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ABSTRACT

Aims: To compare the metabolic power demands between positional groups and examine the temporal profile of elite Gaelic football match play.

Design: Longitudinal observational study.

Methods: Global positional satellite system (GPS) data were collected from 50 elite Gaelic football players from 4 inter-county teams during 35 elite competitive matches over a three season period. A total of 351 complete match samples were obtained for final analysis. Players were categorised based on positional groups; full-back, half-back, midfield, half-forward and full-forward. Instantaneous raw velocity data was obtained from the GPS and exported to a customised spreadsheet which provided estimations of both speed based, derived metabolic power and energy expenditure variables (total distance, high speed distance, average metabolic power, high power distance and total energy expenditure).

Results: Match mean distance was 9222 ± 1588 m, reflective of an average metabolic power of 9.5-12.5 $W \cdot kg^{-1}$, with an average energy expenditure of 58-70 $Kj \cdot kg^{-1}$ depending on position. There were significant differences between positional groups for both speed-based and metabolic power indices. Midfielders covered more total and high-speed distance, as well as greater average and overall energy expenditure compared to other positions ($p < 0.001$). A reduction in total, high-speed, and high-power distance, as well as average metabolic power throughout the match ($p < 0.001$) was observed.

Conclusions: Positional differences exist for both metabolic power and traditional running based variables. The middle three positions (midfield, half-back and half-forward) possess greater activity profiles when compared to other positional groups. The reduction in metabolic power and traditional running based variables are comparable across match play. The current study demonstrates that metabolic power may contribute to our understanding of Gaelic football match-play.

Key Words: activity profile; match analysis; Gaelic football; energy demand; GPS.

INTRODUCTION

Gaelic football is a field sport where high-intensity actions are stochastic in nature following the flow of competitive play [5]. Match analysis of the game is becoming more common with several studies having examined the physical activities of players with particular reference to playing position [12, 18], decrement in running performance across halves[18] and high intensity actions [5]. These studies have typically used activity metrics such as total distance, high speed running, sprint running, peak velocity and number of completed accelerations. These actions have been shown in team sports to be influenced by contextual factors such as opposition and team tactics [9]. More recently accelerations have been reported as an important determinant of Gaelic football competitive match demands [5]; whether this impacts on player performance and match success has yet to be empirically assessed. These applied analyses have assisted in developing our understanding of the physical running demands associated with competitive match-play within elite Gaelic football.

Recently reports from professional soccer [15], rugby league [11] and Australian rules football (AFL) [4] have shown that metabolic power can estimate power output and energetic costs of intermittent running and competitive match play [4, 10, 11]. These investigations provide an additional insight to previous studies which have employed traditional time motion analyses of activity demands of training and match play [4]. Analysis of training activity has revealed a systematic bias for speed based metrics when compared to metabolic power based metrics, with and underestimation of speed based metrics to quantify the true physiological strain associated with match play [4, 10, 11] and training [8]. These metabolic power calculations are based on a theoretical model [13] which allows for the estimation of the energetic cost of accelerations and decelerations during intermittent running and can be applied to a variety of sports involving similar activity profiles [10].

While a number of limitations exist with the model in relation to the validity and reliability [1, 19], the model has been reported to provide energy cost estimates similar to determined measures [10]. Recently studies in soccer have reported very large correlations between aerobic fitness variables and metabolic power estimates of high power distance during professional soccer matches, providing evidence for concurrent validity to this novel approach to indirectly assess the energetic cost of match play [15]. The current model has been applied directly to competitive AFL [4], rugby league [11] and soccer [10, 15] in addition to training analyses [8]. These analyses have shown the model to be sensitive to decrements in running performance during competition within AFL populations [4]. In rugby league metabolic power indices have been shown to be to stable to account for temporal fatigue changes in performance [4, 11].

To date no studies have investigated the metabolic power demands of elite Gaelic football match-play, moreover no studies have used this method to analyse match related fatigue and the energetic profile of competitive play. Therefore the aims of the current study were to: 1) describe the metabolic demands of competitive elite Gaelic football match-play for different positional groups; 2) compare the match activity profile information from traditional speed zone methods to those derived from metabolic power calculations and 3) examine the temporal profile in metabolic power indices during competitive match-play.

MATERIALS AND METHODS

Competitive game data were collected from 50 elite Gaelic football players (Age: 25.6 ± 2.9 years; mass 84.7 ± 8.8 kg; height: 185.4 ± 8.2 cm) from four inter county teams across a four season period. A total of 355 player match files were obtained for analysis. The mean (± SD) number of observations per player was 8.5 ± 6.4 (Range 5-23). Players were categorised into the five distinct positional groups observed in Gaelic football: full-back (n = 64), half-back (n = 77), midfield (n = 71), half-forward (n = 79) and full-forward (n = 64) with only full competitive game data included for final analysis. Informed consent and institutional ethical approval were obtained before the commencement of the investigation.

Players movements were measured using global positioning satellite systems (GPS) sampling at 4 Hz (VX Sport, Lower Hutt, New Zealand). The GPS device was encased within a protective harness between the player's shoulder blades in the upper thoracic-spine region. Before entering the field the GPS device was fixed to the athlete, the device was then activated and satellite lock established for a minimum of 15 minutes before the commencement of each match [16]. All players wore the same GPS unit for each match during the seasons analysed to minimise inter-unit error [6, 7]. The validity and reliability of this device has previously been communicated [2, 17].

Game data was analysed post game with retrospective analysis conducted on all games. Game data were downloaded using the same proprietary software (VXSport View; Firmware 4.01.2.0). Each file was then trimmed so only data recorded during each full game and specifically each quarter when the player was on the field was included for further analysis. The proprietary software provided instantaneous raw velocity data at 0.25 s intervals, which was then exported into a customised spreadsheet (Excel, Microsoft, Redmond, USA). The spreadsheet allowed for calculation of distance covered in the following speed categories; total distance; high speed running (≥17 $km \cdot h^{-1}$, HSR) and sprint distance (≥22 $km \cdot h^{-1}$; SD). The metabolic power equation for estimation of instantaneous energy cost and metabolic power were integrated into the spreadsheet and formed the bases for all variable related to metabolic power analysis. The spreadsheet allowed for estimation of average metabolic power ($W \cdot kg^{-1}$; P_{met}) and total energy expenditure ($kJ \cdot kg^{-1}$), as well as distance (m) and energy produced above high power threshold (>25 W·kg^{-1}; HP). Calculations were provided for equivalent distance (ED), which represents the equivalent steady state distance required to match the estimated energy expenditure during exercise. Additionally, the equivalent distance index (EDI) representing the ratio between ED and total distance was calculated [4, 10, 11].

The assumptions of normality were verified prior to parametric statistical analysis. Firstly a multivariate analysis of variance (MANOVA) was used to compare differences in physical performance variables between positional groups (5) and playing quarter (4). If the chances of a variable having higher and lower differences were >5%, the true effect was deemed to be unclear. Effect sizes (ES) were interpreted as <0.2, trivial; 0.2-0-6, small; 0.6-1.2, moderate; 1.2-2.0, large; >2.0, very large differences in physical performance variables between positional groups [14]. All data are reported as mean and 95% confidence intervals unless otherwise stated.

RESULTS

Selected distance and metabolic power variables for each playing position are shown in table 1. The MANOVA revealed significant main effects for playing position (F = 14.8, p < 0.001). Post hoc analysis revealed that midfielders covered greater total distance compared to all other positions (ES = 0.72-1.39). Similarly, midfielders also had higher relative distances compared to all other positions (ES = 0.71-2.14), while higher values were observed for half-backs and half-forwards compared to full-forwards (ES = 1.25) and full-backs (ES = 1.06). Midfielders also had greater HSD compared to all other positions (ES = 0.80-2.37), while half-backs (ES = 1.04-1.65) and half-forwards (ES = 1.16-1.73) covered more HSD than the other remaining position groups only. Half-forwards covered more SD (ES = 0.55-4.08) and compared to all other positions, followed by half-backs (ES = 0.93-

2.83; 0.86-2.87) and midfielders (ES = 1.06- 2.74; 0.28-2.48), which recorded higher values compared to the remaining position groups. In contrast, the highest P_{met}, energy expenditure and equivalent distance was observed for midfield players (ES = 0.64-2.10; 0.52-1.39; 0.52-1.39), followed by half backs (ES = 0.44-1.29; 0.44-1.36; 0.44-1.36) which were greater than all other positions. The HP variables (i.e. distance, time and power) were greater for midfielders (ES = 0.68-2.36; 0.87-2.16; 0.60-2.25) compared to all other positions, followed by half-backs (ES = 1.00-1.68; 0.95-1.39; 1.00-1.68) and half-forwards (ES = 1.17-1.82; 0.89-1.26; 1.11-1.78), which were greater than all other positions except for midfielders.

Figure 1 shows temporal changes in selected distance and metabolic power variables by playing quarter. The MANOVA revealed significant main effects for quarter (F = 7.26, $p < 0.001$), with subsequent post hoc analyses revealing that the total distance and energy expenditure in the second (ES=0.28; 0.29) and fourth (ES=0.45; 0.44) quarters were reduced compared to the opening quarter only, while the fourth quarter distance was less than both the first (ES = 0.54; 0.54) and second quarter (ES = 0.30; 0.30). There were reductions in HSD, HP distance and P_{met} in the second (ES = 0.28; 0.30; 0.31) and fourth (ES = 0.36; 0.37; 0.37) quarters when compared to the opening quarter, while the fourth quarter (ES = 0.31-0.65; 0.32-0.67; 0.25-0.60) values were lower than all other quarters. The EDI was lower in the second quarter compared to the third quarter only (ES = 0.24).

** Insert table 1 near here**

DISCUSSION

The current investigation implemented a novel approach for estimation of the metabolic demands based on accelerated running to complement the traditional speed based analysis of Gaelic football match-play. The study is the first to provide estimates of the metabolic demands of elite Gaelic football match play. The main findings were that traditional measures of running performance and metabolic power derived parameters differed across positional groupings. In addition we found that high speed running distances were most likely higher when compared to high power derived distances for the middle 3 positional groupings with external positioning groups showing very likely increases in high power distance when compared to traditional analysis methods. Reductions in distance travelled in speed zones and metabolic power measurements were observed across playing quarters. In addition, the percentage differences between the two methods of running performance analysis were shown to be position dependant (See table 1.)

In line with previous literature on team based field sports [4, 8, 10, 11, 18] positional differences for both speed zone classifications including total, high speed and sprint distances were identifed. In addition to these positional variations similar trends were observed for metabolic derived indices during competitive Gaelic football match play. Specifically, midfielders covered a greater total distances and relative intensities ($m \cdot min^{-1}$) which was very likely higher than all other positions. In addition, both high speed and sprint distances were likely higher for midfielders, half-backs and half-forwards when compared to full-backs and full-forwards. These results are comparable to previously reported during Gaelic football match-play [5, 12]. The novel aspect of the current study is the analysis of metabolic power derived indices during match-play, the data collected shows similar trends to traditional running based variables with midfielders having greater P_{met}, total energy expenditure and equivalent distance when compared to all other positions. Midfielders, half-forwards and half-backs perform greater high power activities (i.e greater HP distance and power production) compared to full-backs and full-forwards. These differences in activity profiles may be explained by the specific tactical roles of each playing group e.g. the middle three positions (half-back, midfield and half-forward) in Gaelic football typically have more nomadic roles than other positions, this typically would allow for more space to complete high power activities. Additionally these positional lines have more direct involvement in play as their role is to win the ball and provide a transition of ball from defence to attack, while full-back and full-forward lines are generally required to provide offensive pattern play or a more direct defensive approach against an opposing full-forward.

Insert Figure 1 near here

The metabolic power derived indices reported in the current study provide new insights into the activity profiles of elite Gaelic football competition. The P_{met} for each positional group ranged from 9.5-12.5 W·kg^{-1} which is higher than previously reported for soccer training [8], rugby league match play [11] and Australian rules match play [4] that have utilised the same calculations as reported in this current analysis. Interestingly and similar to data reported in AFL match play [4], the observed EDI was lower than that of soccer training[8] and rugby league [11], suggesting a greater need for Gaelic players to be conditioned towards continual running compared to accelerated running to meet running demands of match-play. This observation is in contrast to soccer and rugby league demands where players run less distance between acceleration and deceleration efforts. The current finding may be explained by the greater field sizes observed in Gaelic football (33% larger) compared to soccer and rugby league. The total energy expenditure ranged from 58-70 Kj·kg^{-1} which is slightly higher than that reported for AFL match play and soccer match play respectively [4, 10]. The energetic expenditure information provided in the current investigation may provide useful data to nutritional practitioners to aid in pre- and post match nutritional intake, which can assist in the optimisation of acute recovery techniques employed by elite Gaelic football teams. Previous studies [3] have shown decreases in body composition (Body mass and % Skinfold BF) across seasonal periods for Gaelic football players. Overall the current data will further help practitioners aid in the maintenance of optimal body composition for Gaelic football players throughout the competitive season through better understanding of match play energetic demands.

Within soccer Gaudino et al. [8] identified that depending on playing position HP distance was between 62 and 84% greater than high speed running distances during training games. As a result the authors cautioned that high speed running may neglect the contribution of accelerated running and therefore underestimate the true energetic cost of training activities. In contrast to this previous study, our results show a reduction in HP distance (2.2-10.1% depending on position) when compared to high speed running during elite Gaelic football match play. This is a finding that is in line with previous investigations within AFL [4] while this was an unexpected finding several factors may explain this discrepancy. Firstly, Gaelic football is a game played on a pitch that is approximately 33% larger than that of a soccer pitch in addition during training games the pitch dimensions are largely compressed. As a result of the above some running efforts in excess of the high speed threshold that occur while accelerating and decelerating will not reach the HP threshold to the similar degree to which they would during a compressed small sided training game. Similarly some running efforts made by Gaelic football players can occur with little or no acceleration and thus would not fall into the HP category of efforts. It is very possible that the structure of Gaelic football provides more opportunities for running efforts that cross the high speed threshold but not the HP thresholds due to both a larger pitch dimension and the absence of an offside rule meaning more space for players. Indeed Gaudino et al. [8] observed that the magnitude of difference between speed zone and isopower methods was inversely related to the amount of high speed activity completed in the training session.

The above findings may be explained by the large emphasis on continual running bouts within elite Gaelic football match play, which therefore impacts the additional contribution of HP distance to Gaelic football match analysis. From a practical perspective the present results show that metabolic power estimates of HP distance provide little additional insight when compared to traditional speed zone running distance variables. While previous studies in Gaelic football have examined changes in running performance during match-play[5], this is the first study in Gaelic football to assess the temporal changes in metabolic power variables during match-play. Our results show that P_{met} and HP distance were reduced in the second and fourth quarters when compared to the first, while in the final quarter all variables were reduced when compared to all other quarters of play. These findings are similar to those found in the other team sports. Similar observations were seen for energy expenditure, with lower values found in the second and fourth quarters of play. There was no clear trend for EDI across the match with small reductions detected in the second and fourth quarters of play. In the current study the observed reduction in metabolic power derived variables were in line with similar changes seen in traditional speed zone running metrics (i.e. total distance, HSR distance and SD) within this study. Collectively these results show that metabolic power and traditional running based metrics may provide similar trends during match play with metabolic power derived variables such as P_{met}, HP distance and energy expenditure appearing to be sensitive to fatigue related reductions in competitive play however these variables follow similar trends seen in total distance, high speed distance and sprint distance.

While the current analysis is novel and metabolic power potentially can offer important contributions to further our understanding of demands within team sports such as Gaelic football, it is essential to consider the assumptions and limitations of the original theoretical model proposed by di Prampero et al. [10]. These relate to the location of the centre of mass of the body and the influence of limb movement on running energetic, the validity of the equation for assessing high equivalent slopes and the influence of air resistance. Additionally the model fails to consider eccentric work and how this influences energetic kinetics during locomotion, while these movements are known to have a low impact on energetic cost they can contribute significantly to muscular fatigue [4]. A further limitation which is common to all forms of locomotion analysis is that game specific actions such as collisions, tackling, kicking and jumping are not accounted for. Additionally post exercise bout energetic cost (excess post-exercise O_2 consumption) is not accounted for by GPS technology as the method utilised player movement as a reference for energetic cost, in contrast, human energetic cost can occur without locomotion [1]. Accordingly, the estimates provided in the current study neglect the contribution of these actions to overall energy expenditure.

CONCLUSION

The current investigation examined the metabolic power demands of elite Gaelic football match play in conjunction with traditional speed derived running variables. The main findings were that positional differences exist for both metabolic power and traditional running. In general midfielders, half-backs and half-forwards had the greater activity profiles when compared to other positional groups. In addition both metabolic power and traditional running metrics followed similar temporal trends across match play. Finally, the HP distance was less across all positional groups when compared to HSR distance, which may be explained by the elevated HSR demands of elite Gaelic football. The study shows that metabolic power data may contribute to our knowledge of the physical demands of Gaelic football competition through providing estimates of energetic expenditure across match play.

PRACTICAL APPLICATION

- ❖ Traditional speed derived running indices such as high speed running are appropriate for analysing match activities during elite Gaelic football match play.

- ❖ Instantaneous acceleration derived energetic and metabolic power measures provide a novel approach for estimation of training and match-play loads, whether these measures provide additional useful information to traditional running based indices is questionable as they follow similar trends.

- ❖ The estimated energetic and metabolic power demands of Gaelic football have been identified for the first time for coaches. The demands allow coaches to create training situations that best replicate these demands for players based on their specific positional requirements.

- ❖ Estimations of energy expenditure during match-play may provide useful information to nutritional experts for energy replacement requirements post training and competitive play.

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TITLES OF TABLES

Table 1 - Match distance and metabolic power variables by playing position (Mean ± 95% CI)

TITLES OF FIGURES

Figure 1 – Selected metabolic power variables shown across quarters of match play.

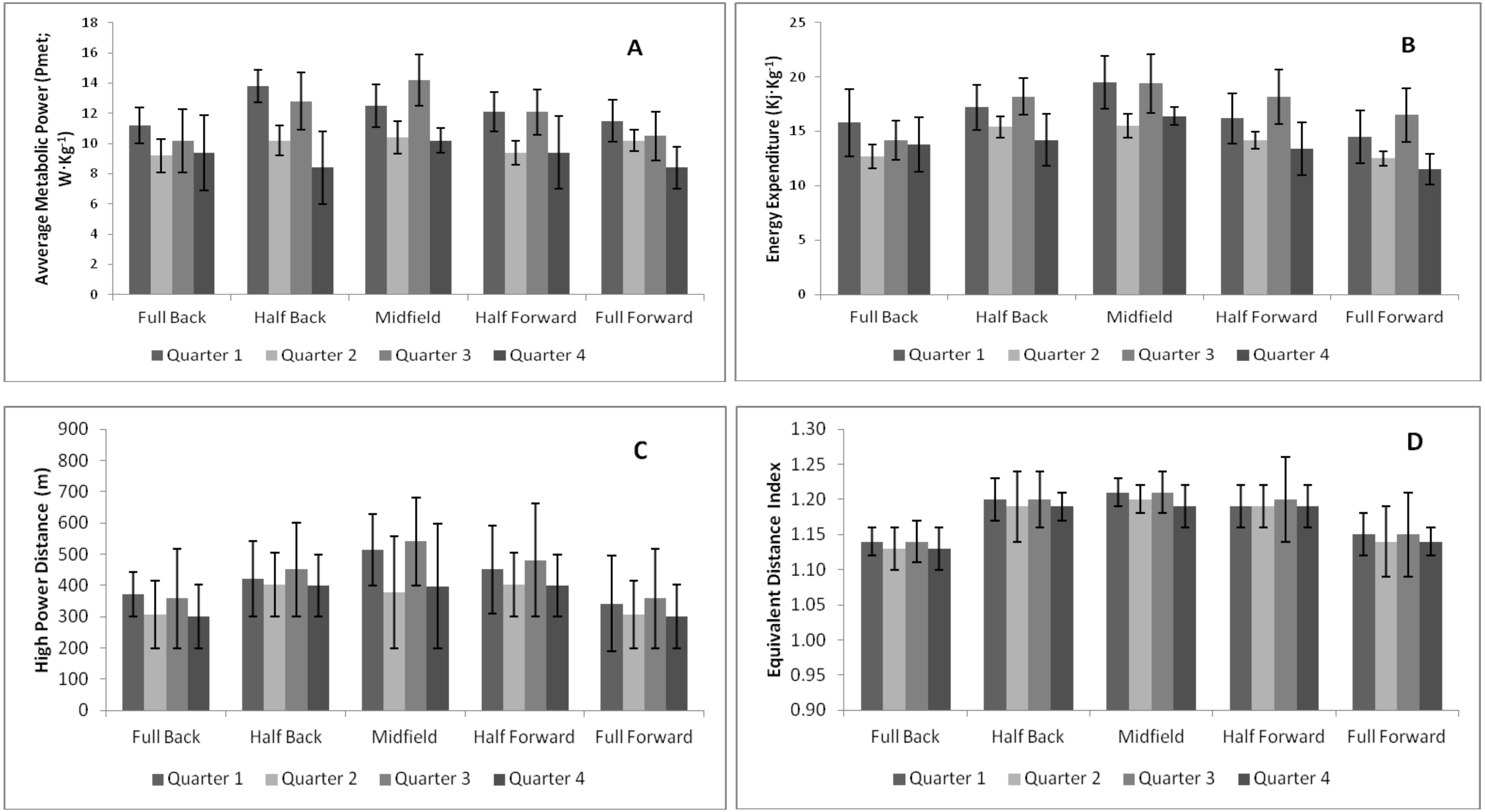
A. Average Metabolic Power (P_{met}; $W \cdot Kg^{-1}$); B. Energy Expenditure ($kJ \cdot Kg^{-1}$); C. High Power Distance (m); D. Equivalent Distance Index

TABLE 1.

	Full-Back (n = 64)	Half-Back (n = 77)	Midfield (n = 71)	Half-Forward (n = 79)	Full-Forward (n = 64)
Distance Variables					
Total Distance (m)	7878 (7437-7920)[abc]	9621 (9341 - 9899)[ade]	10621 (10621-11114)[cde]	10121 (9941 - 10214)[ade]	7870 (7579 – 7974)[abc]
High Speed Distance (m) (≥ 17 $km \cdot h^{-1}$)	1331 (1289-1598)[abc]	1831 (1821 - 2011)[ade]	2021 (1981 - 2562)[cde]	1851 (1824 - 2111)[ade]	1351 (1284 - 1441)[abc]
Sprint Distance (m) (≥ 22 $km \cdot h^{-1}$)	381 (371-391)[abcd]	478 (446 - 498)[de]	458 (438 - 481)[ef]	488 (486 - 501)[ade]	357 (350 - 364)[abc]
Accelerations (n)	165 (146-175)[abc]	204 (184 - 218)[acde]	214 (198 - 245) [bcde]	196 (165 - 198)[ade]	152 (144 - 165)[abc]
Relative Distance ($m \cdot min^{-1}$)	112 (107-116)[abc]	137 (131 - 140)[acde]	151 (141 - 161) [bcde]	144 (137 - 154)[ade]	112 (108 - 118)[abc]
Metabolic Power Variables					
Average metabolic power (P_{met}) ($W \cdot Kg^{-1}$)	10.2 (9.9 - 10.6)[abc]	11.8 (11.1 - 12.1)[de]	12.5 (12.2 - 12.7)[bde]	11.1 (10.9 - 11.4)[de]	9.5 (9.2 - 9.7)[abc]
Energy Expenditure ($kJ \cdot Kg^{-1}$)	59.2 (57.1 - 61.2)[abc]	65.1 (63.1 - 67.5)[de]	70.2 (69.1 - 75.1)[bde]	64.8 (63.4 - 66.4)[de]	58.1 (56.1 - 60.2)[abc]
Equivalent Distance (m)	8697 (8574 - 8799)[abc]	10660 (10584 - 10768)[ade]	11800 (11674 -11915)[bde]	11113 (11087 - 11214)[de]	8688 (8488 - 8947)[abc]
Low Power Distance (m) (<25 $W \cdot kg^{-1}$)	7396 (7084 - 7695)[abc]	8928 (8724 - 9021)[de]	9984 (9784 - 10251)[bde]	9381 (9281 - 9541)[de]	7359 (7259 - 7458)[abc]
High Power Distance (m) (>25 $W \cdot kg^{-1}$)	1301 (1001-1502)[abc]	1732 (1532 - 1951)[ade]	1816 (1745 - 1958) [bde]	1732 (1532 - 1874) [de]	1309 (1109 - 1541)[abc]
Comparisons					
Equivalent vs Total (%)	10.4 (10.2 – 10.6)[ab]	10.8 (10.2 – 11.1)[b]	11.1 (10.8 – 11.3)[bcde]	9.8 (9.4 – 10.2)[de]	10.4 (9.8 – 10.6)[ac]
High Power Distance vs High Speed Distance (%)	-2.2 (-3.2 – 1.1)[abc]	-5.4 (-5.1 – 1.1)[de]	-10.1 (-8.1 - -10.3)[bcde]	-6.4 (-6.2 - - 6.6)[de]	-3.1 (-2.8 – 1.2)[abc]

Significantly different from ***a*** Midfielders, ***b*** Half-Forwards, ***c*** Half-Backs, d Full-Forwards, e Full-Backs (all $p < 0.001$)

FIGURE 1.


A
Avverage Metabolic Power (Pmet; W·Kg-1)
Full Back
Half Back
Midfield
Half Forward
Full Forward
Quarter 1
Quarter 2
Quarter 3
Quarter 4
B
Energy Expenditure (Kj·Kg-1)
Full Back
Half Back
Midfield
Half Forward
Full Forward
Quarter 1
Quarter 2
Quarter 3
Quarter 4
C
High Power Distance (m)
Full Back
Half Back
Midfield
Half Forward
Full Forward
Quarter 1
Quarter 2
Quarter 3
Quarter 4
D
Equivalent Distance Index
Full Back
Half Back
Midfield
Half Forward
Full Forward
Quarter 1
Quarter 2
Quarter 3
Quarter 4