The Match-Play Temporal and Position-Specific Physical and Physiological Demands of Senior Hurlers

ABSTRACT

The aims of the current study were to examine the temporal differences in match running performances and heart-rate (HR) in elite senior hurling players between halves of play and field positions. Global positioning systems (10-Hz) and HR monitors were used to collect data from 48 players over 18 games. Running performances (total distance [TD], relative distance, high-speed running [HSR], sprint efforts [SE], mean length of sprints, and sprint distance [SD]) and HR values (HR_{mean} and HR_{peak}) were assessed. Decrements in TD ($p = 0.009$, ES = -0.15), relative distance ($p = 0.009$, ES = -0.18), HSR ($p = 0.001$, ES = -0.28), SE ($p = 0.001$, ES = -0.23), SD ($p = 0.001$, ES = -0.24), HR_{mean} ($p < 0.001$, ES = -0.38) and HR_{peak} ($p < 0.001$, ES = -0.21) were found between halves. Half backs showed between-half decrements in all metrics ($p < 0.05$) except SD ($p = 0.130$, ES = -0.26). Midfielders ($p < 0.001$, ES = -0.68) and half forwards ($p < 0.001$, ES = -0.79) experienced second half decrements in HSR. No decrements ($p > 0.05$) in running performances were found between halves for full backs. HR_{mean} was lower in full backs ($p = 0.007$, ES = -0.46) and half backs ($p = 0.001$, ES = -0.76) in the second half. Coaches should consider the specific HSR the between-half temporal decrements in half backs, midfielders and half forwards and customize training program design to minimise these decrements.

Keywords: *Team Sport; Performance; Match-Play Demands; High-Speed Running; Sprint Distance; Heart Rate*

INTRODUCTION

Hurling is one of the national sports played in Ireland. All players represent their sub-elite (club) team where the best players are selected to represent their elite (inter-county) team (42). Elite level games attract large attendances of over 80,000 people at the finals in Croke Park with several million people watching on television around the world (34). Counties compete for a Provincial and All-Ireland elite Championship during the playing season of February to September (34). The game is played on a pitch (140 m x 90 m) which is 40% larger compared to a soccer pitch (110 m x 70 m) and contested by two teams of 15 players (1 goalkeeper and 14 outfield players) over a duration of 70-minutes (min) (35 min per half). The primary objective of the game is to outscore the opposing team. Scores are awarded by striking the ball through the opposition goalpost (similar to rugby). A goal (three points) and a point (one point) are awarded once the ball successfully crosses the goal line either under and over the crossbar respectively (34). This invasion-type stick and ball game is physically demanding with periods of high-intensity efforts which are common in other team sports (8). Players' physical, technical and tactical roles differ between the five unique positions (full backs, half backs, midfielders, half forwards, full forwards) (8,41). However, few attempts have described the physical match-play performances of hurling, which may help coaches to prepare players for competition (7,41,42).

Global Positioning Systems (GPS) and heart rate (HR) technology have recently been used to quantify the players' training and match-play loads (7,8,23,41,42). These technologies have been shown to provide valid and reliable measures of team sports performance (10,14). Many studies have used 1 to 5-Hz GPS units during their data collection (7,8,23,26,27). However, it has been reported that such units may lack the sensitivity to quantify changes in high-speed movement compared with 10- to 15-Hz (17).

Several studies have reported the match-play running performances in team sports using GPS (11–13,18,20,29,37). Total distance (TD), relative distance, high-speed running (HSR), sprint distance (SD), (8,40,42) peak velocity and the number of accelerations and decelerations (8) and the worst-case scenarios (40) have previously been reported at senior level. However, even though sprint efforts and the mean length of sprint is known at U21 hurling level (41), no data is currently available for senior hurlers. Monitoring players' HR during match-play has previously been used to describe the intensity of team sport (41,42). Senior hurlers' heart rate (HR) mean (HR_{mean}) and HR peak (HR_{peak}) values have been recorded (7,42). However, adding the percentage of time in each specific HR zone could provide an indication of the physiological responses to the match-play running demands in senior hurling (14). A higher percentage of match-time was spent over 160 b·min^{-1} compared with any other HR zone in both U21 hurling (41) and youth Gaelic football (33). These data are not currently available for senior hurlers. Quantifying these additional running performances and the percentage of time spent in each HR zone could provide a more detailed description of the physical demands of senior hurling, which will help coaches replicate these demands in training. Indeed, as previously reported, spending elements of training time within the high intensity HR zone was shown to increase hurling players' aerobic fitness characteristics (21,24). Furthermore, the use of SSG was found to replicate these match-play demands (22,25).

Positional differences in match-play running performances have been found in hurling (8,41), like other team sports (6,12,18). Differences in TD, HSR, SD and the number of accelerations have been found between positions in senior hurlers, with midfielders players undertaking the highest running performances (TD, HSR, and SD) compared to backs and forwards (8). Notwithstanding, no positional differences have been reported for relative distance, SE and the mean length of sprint for senior hurlers. However, a full detailed description of all these positional metrics is available for U21 hurlers only (41). Consequently, quantifying these additional running performances can provide a more detailed profile of the match-play positional differences in senior hurlers. Even though there were positional differences observed in the running performances, there was no difference in the HR_{mean}, and HR_{peak} found between positions at U21 hurling level (41). Positional HR data are not currently available for senior hurlers. The physiological response to these match-play positional differences could be used to prescribe position-specific conditioning for hurlers (41).

Although the total accumulated distances and HR can give a global indication of the match-play demands, an analysis of how these metrics change as the game progresses could indicate the most demanding periods of play. It has been shown that temporal decrements in running performances exist within team sports, with both low- and high-intensity movements being reduced from first to second half (6,18,27). This has been suggested to be related to the transient fatigue experienced throughout the game (31). Presently, temporal decrements in running performance are reported at senior (elite and sub-elite) (8,42) and U21 hurling level (41). However, the work-rate of elite senior hurling match-play study only included temporal decrements in HSR (8) and the study that investigated the differences in elite and sub-elite senior hurlers (42) used different speed zone classifications to those used at U21 level (41). In addition, the between-half total SD, sprint efforts and the mean length of sprint are not yet known at senior level. Finally, as the role of each position differs, specific between-half changes in running performances and HR could be highlighted, since previous studies have failed to include this analysis. Knowledge of the positional temporal decrements may inform conditioning practices and tactical changes both between positions in-game and the timing of substitutes. Therefore, the aims of the current study were to 1) describe the between-half

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temporal decrements in match running performance and HR values of elite senior hurling players using 10-Hz GPS and HR technology and 2) examine the changes in running performance and HR values during elite match-play competition with respect to position. It was hypothesised that both match-play running performance and HR values would decrease between halves and would be position-specific.

METHODS

Experimental Approach to the Problem

The current observational study was designed to examine temporal differences in match running performances and heart-rate (HR), between halves of play and field positions during elite senior hurling match-play competition. All players in the current study were competing at the highest level (Provincial and All-Ireland Senior Championship) and were selected as they were members of the county's squad that season (2016 – 2018, February to September). Data were only included if a full match (70-min) was completed. The players were classified according to their playing position during each match. The following number of data sets per position were assessed, full backs, *n=44;* half backs, *n=44*; midfielders, *n=30*; half forwards, *n=44* and full forwards, *n=44*. Each player supplied a mean of 4.29 files over 3 playing seasons (2016 - 2018). All games (2016: *n = 4*, 2017: *n = 8*, 2018: *n = 6*) took place between 14.00 and 21.00 hours, and temperatures ranged from 12 to 22°C. GPS was used to determine specific running performance variables, and HR monitors were used to collect HR during match-play. The players were requested to abstain from strenuous physical activity in the 24 hours before competitive matches and to report to the game fully hydrated (41).

Subjects

Forty-eight (*n* = *48*) elite male hurlers with a mean (± *SD*) age, height and body mass of 27 ± 5 years, 181 ± 6 cm and 88 ± 5 kg respectively, volunteered to participate in the present study. After ethical approval, the subjects were informed of the purpose, procedures and potential risks involved. They were also informed that they were free to withdraw from the study at any time. Written informed consent and medical declaration were obtained from the participants in line with the procedures set by the local Institution's Research Ethics Committee. The local Ethics Committee approved all procedures, and the study was conducted according to the Declaration of Helsinki (1975) for studies involving human subjects.

Procedures

Height and body mass without footwear and minimal clothing using a stadiometer (Seca 217, Seca Ltd., Hamburg, Germany) and Seca Weighing Scales (Seca Ltd., Hamburg, Germany) were recorded during the familiarization session. The running performances were recorded using 10-Hz GPS units and 100-Hz triaxial accelerometer (STATSports, Viper, Northern Ireland) (2,5,40,41). The number of satellites was 19 ± 7, and the horizontal dilution of precision was 1 ± 1 across all games (41). GPS data were downloaded and further analysed by STATSports, Viper software (firmware: 2.7.1.83). The validity and reliability of these GPS units have been previously established (3). Such GPS units reported distance bias of 2.53% during 10 m shuttle runs and a bias of 3.5% in average speed during 20 m shuttle run (3). Intra unit reliability showed a coefficient of variation of 1.6% during 400 m distance trial (4). These units have shown a match-to-match coefficient of variation of 17.2% for HSR distance. The GPS unit (dimensions: 86 mm x 33 mm x 14 mm, mass 50 g) was placed within a pouch between the player's shoulder blades (upper thoracic-spine) in a sports vest and worn under the playing jersey. GPS activation and satellite lock were established 15 min before warm-up commencement (19). Beat-by-beat HR was continuously collected using a HR transmitter belt (Team Polar, Polar Electro Oy, Kempele, Finland), which was worn around the subject's chest (41). Monitoring HR has been shown to be a valid measure of exercise intensity in invasion games (35). The participants were familiarized with GPS and HR technology during team training sessions before data collection.

Data collected from the GPS units included TD (m) and relative distance ($m\cdot min^{-1}$). The intensity of each movement was categorized as the distances covered (m) in the following zones, passive: ≤ 6.9 $km\cdot h^{-1}$, slow: 7-11.9 $km\cdot h^{-1}$, medium: 12-16.9 $km\cdot h^{-1}$, HSR: 17-21.9 $km\cdot h^{-1}$ and SD ≥ 22 $km\cdot h^{-1}$ (8,41). The total sprints efforts (≥ 22 $km\cdot h^{-1}$) and the mean length of sprint were collected (8,41). Peak HR (HR_{peak}) was taken as the highest HR recorded during the game and per half. HR_{mean} was assumed as the mean value of HR attained by the player during the entire competitive match-play duration and per half (41). Time spent in each HR zone (zone 1: ≤ 50 $b\cdot min^{-1}$; zone 2: 50-80 $b\cdot min^{-1}$; zone 3: 80-120 $b\cdot min^{-1}$; zone 4: 120-160 $b\cdot min^{-1}$; zone 5: > 160 $b\cdot min^{-1}$) was also collected (41). GPS and HR data was downloaded to a computer through the STATSport analysis software (STATSport Viper 1.2) to be stored and analyzed after each game. On downloading, each GPS unit was labelled as the playing position. First and second half data were identified by a timestamp and manually exported into a Microsoft Excel spreadsheet (Microsoft, Redmond, USA).

Statistical Analysis

All statistical analysis was performed using SPSS for Windows (Version 22, SPSS Inc. Chicago, IL, USA). Descriptive analysis and assumptions of normality were verified before parametric statistical analysis was used. The analysis was performed using a two-way (position x half) mixed design (ANOVA). When an interaction occurred, a Bonferroni post-hoc correction was used to detect differences between positions (five levels: full backs, half backs, midfielders, half forwards, full forwards) and playing half (two levels: first and second half). Additionally, a further ANCOVA was performed to detect a possible difference in temporal decrements between positions, considering first half as covariate. The dependent variables across the range of analysis were, TD, relative distance, HSR distance, SD, the total sprint efforts (n), mean length of sprint, HR_{peak}, HR_{mean} and time spent in each HR zone, with match periods and playing positions as independent factors. Standardised effect sizes (ES) were calculated with ≤ 0.20: *trivial*, 0.21 - 0.60: *small*, 0.61 - 1.20: *moderate*, 1.21 - 2.00: *large* and 2.01 - 4.00: *very large* as recommended by Hopkins (16). Statistical significance was set at an accepted level of $\alpha < 0.05$. Data are presented as mean, standard deviation (± SD) and 95% confidence intervals (95% CI).

RESULTS

The descriptive statistics for TD, relative distance, HSR, sprint efforts, mean length of sprint, SD, HR_{peak}, and HR_{mean} are presented in Table 1. The results showed that elite male senior hurling players covered **112 ± 16** m·min^{-1} **with** the greatest distance covered in the passive zone (3073 ± 408 m: 95% CI 3016 – 3113). The distance covered in slow and medium zones was 1838 ± 415 m (95% CI 1832 – 1908), 1699 ± 519 m (95% CI 1695 – 1786) respectively. HSR **(851 ± 307 m)** and SD **(340 ± 109 m)** accounted for 11% and 4% respectively of the TD covered during match-play. The maximum velocity was 30.3 ± 1.8 km·h^{-1}.

Please insert Table 1 near here

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Please insert Figure 1 near here

The between half differences for relative distance, HSR and SD are shown in figure 1. There was a temporal decrement observed in relative distance (Mean Difference [MD] -3 m·min^{-1}, 95% CI -5 to -1, ES = -0.18), HSR (MD -47 m, 95% CI -60 to -34, ES = -0.28) and SD (-16 m, 95% CI -26 to -6, ES = -0.24) in the second half.

Please insert Table 2 near here

The descriptive statistics for TD, sprint efforts, mean length of sprint, HR_{peak}, and HR_{mean} per position per half are presented in Table 2. Only half backs and full forwards performed a lower (*trivial*) TD, relative distance and mean length of sprints in the second half. HSR decreased from first to second half in the half backs (*trivial*), midfield (*moderate*) and half forwards (*moderate*). The SD decreased (*small)* only for midfielders and half forwards with half backs the only position to perform a *smaller* sprint efforts in the second half compared to the first half. All positions except half forwards had a *small*-to-*moderately* lower HR_{peak} in the second half (Table 2).

Results comparing positions during the entire match, showed that full backs covered a *moderately* lower TD than half backs ($p < 0.001$, MD -1280 m, 95% CI -1727 to -834, ES = -1.17), midfielders ($p < 0.001$, MD -1445 m: 95% CI -1941 to -949, ES = -1.32) and half forwards ($p < 0.001$, MD -982 m: 95% CI -1392 to -572, ES = -0.90) but greater TD than full forwards ($p = 0.028$, MD 465 m: 95% CI 28 to 901, ES = 0.42). Full forwards covered *largely* lower TD than half backs ($p < 0.001$, MD -1746 m, 95% CI -2214 to -1278, ES = -1.60), midfielders ($p < 0.001$, MD -1909 m: 95% CI -2425 to -1394, ES = -1.75) and half forwards (p < 0.001, MD -1447 m: 95% CI -1881 to -1014, ES = -1.32). Full forwards experienced a *largely* greater decrease in TD between halves compared with midfielders (p = 0.004, MD -487 m: 95% CI -874 to -99, ES = -1.75) and half forwards (p = 0.025, MD -343 m: 95% CI -662 to -24, ES = -1.30).

Full backs covered a *largely* lower relative distance than half backs (p < 0.001, MD -18m·min^{-1}, 95% CI -25 to -12, ES = -1.24), midfielders (p < 0.001, MD -21 m·min^{-1}: 95% CI -28 to -14, ES = -1.39) and half forwards (p < 0.001, MD -14 m·min^{-1}: 95% CI -20 to -8, ES = -1.85) but greater TD than full forwards (p = 0.028, MD 7 m·min^{-1}: 95% CI 0.4 to 12.9, ES = 0.42). Full forwards covered a *largely* lower relative distance than half backs (p < 0.001, MD -25 m·min^{-1}: 95% CI -32 to -18, ES = -1.24), midfielders (p < 0.001, MD -27 m·min^{-1}: 95% CI -35 to -20, ES = -1.39) and half forwards (p < 0.001, MD -21 m·min^{-1}: 95% CI -27 to -14, ES = -1.85). Full forwards experienced a largely greater decrease in relative distance between halves compared with midfielders (p = 0.004, MD -14 m: 95% CI -25 to -3, ES = -1.75) and half forwards (p = 0.026, MD -10 m: 95% CI -19 to -1, ES = -1.27). All other positions experienced no significant differences between-half decrements.

Half backs, midfielders and half forwards covered greater HSR than full backs (half back, p < 0.001, MD 415 m·min^{-1}: 95% CI 277 to -554, ES = 1.35; midfield, p < 0.001, MD 283 m·min^{-1}: 95% CI 130 to 438, ES = 0.92 and half forwards, p < 0.001, MD 283 m·min^{-1}: 95% CI 156 to 411, ES = 0.92). Half backs, midfielders and half forwards also covered greater HSR full forwards (half back, p < 0.001, MD 429 m·min^{-1}: 95% CI 284 to 574, ES = 1.40; midfield, p < 0.001, MD 298 m·min^{-1}: 95% CI 138 to 458, ES = 0.97 and half forwards,

$p < 0.001$, MD 298 m·min^{-1}: 95% CI 163 to 432, ES = 0.98). No significant differences between-half decrements were observed among positions.

Half backs covered *moderately* shorter mean length of sprints than full forwards ($p = 0.036$, MD -1 m·min^{-1}: 95% CI -3 to 0, ES = -0.68). No other difference ($p > 0.05$) between positions was observed over the full game. Full forwards increased their mean length of sprint by a *small* amount between halves more than full backs ($p = 0.018$, MD 2 m: 95% CI 0 to 5, ES = -0.58) and midfielders ($p < 0.047$, MD 3 m: 95% CI 0 to 5, ES = -0.70).

There was no difference ($p > 0.05$) between positions for sprint efforts in the full game. Half forwards covered greater SD than full backs ($p = 0.034$, MD 55 m·min^{-1}: 95% CI 2 to 108, ES = 0.51) and half backs ($p = 0.031$, MD 60 m·min^{-1}: 95% CI 3 to 118, ES = 0.55). No significant differences between-half decrements in sprint efforts and SD were observed among positions.

Please insert Figure 2 near here

For the entire match, the subjects spent 44% of the match time over 160 b·min^{-1}, and 43% between 120 - 160 b·min^{-1} compared with 11% ($p < 0.001$) between 80 - 120 b·min^{-1} and 2% between 50 - 80 b·min^{-1} ($p < 0.001$). No time was spent in the lowest HR zone (< 50 b·min^{-1}, $p < 0.001$). The time spent in HR zones increased in the 2nd half in zone 2 ($p = 0.008$, MD 51 seconds: 95% CI 14 to 89, ES = 0.47), zone 3 ($p < 0.001$, MD 240 sec: 95% CI 165 to 323, ES = 0.69) and zone 4 ($p = 0.002$, MD 228 sec: 95% CI 93 to 363, ES = 0.45) but decreased in zone 5 ($p < 0.001$, MD -511 sec: 95% CI -674 to 348, ES = -0.75). Figure 1 shows the percentage of time spent in each HR zone per half.

There was no difference in HR_{mean} between positions for the full game. Half backs had a moderately greater decreased in HR_{mean} than midfielders ($p = 0.020$, MD -10 $b \cdot min^{-1}$: 95% CI -19 to -1, ES = -0.91) and half forwards ($p = 0.036$, MD -8 $b \cdot min^{-1}$: 95% CI -16 to 0, ES = -0.73) between halves. Full backs had a higher HR_{peak} than half backs ($p = 0.034$, MD 7 $b \cdot min^{-1}$: 95% CI 3 to 14, ES = 0.78) over the full duration of match-play. There was no difference in HR_{peak} between positions for temporal decrement between halves.

DISCUSSION

The current study aimed to describe the temporal decrements in match running performance and HR in elite senior hurling players and examine these changes with respect to position. The overall total running performances were similar to previously found at elite senior hurling level (8). Between-position differences existed for TD, relative distance, HSR, mean length of sprint, SD and HR_{peak} but not for sprint efforts and HR_{mean} during the full duration of match-play. Although it was hypothesized that fatigue would affect the between-half running performances, the current results show that the between-half decrements were *trivial* or *small*. Overall *trivial* decreases in TD and relative distance and *small* decreases in HSR, sprint efforts, SD, HR_{mean} and HR_{peak} were observed between halves, whatever the playing position. Half backs were the only position to decrease in all metrics except for SD. In addition, half backs, midfielders and half forwards performed lower HSR in the second half, whereas full backs and full forwards maintained HSR in both halves.

Previous work-rate demands in senior hurling showed that players covered similar TD (7617 ± 1219 m), SD (319 ± 129 m) and maximum speed (29.6 ± 2.2 $km \cdot h^{-1}$) to those found in the current study (8). In addition, the relative distance in the present study compares with previous findings in elite senior hurling (~109 $m \cdot min^{-1}$) (8), U21 hurling (~112 $m \cdot min^{-1}$) (41), Gaelic football (~116 $m \cdot min^{-1}$) (27) and soccer (~113 $m \cdot min^{-1}$) (37), but larger than that found in sub-elite senior hurling (~93 $m \cdot min^{-1}$) (42) and rugby (~85 $m \cdot min^{-1}$) (15). In sub-elite hurling, the differences in the ball-in-play time, technical skills performed and the off-the-ball movements may explain the discrepancies between elite and sub-elite senior hurlers. In rugby, in addition to the difference in pitch size, the high-contact nature where players are tackled and brought to the ground may limit the time to run and may restrict the distances covered per minute compared to the present results in elite hurling. HSR running in the current study is lower than previously reported in senior hurling and Gaelic football players (8,26). However, the present study separated HSR and SD to allow coaches to prescribe specific training content per running speed. As U21 hurlers move up to compete at senior level, specific speed zones are necessary to aid the transition between levels (41). Senior hurlers in the present study covered more HSR and SD than U21 hurlers (41), although this is almost certainly due to the additional 10 min match duration in senior hurling games, given the similar relative distance covered (41). The current results show a shorter mean length of sprint was performed compared to 21 ± 5 m in rugby (30), 21 ± 3 m in soccer (1) and 27 (95% CI 24.0 to 30.9) m in Australian football (11). There are no previous data for the mean length of sprint in senior hurling, but the current results are similar to those found at U21 level (16 ± 5 m) (41). Differences in speed-zone classification make it difficult to compare the mean length of sprint between sports. Importantly, the differences in methods of carrying the ball between these team sports may account for these differences. In hurling, players are only permitted to carry the ball in their hand for a maximum of four consecutive steps, after that they must carry the ball on their hurley where opposition players are free to dispossess them. Once the player has been tackled and has their number of steps taken, they may have to change their speed and change their direction to avoid the opponent or regain possession if dispossessed. Therefore, their speed may drop below the sprint threshold (≥ 22 $km{\cdot}h^{-1}$). In contrast, rugby players can carry the ball for an unlimited number of steps, in Australian football players are permitted to carry the ball for 10 consecutive steps and in soccer the ball is on the ground where players can kick and give chase. Thus, the sports-specific game rules may account for the differences between these team sports.

The hurlers in the present study recorded similar HR_{mean} compared with players in U21 hurling (165 ± 9 $b{\cdot}min^{-1}$) (41), Australian football (168 ± 8 $b{\cdot}min^{-1}$) (38), soccer (165 ± 11 $b{\cdot}min^{-1}$) (20) and rugby (172 $b{\cdot}min^{-1}$: 95% CI 167 to 177 $b{\cdot}min^{-1}$) (13). Senior hurlers' HR_{peak} was also similar to U21 hurlers (190 ± 7 $b{\cdot}min^{-1}$). The similarity in the intensity of HSR, sprint efforts and SD in each game may account for the similarity in reaching HR_{mean} and HR_{peak}. It has been shown that comparable relative distance and running speeds with the present competitive match-play results have been achieved in small-sided hurling training games (23). Thus, using small-sided games within hurling training would be of benefit to replicate the match-play competitive demands of senior hurling.

The TD, relative distance, HSR, sprint efforts and SD all decreased in the second half. Temporal decrements in running performance between halves were also previously found in hurling (8,41,42), Gaelic football (27), soccer (6) and rugby (18). These between-half decrements may be due to motivation, opposition dominance or other match-related factors (8,36). In addition, substitutes in soccer were found to perform more running per minute than those who played the full duration of matches (31). The players' relative distance, HSR and SD all experienced similar decrements. However, the decrements observed in the present study were *trivial* to *small* and in a lesser extent compared to sub-elite senior hurling and U21 hurling level (41,42). It may be argued that the volume and frequency of training at elite senior level is higher than at sub-elite senior and U21 level, this may account for lower decrements found at senior level. Additionally, elite senior hurlers have access to one and sometimes two strength and conditioning coaches, whereas sub-elite senior and U21 hurlers rarely do. This lack of specialised guidance offered by these strength and conditioning coaches may also be a factor in players at sub-elite or U21 level experiencing greater temporal decrement in the second half. Additionally, elite senior hurlers are permitted 15 min for half-time compared to 10 min for sub-elite and U21 hurlers. This additional 5 min recovery in the middle of the game may account for the lower temporal decrements at senior level. The overall match duration of senior hurling is 10 min shorter than rugby and Australian football and 20 min shorter than in soccer. Therefore, this reduced match time in hurling may limit the temporal decrement experienced between halves compared to other team sports with longer match duration (6,11,18). With minimal between-half running decrements observed in the current study, conditioning the players to prevent fatigue should not be the only focus of training. Thus, additional time may be allocated to develop the technical and tactical elements of the game.

Hurlers' HR values (HR_{mean} and HR_{peak}) decreased in the second half. These results are in agreement with those found previously in hurling and other team sports (7,13,34,41). Previous HR_{mean} data in a competitive senior (first half: 163 ± 14 b·min^{-1} vs. second half: 160 ± 15 b·min^{-1}) and U21 (170 ± 9 b·min^{-1} vs. 161 ± 12 b·min^{-1}) hurling match showed temporal decrements between first and second halves (7,41). Similar HR_{mean} decrements were found

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between halves in rugby (177 vs. 167 b·min^{-1}) (13), soccer (164 ± 1 vs. 158 ± 1 b·min^{-1}) (32) and Australian football (173 ± 8 b·min^{-1} vs. 163 ± 16 b·min^{-1}) (38). Hurlers in the present study spent the longest time above 160 b·min^{-1} in the first half, which is similar to what was found in U21 hurlers (41). The time spent in each HR zone changed between halves in the current study. There was less time spent above 160 b·min^{-1} in the second half compared to the first. This time was distributed across the next three lower HR zones (50-80 b·min^{-1}, 80-120 b·min^{-1} and 120-160 b·min^{-1}) in the second half. Such a shift towards a greater time in the lower HR zones is coupled with the *trivial*-to-*small* decrements in running performance. Previously, it has been suggested that team sports athletes may adopt an efficient pacing strategy to meet the match-play demands (9,39). Thus, players who completed the full game may have adopted a pacing profile, as observed by the minimal decline in total and HSR distance.

Results from the current study are the first to describe the positional between-half decrements in senior hurling. Previously, between-half decrements have been observed in elite and sub-elite senior (42) and U21 hurling (41). The typical role of each position and their pitch location in hurling may account for the difference in running and HR performance, similar to other team sports (1,18,27,28). Both full backs and full forwards are located closer to the goal and tend to remain there to score or prevent scores (40). In contrast, half backs, midfielders and half forwards are located around the middle of the field and may spend more time closer to the ball than full backs and full forwards (8,41). Therefore, as the majority of HSR actions have been reported to occur close to the ball (34), these positions around the middle of the field (half backs, midfielders and half forwards) may be involved in more ball related actions, which may have had an impact on the players' running and HR results. Full backs had a higher HR_{peak} compared to half backs. There was no difference in HR_{mean}

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between positions. Half backs covered more TD, relative distance and HSR distance than full backs. Half backs, midfielders and half forwards covered more HSR distance compared to full backs and full forwards. Similar results have been found in U21 hurling (41). A general hierarchy was also found in senior elite hurling, midfielders covered more HSR distance than any other position, with both full backs and full forwards covering the least (8). Teams' tactical style of play, where they strike the ball directly to land in the full forward line may also account for the limited running required by the full forwards and full backs compared to half backs, midfielders and half forwards who have to run towards those in the full back or full forward positions to support them in attack or defence (42).

All positions recorded their highest HR_{peak} in the first half and experienced *trivial* to *small* decrements in the second half. The highest running demands were performed in all positions in the first half and this may explain the HR_{peak} being higher in the first half. Half backs experienced *moderately* greater decrement in HR_{mean} between halves compared to midfielders and half forwards. This greater decrease in HR_{mean} in full forwards may have derived from a reduction in TD in the second half. Half backs (TD, sprint efforts and a *small* increase in the mean length of sprint), midfielders (SD) and half forwards (SD) experienced *small* decrements in running performance between halves. In contrast, full backs showed no decrement in any metric between halves, while the full forwards had a *small* decrement in TD and relative distance in the second half. The half backs role in running back and laterally along the line to offer the full backs protection may explain the decrement in running performance in the second half. As midfielders and half forwards covered similar TD distance in each half, this may have caused fatigue, which was observed in the decrease in SD. Full forwards experienced a *largely* greater decrease in TD and relative distance between halves compared with midfielders and half forwards. As full forwards engaged in more demanding actions (greater mean length of sprints) in the second half, this may have resulted in greater fatigue compared to midfielders and half forwards. Therefore, this may explain the greater decrease in TD and relative distance in the second half in full forwards. In addition, full forwards had a *smaller*-to-*moderately* greater increment in the mean length of sprint between halves than full backs and midfielders respectively. The full forwards, in an attempt to gain possession of the ball before the full backs, may run further towards the incoming ball to collect it. Whereas, the full backs may stay in a defensive position to prevent the full forwards scoring. Additionally, midfielders in possession usually strike the ball into the full forward position to set up a score. The movement of the ball between positions may reduce the need for the midfielders to sprint with the ball into the full forward position. This may explain why full forwards experienced *moderately* greater increment in the mean length of sprint than midfielders.

The present study comes with some acknowledged limitations. Firstly, the current study only assessed the running and HR values during match-play, no attempt was made to include the technical elements of the game. As hurling has been previously described as a fast and skilful game, future studies should include the technical aspects along with the physical demands to understand the impact technical skills have on running and HR during competition. Secondly, the speed of each sprint was calculated once players passed 22 $km \cdot h^{-1}$. Thus, each sprint could be equal to this threshold ($\geq$ 22 $km \cdot h^{-1}$), but also could have been any speed up to the peak velocity value recorded. Accordingly, the actual intensity of the sprints across the duration of match-play needs to be further investigated. Finally, the current study presented time in HR zones per playing half. However, this is an accumulation of time spent in each HR zone and may not fully present the variability of HR during each half. Future studies should assess the variability of HR per minute and assess the variability across playing halves. In addition, further analysis of the match-play demands which include accelerations, decelerations and metabolic power profiles of senior hurling players need to be investigated.

PRACTICAL APPLICATIONS

The current study provides an insight into the temporal decrements in match running performances and HR in elite senior hurling players between halves of play and between positions. With minimal between-half running decrements observed in the current study, conditioning the players to prevent fatigue should not be the only focus of training. Therefore, additional time may be allocated to develop the technical and tactical elements of the game. However, practice routines need to include longer lengths of sprints towards the end of practice. Coaches may consider position-specific conditioning for running performances (TD, relative distance, HSR, mean length of sprint, SD) that show differences, but all positions can train together to perform the same sprint efforts. Conditioning for the half backs, midfielders and half forwards need to ensure that each position can repeat HSR distance for the full duration of match-play. In addition, those playing in the half back line experienced performance decrements in all running, HR_{mean} and HR_{peak} values except SD, even though the total values were similar to that of midfielders. Half backs need to be conditioned to repeat these running performances for the duration of the game. Coaches may consider rotating players from the half back position to the full back position for periods during the game where TD, relative distance and HSR is less demanding. The HR profile assessed as time spent in each HR zone changes in the second half. Monitoring HR within training could be used to ensure activities being performed are intense enough to elevate HR similar to match-play.

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REFERENCES

1. Andrzejewski, M, Chmura, J, Pluta, B, and Konarski, JM. Sprinting activities and distance covered by top level Europa league soccer players. *Int J Sports Sci Coach* 10: 39–51, 2015.

2. Beato, AM, Coratella, G, Schena, F, and Hulton, AT. Evaluation of the external and internal workload in female futsal players. *Biol Sport* 34: 227–231, 2017.

3. Beato, M, Bartolini, D, Ghia, G, and Zamparo, P. Accuracy of a 10 Hz GPS unit in measuring shuttle velocity performed at different speeds and distances (5 - 20 M). *J Hum Kinet* 54: 15–22, 2016.

4. Beato, M, Devereux, G, and Stiff, A. Validity and reliability of global position system units (STATSports Viper) for measuring distance and peak speed in sports. *J Strength Cond Res* Epub ahead of print, 2018.

5. Beato, M, Impellizzeri, FM, Coratella, G, and Schena, F. Quantification of energy expenditure of recreational football. *J Sports Sci* 34: 2185–2188, 2016.

6. Carling, C and Dupont, G. Are declines in physical performance associated with a reduction in skill-related performance during professional soccer match-play? *J Sports Sci* 29: 63–71, 2011.

7. Collins, K, Doran, DA, and Reilly, TP. The Physiological Demands of Hurling Match-Play. *Ergonomics*, 2010.

8. Collins, K, McRobert, A, Morton, JP, O'Sullivan, D, and Doran, DA. The Work-Rate of Elite Hurling Match-Play. *J Strength Cond Res* 32: 805–811, 2018.

9. Coratella, G, Beato, M, and Schena, F. The specificity of the Loughborough Intermittent Shuttle Test for recreational soccer players is independent of their

intermittent running ability. *Res Sport Med* 24: 363–374, 2016.

10. Coutts, AJ and Duffield, R. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport* 13: 133–135, 2010.

11. Coutts, AJ, Kempton, T, Sullivan, C, Bilsborough, J, Cordy, J, and Rampinini, E. Metabolic power and energetic costs of professional Australian Football match-play. *J Sci Med Sport* 18: 219–224, 2015.

12. Coutts, AJ, Quinn, J, Hocking, J, Castagna, C, and Rampinini, E. Match running performance in elite Australian Rules Football. *J Sci Med Sport* 13: 543–548, 2010.

13. Cunniffe, B, Proctor, W, Baker, JS, and Davies, B. An Evaluation of the physiological demands of elite rugby union using global positioning system tracking software. *J Strength Cond Res* 23: 1195–1203, 2009.

14. Esposito, F, Impellizzeri, FM, Margonato, V, Vanni, R, Pizzini, G, and Veicsteinas, A. Validity of heart rate as an indicator of aerobic demand during soccer activities in amateur soccer players. *Eur J Appl Physiol* 93: 167–172, 2004.

15. Gabbett, T. Influence of ball in play time on the activity profiles of rugby league match play. *J Strength Cond Res* 29: 716–721, 2015.

16. Hopkins, WG. A spreadsheet for deriving a confidence interval, mechanistic inference and clinical inference from a p value. *Sportscience* 11: 16–20, 2007.

17. Jennings, D, Cormack, S, Coutts, AJ, Boyd, LJ, and Aughey, RJ. Variability of GPS units for measuring distance in team sport movements. *Int J Sports Physiol Perform* 5: 565–569, 2010.

18. Jones, MR, West, DJ, Crewther, BT, Cook, CJ, and Kilduff, LP. Quantifying positional and temporal movement patterns in professional rugby union using global

positioning system. *Eur J Sport Sci* 15: 488–496, 2015.

19. Maddison, R and Ni Mhurchu, C. Global positioning system: a new opportunity in physical activity measurement. *Int J Behav Nutr Phys Act* 6: 73, 2009.

20. Mallo, J, Mena, E, Nevado, F, and Paredes, V. Physical Demands of Top-Class Soccer Friendly Matches in Relation to a Playing Position Using Global Positioning System Technology. *J Hum Kinet* 47: 179–188, 2015.

21. Malone, S and Collins, K. Relationship between Individualized Training Impulse and Aerobic Fitness Measures in Hurling Players Across a Training Period. J. Strength Cond. Res. 30: 3140–3145, 2016.

22. Malone, S and Collins, KD. Effect of Game Design, Goal Type, and Player Numbers on the Physiological and Physical Demands of Hurling-Specific Small-Sided Games. J. Strength Cond. Res. 31: 1493–1499, 2017.

23. Malone, S, Collins, KD, and Doran, DA. The running performance and estimated energy cost of hurling specific small-sided games. *Int J Sports Sci Coach* 11: 853–858, 2016.

24. Malone, S, Hughes, B, and Collins, K. The Effect of Training Load Distribution on Aerobic Fitness Measures in Hurling Players. *J Strength Cond Res* Epub ahead of print, 2017.

25. Malone, S, Hughes, B, and Collins, K. The influence of exercise to rest ratios on physical and physiological performance during hurling specific small-sided games. *J Strength Cond Res* Epub ahead of print, 2017.

26. Malone, S, Solan, B, and Collins, K. The running performance profile of elite Gaelic football match-play. *J Strength Cond Res* 31: 30–36, 2016.

27. Malone, S, Solan, B, Collins, K, and Doran, D. The positional match running performance in elite Gaelic football. *J Strength Cond Res* 30: 2292–8, 2016.

28. McGahan, JH, Mangan, S, Collins, K, Burns, C, Gabbett, T, and Neill, CO. Match-play running demands and technical performance among elite Gaelic footballers. *J Strength Cond Res* Epub ahead of print, 2018.

29. McGuinness, A, Malone, S, Petrakos, G, and Collins, K. The Physical and Physiological Demands of Elite International Female Field Hockey Players During Competitive Match-Play. *J Strength Cond Res* Epub ahead of print, 2017.

30. McLellan, CP, Coad, S, Marsh, D, and Lieschke, M. Performance analysis of super 15 rugby match-play using portable micro-technology. *J Athl Enhanc* 2, 2014.

31. Mohr, M, Krustrup, P, and Bangsbo, J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519–528, 2003.

32. Mohr, M, Krustrup, P, Nybo, L, Nielsen, JJ, and Bangsbo, J. Muscle temperature and sprint performance during soccer matches - Beneficial effect of re-warm-up at half-time. *Scand J Med Sci Sport* 14: 156–162, 2004.

33. Reilly, B, Akubat, I, Lyons, M, and Collins, K. Match play demands of elite youth Gaelic football using global positioning system tracking. *J Strength Cond Res* 29: 989–996, 2015.

34. Reilly, T and Collins, K. Science and the Gaelic sports: Gaelic football and hurling. *Eur J Sport Sci* 8: 231–240, 2008.

35. Rodrigues, VM, Ramos, GP, Mendes, TT, Cabido, CE., Melo, ES, Condessa, LA, et al. Intensity of offical futsal matches. *J Strength Cond Res* 25: 2482–2487, 2011.

36. Ryan, S, Coutts, AJ, Hocking, J, and Kempton, T. Factors Affecting Match Running Performance in Professional Australian Football. *Int J Sports Physiol Perform* 1–19, 2017.

37. Torreño, N, Munguía-Izquierdo, D, Coutts, A, Villarreal, S de E, Asian-Clemente, J, and Suarez-Arrones, L. Relationship between external and internal load of professional soccer players during full-matches in official games using GPS and heart rate technology. *Int J Sports Physiol Perform* 11: 940–946, 2016.

38. Veale, JP and Pearce, AJ. Physiological responses of elite junior Australian rules footballers during matchplay. *J Sport Sci Med* 8: 314–319, 2009.

39. Waldron, M and Highton, J. Fatigue and pacing in high-intensity intermittent team sport: An update. *Sport Med* 44: 1645–1658, 2014.

40. Young, D, Malone, S, Beato, M, Mourot, L, and Coratella, G. Identification of maximal running intensities during elite hurling match-play. *J Strength Cond Res* Epub ahead of print, 2018.

41. Young, D, Mourot, L, Beato, M, and Coratella, G. The match heart-rate and running profile of elite under 21 hurlers during competitive match-play. *J Strength Cond Res* Epub ahead of print, 2018.

42. Young, D, Mourot, L, and Coratella, G. Match-play performance comparisons between elite and sub-elite hurling players. *Sport Sci Health* 14: 201–208, 2018.

Figure caption

Figure 1. Mean ± SD relative, high-speed and sprint distance covered per half is shown.

*** Significant difference ($p < 0.05$) between halves**

Figure 2. Mean % time ± SD spent in each heart rate zone per half is shown.

* Significant difference ($p < 0.05$) between halves

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