The Work-Rate of Elite Hurling Match-Play

ABSTRACT

The current study describes the global work-rate of elite hurling match-play and the influence which positional difference has on work-rate is considered. The movement of ninety-four players was recorded using GPS, sampling at 4Hz in a total of 12 games. Data were classified according to the positional line on the field and period of the match. The total and high speed distance of match-play was 7617 ± 1219 m (95% CI, 7367 - 7866) and 1134 ± 358 m (95% CI, 1060 − 1206) respectively. The maximum speed attained was 29.8 ± 2.3 $km{\cdot}hr^{-1}$ with a mean speed of 6.1 ± 1 $km{\cdot}hr^{-1}$. The second (271 ± 107 m [p=.001; ES=0.25]), third (278 ± 118 m [p=.001; ES=0.21]) and fourth quarter (255 ± 108 m [p=.001; ES=0.31]) high speed running distance differed significantly from the first quarter (330 ± 120 m). There was a significant difference in total (p=.001; ES=0.01-0.85), high speed running (p=.001; ES=0.21-0.76) and sprint (p=0.013; ES=0.01-0.39) distance across the positions, with midfielders undertaking the highest volume of work, followed by the half-forward and half-back lines and finally the full-forward and full-back lines. A decrease in high speed running distance appears to occur through out the game and in particular at the latter stages of each half. Distinct positional work profiles are evident. The present finding provide a context upon which training which replicates the work-rate of match-play may be formulated, thus helping to improve the physical preparation of elite players.

Keywords: Gaelic sport, running performance, high-intensity, positional variation.

INTRODUCTION

Hurling is a stick and ball invasion game similar to lacrosse and field hockey.[35] The sport is the national game of Ireland and one of the world's most dynamic field games.[10] The sport has experienced growing international participation and expansion with elite games recently played at one of the homes of baseball, Fenway Park in Boston. Notwithstanding the popularity, research into the work-rate of hurling has lagged behind Gaelic football and other field games.[7,11,33,32] Few attempts to directly measure the work-rate of hurling match-play have been made.[10,16] Inferences as to the work-rate and training requirements of hurling have been extrapolated from other field games particularly Gaelic football predicated upon obvious similarities that exist with regard to field dimensions and match duration.[25,33,35] For example, during Gaelic football match-play (which is also played over 70 min) the distance covered was estimated to be 8815 ± 1287 m with the mean high speed running distance (≥17 $km \cdot hr^{-1}$) covered being 1695 ± 503 m. The high speed running distance is reflective of a work-rate of 24 ± 7.2 $m \cdot min^{-1}$.[11] The work-rate observed in Gaelic football may provide some insights, however investigation into the work-rate demands of elite hurling match-play is essential due to the fundamental differences in the games.[33] The playing style of Gaelic football is akin to basketball where support play is important when transitioning from defense to attack. In hurling the ball is regularly struck with the hurley and launched over large distances from defense to attack where players are required to contest possession. It is these aerial contests and the mode of transition that creates an interesting and entertaining viewing spectacle.

Similar to other invasion field sports hurling constitutes a form of intermittent exercise in which the timing of efforts are acyclical and unpredicatable.[33] During match-play a wide range of offensive and defensive skills are executed at high speed, play shifts rapidly from end-to-end due to the large distances the ball can travel (~100 m +). Rapid accelerations and decelerations, changes of direction, unorthodox movement patterns make hurling match-play a unique viewing spectacle. These patterns of play are likely contributors' to the observed high levels of physiological strain and energy expenditure. The mean heart rate reported for the first and second half of match-play was 84% and 82% of HR_{max} respectively.[10] A detailed work-rate analysis to assess positional and temporal variation in performance does not currently exist for the sport of hurling.[25,33,34]

Recent technological advancement in global positioning system (GPS) monitoring technology permits highly detailed analysis of work-rate.[13,14,17,30] The information juxtaposed on the corresponding physiological responses to match-play identifies the internal and external load placed on players.[9,10] Such data indicates the presence of positional difference as well as temporal variations in performance indicated by deterioration in high-intensity distance and sprinting efforts across the course of a game in soccer,[5,9,15,28,29] Rugby,[1,27,36,37] Australian football[6,13,14] and Gaelic football.[22,23] The absence of contemporary research on work rate in hurling limits applied practitioners ability to place in context there own GPS data and the ability of coaches to prescribe training based on the demands of the game. The purpose of the present study was to determine the global work-rate during elite competitive hurling match-play and identify the influence positional difference has on this work-rate. It was hypothesized that the work rate of elite hurling players would be position specific.

METHODS

Experimental Approach to the Problem

The current observational study was constructed to determine the global work-rate during elite competitive hurling match-play using GPS technology with the influence which position has on this work-rate considered. Ninety-four (26 ± 4 years) elite hurling players participated in the study with each participant providing one work-rate sample. All participants of the current study were competing at the highest level of competition (national hurling league and All-Ireland championship). Matches took place between 14:00 and 20:00, and in conditions with a mean temperature 14 ± 6 °C. Participants were requested to abstain from vigorous activity in the 24-48 hours prior to the event, with an emphasis placed on fluid and carbohydrate consumption.

Participants

In this investigation an observational design was used to examine the work-rate in elite hurling match-play. Data was only included if the participant completed the full game of 70 minutes (two 35 minutes halves). Data were classified according to the positional line on the field, see figure 1 (full-back line n=3 and half-back line, n=3; midfield, n=2; half-forward line, n=3; full-forward line, n=3). All participants were informed of study requirements, the collection protocols, the risks involved and the equipment to be used. The participants was familiarized with the technology during organized training sessions prior to the data collection. Study approval was granted from the local Research Ethics Committee.

Figure 1 around here

Experimental Procedures

The participants wore GPS technology (VXsport, New Zealand) acquiring data at 4Hz and containing a triaxial acceloremter and magnetometer in a total of 12 games. The GPS equipment used (76 g; 48 mm x 20 mm x 87 mm) was secured in a modified vest (VXsport, New Zealand) and placed on the upper back of the player to ensure range of movement were not restricted. The GPS technology has been shown to be a valid and reliable way of measuring distance and velocities in a range of intermittent field sports.[3,8,19,20,24] The reliability of the VXsport GPS for distance covered, peak speed, and mean speed has been previously reported.[24] A test-retest of the GPS devices using a change of direction and speed circuit identified a non-significant difference for the total distance (300.5 ± 3.3; 303.6 ± 5.6 m), peak speed (23.9 ± 1.9; 24.1 ± 1.3 km·hr^{-1}), and mean speed (10.2 ± 1.0; 10.2 ± 0.9 km·hr^{-1}). The typical error (TE ± 95% confidence interval [CI]) was 0.84 ± 0.3 for total distance, 0.75 ± 0.26 for peak speed, and 0.55 ± 0.19 for mean speed. The coefficient of variation (CV% ± 95% CI) was 1.0 ± 0.4 for the total distance, 4.2 ± 1.5 for peak speed, and 4.4 ± 1.5 for mean speed.

Data Analysis

Upon completion of the game, GPS data were downloaded from the units and analysed (VXSport View, New Zealand). Each movement category was coded as 1 of 5 speed zones (Table 1) and the distances covered in meters for the following movements were recorded, 1-6.9 km·hr^{-1} (passive), 7-11.9 km·hr^{-1}, (slow), 12-16.9 km·hr^{-1} (medium), 17-21.9 km·hr^{-1} (fast) and ≥22 km·hr^{-1} (maximal).[27] For the purpose of the current investigation work-rate is identified as total distance (m), high speed running (≥17 km·hr^{-1}) distance (m) and sprint (≥22 km·hr^{-1}) distance (m). High speed running distance was also quantified for each quarter.

Table 1 around here

An acceleration was classified when a participant changes speed by 2 km·hr^{-1} within 1 s. The change was triggered over a minimum time of 2 s (i.e. to be sure that it is real acceleration motion and not a lunge). The acceleration stops when the player decelerates to <75% of maximum speed reached in the preceding acceleration event. Maximum acceleration is calculated using the 0.25 second sample points; dV/dT. The mean was classed by dV/dT for the total acceleration time and distance. Modified velocity ranges (0 − 2.1, 2.11 − 3.6, 3.61 − 5.6 and ≥5.61 m.s^{-1}) described by Dwyer and Gabbett[17] were used to identify rapid, short-duration efforts.

Statistical Analysis

The means, standard deviations and 95% confidence intervals were calculated for each speed zone, total distance, high speed running distance, sprint distance and the number of accelerations. Analysis was performed using a two-way (position × quarter) mixed design ANOVA with a Bonferrroni post hoc test. Significance was accepted at a level of $p<0.05$. Standardized effect sizes (ES) were calculated with <0.2, 0.21- 0.6, 0.61-1.20, 1.21-2.00 and 2.01-4.0 representing trivial, small, moderate, large and very large differences, respectively.[36] Statistical tests were performed using SPSS for Max (Version 22, SPSS Inc. Chicago, USA).

RESULTS

Work-Rate Independent of Position

A gradient of distance covered with respect of speed zones is observed with the greatest volume observed in zone 1 [3110 ± 334 m (95% CI, 3041 – 3178)], with each zone thereafter decreasing in distance. The distance covered in zone 2 and 3 was 1797 ± 463 m (95% CI, 1703 – 1892) and 1576 ± 589 m (95% CI, 1456 – 1697), respectively. The lowest distance was observed in zone 4 [815 ± 274 (95% CI, 759 – 871)] and 5 [319 ± 129 m (95% CI, 292 – 345). The mean total distance of match-play was 7617 ± 1219 m (95% CI, 7367 - 7866), with the total high speed running (≥17 $km{\cdot}hr^{-1}$) distance 1134 ± 358 m (95% CI, 1060 − 1206), and the total sprint (≥22 $km{\cdot}hr^{-1}$) distance was 319 ± 129 m (95% CI, 292 − 345). The maximum speed achieved was 29.6 ± 2.2 $km{\cdot}hr^{-1}$ with a mean speed of 6.1 ± 1 $km{\cdot}hr^{-1}$. The acceleration profile of the players indicates that an intense activity takes place every 22

s. The participants in the current study undertook 189 ± 34 (95% CI, 181 – 194) accelerations with 23 ± 11 (95% CI, 21 – 25) accelerations in the velocity zone of 0-2.1 $m \cdot s^{-1}$, 104 ± 27 (95% CI, 99 – 109) accelerations in the velocity zone 2.11 − 3.6 $m \cdot s^{-1}$, 53 ± 11 (95% CI, 50 – 55) accelerations in the velocity zone 3.61 − 5.6 $m \cdot s^{-1}$ and 9 ± 4 (95% CI, 8 – 9) accelerations at velocities ≥ 5.6 $m \cdot s^{-1}$.

A significant (p=.001; ES=0.25) decrease in high speed running distance was observed between the first (330 ± 120 m: 95% CI, 305 − 355) and second (271 ± 107 m: 95% CI, 249 − 293) quarter. A minor increase (ES=0.03) in high speed running distance was observed between the second and third (278 ± 118 m: 95% CI, 254 − 302) quarters with a significant decrease (p=.041; ES-0.23) observed between the third and fourth (255 ± 108 m: 95% CI, 233 − 277) quarters. The second (p=.001; ES=0.25), third (p=.001; ES=0.21) and fourth quarter (p=.001; ES=0.31) high speed running distance differed significantly from the first quarter.

Work-Rate and Position

The positional differences in work-rate data can be viewed in table 2. There was a significant difference in total (p=.001; ES=0.01-0.85), high speed running (p=.001; ES=0.21-0.76) and sprint (p=0.013; ES=0.01-0.39) distance across the positions. A general hierarchy is evident with the midfielders being the highest performers in total, high speed running and sprint distance. A unique profile is evident with half-forwards exhibiting the greatest drop in high speed running distance (27%) between the first and fourth quarter, this was followed by the half-backs (24%) and full-forwards (23%). The midfielders (22%) and full-backs (13%) had the lowest decrease in high speed running performance.

Table 2 around here

DISCUSSION

The purpose of the present study was to examine the work-rate elicited during elite level competitive hurling match-play. The secondary purpose was to identify the influence of position on work-rate. The work-rate of the game is relatively high and compares with other field games.[7] Current findings indicate a deterioration in high speed running over the course of the game. A hierarchy in positional work-rate is evident with midfield players undertaking the highest work-rates. The decrement in high speed running performance was position specific with half-forwards experiencing the greatest deterioration. While these observations are consistent with other field based team sports, this is the first detailed report assessing the movement demands of elite hurling match-play.[1,11,17,18,22]

The present study focused on the performance of ninety-four elite hurlers. The total distance covered by the players in the current study was lower than observed for Gaelic footballers.[11,12,23] The relative work-rate of 109 ± 17 $m{\cdot}min^{-1}$ is comparable to rugby league backs (109 $m{\cdot}min^{-1}$) but less than soccer (119 $m{\cdot}in^{-1}$).[1,29] The work-rate profile is indicative of largely aerobic submaximal activity which is similar to the metabolic loading of Gaelic football and other field sports.[33,34] The majority of high speed running efforts occurs close to the hurling ball and may determine the outcome of crucial events in the game.[33] The high speed running classed as speeds ≥17 $km{\cdot}h^{-1}$ is 39% lower than observed for Gaelic football (1695 ± 503 m), which may reflect the unique dynamics of hurling. However the acceleration profile of hurling match-play is similar to that reported for Gaelic football (184 ± 40 accelerations).[12,23]

Despite the shorter duration of hurling match-play (70 minutes) compared to other field-based invasion games, significant impairments in high speed running performance covered over the course of a game were identified. Furthermore, the performance deteriorated across each half with the second quarter lower than the first, and the fourth quarter lower than the third. The third to fourth quarter data indicates that 15 minutes rest at half time does not facilitate a restorative effect in high speed running performance. It is unclear if team success, motivation, fitness, nutritional status or match tactics influence the observed deterioration in performance. A similar performance decrement pattern has been observed in Gaelic football, soccer and Australian football.[6,15,23,25] Notwithstanding team tactics and the oppositions work-rate there are likely a range of factors related to the decrement in performance observed during match-play which may including metabolic as well as central nervous system fatigue. In light of such findings, the training for hurling should emphasize the performance of and recovery from repeated high-intensity efforts similar to that advocated in other invasion field games.[28] It is unclear if a reduction in glycogen similar to observations in other field sports, plays a role in the performance decrement observed in hurling match-play, and thus warrants investigation.[4,5,38]

In Gaelic football the work-rate and performance profile of players has been assessed with regard to playing position, segmenting players into 3 distinct groups, backs, midfielders and forwards.[21,26] Following this schema, in hurling a hierarchy is evident whereby midfielders undertake the greatest volume of work in terms of total distance, high speed running distance and volume of accelerations compared to backs or forwards. The midfield role involves linking defense and attack through supporting players in possession. When backs and forwards are further sub-classified into full-backs and half-backs, and half-forward and full-forward, it is clear that full-backs undertake the least total and high speed distance, with half-backs and full-forwards possessing similar profiles. Recent findings in elite Gaelic football indicate a similar ‘bell shaped’ positional profile to the current investigation with midfielders possessing the highest work rate.[25] The present data supports the view that work-rate is closely related to the positional roles.[33] The evolution of the game has seen an increased priority on the half-forward line occupying a similar role to midfielders who must now work deep into the defence and link the play. The development of this role may explain the half-forward line being the second highest in terms of overall distance and high speed running distance. Researchers in future may benefit in segmenting backs and forwards into the line of the pitch which they occupy rather than their role as a back or forward as there is evidence of distinct differences in work-rate profiles across the lines. The decrease in high speed running distance of the central players observed across the game requires consideration for the preparatory practices and possibly 'in game' fuelling practices. The coach may need to consider the positional characteristics of all players when structuring physical training and game specific nutrition strategies.[4,38] Recent research has indicated that small sided games can be an effective training methodology for hurling and consideration should be made to the position which players occupy.[22] The high work rate of the central eight players may indicate a need for an increased focus on carbohydrate supplementation during match-play to attenuate the decrement running performance observed.[4]

The results of the current investigation need to be interpreted within the context of the study limitations. No measure of physical contact was recorded, with body-on-body contact an important consideration of the game demands and are likely to have a bearing on the physiological demands of the games.[1] Furthermore, in this investigation, match dynamics (home and away team; winning and loosing; ranking of opposition) and styles of play were not considered. An appreciation of this information may provide context to the data within. Previous research has utilized the current demarcation thresholds for high speed and sprint distances.[11,22,35,37] Future research should consider the utilization individualized thresholds rather than default demarcation points.[38] Furthermore the importance of tactical substitutions particularly in the midfield position during the second half of match play warrants further investigation. Finally future research should consider alternative models for measurement of work-rate. The known importance of accelerations and decelerations[23] in team sports work-rate profile needs consideration, and as such the analysis of the metabolic power profiles of hurling should be undertaken to help our understanding of the energetic cost of the game.

PRACTICAL APPLICATIONS

Present data indicate hurling is a demanding physically dynamic game similar to other field sports. Periods of high intensity efforts are superimposed upon an aerobic background on average every 22 s. As such the game of hurling demonstrates a decrease in high speed running distance covered through out the game and in particular at the latter stages of each half. Coaches need to consider this profile when constructing training with particular emphasis on the performance of and recovery from repeated high-intensity efforts. Coaches may need to consider recent research on the utilization of small sided hurling games as an appropriate training methodology for this population.[22] Distinct positional profiles are evident with midfielders undertaking the highest volume of work, followed by the half-forward and half-back lines and finally the full-forward and full-back lines. The positions that undertook the highest volume of work also possessed the highest performance decrement. Players need to be adequately prepared to meet the demands of the game and as such coaches should focus on the positional needs of each player. Continued evaluation of the work-rate of the game is warranted to develop a clearer picture of the evolving nature of hurling. As such the data provided herein is important as it is the first to document the work-rate of elite hurling match-play.

REFERENCES

1. Austin, D, and Kelly, S. Positional differences in professional rugby league match-play through the use of global positioning systems (GPS). *J Strength Cond Res* 27: 14-9, 2013.
2. Ball, K, and Horgan, B. Performance analysis of kicking and striking skills in Gaelic sports. In D. M. Peters, P. O' Donoghue (Eds.), *Performance Analysis of Sport IX* (2nd ed., pp. 117–123). Routledge, London; 2013.
3. Barbero-Alverez, JC, Coutts, AJ, Granda, J, Barbero-Alverez, V, and Castanga, C. The validity and reliability of a global positioning satellite system device to assess speed and repeated sprint ability (RSA) in athletes. *J Sci Med* 13(2): 232-235, 2010.
4. Beasley, K J. Nutrition and Gaelic Football: Review and Recommendations and Future considerations. Int J Sport Nutr Exerc Metab 25(1): 1-13, 2015.
5. Bendiksen, M, Bischoff R, Randers, MB, Mohr, M, Rollo, I, Suetta, C, Bangsbo, J, and Krustrup, P. The Copenhagen Soccer Test: physiological response and fatigue development**.** *Med Sci Sports Exerc* 44(8): 1595-603, 2012.
6. Brewer, C, Dawson, B, Heasman, J, Stewart, G, and Cormack, S. Movement pattern comparisons in elite (AFL) and sub-elite (WAFL) Australian football games using GPS. *J Sci Med Sport 13*(6): 618–623, 2010.
7. Brown, J, and Waller, M. Needs analysis, physiological response, and program guidelines for Gaelic football. *Strength Cond J* 36: 73 – 81, 2014.
8. Buchheitt, M, Allen, A, Poon, T, Mondonutti, M Gregson, W, Di Salvo V. Integrating different tracking systems in football: multiple camera semi-automatic system, local positioning measurement and GPS technologies. J Sports Sci 32(20): 1844 – 1857, 2014.
9. Castellano, J, and Casamichana, D. Heart rate and motion analysis by GPS in beach

soccer. *J Sports Sci Med 9*(1): 98–103, 2010.

10. Collins, K, Doran, DA, and Reilly, TP. The Physiological demands of competitive hurling match-play. In M. Anderson (Ed.), *Contemporary Ergonomics and Human Factors* (pp. 591–595). CRC Press, London; 2010.
11. Collins, K, Reilly, T, Morton, JP, McRobert, A, and Doran, D. (2014). Anthropometric and Performance Characteristics of Elite Hurling Players. *J Athl Enhancement* 3:6, 2014.
12. Collins, K, Solan, B, and Doran, DA. A preliminary investigation into high-intensity activity during elite Gaelic football match-play. *J Sports Ther* (1): 10, 2013.
13. 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(2): 219 – 224, 2015.
14. Coutts, AJ, Quinn, J, Hocking, J, Castagna, C, and Rampinini, E. Match running performance in elite Australian Rules Football. *J Sci Med Sport 13*(5): 543–548, 2010.
15. Di Salvo, V, Gregson, W, Atkinson, G, Tordoff, P, and Drust, B. Analysis of High Intensity Activity in Premier League Soccer. *Int J Sports Med 30*(03): 205–212, 2009.
16. Donoghue, P, Donnelly, O, Hughes, L, and McManus, S. Time-motion analysis of Gaelic games. *J Sports Sci 22*(3): 255–256, 2004.
17. Dwyer, DB, and Gabbett, TJ. Global positioning system data analysis: Velocity ranges and a new definition of sprinting for field sport athletes. *J Strength Cond Res 26*(3): 818–824, 2012.
18. Hopkins, W, Marshall, S, Batterham, A, and Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 41(1):3-12, 2009.
19. Jennings, D, Cormack, S, Coutts, AJ, Boyd, LJ, and Aughey, RJ. The validity and reliability of GPS units for measuring distance in team sport specific running patterns. Int *J Sports Physiol Perform* 5: 328 – 341, 2010.

20. Johnston, RJ, Watsford, ML, Pine, MJ, Spurrs, RW, Murphy, AJ, and Pruyn, EC. The validity and reliability of 5-Hz global positioning system units to measure team sport movement demands. *J Strength Cond Res* 26: 758 – 765, 2012.
21. Keane, S, Reilly, T, and Hughes, M. Analysis of work-rates in Gaelic football. *Aus J Sci Med Sport 25*: 100–102, 1993.
22. Malone, S, and Collins, K. The Influence of pitch size on running performance and physiological responses during hurling specific small-sided games. *J Strength Cond Res* EPub, Ahead of print, 2016.
23. Malone, S, Solan, B, Collins, K, and Doran, D. The metabolic power and energetic demands of elite Gaelic football match play. *J Sports Med Phys Fitness* EPub, Ahead of print, 2016
24. Malone, S, Collins, DK, McRobert, AP, Morton, J, and Doran, DA. Accuracy and reliability of VXsport global positioning system in intermittent activity. In: Proceedings of the 19th Annual Congress of the European College of Sport Science, 2-5th July, Amsterdam, 2014.
25. Malone, S, Solan, B, Collins, K, and Doran, D. The Positional Match Running Performance of Elite Gaelic Football. *J Strength Cond Res* 30(8): 2292-2298, 2016.
26. McIntyre, MC. Physiological profile in relation to playing position of elite college Gaelic footballers. *Brit J Sports Med 39*(5): 264–266, 2005.
27. McLellan, CP, Lovell, DI, and Gass, GC. Performance analysis of elite Rugby League match play using global positioning systems. *J Strength Cond Res 25*(6): 1703–1710, 2011.
28. 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*(7): 519–528, 2003.

29. Rampinini, E, Impellizzeri, FM, Castagna, C, Coutts, AJ, and Wisloff, U. Technical performance during soccer matches of the Italian Serie A league: effect of fatigue and competitive level. *J Sci Med Sport 12*(1): 227–233, 2009.
30. Randers, MB, Mujika, I, Hewitt, A, Santisteban, J, Bischoff, R, and Solano, R. Application of four different football match analysis systems: a comparative study. *J Sports Sci 28*(2): 171–182, 2010.
31. Reardon, C, Tobin, DP, and Delahunt, E. Application of Individualized Speed Thresholds to Interpret Position Specific Running Demands in Elite Professional Rugby Union: A GPS Study. *PLoS One* 24;10(7), 2015.
32. Reilly, B, Akubat, I, Lyons, M, and Collins, DK. Match-play demands of elite youth Gaelic football using global positioning system tracking. *J Strength Cond Res* 29(4): 989 – 996, 2015.
33. Reilly, T, and Collins, K. Science and the Gaelic sports: Gaelic football and hurling. *Eur J Sport Sci 8*(5): 231–240, 2008.
34. Reilly, T, and Doran, D. Science and Gaelic football: a review. *J Sports Sci 19*(3): 181–193, 2001.
35. Reilly, TP. Endurance Aspects of Soccer and Other Field Sports. In R. J. Shephard and P. O. Astrand (Eds.), *Endurance in Sport* (2nd ed., pp. 900–930). Blackwell Science, London; 2000.
36. Ross, A, Gill, N, and Cronin, J. The match demands of international rugby sevens. *J Sport Sci* 33(10): 1035 – 1041, 2015.
37. Sirotic, AC, Coutts, AJ, Knowles, and H, Catterick C. A comparison of match demands between elite and semi-elite rugby league competition. *J Sports Sci 27*(3): 203–211, 2009.
38. Williams C, and Rollo, I. Carbohydrate nutrition and team sport performance. *Sports Med* 45(1):13-22, 2015.

Table 1. The movement category classification during elite hurling match-play, modified from McLellan et al.[24]

Zone	$km \cdot h^{-1}$	Classification	Definition
1	0 – 6.9	Passive	Standing or walking at low intensity, no flight phase associated with movement in any direction.
2	7 – 11.9	Slow	Running in any direction with minimal flight phase and minimal arm swing.
3	12 – 16.9	Medium	Running in any direction with progressive acceleration and increased arm swing.
4	17 – 21.9	Fast	Running at near maximum pace with near maximal stride length, stride frequency and arm swing.
5	≥22	Maximal	Running with maximal effort.

Table 2: The positional difference in work-rate of elite hurling match-play. Data are mean ± SD and 95% CI

Position	Total Distance (m)	95% CI	High Speed Running Distance (m)	95% CI	Sprint Distance (m)	95% CI	Accelerations	95% CI
Full-Backs (n=22)	6548 ± 786*^[a]	6199 - 6896	880 ± 204*^	789 - 970	291 ± 90	251 - 331	162 ± 28*^[a]	149 - 175
Half-Backs (n=22)	8046 ± 686*	7742 - 8350	1043 ± 245*	934 - 1151	275 ± 124*	220 - 330	198 ± 26	186 - 209
Midfield (n=16)	8999 ± 676	8639 - 9360	1571 ± 371	1373 - 1768	404 ± 166	41 - 316	223 ± 25^	209 - 236
Half-Forwards (n=20)	7975 ± 845*	7589 - 8370	1249 ± 262*	1126 - 1371	348 ± 127	288 - 406	194 ± 28*^	181 - 207
Full-Forwards (n=14)	6530 ± 1112*[a]	5888 - 7172	1008 ± 359*	823 - 1192	292 ± 105	231 - 352	163 ± 24*^[a]	149 - 177
Effect Size	0.01 – 0.85		0.21 - 0.76		0.01 – 0.39		0.02 – 0.75	

** Significantly different ($p<.05$) from the midfield*

^ Significantly different ($p \leq .05$) from the half-forward line

[a] *Significantly different ($p \leq .05$) from the half-back line*

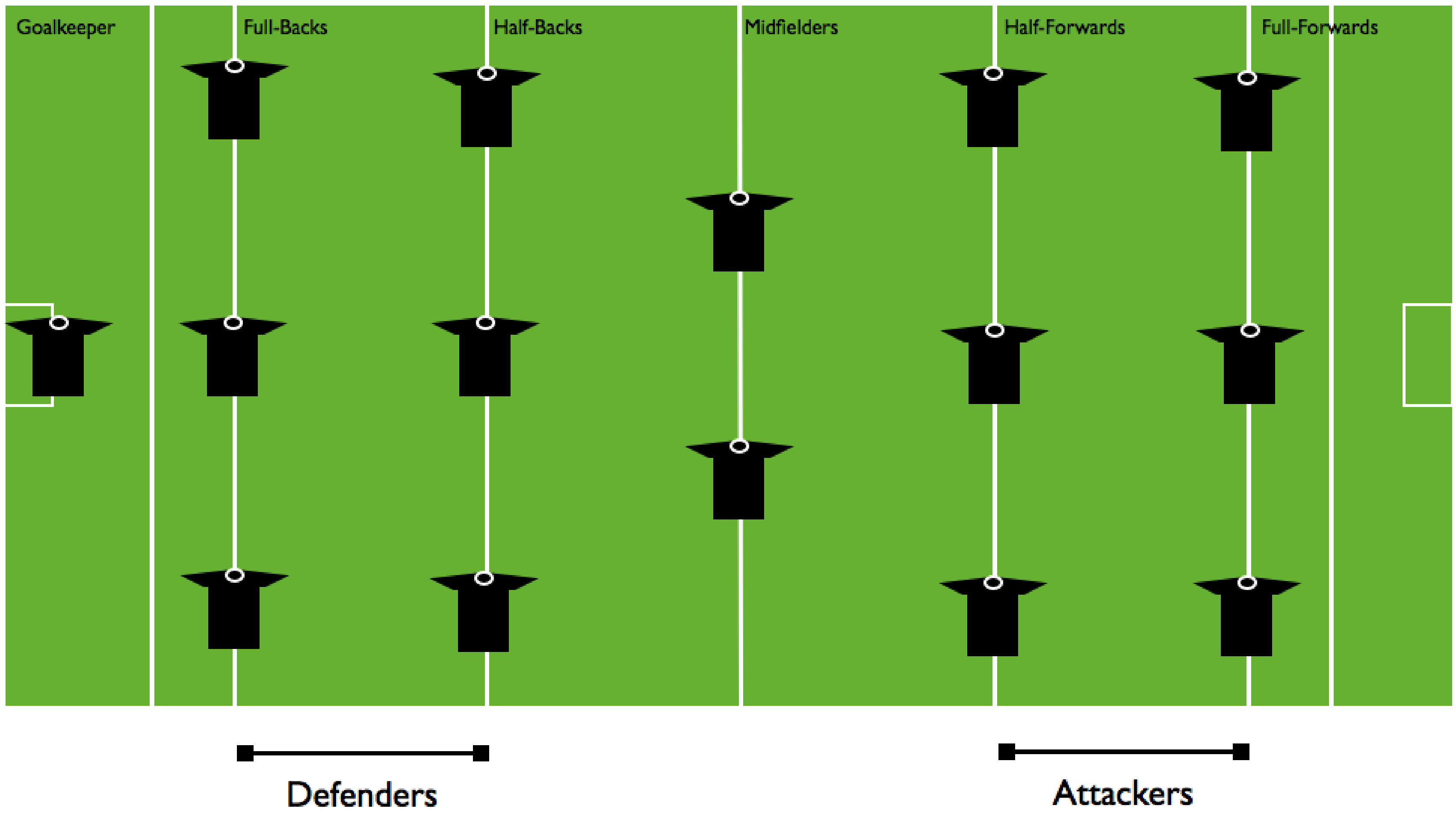

Figure 1. A schematic of a hurling pitch and the positional lay out.