Factors that influence running intensity in interchange players in professional rugby league

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ABSTRACT

Rugby league coaches adopt replacement strategies for their interchange players to maximize running intensity, however it is important to understand the factors which may influence match performance. ***Purpose:*** To assess the independent factors affecting running intensity sustained by interchange players during professional rugby league. ***Methods:*** Global positioning system (GPS) data were collected from all interchanged players (starters and non-starters) within a professional rugby league squad across 20 matches of a National Rugby League (NRL) season. A multilevel mixed model approach was employed to establish the effect of various technical (attacking and defensive involvements), temporal (bout duration, time in possession etc.) and situational (season phase, recovery cycle etc.) factors on the relative distance covered and average metabolic power (P_{met}) during competition. Significant effects were standardised using correlation coefficients, and the likelihood of the effect was described using magnitude-based inferences. ***Results:*** Superior intermittent running ability resulted in *very likely large* increases in both relative distance and P_{met}. As the length of a bout increased, both measures of running intensity exhibited a *small* decrease. There were at least *likely small* increases in running intensity for matches played after short recovery cycles and against strong opposition. During a bout, the number of collision-based involvements increased running intensity, whilst time in possession and ball time-out-of-play decreased demands. ***Conclusions:*** These data demonstrate a complex interaction of individual and match-based factors that require consideration when developing interchange strategies, and the manipulation of training loads during shorter recovery periods and against stronger opponents may be beneficial.

Keywords: Performance analysis, coaching, football, metabolic power.

INTRODUCTION

The quantification of competition movement demands in rugby league is now a common practice, primarily through the use of global positioning systems (GPS).[1-3] The analysis of match-play data has proved useful for differentiating positional demands[3], monitoring workload[1,2] and for developing recovery strategies.[4] Moreover, recent research[1] has demonstrated considerable match-to-match variability in physical performance measures such as high and very-high speed running, which highlights the need to investigate the factors that contribute to these changes in competition output. For example, the running demands of rugby league have been shown to be affected by both individual fitness capacities[5] and the quality of the opposition.[6] Whilst these findings are useful, it is important to note that these variables may not influence match performance in isolation, and it may be that controlling for the confounding effect of multiple variables simultaneously is the most appropriate method.

To account for the influence of multiple factors, Kempton and Coutts[7] utilized a multilevel mixed modelling approach to assess the independent effects of a variable whilst concurrently controlling for a range of other variables. It was found that the total relative ($m \cdot min^{-1}$) and high-speed ([HS]; $m \cdot min^{-1}$) distances were reduced as a result of short recovery cycles, playing away from home and early competition games of the season. In addition, running intensity was decreased through increased defensive loads, but remained unaffected by attacking involvements, and players exhibiting greater aerobic abilities were also able to sustain a greater running intensity throughout match-play. Whilst these findings are useful for the development of specific preparation and recovery strategies, it is possible that for interchanged players, the time spent on the field may substantially influence the running intensity maintained throughout that bout.

Modern interchange strategies utilized by professional rugby league teams require backs to complete the entire match, whilst forwards often complete the match in two or more bouts.[8] Previous research has demonstrated a decline in running intensity throughout an interchange bout amongst interchange professional rugby league players, potentially due to transient fatigue as a result of match-play.[9] However no study has yet investigated the impact of bout duration of the running intensity maintained, and such information could assist coaches in developing interchange plans.

In addition to the difference in match time between interchange and non-interchange players,[8,9] it is also important to address the differences in the physical requirements of these positions during match-play. For example, hit-up forwards (prop and second row) have been shown to be involved in more collisions, relative to playing time, than any other positional group.[8] As a result of this increased contact load, it is important to control for attacking and defensive collisions when investigating the movement demands of these positions.[7] This, combined with the spatial limitations imposed on rugby league players due to the presence of opposition players, would indicate that players in these positions may be unable to achieve the same total or high-speed relative distances as other players who are more laterally positioned[2]. It therefore may be beneficial to also assess the acceleration-based running requirements when investigating the running demands of interchanged rugby league players. The metabolic power (P_{met}) method represents a theoretical model for quantifying team sports movement demands, where the energetic cost of accelerated and decelerated running is accounted for.[10,11] Specific to rugby league, Kempton et al.[2] reported that hit-up forwards covered 76% more distance over a high-power threshold of 20 $W \cdot kg^{-1}$ when compared to an equivalent traditional high-speed threshold of 14.4 $km \cdot h^{-1}$, further demonstrating the importance of quantifying accelerated running for this position.

Overall, it can be seen that the competition requirements of interchange rugby league players are unique, and as a result they should be assessed independently of full-match players. Therefore, this study adapted the mixed model approach of Kempton and Coutts,[7] to assess the factors affecting the running intensity sustained by interchange rugby league players. Specifically, this study investigated the independent effects of bout duration, match location, recovery length, season phase, opposition strength and recent form, match outcome, time out of play, time in possession, tackles made and received, and individual player fitness on the running intensity achieved by these players. The findings of this study may assist coaches in formulating interchange strategies, which is particularly important given the recent decrease in number of available interchanges from ten to eight.

METHODS

Subjects

Eighteen professional rugby league players (26.8 ± 5.3 yr, 102.2 ± 9.9 kg, 1.86 ± 0.05 m) from the same club were recruited for this study. This cohort included 14 middle forwards (props and locks) and four hookers, and was representative of all interchange players (starters and non-starters) throughout the season. Due to the coaching strategies of the team, no edge forwards were interchanged tactically (only substituted in the case of injury), and therefore these players were removed from analysis. Prior to the commencement of the study, all subjects were informed of the aims and requirements of the research, and informed consent was obtained. The Institutional Human Ethics Committee approved all experimental procedures.

Methodology

Data were collected during 24 matches across the 2014 National Rugby League (NRL) competitive season (10 wins, 14 losses, final position 12th), to determine the effects of various contextual factors on the running performance of interchange players. Matches were played on outdoor grass surfaces between the hours of 14:00-20:00. Each match was classified according to season phase as early season (mean match-day temperature ± SD, 25.1 ± 5.9º C), mid-season (18.2 ± 3.6º C) or late-season (19.3 ± 2.6º C) for matches 1-8, 9-16 and 17-24, respectively. Further, match location (home or away) and recovery cycle length (long, ≥ 7 days or short, 5-6 days) were used to describe match conditions. Opposition strength was categorized according to both final ladder position (strong, average or weak) and opposition recent form (no. of wins in last 5 matches). Match result was recorded as won or lost, and points-differential in each game was taken as the score difference between the two sides at the end of each game. To account for collisions in both attack and defence, a commercial statistics supplier (Prozone, Sydney, Australia) provided the count of times each player was tackled (n) and the count of tackles effected by each player during each bout (n). In addition, time in possession and total time (min) in which the ball was out of play was recorded. Individual intermittent running ability was assessed via the maximum speed attained before exhaustion (vIFT) using the 30:15 Intermittent Fitness Test,[12] approximately 4 weeks prior to the start of the season.

Competition movement demands were recorded using GPS units at a sampling rate of 15 Hz (SPI HPU, GPSports, Canberra, Australia). Whilst the validity and reliability of these units for quantifying total distance covered during team sports has previously been described,[13] the inter-unit reliability for quantifying the acceleration-based movement demands of team sports has been challenged.[14] To minimize such error, each player was fitted with the same unit for the entire season. Matches were completed in open stadiums, where the number of satellites and horizontal dilution of precision (HDOP) were 8.3 ± 1.4 and 1.1 ± 0.1, respectively. Each unit was fitted into a customized padded pouch in the player's jersey, positioned in the centre of the back slightly superior to the scapulae. The average duration spent on the field by each player was 48.6 ± 14.6 min, which was broken up into 2-4 bouts (each lasting 22.0 ± 8.2 min). The average number of observations per player was

16.1 ± 13.3. Upon completion of each match, match files were downloaded using the appropriate proprietary software (Team AMS, GPSports, Canberra, Australia). Following this, data were trimmed to only include the time spent on the field and each bout was treated as a separate file. In the case that an interchange bout was broken up by the half-time break, the period was divided into two individual bouts, and analyzed accordingly. The total distance covered during each bout was divided by bout duration to obtain the relative total distance ($m \cdot min^{-1}$).

In addition to relative distance, the P_{met} achieved throughout each interchange bout, calculated using the methods of Osgnach et al.,[11] was selected as the dependant variable in preference of the high-speed running measure utilized by Kempton and Coutts.[7] High-speed running has been shown to underestimate the high-intensity activities of competition that are performed at low speeds, particularly for positions regularly interchanged such as hit-up forwards.[2] As such, the P_{met} measure was included as a primary outcome measure. Whilst previous research has shown varying accuracy of this method for quantifying the energetic cost of team sports movements,[15-17] this measure has emerged as a stable measure of locomotor load (CV% = 4.5%),[18] where acceleration and velocity-based movements are accounted for. Considering the spatial restrictions placed on interchanged players due to the presence of opposition players,[2] P_{met} was chosen as an appropriate reflection of external load during competition.

Statistical Analysis

Multilevel linear mixed effect models were constructed, utilizing a similar design to that of Kempton and Coutts.[7] Two separate models were constructed to examine the influence of various match play and player characteristics on each of the dependent running measures including relative distance and P_{met} (Table 1). These 2-level models included both random and fixed effects[19] with units of analysis (individual bout) nested in clusters of units (individual player). Prior to analysis, the dependent variables, relative distance, and P_{met} values were log transformed, providing percentage effect of the mean[20].

Table 1 near here

In the model design, a 'step-up' approach was used where only a fixed intercept and the level 2 random factor (player) were included.[19] Following this, each level 1 fixed effect was added and retained if statistical significance was demonstrated (p < 0.05) and improved the model information as determined by a likelihood ratio test. The order of entry of the fixed effects into the model was trialled a variety of different ways, and determined to have no effect on the final outcome of the model. The *t* statistics from the mixed models were converted to effect size correlations (ES) and associated 90% confidence intervals (90% CI).[21] Effect size correlations were interpreted as <0.1, trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, very large; 0.9-0.99, almost perfect; 1.0, perfect. Furthermore, the likelihood of the observed effect was established using a progressive magnitude-based approach, where quantitative chances of the true effect were assessed qualitatively, as: <1%, *almost certainly not*; 1-5%, *very unlikely*; 5-25%, *unlikely*; 25-75%, possibly; 75-97.5%, *likely*; 97.5-99% *very likely*; >99%, *almost certainly*.[22] All statistical analyses were conducted R statistical software (R.2.1, R foundation for Statistical Computing)[23] using the *lme4* and *psychometric* packages.

RESULTS

The percentage effect of various covariates on relative distance covered (Model 1) and P_{met} sustained (Model 2) for interchange players during match play are presented in Table 2. From the model output, the exponential intercept depicts the mean log transformed value for the outcome variable, whereas the coefficient intercept reflects the change associated with a one-unit change in this. For example, individual fitness level assessed using the IFT test possessed the greatest influence on the running demands achieved by interchange players, where a one-unit increase in the exponential intercept value is associated with a 1.4 unit increase in IFT score. This resulted in *very likely large* increases in both relative distance covered and P_{met} maintained throughout the bout. Tackling involvements occurring both in attack and defence resulted in at least *likely small* increases in running intensity. *Small* increases were also observed in both dependant measures for matches played against strong opposition (*likely* to *very likely)* and following a short recovery period (*very likely)*. There were *likely* and *possibly small* increases in P_{met} during the mid and late stages of the season, respectively, whilst relative distance covered remained unaffected during this period. There were at least *very likely small* decreases in both measures of running intensity as a result of increased bout duration. Similarly, this was evident when a greater time spent in possession and a higher quantity of ball-out-of-play time occurred. Neither measure of match result (win/loss or points differential) had a significant impact within either model.

Table 2 near here

DISCUSSION

This study utilized a mixed models approach to examine the influence of individual fitness and various match characteristics on interchange players' running intensity during professional rugby league match-play. It was observed that individual intermittent fitness ability was the largest contributor to running intensity achieved throughout a bout amongst these players. In addition, matches played following a short recovery period, against strong opponents, and involving more physical collisions all resulted in increased running demands. In contrast, longer bouts involving more time in possession and greater ball-out-of-play time, and against teams in good recent form all reduced the movement demands of interchanged players. Based on these findings, interchange strategies may be more appropriately structured and manipulated to account for such environmental and situational variants each match.

Intermittent running ability is critical to rugby league, and has been shown to differentiate match performance amongst professional players.[5] As such, the IFT was chosen as an appropriate reflection of an individual's fitness ability, specific to the sport.[12] The present study observed a large increase in both relative distance covered and P_{met} as a result of increased intermittent running ability. Our findings are very similar to those of Kempton and Coutts,[7] where large increases in running intensity were observed in players exhibiting greater aerobic fitness. Despite the difference in fitness tests utilized, the similarity in the magnitude of the effect suggests that this had little impact on the outcome. Therefore, these findings collectively demonstrate that irrespective of the interchange classification of the players in the present study, individual fitness capacities are imperative in achieving greater running intensities throughout rugby league competition, possibly due to an accelerated rate of energy restoration between high-intensity efforts.[24]

Modern interchange strategies permit middle forwards and hookers to complete intense bouts of activity before being replaced by a substitute player.[9,25] During these bouts, players are exposed to a higher frequency of physical collisions compared to their full-match counterparts.[8] Kempton and Coutts[7] recently suggested that the running intensity achieved throughout a match is decreased as a result of increased defensive collisions. However, these findings may have been confounded by the inclusion of both interchange and full-match players in the analysis. For example, whilst defensive involvements might induce poorer locomotive output in full-match players, the requirement of "middle" players to quickly retreat into the defensive line following a contact situation might lead to an increased running intensity compared to players who are less involved in collisions. This is supported by the findings of Austin et al.,[26] who demonstrated that contact situations are normally preceded by a bout of high-intensity running. The findings of the present study suggest that interchange players who experience more contact situations exhibit a greater running intensity as a result. However other factors must also be considered.

When considering the relationship between contextual factors and running output amongst interchange players, it is important to account for the varying duration of bout required of this position. In the present study, the week-to-week interchange strategy of the team in question remained relatively constant, and the length of the bout required of the player resulted in a decrease in running intensity throughout that bout. This is in support of Waldron et al.,[9] who observed a decrease in both total and high-speed relative distance as an on-field bout progressed amongst professional rugby league players. Taken together, these findings are indicative of an accumulation of fatigue throughout an on-field bout, however it is important to note that this is not a result of the duration of the bout alone, and is rather an interaction of multiple factors. For example, the running demands and resultant fatigue of defending are far greater than time spent attacking,[27] which explains the small decrease in running intensity as a result of time in possession observed in the present study. Further, during a match, regular stoppages occur for a number of reasons including video referrals for refereeing decisions, or time off for injury. The present study found small decreases in running performance occurred as a result of an increase in ball-out-of-play time. These stoppages allow players to recover from intense periods of play, therefore potentially prolonging the length of their interchange bout. As a result, coaches must take care when employing replacement strategies based on time on the field alone, and should make informed decisions incorporating all available contextual information to maximize team performance.

The findings of the present study show that during matches against strong opposition, interchange players cover a greater relative distance throughout each on-field bout. In contrast, Kempton and Coutts[7] reported no change in relative distance covered as a result of opposition strength, but did observe *small to moderate* influences on high-speed running. The small increase in P_{met} may reflect the more appropriate measure of high-intensity running amongst this cohort, and therefore it could be suggested that matches completed against strong opposition result in a greater overall high-intensity running demand. In addition, the current study attempted to quantify recent form by accounting for the number of wins achieved in the last five games played, which resulted in slight decreases in both measures of running intensity. However, recording wins alone may not appropriately for the context of those wins in relation to the entire competition, or the strength of the opposition defeated. As such, future research may benefit from accurately quantifying recent form, accounting for these contextual factors. Recently, amongst semi-elite interchange rugby league players, Black and Gabbett[28] observed an increase in running intensity towards the end of a match players competing in losing teams. Interestingly, the present study observed no effect of match outcome on the running intensity achieved by interchanged players, which may reflect the higher quality of players in the current cohort, or the lack of differentiation of where a bout occurred throughout the match for these players.

Another contextual factor that may be accounted in the planning of interchange strategies is the recovery period between consecutive matches. Whilst previous research[7] showed that shorter match recovery periods resulted in decrements in running intensity measures, the present study showed contrary evidence of this, identifying that reduced recovery periods (5-6 days) positively influenced both measures of running intensity. It is suggested that the successful attenuation of training loads during shorter recovery periods may have assisted in the dissipation of fatigue, permitting athletes to re-perform in a superior physiological state. It is possible that the dissimilarities in these findings may be attributable to discrepancies in training loads between the two clubs, particularly in the days prior to match-play. Whilst this is difficult to ascertain, future research may investigate this utilizing data from multiple teams that adopt different training load strategies, determining the resultant effect on match performance, or examining physiological measures of fatigue such as salivary immune and endocrine indicators.[29,30]

Interestingly, it was noted that mid to late season games had a positive effect on P_{met} of interchange players. These findings are in support of Kempton and Coutts,[7] where early season games negatively affected running intensity, indicating that games later in the season demonstrated greater running intensities. Possible reasons for this may be the heightened importance of achieving a higher ladder position to make finals toward the end of the season or environmental factors such as reduced thermal strain during the winter months. Further, these findings may be evidence of successful training load periodization and enhanced recovery strategies adopted to attenuate cumulative fatigue throughout a congested match schedule. In contrast to the observed effect of season phase on running intensity, results of the present study showed no notable effect of match location (home or away) on either measure of running intensity. This is in contrast to the findings of Kempton and Coutts,[7] where matches played away from home negatively influenced the running intensities achieved. This discrepancy between findings may be a result of the inclusion of only interchanged players in the present study, where it is possible that the reduced playing duration of these players may diminish the effects of match location. As such, more scope for research exists to examine the effect of match location particularly when extended travel is required on the potential of this to affect match performance.

There are several limitations that must be considered when interpreting the findings of this study. Firstly, the study was able to recruit one team in isolation, and therefore the results may differ between teams due to differences in coaching strategy, or overall team performance. Secondly, only one measure of physical fitness was able to be taken prior to the start of the season, and it may be that fitness levels may deviate throughout the course of a season. Lastly, outside of the collision counts provided in the present study, no attempt was made to quantify the intensity or physical cost of the contact situation. Whilst this is undoubtedly an important element of match-play within interchange rugby league players, current technology is unable to detect the isometric contractions that form a large component of the "wrestle" situation. As a result, it was a focus of the current research to quantify the running demands of these players only, and therefore these results must be taken cautiously.

PRACTICAL APPLICATIONS

The findings of this study permit coaching staff to adopt evidence based replacement strategies that consider the multifaceted interplay of factors that potentially affect running performances, facilitating maximum team performance. During match play, athletes are inhibited in their ability to generate running intensity when the ball is out of play, and this should be considered before making replacement interchange decisions. In addition, the relative demands of attacking play seem to be less demanding than defensive play, and therefore may allow a player to prolong an on-field bout. The ability to maintain a high running intensity throughout an interchange bout may be attenuated by the development of intermittent fitness abilities, including exposure to regular collision events. Tailoring of recovery strategies as well as manipulating training loads during shorter recovery periods and when playing greater opposition strength may also help facilitate the increased running demands inflicted by these contextual factors.

CONCLUSION

This study examined the independent effects of various match-related, contextual and individual characteristics on the running intensities of interchange players during professional rugby league match-play. The statistical approach utilized provides a comprehensive understanding of the percentage effect of the various interacting factors, superior to that of commonly used statistical methods. Factors recognized to have had the greatest detrimental effect on the running intensity included longer bout durations, greater opposition strength, the longer the time the ball was out of play and time spent in attack. In contrast, factors positively influencing the running intensities included the tackling involvements (the number of tackles made by the player and the number of tackles made to the player) and a shorter match recovery period.

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