Original Article

Activity profile, PlayerLoad™ and heart rate response of Gaelic football players: A pilot study

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ABSTRACT

The objectives of this study were to; quantify positional differences in the activity profiles of Gaelic football players and to evaluate decrements in physical performance during a pre-season competition. Global positioning system (GPS) data was recorded from 36 players from 3 teams across 5 games. The relative distance covered in locomotor activities, peak speed, relative PlayerLoad™ (PL.min^{-1}) and heart rate responses were evaluated between playing positions and across match periods using a mixed model analysis. The mean relative distance of 92.4 ± 23.3 m.min^{-1} covered, comprised 28.4 ± 10.2 m.min^{-1} of high intensity running (m.min^{-1} ≥ 4.0 m.s^{-1}) and 9.9 ± 3.9 m.min^{-1} of very high intensity running (m.min^{-1} ≥ 5.5 m.s^{-1}). High intensity running and relative PlayerLoad™ (PL.min^{-1}) was significantly higher in half-backs, midfielders and half-forwards compared to the full-backs, whereas only the half-backs and half-forwards displayed significantly greater values compared to full-forwards. When compared to the first 15 min (P1) of the game, analysis of pooled positional data revealed significant declines in; overall relative distance covered, jogging (≥2.0 - < 4.0 m.s^{-1}), running (≥4.0 - <5.5 m.s^{-1}), high intensity running and PL.min^{-1},in P2 (20-35 min) and P4 (55-70 min). Significant reductions in average heart rate were also found between the first and second halves and between P1 with both P3 and P4. These results highlight differences in the physical performance requirements of specific positions and provide evidence of reductions in work-rate during games. Coaches can use this information to inform the development of both team and position-specific conditioning programmes. **Keywords:** Performance analysis; Team sport; GPS; Accelerometer; Pre-season.

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INTRODUCTION

Gaelic football, the most popular sport in Ireland has been described as a hybrid of soccer and Australian football (Cullen et al., 2013). It is played using a round ball on a rectangular pitch measuring 90 m x 140 m. Inter-county games are contested by two teams of 15 players and consist of two 35-min halves plus stoppage time. Competition begins with the National League in January and concludes in September following the All-Ireland Championship. Recent studies found that players covered distances of 116 ± 21 $m \cdot min^{-1}$ and attained peak speeds of 8.4 ± 0.5 $m \cdot s^{-1}$ during match play (Malone et al., 2017b; Malone et al., 2016), which is comparable to the ~110 - 120 $m \cdot min^{-1}$ and ~7.9 $m \cdot s^{-1}$ reported for professional soccer players during pre-season (Mallo et al., 2015; Wehbe et al., 2014). Although amateur, Gaelic footballers adopt a quasi-professional regimen incorporating resistance exercises and pitch conditioning (Beasley, 2015), with weekly training loads of 3475 ± 596 AU reported using session-RPE (Malone et al., 2017a), being comparable to those found in Australian football (Veugelers et al., 2016).

Physical contact in Gaelic football is accentuated by man-to-man marking (Reilly and Doran, 2001), shoulder charging and tackling. These impacts can contribute to high levels of fatigue (Mooney et al., 2013), potentially contributing to reductions in work-rate. Using 4 Hz GPS devices, Malone et al. (2017b) found that the total distance covered during games decreased in the second, third and fourth quarters, and high speed running (≥4.7 $m.s^{-1}$) distance decreased in the second and fourth quarters. A positional hierarchy existed with middle-third (i.e. half-back, midfield, and half-forward) players having superior work-rates compared to the inside (i.e. full-back and full-forward) players (Malone et al., 2017b; Malone et al., 2016; Mangan et al., 2017a). Middle-third players also experienced the greatest declines in high speed running and sprinting (≥6.1 $m.s^{-1}$) between the first and second half (Malone et al., 2016) and between quarters of match play (Malone et al., 2017b). Interestingly, Reilly and Keane (2002) found no difference in heart rate between the first and second half or between the first and last 10 min of the game.

In studies employing 1-5 Hz GPS, fatigue has been shown to impair activity profiles in Australian football through reductions in work-rate across halves and quarters (Coutts et al., 2010; Mooney et al., 2013). Similarly, time motion analysis studies in soccer have found a reduction in high intensity running (> 4.0 – 4.2 $m.s^{-1}$) through comparisons of the first and last 15 min periods (Bradley et al., 2009), supporting the contention that fatigue levels increase towards the end of games (Waldron and Highton, 2014). In addition to activity profiles and physiological responses, analysis of work-rate and fatigue could be enhanced by the inclusion of the composite variable PlayerLoad™ (Boyd et al., 2011). This accumulates from the accelerations, decelerations, changes of direction and non-running activities such as kicking, jumping and impacts (Young et al., 2012) and can be used to quantify the overall physical loads experienced by players (Cummins et al., 2013; McLellan et al., 2011).

In summary, GPS systems can accurately quantify distances (Scott et al., 2016), enabling comparisons to be made within and between sports. An increase in the sampling rate to 10 Hz may attenuate the previous limitations related to evaluation of distance during high intensity running associated with 1-5 Hz models (Scott et al., 2016). Thus, the purpose of this investigation was to use a 10 Hz GPS device with integrated microsensors, to quantify positional differences in the activity profiles, PlayerLoad™ and heart rate characteristics of Gaelic footballers. A secondary aim was to evaluate declines in physical performance across match periods.

MATERIALS AND METHODS

Participants

Thirty-six male players from 3 senior teams with a mean (±SD) age of 24 ± 3 years participated in this observational study. In total, 50 match files were obtained from 5 games (1-3 files per player). A small winning or losing margin of <5 points was associated with 37 files, whereas the remaining 13 files were acquired from players following a large defeat (between 6-11 points). Goalkeepers and substituted players were excluded as only complete match files from outfield players were examined. The 5 positional categories used were; full-back (n=12), half-back (n=12), midfield (n=4), half-forward (n=10) and full-forward (n=12), as described previously (Reilly et al., 2015). The university research committee granted ethical approval and all players provided written informed consent prior to commencing the study.

Measures

Physical performance was analysed using the relative intensity of locomotion, which reflected the distance travelled per minute of game time (Cummins et al., 2013). Relative distance ($m \cdot min^{-1}$) was used to facilitate comparison of match samples of differing duration (Kempton et al., 2015). The locomotor speeds ($m \cdot s^{-1}$) used to classify; standing (≥0.00 – <0.19), walking (≥0.19 – <2.00), jogging (≥2.00 – <4.00), running (≥4.00 – <5.50), high speed running (≥5.50 – <7.00), and maximal speed running (≥7.00), were based on activity profiles and thresholds reported previously in Australian football (Coutts et al., 2010; Duffield et al., 2009; Johnston et al., 2014) and soccer (Bradley et al., 2009; Mallo et al., 2015; Rampinini et al., 2007; Wehbe et al., 2014). The starting speed for each activity zone represented the end point for the preceding zone, ensuring that all data was included in the analysis. Other match measures included; high intensity running ($m \cdot min^{-1}$ ≥4.0 $m \cdot s^{-1}$), very high intensity running ($m \cdot min^{-1}$ ≥5.5 $m \cdot s^{-1}$) and peak speed ($m \cdot s^{-1}$). Also PlayerLoad™, calculated as the square root of the sum of the squared instantaneous rate of change in acceleration in the forward, vertical and sideward directions and divided by a scaling factor of 100 (Boyd et al., 2011), was accrued during games and reported relative to playing time ($PL \cdot min^{-1}$). Absolute values of peak and average heart rate ($b \cdot min^{-1}$) are presented due to an absence of maximum heart rate data. Heart rate information was not obtained from two players (1 half-back and 1 full-forward), resulting in a total of 48 measurements. As match halves and calculated quarters varied in duration, a period of 15 min was also selected to investigate potential decrements in work-rate. This analysis incorporated the first 15 min and last 15 min of each half (including stoppage time) with the corresponding periods being defined as; P1: 0-15, P2: ≈20-35, P3: 35-50 and P4: ≈55-70 min. The middle section of each half (i.e. 15-20 min) was not reflected in the period comparison.

Design and procedures

Microtechnology devices were used to measure the activity profiles of Gaelic footballers during a pre-season competition. The GPS units sampled at 10 Hz (OptimEye S5, Catapult Sports, Australia) and incorporated a 100 Hz tri-axial accelerometer (Firmware v6.92). The devices (mass 66.8 g; 96 x 52 x 14 mm) were inserted into a custom-made vest, which was worn under the player's shirt. The mean (±SD) number of GPS satellites acquired during the games was 14.3 ± 1.3. The mean (±SD) horizontal dilution of precision score of 0.58 ± 0.05 reflected the geometrical arrangement of the satellites and indicated the acceptable accuracy of the signal (Jennings et al., 2010). Heart rate was also measured via radio-telemetry (Polar T31, Finland). Post-game data was downloaded using the Sprint software (v5.1.7) and exported into Microsoft Excel (Microsoft, USA) for evaluation.

Statistical analysis

Data were analysed using SPSS for Windows (Version 24; SPSS Inc., Chicago, Illinois, USA). Data are presented as mean ± SD and outcome variables were examined for outlying effects. Performance variables were evaluated across specific match periods and between positions using a mixed model analysis of variance, where position was treated as a fixed effect, period as a repeated measure and the model intercept was deemed to be a random effect for each match. Where significant effects were observed, Bonferroni post hoc tests were used. Statistical significance was accepted at $p \leq 0.05$. Correlations between repeated measures for each dependent variable were examined and where significant correlations where found, the covariance structure of the repeated measures was assumed to be first order ante-dependence. The remaining variables were assumed to have a diagonal covariance structure as they had low levels of correlation between the repeated measures but differing levels of variation within each repeat. The errors of each mixed analysis model were examined using a Shapiro-Wilks test for normality. Where these were found to be significant, a log transformation was conducted on the dependent variable and the analysis was repeated.

Table 1. Full game match activity measures between different positional groups (adjusted for half), mean ± SD.

Match measure	Full-back (n = 12)	Half-back (n = 12)	Midfield (n = 4)	Half-forward (n = 10)	Full-forward (n = 12)	Mean (n = 50)
Playing time (m:s)	74:12 ± 1:05	74:14 ± 1:00	74:02 ± 0:12	74:26 ± 1:21	74:41 ± 1:15	74:21 ± 1:06
Relative distance (m·min^{-1})	67.0 ± 13.0	113.2 ± 16.0 ^{a,e}	100.3 ± 13.2 ^{a}	107.2 ± 10.9 ^{a,e}	82.0 ± 18.3 ^{a}	92.4 ± 23.3
Stand (m·min^{-1})	0.6 ± 0.1	0.4 ± 0.1 ^{a}	0.5 ± 0.2	0.4 ± 0.2 ^{a}	0.4 ± 0.1 ^{a}	0.5 ± 0.1
Walk (m·min^{-1})	27.0 ± 5.1	32.8 ± 2.4 ^{a,e}	33.5 ± 6.5 ^{a}	31.1 ± 5.9	27.4 ± 5.7	29.8 ± 5.5
Jog (m·min^{-1})	23.3 ± 6.1	42.5 ± 7.5 ^{a,e}	37.9 ± 8.4 ^{a}	43.6 ± 8.2 ^{a,e}	31.4 ± 11.4 ^{a}	35.1 ± 11.6
Run (m·min^{-1})	10.6 ± 3.8	26.7 ± 6.6 ^{a,c,e}	20.6 ± 5.9 ^{a}	22.9 ± 3.5 ^{a,e}	15.2 ± 4.3 ^{a}	18.8 ± 7.8
High speed run (m·min^{-1})	5.1 ± 1.8	11.5 ± 3.2 ^{a,e}	8.1 ± 1.6 ^{a}	9.2 ± 2.5 ^{a}	7.5 ± 2.8 ^{a}	8.3 ± 3.4
Maximum speed run (m·min^{-1})	1.6 ± 1.2	1.4 ± 0.9	1.4 ± 0.9	2.1 ± 1.9	2.1 ± 1.4	1.7 ± 1.3
HIR (m·min^{-1} ≥4.0 m·s^{-1})	17.3 ± 5.9	39.5 ± 8.8 ^{a,e}	30.0 ± 3.7 ^{a}	34.2 ± 3.3 ^{a,e}	24.8 ± 6.5 ^{a}	28.8 ± 10.4
VHIR (m·min^{-1} ≥5.5 m·s^{-1})	6.8 ± 2.5	12.9 ± 3.6 ^{a}	9.5 ± 2.4	11.2 ± 3.7 ^{a}	9.5 ± 3.8	10.0 ± 3.9
Peak speed (m·s^{-1})	8.0 ± 0.4	7.6 ± 0.3	7.8 ± 0.6	7.8 ± 0.5	8.0 ± 0.6	7.8 ± 0.5
Peak heart rate (b·min^{-1})	191 ± 6	192 ± 9	197 ± 7	192 ± 10	190 ± 11	192 ± 9
Average heart rate (b·min^{-1})	157 ± 12	165 ± 7	169 ± 6	167 ± 9	160 ± 11	162 ± 10
Relative PL (PL·min^{-1})	7.0 ± 1.4	10.2 ± 1.6 ^{a,e}	9.8 ± 1.6 ^{a}	10.2 ± 1.3 ^{a,e}	8.6 ± 1.6 ^{a}	9.0 ± 1.9

HIR = high intensity running; VHIR = very high intensity running; PL = Player Load. Symbols indicate significantly different ($p \leq 0.05$) from full-back (a); midfield (c); and full-forward (e).

Table 2. Match activity measures for each period and half (all players combined, n=50), mean ± SD.

Variable	P1 0–15 min	P2 20–35 min	P3 35-50 min	P4 55-70 min	First half	Second half
Playing time (m:s)	15:00 ± 0:00	15:00 ± 0:00	15:00 ± 0:00	15:00 ± 0:00	37:24 ± 1:09	36:57 ± 0:24
Relative distance (m·min^{-1})	101.7 ± 29.1	92.0 ± 26.2 $^{\alpha}$	92.7 ± 27.3 $^{\alpha}$	89.8 ± 24.6 $^{\alpha}$	93.5 ± 25.2	91.3 ± 23.4
Stand (m·min^{-1})	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.2 ± 0.1	0.2 ± 0.1
Walk (m·min^{-1})	5.9 ± 1.2	6.2 ± 1.3	5.7 ± 1.2	6.2 ± 1.3	15.1 ± 3.0	14.7 ± 2.8
Jog (m·min^{-1})	8.2 ± 3.1	7.0 ± 2.7 $^{\alpha}$	7.1 ± 2.8 $^{\alpha}$	6.8 ± 2.7 $^{\alpha}$	18.1 ± 6.3	17.0 ± 5.9
Run (m·min^{-1})	4.5 ± 2.1	3.7 ± 1.7 $^{\alpha}$	4.0 ± 1.9	3.5 ± 1.7 $^{\alpha}$	9.5 ± 4.2	9.3 ± 3.9
High speed run (m·min^{-1})	1.9 ± 1.0	1.7 ± 0.9	1.7 ± 1.1	1.5 ± 0.7	4.2 ± 1.8	4.1 ± 1.8
Maximum speed run (m·min^{-1})	0.3 ± 0.3	0.3 ± 0.3	0.4 ± 0.4	0.4 ± 0.3	0.8 ± 0.7	1.0 ± 0.8
HIR (m·min^{-1} ≥ 4.0 m·s^{-1})	6.7 ± 2.7	5.7 ± 2.4 $^{\alpha}$	6.2 ± 2.7	5.4 ± 2.2 $^{\alpha}$	14.5 ± 5.6	14.3 ± 5.3
VHIR (m·min^{-1} ≥ 5.5 m·s^{-1})	2.3 ± 1.1	2.0 ± 1.0	2.2 ± 1.2	1.8 ± 0.8	5.0 ± 2.2	5.1 ± 2.0
Peak speed (m·s^{-1})	7.2 ± 0.6	7.4 ± 0.6	7.4 ± 0.5	7.4 ± 0.7	7.6 ± 0.5	7.7 ± 0.5
Peak heart rate (b·min^{-1})	189 ± 9	187 ± 10	185 ± 9	185 ± 9	190 ± 9	187 ± 9
Average heart rate (b·min^{-1})	167 ± 12	165 ± 12	160 ± 9 $^{\alpha}$	160 ± 11 $^{\alpha}$	165 ± 11	160 ± 10*
Relative PL (PL·min^{-1})	9.9 ± 2.5	9.0 ± 2.2 $^{\alpha}$	9.1 ± 2.3	8.7 ± 2.0 $^{\alpha}$	9.1 ± 2.1	8.9 ± 2.0

HIR = high intensity running; VHIR = very high intensity running; PL = Player Load. Symbols indicate significantly different ($p \leq 0.05$) from P1 (α) and first half (*).

RESULTS

Full game positional analysis

Positional differences in match activities are summarised in Table 1. The relative distance covered was significantly greater ($p \leq 0.001$) among half-backs and half-forwards than full-backs or full-forwards, and among midfielders ($p \leq 0.001$) and full-forwards ($p \leq 0.05$) compared to full-backs. Similarly, jogging ($p \leq 0.01$) and running ($p \leq 0.001$) distances were significantly greater in midfielders than full-backs and in both half-backs and half-forwards than either full-backs or full-forwards ($p \leq 0.001$). The full-forwards performed significantly more jogging ($p \leq 0.01$) and running ($p \leq 0.05$) than the full-backs. Full-backs covered significantly less distance in high speed running than half-backs ($p \leq 0.001$), half-forwards ($p \leq 0.001$), midfielders ($p \leq 0.01$) and full-forwards ($p \leq 0.01$). Only the half-backs performed more high speed running compared to full-forwards ($p \leq 0.001$). There were no significant positional differences in maximum speed running or peak speed. Half-backs ($p \leq 0.001$), midfielders ($p \leq 0.001$), half-forwards ($p \leq 0.001$), and full-forwards ($p \leq 0.01$) performed more high intensity running than the full-backs, whereas only the half-backs ($p \leq 0.001$) and half-forwards ($p \leq 0.05$) performed more high intensity running than full-forwards. Half-backs

($p \leq 0.001$) and half-forwards ($p \leq 0.05$) performed significantly more very high intensity running than full-backs. The PL.min^{-1} was significantly higher among middle-third players than full-backs ($p \leq 0.001$) and among half-backs and half-forwards compared to full-forwards ($p \leq 0.05$). There were no significant differences in average or peak heart rate between positions.

Table 3. Positional differences in activity profiles between periods and halves, mean ± SD.

Variable	P1 0–15 min	P2 20–35 min	P3 35-50 min	P4 55-70 min	First Half	Second half
Full-back *(n = 12)*						
Walk (m·min^{-1})	5.3 ± 1.2	5.5 ± 1.5	5.4 ± 1.1	5.6 ± 1.4	13.6 ± 3.1	13.4 ± 2.5
Jog (m·min^{-1})	5.1 ± 1.3	4.2 ± 1.4	5.0 ± 1.7	4.9 ± 1.8	11.4 ± 2.6	11.9 ± 4.0
Run (m·min^{-1})	2.2 ± 1.0	1.8 ± 0.8	2.6 ± 1.3	2.3 ± 1.2	4.8 ± 1.5	5.8 ± 2.7
High speed run (m·min^{-1})	1.1 ± 0.5	0.9 ± 0.5	1.0 ± 0.8	1.2 ± 0.6	2.4 ± 0.8	2.7 ± 1.4
Maximum speed run (m·min^{-1})	0.3 ± 0.4	0.4 ± 0.3	0.4 ± 0.3	0.3 ± 0.3	0.8 ± 0.7	0.9 ± 0.6
Half-back *(n = 12)*						
Walk (m·min^{-1})	6.6 ± 0.7	6.8 ± 0.6	6.3 ± 0.5	6.8 ± 0.8	16.5 ± 1.5	16.2 ± 1.6
Jog (m·min^{-1})	10.1 ± 2.1	8.6 ± 2.4	9.0 ± 1.8	7.4 ± 2.3 $^{\alpha}$	22.3 ± 4.5	20.2 ± 4.3
Run (m·min^{-1})	6.3 ± 1.5	5.3 ± 1.6	5.7 ± 1.7	4.8 ± 1.8 $^{\alpha}$	13.7 ± 3.4	12.9 ± 3.5
High speed run (m·min^{-1})	2.5 ± 0.8	2.5 ± 0.8	2.6 ± 1.1	1.8 ± 1.0 $^{\alpha, \beta, \gamma}$	5.7 ± 1.5	5.8 ± 2.0
Maximum speed run (m·min^{-1})	0.3 ± 0.3	0.2 ± 0.2	0.2 ± 0.3	0.3 ± 0.3	0.7 ± 0.6	0.7 ± 0.5
Midfield *(n = 4)*						
Walk (m·min^{-1})	6.7 ± 1.4	6.6 ± 1.0	6.8 ± 1.6	7.2 ± 1.4	16.4 ± 2.8	17.1 ± 3.1
Jog (m·min^{-1})	10.1 ± 2.2	7.9 ± 2.0	7.1 ± 2.5 $^{\alpha}$	6.9 ± 1.1 $^{\alpha}$	21.2 ± 4.5	16.7 ± 4.9
Run (m·min^{-1})	5.0 ±1.9	3.9 ± 0.9	4.1 ± 1.7	3.6 ± 1.1	11.2 ± 2.4	9.3 ± 2.4
High speed run (m·min^{-1})	2.1 ± 1.2	1.6 ± 0.6	1.9 ± 0.5	1.0 ± 0.2	4.3 ± 1.6	3.8 ± 1.2
Maximum speed run (m·min^{-1})	0.1 ± 0.1	0.2 ± 0.2	0.4 ± 0.3	0.5 ± 0.5 $^{\beta}$	0.3 ± 0.8	1.0 ± 1.1
Half-forward *(n = 10)*						
Walk (m·min^{-1})	6.4 ± 0.9	6.5 ± 1.1	5.8 ± 1.4	6.2 ± 1.4	16.0 ± 2.9	15.1 ± 3.7
Jog (m·min^{-1})	10.8 ± 2.4	8.5 ± 1.9 $^{\alpha}$	8.3 ± 1.7 $^{\alpha}$	8.7 ± 2.8 $^{\alpha}$	22.9 ± 5.4	20.8 ± 3.0
Run (m·min^{-1})	5.8 ± 1.2	4.4 ± 1.1 $^{\alpha}$	5.0 ± 1.1	4.3 ± 1.3 $^{\alpha}$	11.6 ± 3.1	11.4 ± 3.3
High speed run (m·min^{-1})	2.2 ± 0.9	1.9 ± 0.7	1.8 ± 0.8	1.6 ± 0.5	4.8 ± 1.5	4.4 ± 0.1
Maximum speed run (m·min^{-1})	0.4 ± 0.4	0.3 ± 0.3	0.5 ± 0.6	0.3 ± 0.3	0.9 ± 0.3	1.1 ± 0.8
Full-forward *(n = 12)*						
Walk (m·min^{-1})	5.2 ± 1.2	5.9 ± 1.4	5.1 ± 1.2	5.8 ±1.3	13.9 ± 3.3	13.5 ± 2.6
Jog (m·min^{-1})	6.6 ± 2.5	6.6 ± 2.4	6.1 ± 3.5	6.6 ± 3.0	15.7 ± 5.1	15.7 ± 6.7

Run (m·min^{-1})	3.6 ± 1.6	3.1 ± 1.0	2.9 ± 1.5	2.8 ± 1.2	7.9 ± 2.5	7.3 ± 2.5
High speed run (m·min^{-1})	1.9 ± 1.0	1.6 ± 0.8	1.4 ± 1.0	1.5 ± 0.5	3.9 ± 1.6	3.6 ± 1.4
Maximum speed run (m·min^{-1})	0.4 ± 0.4	0.4 ± 0.4	0.6 ± 0.5	0.5 ± 0.4	0.8 ± 0.7	1.2 ± 0.8

Symbols indicate significantly different ($p \leq 0.05$) from P1 (α); P2 (β); and P3 (γ).

Table 4. Positional differences in relative distance, high intensity running, peak speed and heart rate between periods and halves, mean ± SD.

Variable	P1 0–15 min	P2 20–35 min	P3 35-50 min	P4 55-70 min	First Half	Second half
Full-back *(n = 12)*						
RD (m·min^{-1})	68.4 ± 13.4	62.4 ± 15.1	71.0 ± 19.0	70.5 ± 20.1	64.9 ± 11.1	69.1 ± 17.9
HIR (RD ≥ 4.0 m·s^{-1})	3.6 ± 1.5	3.1 ± 1.2	4.1 ± 1.9	3.9 ± 1.8	7.9 ± 2.5	9.4 ± 4.1
VHIR (RD ≥ 5.5 m·s^{-1})	1.4 ± 0.7	1.3 ± 0.6	1.4 ± 0.9	1.6 ± 0.7	3.2 ± 1.3	3.6 ± 1.6
Peak speed (m·s^{-1})	7.3 ± 0.5	7.7 ± 0. 6	7.6 ± 0. 4	7.4 ± 0.8	7.8 ± 0.6	7.8 ± 0.4
Peak heart rate (b·min^{-1})	187 ± 7	184 ± 8	184 ± 8	186 ± 11	188 ± 5	188 ± 9
Half-back *(n = 12)*						
RD (m·min^{-1})	125.6 ± 16.5	114.1 ± 22.0	116.5 ± 20.0	103.1 ± 22.2 α	116.3 ± 18.9	110.2 ± 17.0
HIR (RD ≥ 4.0 m·s^{-1})	9.1 ± 1.8	8.0 ± 2.3	8.6 ± 2.4	6.9 ± 2.6 α	20.2 ± 4.6	19.4 ± 4.7
VHIR (RD ≥ 5.5 m·s^{-1})	2.8 ± 0.8	2.7 ± 1. 0	2.8 ± 1.2	2.1 ± 1.1	6.4 ± 1.9	6.5 ± 2.1
Peak speed (m·s^{-1})	7.1 ± 0.5	7.3 ± 0.4	7.1 ± 0.3	7.2 ± 0.6	7.6 ± 0.4	7.4 ± 0.4
Peak heart rate (b·min^{-1})	189 ± 8	189 ± 8	184 ± 7	186 ± 7	190 ± 9	188 ± 6
Midfield *(n = 4)*						
RD (m·min^{-1})	117.6 ± 14.3	99.2 ± 11.7	98.9 ± 19.5	93.6 ± 14.2	105.2 ± 12.0	95.4 ± 12.2
HIR (RD ≥ 4.0 m·s^{-1})	7.3 ± 1.0	5.8 ± 1.2	6.4 ± 1.4	5.1 ± 1.0	15.9 ± 2.4	14.1 ± 2.4
VHIR (RD ≥ 5.5 m·s^{-1})	2.2 ± 1.3	1.8 ± 0.8	2.3 ± 0.6	1.4 ± 0.4	4.7 ± 2.2	4.8 ± 1.7
Peak speed (m·s^{-1})	7.0 ± 0.3	7.2 ± 0.6	7.5 ± 0.5	7.4 ± 1.0	7.3 ± 0.4	7.8 ± 0.5
Peak heart rate (b·min^{-1})	191 ± 8	190 ± 8	191 ± 6	190 ± 8	192 ± 10	195 ± 9
Half-forward *(n = 10)*						
RD (m·min^{-1})	124.8 ± 11.4	105.8 ± 12.9 α	105.0 ± 8.9 α	103.3 ± 21.0 α	109.9 ± 12.0	104.4 ± 15.1
HIR (RD ≥ 4.0 m·s^{-1})	8.4 ± 1.5	6.7 ± 1.2 α	7.4 ± 1.4	6.2 ± 1.6 α	17.3 ± 1.5	16.9 ± 2.6
VHIR (RD ≥ 5.5 m·s^{-1})	2.6 ± 1.0	2.3 ± 0.8	2.3 ± 0.9	1.9 ± 0.6	5.7 ± 1.8	5.6 ± 0.9
Peak speed (m·s^{-1})	7.4 ± 0.6	7.4 ± 0.4	7.4 ± 0.6	7.2 ± 0.4	7.6 ± 0.6	7.7 ± 0.6
Peak heart rate (b·min^{-1})	192 ± 10	188 ± 11	186 ± 10	184 ± 10	192 ± 8	186 ± 7
Full-forward *(n = 12)*						
RD (m·min^{-1})	86.6 ± 22.2	85.4 ± 21.1	78.4 ± 29.8	83.5 ± 23.7	81.7 ± 16.7	82.3 ± 21.7

HIR (RD ≥ 4.0 m·s^{-1})	5.9 ± 2.4	5.1 ± 1.4	4.9 ± 2.5	4.7 ± 1.5	12.6 ± 3.6	12.1 ± 3.5
VHIR (RD ≥ 5.5 m·s^{-1})	2.3 ± 1.3	1.9 ± 1.0	2.0 ± 1.4	1.9 ± 0.8	4.8 ± 2.1	4.8 ± 1.9
Peak speed (m·s^{-1})	7.3 ± 0.6	7.3 ± 0.6	7.5 ± 0.7	7.6 ± 0.9	7.6 ± 0.5	8.0 ± 0.6
Peak heart rate (b·min^{-1})	186 ± 13	185 ± 14	183 ± 10	182 ± 10	189 ± 13	184 ± 10

RD = relative distance; HIR = high intensity running; VHIR = very high intensity running. Symbols indicate significantly different (p ≤ 0.05) from P1 (α).

Period and half comparison – all players

Table 3 illustrates the significant decline in relative distance covered between P1 and the other three periods (P2 and P3; $p \leq 0.05$ and P4; $p \leq 0.01$). Significantly less jogging was performed during P2, P3 and P4 than in P1 ($p \leq 0.01$). Compared to P1 there was a significant decline in running, high intensity running and PL. min^{-1} in both P2 ($p \leq 0.05$) and P4 ($p \leq 0.01$). There was a significant decrease ($p \leq 0.01$) in average heart rate from P1 to both P3 and P4 coinciding with a significant decline ($p \leq 0.05$) in heart rate in the second half.

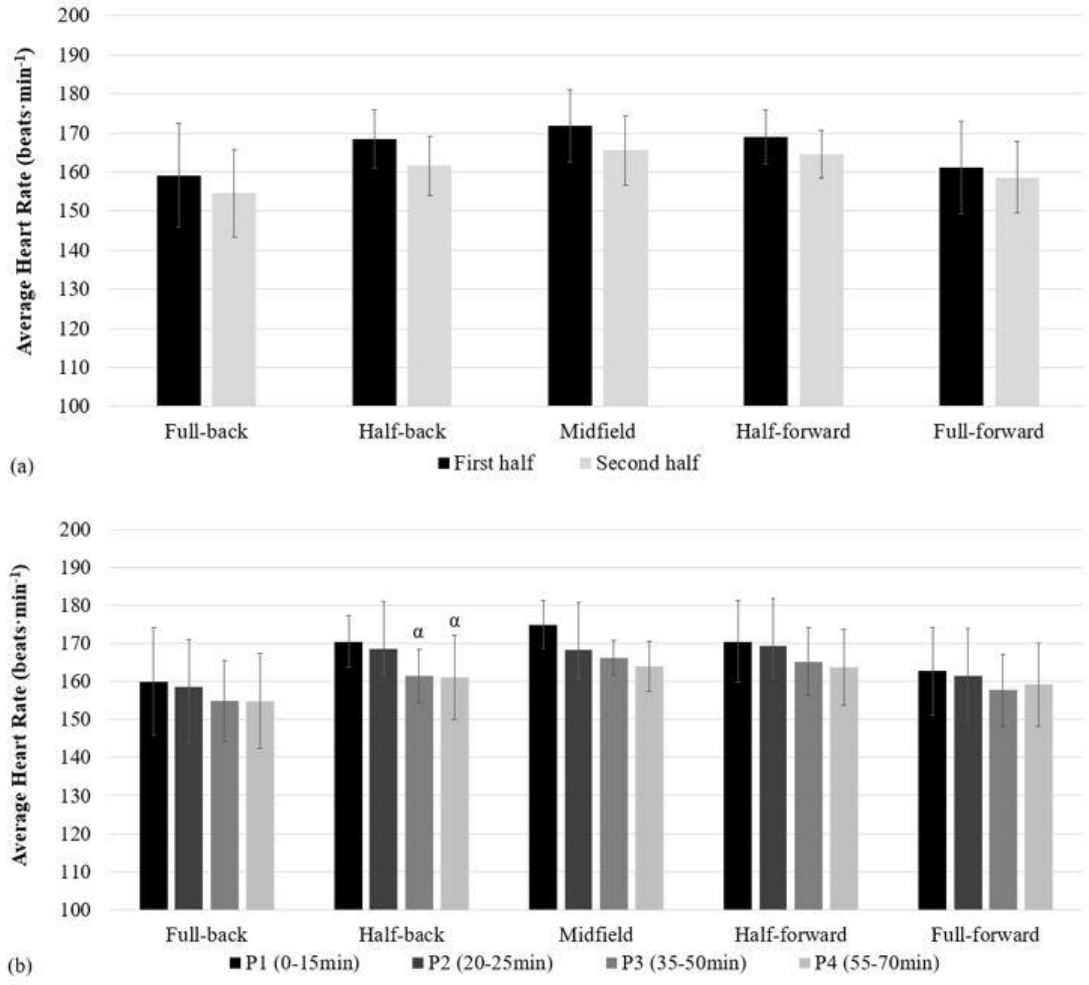

Figure 1. Differences in average heart rate during (a) first and second halves and (b) across four match periods, mean ± SD. Symbols indicate significantly different ($p \leq 0.05$) from P1 (α).

Within player comparison – periods and halves

Significant differences were observed in the activity profiles of the middle-third players as the games progressed (Tables 3 and 4). Among half-backs, there was a significant decline in jogging and running between P1 and P4 ($p \leq 0.01$) and in high speed running between P1 and the other three periods ($p \leq 0.05$). There was a significant decline in jogging among half-forwards from P1 to P2 and P3 ($p \leq 0.01$) and P4 ($p \leq 0.05$) and also in running between P1 and both P2 and P4 ($p \leq 0.05$). Jogging declined between P1 and both P3 and P4 ($p \leq 0.05$) whereas maximal speed running increased between P2 and P4 ($p \leq 0.05$) in midfielders. In comparison to P1, the relative distance covered significantly decreased in half-forwards in P2, P3 and P4 ($p \leq 0.05$) and in half-backs in P4 ($p \leq 0.01$). High intensity running significantly decreased in half-backs ($p \leq 0.05$) and half-forwards ($p \leq 0.01$) between P1 and P4. Neither the full-backs nor full-forwards experienced any significant differences in activity profiles between match periods or halves. There were no significant differences in average heart rate or PL.min^{-1} between the first and second half (Figures 1a and 2a). Average heart rate decreased significantly among half-backs from P1 to both P3 and P4 ($p \leq 0.05$) (Figure 1b). The relative PL.min^{-1} declined significantly from P1 to P4 in half-backs ($p \leq 0.01$) and midfielders ($p \leq 0.05$) and from P1 to P2, P3 and P4 in half-forwards ($p \leq 0.05$) (Figure 2b).

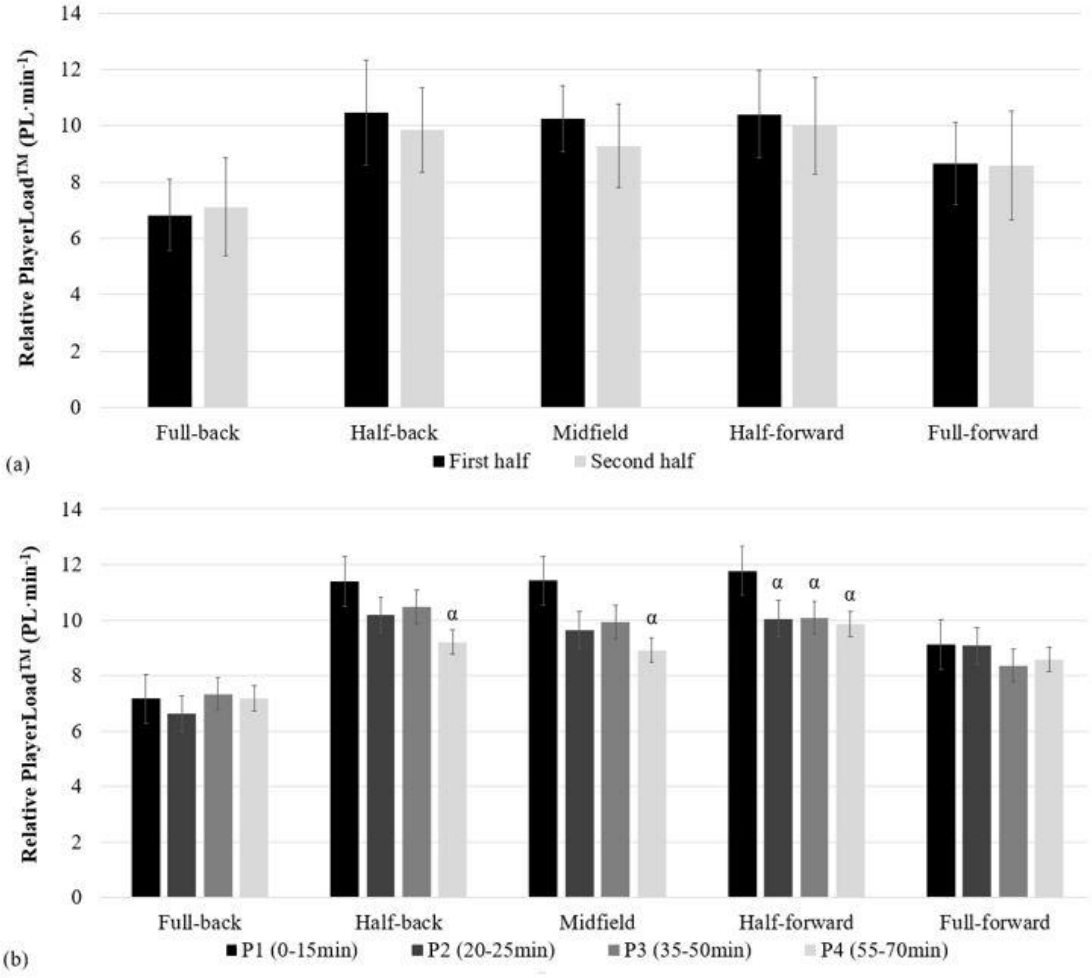

Figure 2. Differences in PL·min^{-1} during (a) first and second halves and (b) across four match periods, mean ± SD. Symbols indicate significantly different ($p \leq 0.05$) from P1 (α).

DISCUSSION

This study is the first to use 10 Hz GPS to document the activity profile, PlayerLoad™ and heart rate characteristics of senior Gaelic footballers. Middle-third players exhibited greater activity profiles compared to the inside offensive and defensive players. The half-backs had the highest i) overall relative distance, ii) high intensity running and iii) very high intensity running, followed by the half-forwards and midfielders. Consequently, these players experienced the greatest declines in performance when comparing the first 15 min (P1) with the last 15 min (P4) of match play. Compared to P1, there was a significant reduction in the relative distance covered in P2, P3 and P4 when the data was pooled across all positions. Jogging, running, high intensity running, and PL.min^{-1} also declined significantly in both P2 and P4 compared to P1. Average heart rate decreased significantly between the first and second halves and between P1 with both P3 and P4.

The highest total distances covered by elite Gaelic footballers has been found to occur during the final stages of the All-Ireland championship (Mangan et al., 2017b). Not surprisingly, the mean relative distance covered in this pre-season study was lower than the values reported previously (Malone et al., 2017b; Malone et al., 2016), although specific factors may have contributed to this underestimation. Collective training restrictions are placed on inter-county teams during the months of November and December. Consequently, interindividual variability in aerobic fitness levels due to differences in training start date and individual and team programme prescription may have impacted on the ability to sustain high work-rates during games (Reilly and Doran, 2001). Also, full-backs and full-forwards who accounted for almost 50% of the players analysed, performed less running compared to the half-backs, midfielders and half-forwards. Previous studies found that midfielders were the most active during match play (Malone et al., 2017b; Malone et al., 2016; Mangan et al., 2017a). In the current study only 4 of the 14 midfielders evaluated were subsequently analysed due to the regular substitution of this physically demanding position.

The average heart rate in this study was comparable to the 160 ± 6 b.min^{-1} and 165 ± 11 b.min^{-1} reported previously in Gaelic football (Reilly and Keane, 2002) and soccer (Mallo et al., 2015) respectively, reflecting the physiological strain from alterations between low and high intensity activities (Reilly and Doran, 2001). Both high intensity and very high intensity running were also similar to the ~28.3 m.min^{-1} and ~9.1 m.min^{-1} reported for soccer players in pre-season games (Mallo et al., 2015). Although the mean peak speed reported in Table 1 was similar to that found in soccer (Mallo et al., 2015), the Gaelic footballers covered a greater relative distance at high speed but less at maximum speed, perhaps due to a limited focus on speed development during the pre-season, combined with the inferior quality of the playing surface. The Gaelic football games were played in winter on wet surfaces, whereas the soccer games were played during the summer on likely optimum dry surfaces. Moreover, previous Gaelic football studies reported higher peak speeds in games played mainly in spring and summer (Malone et al., 2017b; Malone et al., 2016).

The half-backs performed the most distance running and at high speed, and had the highest values for high- and very high-intensity running in contrast to previous findings which highlighted the superior performance of midfielders (Malone et al., 2017b; Malone et al., 2016). In addition to their primary defensive and man-marking roles, half-backs are required to initiate attacks from possession restarts, launch counter-attacks following turnovers, perform support and decoy runs into the offensive third and provide passing options for other players. Not surprisingly, the half-forwards, who are in direct opposition, demonstrated the second highest running metrics. Additionally, midfielders, who are tasked with facilitating the transition from defensive to offensive play (Reilly et al., 2015), covered more relative distance than both the full-backs and full-forwards (Malone et al., 2017b; Malone et al., 2016). The greater relative distance covered by the middle-third players

and increased acceleration, deceleration and change of direction requirements from game related activities is reflected in the higher PL.min^{-1} experienced. Although, the PL.min^{-1} values were lower than the 11 to 16 PL.min^{-1} reported for Australian footballers in-season (Boyd et al., 2013), this disparity may perhaps be attributed to the longer duration and higher intensity of games and unlimited interchange of players.

In contrast to previous findings, the highest peak speed was recorded among full-forwards and full-backs rather than midfielders (Malone et al., 2017b; Malone et al., 2016). Full-forwards accelerate and move at high speeds to evade defenders, create space, receive a pass or attempt to score. The full-backs have to anticipate or respond to these movements, to deny space, intercept passes or to block scoring attempts. The full-forwards also performed more high intensity running than the full-backs, perhaps influenced by the greater defensive and player-tracking responsibilities presently required. Since a tactical analysis was not conducted, it was not possible to determine the influence of zonal defensive systems (Bradley and O'Donoghue, 2011) on the activity profile of full-backs.

Higher physical effort during the initial phases of the game may influence subsequent running performance (Malone et al., 2017b) and contribute to the onset of fatigue during the latter part of the game (Coutts et al., 2010) with players demonstrating the highest activity profiles potentially being most susceptible (Aughey, 2010; Coutts et al., 2010; Malone et al., 2016). Half-backs had the most significant declines in performance variables from P1 to P4 and were the only positional group to exhibit significant reductions in average heart rate (P1 v both P3 and P4). High intensity running declined significantly in half-backs and half-forwards from P1 to P4 and these players along with midfielders also demonstrated significant reductions in PL.min^{-1} from P1 to P4. It is unclear whether these decrements were related to metabolic or central nervous fatigue or indeed pacing strategy (Malone et al., 2016). Dynamic physiological alterations and external factors such as pre-match context and importance, and/or fitness levels could potentially have influenced the effort levels (Edwards and Noakes, 2009) and may help to explain the intra-match variation (Malone et al., 2017b). Although these findings are similar to those reported previously (Coutts et al., 2010; Malone et al., 2017b; Malone et al., 2016; Mooney et al., 2013), further evaluation is necessary to validate the reduction in physical performance. Moreover, activity profile, heart rate and PlayerLoad™ observations should be considered in context to the match score, tactical strategies, positional restrictions, location of the ball and active time in match play (Mohr et al., 2003). Also, the influence of the opponent's competitive ability on overall work-rate and fatigue (Rampinini et al., 2007) cannot be discounted (Coutts et al., 2010).

The methodological limitations should be considered in interpreting these findings. This limited sample may be subject to positional bias as 50% of the players were comprised of full-backs and full-forwards and only 4 midfielders were included. The emphasis placed on physical performance and match outcome may have varied among the participating teams. There was no consideration of how match context or score affected running performance. Fitness levels were not evaluated and the players' conditioning may have influenced the activity profiles obtained. Future research should evaluate activity profiles combined with match analysis to determine if decrements in physical performance are due to fatigue or alterations in tactical strategy. Moreover, the integration of physical and technical data will enable examination of the performance capacity of players. Investigation of player metrics during league and championship games may help to reveal the fitness capacities required to optimise performance and facilitate the establishment of position specific benchmarks.

CONCLUSION

This novel investigation demonstrates the value of using 10 Hz GPS devices to evaluate the activity profiles of Gaelic footballers, supporting and extending existing research. The use of previously defined speed thresholds facilitated meaningful comparisons with other team sport players and the activity profiles presented can act as a benchmark for future research. Positional differences were apparent with middle-third players demonstrating greater physical performance compared to inside players. Decrements in work-rate were evidenced by declines in high intensity running and PL.min^{-1} across match periods (P1 vs P2 and P4) and in average heart rate between the first and second halves. Since ability to perform repeated high intensity running actions is likely to influence performance and match outcome, the development of this capacity should be prioritised in the preparation of inter-county teams.

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