and 8,000 m, respectively, depending on their playing position (13,17,21,23,30,36). Whilst match running performance is intermittent in nature, the importance of high-speed running has become increasingly apparent for elite players (1,12,14,16,28,31,32,35). For example, a reduction in high-speed running of approximately 5-12 % between the first and second halves of matches has been reported for elite rugby league players (18-19,28,31,35). Decrements in high-speed running appear to be a characteristic of elite rugby league matches, with sub-elite players showing no change between halves (28). Furthermore, elite National Rugby League (NRL, Australia) players have been reported to run at higher intensities (~21 % greater distance at high-speed) than Super League players (UK) and, whilst reductions in high speed running were apparent between-halves of a match in both groups, NRL players were able to preserve their running speed by ~ 23 % more than Super League players (32). These findings were suggested to reflect the superior playing standard of NRL players (32). Over 50 % of repeated high-speed efforts occur within five minutes of a try and in close proximity to other 'critical' periods during elite rugby league matches (14). Collectively, the evidence suggests that the capacity to sustain high-speed running, particularly during critical match periods, is likely to facilitate the performance of elite rugby league players.

A reduction in high-speed running distance during other team sports, such as soccer, was originally reported in the 5-min period that immediately followed the most intense (i.e. peak in high speed movement) period of the match, suggesting that soccer players do not maintain high-speed running for sustained periods of time (3,5,24). Similar observations have since been made in rugby league matches and are thought to indicate 'transient fatigue or pacing' (16,18-

19,35). For example, Hulin et al. (16) reported reductions of approximately 50 % ($\sim 17 \text{ m}\cdot\text{min}^{-1}$ ¹ cf. $\sim 8 \text{ m}\cdot\text{min}^{-1}$) in high-speed running between the peak and subsequent periods of matches among rugby league players. Two techniques have been used to identify peak periods in team sports matches; one uses the highest running intensity recorded across consecutive 5-min periods (3-4,16,24), whilst the other uses a rolling average (8,10,33). While the former of these techniques appears to underestimate the latter, perhaps owing to an overlap in peak running activity between consecutive 5-min periods (33), both are able to detect transient fatigue during matches. From a metabolic perspective, this should be anticipated, given the limited capacity of non-oxidative energy systems, which are relied upon to support high-speed exercise (29). Reductions in high-speed exercise during matches have been attributed to a variety of mechanisms that are both centrally and peripherally mediated (3-5,24,34-35). These temporary reductions in high-speed movement have many potential consequences in a match scenario. For example, the ability to perform demanding defensive duties for prolonged periods, yet retain the ability to execute subsequent high-speed offensive plays such as counterattacks, can shift the 'momentum' of a match. However, the ability to perform these actions could be compromised if they were to follow an intense period of activity. Acute fatigue induced after a high-speed bout could also expose players to an increased risk of injury (11). Owing to the potential deleterious effects of transient fatigue during matches in rugby league, specific high-speed training programmes are often adopted to prepare players for a 'worst-case scenario' during matches (1,2,17).

In a recent study, Kempton et al. (19) reported differences between the peak and subsequent 5-min periods during elite rugby match performance to reaffirm the presence of transient fatigue. Replicating a previous technique applied in elite soccer (6), the authors also investigated the effect of 'contextual' factors, such as ball-out-of play time. Notably, Kempton et al. (19)

reported that ball-out-of-play time was lower during the 5-min peak periods compared to the subsequent 5-min periods of running speed. Accordingly, it was suggested that the observed high-speed running reductions could be explained by the time that the ball was in play, rather than an indication of transient fatigue or pacing (19). A reduction in ball-in-play time might have been anticipated, given the known influence of external factors, such as team tactics and opponents activity on movement profiles in team sport (22,27). It is possible that ball-in-play time has a particularly strong influence on the movement parameters of rugby league players as these periods could be utilised for recovery in preparation for the subsequent phase of play. Moreover, there is potentially little advantage to performing high-speed movements when the ball is not in-play, owing to the positional and territorial restrictions of the game, which draws players towards the gain line before a re-start. Fundamental features of rugby league, such as the offside rule, also limit the space available for players to move into when the ball is not in play. These suggestions logically question the existence of transient fatigue.

The findings of previous studies could have implications for a large body of research in team sport that has attempted to validate the phenomenon of transient fatigue. However, no study has attempted to explore the relationships between ball-in-play time and high-speed running during peak and subsequent 5-min periods in elite rugby league matches. Furthermore, no study has adopted the correct statistical procedure to directly evaluate of the effects of ball-in-play time on transient fatigue during team sports matches. For example, it is possible to statistically control for confounding variables, assuming that they have an influence on the dependent measures. Ball-in-play time is one of the suggested confounding variables and ought to be treated in this way. However, covariates must meet specific assumptions before they can be considered as such. One example of these assumptions is the presence of a relationship between the candidate covariate (ball-in-play time) and dependent variable (high-speed running), which

is an analysis that can be simply performed using a statistical software package. Given the potential implications of previous findings, it is important that a correct statistical approach is adopted for corroboratory purposes. Therefore, first aim of this study was to evaluate the differences in high-speed running between peak 5-min, subsequent 5-min and mean 5-min of elite rugby league matches. The second aim of this study was to establish the relationship between high-speed running and ball-in-play time during 5-min peak and 5-min subsequent periods, thus establishing the role of ball-in-play time as a covariate. The findings of this study will be useful to coaches in the design of appropriate conditioning practices that more closely replicate the movement characteristics of match play.

METHODS

Experimental Approach to the Problem

To determine the presence of transient fatigue, 5-min periods of peak high-speed running were compared to the subsequent 5-min period and the match mean 5-min period for each player during the 73 performances. The same comparisons were carried out on ball-in-play time in order to determine whether this was affected by match periods. Whilst it is known that between-match variability can be high (~14 % in rugby league matches; 20), this study followed a repeated-measures design and did not compare between matches, teams or players. A *post-hoc* power calculation (G*Power, Version 3.1.9.2, Universität Kiel, Germany) showed that with an alpha-level of $P < 0.05$, the current sample ($n = 73$) was large enough to detect the smallest of significant effect sizes ($ES = 0.5$) with a power of 0.97. A correlational analysis was also performed to confirm the assumed relationship between ball-in-play time and high-speed running, as this is currently thought to confound the typical analyses of transient fatigue in team sports, such as rugby league.

Participants

After institutional ethics approval, 24 male rugby league players from the same professional Super League club participated in the study (18.9 ± 1.2 y, 1.83 ± 0.05 m, 95.9 ± 9.7 kg). All players trained three times per week, consisting of technical/skill work and strength and conditioning. Data were collected from five different matches, providing a total of 73 match files for analysis. Of the five matches analysed, four were won and one was lost, with a mean score deficit of 23 ± 18 points. Both the club, players and their parent guardians (where necessary) were fully informed of the procedures and provided written informed consent for their data to be included in the study. Among the squad, there were positional groups of: props ($n = 5$), back row ($n = 5$), outside backs (wingers, centres and full back; $n = 10$) and pivots (stand-off, scrum-half and hooker; $n = 4$). Players who did not participate for at least five minutes subsequent to their 5-min peak high speed period were excluded from the data analysis.

GPS data collection

Each participant was fitted with a 5 Hz non-differential Global Positioning System (GPS; SPI-Pro, GPSports, Canberra, Australia), which was securely placed into a purpose-made sleeveless vest (GPSports, Canberra, Australia) between the scapulae. The GPS data were downloaded using Team AMS (GPSports, Canberra, Australia) software and exported to a purpose-designed spreadsheet for further analysis. High speed running (>14.4 km·h⁻¹) (27,31,35-36), expressed as m·min⁻¹ was recorded for each 5-min segment of the match, with the highest locomotive rate being taken as the 'peak period' (i.e. the highest pre-defined period), the 5-min period that followed being recorded as the 'subsequent period' and the mean of all 5-min

periods taken as the 'mean period' (24). The current demarcation of high-speed has been used previously to define match-related fatigue in rugby league matches (31,35). The GPS devices are commonly used to demarcate high- ($> 14.4 \text{ km}\cdot\text{h}^{-1}$) and low-speed zones ($< 14.4 \text{ km}\cdot\text{h}^{-1}$) (18,34,35) and are reliable enough to detect changes in high-speed running between match periods (26,37). The same GPS units were fitted to each player throughout all of the matches, thus controlling for any potential inter-unit variability (9). The amount of time (s) the ball was in play (ball-in-play time) for each of the 5-min periods (peak, subsequent and mean) was analysed after the match using a video recording and a manual notational analysis procedure (Sportscode Gamebreaker, Version 8.2.1, Sportstec, NSW, Australia). The intra-rater reliability of the analyst, expressed as a coefficient of variation, was 2%. The same experienced analyst was used throughout the study.

Statistical analysis

The data were initially checked for normality using a Kolmogorov-Smirnov test and homogeneity of variances. To consider ball-in-play time as a covariate, relationships between ball-in-play time and high-speed running at each level of the independent variable (peak, subsequent and mean periods) were evaluated using Pearson's correlation coefficient (r). The strength of the relationships were considered as: $< 0.3 =$ weak, $0.3-0.5 =$ moderate; $> 0.5 =$ strong; 7). The effects of other factors, such as field position, were not included in the hypothesis of this study and were not deemed relevant to the current analysis because transient fatigue has not been shown to depend on this factor. A one-way analysis of variance with repeated measures (ANOVA-RM) was used to compare high-speed running and ball-in-play time between peak, subsequent and mean periods of all matches. Follow-up pairwise differences were identified using paired t -tests to remove the bias of correction methods (25)

and effect sizes (ES) were calculated and interpreted as: ≤ 0.2 trivial, > 0.2 small, > 0.6 moderate, > 1.2 large, > 2.0 very large, and > 4.0 extremely large (15).

Secondary to traditional hypothesis testing, magnitude-based inferences (MBIs) were used to identify clinical differences in the dependent variables between peak, subsequent and mean 5-min periods. Raw data were log-transformed to account for non-uniformity of effects. For the MBIs, threshold probabilities for a substantial effect based on the 90 % confidence limits (15) were: <0.5 % most unlikely, 0.5–5 % very unlikely, 5–25 % unlikely, 25–75 % possibly, 75–95 % likely, 95–99.5 % very likely, 99.5 % most likely. Thresholds for the magnitude of the observed change in the dependent variables were determined as the within-participant standard deviation $\times 0.2$ (small) 0.6 (moderate) and 1.2 (large) (15). Effects with confidence limits across a likely small positive or negative change were classified as unclear (15). The uncertainty of effects was based on 90 % confidence limits for all variables. A custom spreadsheet was used to perform all of the calculations (<http://www.sportsci.org/>).

The homogeneity of regression slopes, an assumption of ANCOVA-RM, was analysed using a customised model. Statistical significance was set at $P < 0.05$ and data were reported as mean \pm standard deviation unless otherwise stated. All data were analysed using Statistical Package for the Social Sciences (SPSS for Windows, version 18.0, SPP Inc., Chicago, IL).

RESULTS

Relationships between ball-in-play time and high-speed running

There was no relationship between ball-in-play time and high-speed running for peak ($r = -0.01$, 95 % CI [0.24, 0.22], $P = 0.934$), subsequent ($r = 0.11$, 95 % CI [-0.12, 0.30], $P = 0.360$) or mean 5-min periods ($r = -0.13$, 95 % CI = [0.35, 0.10], $P = 0.27$) (Figures 1-3).

*****Insert Figures 1, 2 and 3 here*****

Comparison of five-minute periods

There was an effect of match period for high-speed running ($F_{(1.6,117.4)} = 291$, $P < 0.001$), with *post-hoc* tests revealing differences ($P < 0.001$; ES = 1.6, 95 % CI [1.1, 2.1]; *most likely lower*; mean difference = 14.6, 95 % CI [12.6, 16.5] $\text{m}\cdot\text{min}^{-1}$) between the peak and subsequent, peak and mean ($P < 0.001$; ES = 1.7, 95 % CI [1.4, 2.0]; *most likely lower*; mean difference = 13.7, 95 % CI [11.7, 14.6] $\text{m}\cdot\text{min}^{-1}$) but not between the subsequent and mean periods ($P = 0.201$; ES = -0.3, 95 % CI [-0.5, -0.1]; *unlikely higher*; mean difference = -1.4, 95 % CI [-3.0, 0.1] $\text{m}\cdot\text{min}^{-1}$) (Figure 4). For ball-in-play time, there was an effect of match period ($F_{(1.5,109.4)} = 19.5$, $P < 0.001$), with *post-hoc* tests revealing differences between the peak and subsequent ($P < 0.001$; ES = 0.8, 95 % CI [0.5, 1.4]; *most likely lower*; mean difference = 30, 95 % CI [18, 43] s), peak and mean periods ($P = 0.036$; ES = 0.5, 95 % CI [0.3, 0.7]; *most likely lower*; mean difference = 13, 95 % CI [4, 22] s) and the subsequent and mean periods ($P = 0.002$; ES = 0.6, 95 % CI [0.4, 0.8]; *most likely higher*; mean difference = -18, 95 % CI [-27, -9] s) (Figure 5).

*****Insert Figures 4 and 5 here*****

The assumptions of repeated measures ANCOVA were violated based on the non-significant relationship ($P > 0.05$) between ball-in-play time and high-speed running (Figures 1-3). Whilst

homogeneity was reported between the regression slopes, signified by no interaction between the match period and ball-in-play time ($P = 0.504$), the covariate and the treatment effect were not independent of one another, denoted by the differences in ball-in play time between match periods (Figure 5).

DISCUSSION

Using the same statistical approach to others (18), there were differences (*'most likely'*) in high-speed running between peak 5-min and subsequent 5-min periods of rugby league matches (Figure 4). However, there were no differences in high-speed running between the subsequent 5-min and the mean 5-min periods (Figure 4). Similar conclusions have been reached previously among rugby league players (18). These findings show that high-speed running cannot be maintained for prolonged periods, but that subsequent bouts of running do not necessarily need to be performed below the match mean. Whilst it is more common to observe differences in high-speed running between subsequent and mean 5-min periods in team sports, it is possible that players reduced their running speed in response to afferent cues, such that the mean physical demands can be recommenced (34). Collectively, the current findings are largely as anticipated and indicate the occurrence of transient fluctuations in match running that are reflective of fatigue or the attempt to avoid a reduction in match running below the match mean.

Owing to recent suggestions that ball-in-play time directly influences high-speed running fluctuations between 5-min match periods (6,19), the analysis was extended to account for ball-in-play time as a covariate. However, the principal finding of this study is that ball-play-time

has no influence on the fluctuations in high-speed running between peak 5-min and subsequent 5-min periods of rugby league matches. There was no relationship observed between ball-in-play time and high-speed running for any match period. This study is the first to recognise that transient fatigue can be analysed in rugby league matches without accounting for ball-in-play time. The authors would encourage others to take similar statistical steps to establish the generalizability of our findings to a larger population. If similar results are found, ball-in-play time could be disregarded when evaluating transient fatigue during matches. Other approaches, such as multi-level modelling can also be used in a similar manner to account for the potential influence of other contextual factors on transient fatigue.

It is understandable, and entirely logical, to question the potential effects of ball-in-play time on high-speed running, given the potential opportunity for players to recover during this time. Consistent with previous reports (19), the current findings show that ball-in-play time is also different between peak, subsequent and mean 5-min periods. Whilst this might appear to show that ball-in-play time directly influences high-speed running, these assumptions are misleading and are not based on a suitable statistical approach. That is; despite corresponding systematic mean changes in both of these variables across match periods, there is no proportional relationship between them. In other words, the ball being in or out of play does not determine the high-speed running of a rugby league player.

Previous authors have recognised that reduced ball-in-play time in the 5-min subsequent (post-peak) period could be related to a conscious tactical decision made by players to kick the ball into touch, ostensibly to reduce the demands of the match (15-16). This could also be considered as part of a complex pacing strategy, employed by players to avoid damaging

physiological ‘failure’, thus guarding against a more pronounced physical expression of fatigue (2,4,34). Indeed, it is extremely likely that some rugby league players do perform lower speed running during this period and utilise this time to recover from a high-speed bout of running. However, with the current findings in mind, it is equally as likely that some players use the ball-out-of play time to reorganise their field positions for tactical purposes, resulting in higher speed movements, rather than lower speed recovery. This might have been anticipated as it is extremely unlikely that all players recover at the same time and it might be necessary for some players to provide cover for others who have been more involved in the match in the preceding period. Therefore, reductions in ball-in-play time do not necessarily rule out high-speed running. Future research is necessary to establish the effects of other ‘contextual factors’, such as defensive or offensive periods (19), whilst adopting a suitable statistical approach.

This study has reaffirmed the presence of transient fatigue during elite rugby league matches and questioned the influence of ball-in-play time as a confounding factor. Therefore, rugby league practitioners who currently adopt training practices, intending to extend bouts of high-speed running and facilitate transient recovery, should not be discouraged from their approach. For tactical reasons, rugby league players and coaches should also be aware that not all players are recovering when the ball is out of play and, in contrast, might be performing high-speed running. This has further implications for training practices that utilise ball-out-of play periods to permit recovery, as this is not reflective of every match scenario.

PRACTICAL APPLICATIONS

The current findings question the validity of training drills designed to mimic ball-out-of-play periods by transiently lowering running demands. Practitioners could use this information, alongside published data, to design training drills that distribute running demands of matches

more accurately and encourage, high-speed running periods when the ball is not active. For example, coaches might consider having players perform repeated effort sprints between bouts of game-specific activities rather than allowing players to walk or rest. This is potentially quite important as the intensity of training drills (such as phase-plays and conditioned games) typically focus on ball-in-play scenarios and do not consider the intensity of running demands when the ball is 'dead'. This often includes movement in different areas of the pitch and using different forms of locomotion. In addition, strength and conditioning practitioners who quantify transient fatigue during matches and use this as a performance indicator do not need to statistically control for ball in play time in order to do so.

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