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# Variability of physical performance and player match loads in professional rugby union

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ABSTRACT

*Objectives:* To examine the within- and between-player variability of physical performance and player match loads in professional rugby union.
*Design:* A single cohort, observational study.
*Methods:* Physical match performance data were collected from 28 male, professional, English Championship players over 15 competitive matches. Using microsensors, the variables selected for analysis were total distance, low-speed running distance, high-speed running distance, very high-speed running distance, total impacts, repeated high-intensity efforts, body load (PlayerLoad$^{TM}$), and low velocity (<7.2 km h$^{-1}$) body load. Ratings of perceived exertion represented match internal loads. Variability was quantified using the coefficient of variation, with the meaningful interpretation of change in physical performance and match loads calculated using magnitude-based inferences.
*Results:* We found large between-match (within-player) variation for high-speed running distance (27.6%; ±90% confidence limits 6.9% [forwards], 20.1%; ±4.1% [backs]), very high-speed running distance (68%; ±19%, 34.1%; ±7.5%), total impacts (24.0%; ±5.9%, 36.4%; ±7.9%) and repeated high-intensity efforts (18.7%; ±4.4%, 39.5%; ±8.8%), with moderate variability for match ratings of perceived exertion (8.2%; ±1.8%, 10.8%; ±2.1%), body load (7.3%; ±1.7%, 10.0%; ±2.0%) and low velocity body load (8.9%; ±2.0%, 10.7%; ±2.1%). Threshold values for likely substantial between-match changes in high-intensity physical performance measures ranged from 21% to 76%, and were ∼10% for match ratings of perceived exertion, body load and low velocity body load.
*Conclusions:* Within- and between-player variability of high-intensity activity in professional rugby union is large, yet ratings of perceived exertion, body load and low velocity body load appear more stable by comparison and may be interpreted with greater accuracy.


## 1. Introduction

By means of video-based time-motion analysis[1–3] and, more recently, microsensor technology,[4–6] the physical demands of rugby union competition have been extensively documented. Match-play is characterized by short, intermittent bouts of high-intensity activity, such as sprinting and high-speed running,[6,7] accelerations and changes of direction under high velocities,[5,7] tackling,[1,2,8] static exertions,[2,3] and repeated high-intensity efforts (RHIE)[4,9]—all of which are interspersed with longer periods of movements performed at lower intensities.[5,10] Given the physiologically taxing nature of these performance demands, high player match loads are inherent during rugby union competition.[4,5] Player match loads may relate to the totality of mechanical stress experienced during movements and collisions,[11] as well as the player's relative physiological response to the work performed (i.e. the internal load).[12,13]

Team sport performance is a multifactorial construct that is stochastic and unstable in nature,[14] meaning that within-player (between-match) variability of physical performance and resultant match loads is inherent.[15–17] During competition, influences such as the opposing team,[18] win/lose margin or frequency,[19] interchange players[19] and season phase[15,16] are likely to influence the demands of match-play and subsequent match-to-match

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variability of physical performance and player match loads. In a complex and highly structured sport such as rugby union, the variability of physical performance and player match loads are also likely to differ between-players, given the notable discrepancies in position-specific roles, technical competency and anthropometry.[10]

The variability of physical performance and player match loads have previously been reported for other football codes such as soccer,[16] rugby league,[17] and Australian Football (AFL).[15,20] Gregson et al.[16] established large between-match coefficients of variation (CV) for a variety of high speed running parameters in professional soccer, including distance covered between 19.8 and 25.2 km h$^{-1}$ (CV = 16.2%; ±95% confidence limits [CL] 6.4%). Similar findings have recently been observed by Kempton et al.,[17] who noted large between-match variability in both high- (>15 km h$^{-1}$; CV = 14.6%; ±90% CL 2.2%) and very high-speed running (>21 km h$^{-1}$; 37%; ±6.1%) during professional rugby league competition. Moderate to high within-player variability has also been evidenced for high- (>14.4 km h$^{-1}$; CV = 11.7–13.8%) and very high-speed running (>19.9 km h$^{-1}$; CV = 15.1–20.9%) during AFL competition, yet the between-match variation of total body load appears lower in comparison (CV = 7.2–10.5%).[15] As well as this, Weston et al.[20] reported moderate within-player CVs (7.9%; ±90% CL 5.5%) in ratings of perceived exertion (RPE)—as a marker of relative internal load—following AFL match-play. Despite this, no attempts have yet been made to quantify the variability of physical performance and player match loads in rugby union.

The quantification of within- and between-player performance variability in team sports helps to establish reference values for the smallest worthwhile change in outcome measures and permits a better understanding of meaningful between-match changes on an individual (athlete) level.[21,22] Given that playing position influences match activities within rugby union,[10,23,24] it is likely that, as in soccer[16] and AFL,[15] the variability of physical performance and player match loads are also influenced by positional demands. Separating players into positional groupings of forwards and backs explains a large proportion (~58% and ~45%, respectively) of the shared variance in match-play time-motion characteristics during rugby union competition, yet the overall similarities between these two groups are trivial.[24] Therefore, the aims of our investigation were twofold. First, we aimed to determine the within- and between-player variability of physical performance and player match loads for two distinct positional groups (forwards and backs) in rugby union. Secondly, we aimed to establish threshold values for the interpretation of between-match changes in physical performance and player match loads on an individual level.

## 2. Methods

Twenty-eight professional rugby union players (mean ± SD; age: 27 ± 4 years; height: 187 ± 8 cm; body mass: 101 ± 14 kg) who represented a RFU English Championship team were used in our investigation. The initial sample included 15 forwards (age: 28 ± 4 years; height: 192 ± 7 cm; body mass: 112 ± 5 kg) and 13 backs (age: 27 ± 4 years; height: 181 ± 4 cm; body mass: 88 ± 6 kg). Physical performance, and player match load data were collected from 15 matches in total during the 2012/2013 season (win: loss ratio = 4: 1, aggregate points for = 377, aggregate points against = 215). Of these fixtures, 9 matches were played at home and 6 matches were played away from home. The sample included 12 matches played in the RFU English Championship and 3 matches played in the British & Irish Cup. Ethical approval was granted via Teesside University's institutional ethics committee.

During the games, each player wore a bespoke harness carrying a microsensor (MinimaxX$^{TM}$ S4, Catapult Innovations, Melbourne, Australia) which contained a 10 Hz global positioning system (GPS) and a 100 Hz; tri-axial accelerometer, gyroscope and magnetometer. The measurement error (CV) in 10 HZ GPS for total distance, distance covered ≥15 km h$^{-1}$ and distance covered >20 km h$^{-1}$ during team sport specific movements is reported to be 1.9%, 4.7 and 10.5%, respectively.[25] The interunit reliability of the MinimaxX$^{TM}$ 10 Hz GPS is good for the measurement of total distance (typical error of measurement [TEM] = 1.3%) and distance covered 14–20 km h$^{-1}$ (TEM = 4.8%),[26] but less so for distances covered >20 km h$^{-1}$ (TEM = 11.5%).[26] The highly responsive, tri-axial accelerometers embedded within MinimaxX$^{TM}$ units allow for the measurement of force-dependent mechanical loads incurred from team sport specific movements and player collisions, which is beyond the scope of GPS or video-based methods in isolation.[11,20] The within- (CV = 0.91–1.05%) and between-device (CV = 1.02–1.10%) reliability of data derived from the 100 Hz, triaxel accelerometers is high.[11]

Data were downloaded post-match using Logan Plus 4.2 software (Catapult Innovations, Melbourne, Australia), with half-time and injury time excluded from further analysis. All physical performance measures were represented in absolute and relative terms, indicative of volume and intensity, respectively. Relative measures were calculated as the absolute measure divided by on-field time. We set the minimum number of games-per-player and players-per-game in each positional group at 3.[20] For the analysis of the absolute performance measures and player match loads, only players who completed the full game were included. This gave a total of 82 match observations from 6 forwards (range = 3–9 games; 35 match observations) and 8 backs (range = 3–8 games; 47 match observations). For the analysis of relative performance measures, all player observations were included regardless of field time. This gave a total of 172 match observations from 15 forwards (range = 3–12 games; 89 match observations) and 13 backs (range = 3–11 games; 83 match observations).

Movement demands were quantified using overall total distance (TD), which was further split into arbitrary velocity bands of low-speed running distance (LSR; 0–14.9 km h$^{-1}$), high-speed running distance (HSR; 15.0–19.9 km h$^{-1}$), and very high-speed running distance (VHSR; 20.0–36.0 km h$^{-1}$). The association between total impacts recorded by MinimaxX$^{TM}$ units and video-based notation methods is reported to be most likely near perfect (r = 0.96; ±90% CL 0.04),[27] therefore, collision demands were appraised using total number of player impacts (TI) sustained during match-play. A RHIE has previously been defined as ≥3 consecutive high-speed efforts or impacts (tackle, scrum, ruck, and maul activities) occurring within 21 s.[9,28] In rugby union, the RHIE is a valid performance construct that represents the most demanding passage of play and often occurs at critical periods during a game.[9] Accordingly, a RHIE was measured as per Gabbett et al.[28] and the total number of bouts performed per game were recorded.

We used RPE (arbitrary units [AU]) as our indicator of match internal load, given the validity of this measure to accurately reflect the relative physiological stress imposed on team sport athletes during competition.[12] All players were familiar with the 10-point RPE scale (CR10)[29] and scores were provided independently ~30 min post-match. To represent the totality of mechanical loads experienced by the players during match-play, PlayerLoad$^{TM}$ (PL; arbitrary units [AU]) was computed as a vector magnitude derived from the root mean square of accelerations recorded in the three principal axes of movement, measured using a 100 Hz piezoelectric linearsensor (Kionix: KXP94) embedded within the microsensor units.[11] Finally, given the frequency of static exertions in rugby union,[2,3] we used the slow component of PL ($PL_{SLOW}$) to isolate the sum of PL accumulated at low velocities only (<7.2 km h$^{-1}$).

Raw data are presented as the mean ± SD. Prior to analysis, all data were log transformed to reduce the error occurring from non-uniform residuals (heteroscedasticity) that is typical from