QUANTIFYING
AFL PLAYER GAME DEMANDS USING GPS TRACKING

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Introduction

Over the past 50 years, knowledge of the physiological response to exercise and the application of scientific principles has had a substantial impact on improving performance. In an era dominated by technology in all aspects of society, sporting performance has been more heavily scrutinised and monitored, further improving athlete performance. Team sports have probably been the most difficult sporting area to assess objectively for performance demands, due to the complex interactions of players and the varying intensities experienced throughout and between games.

Traditionally, player demands in team sports have been assessed through the use of time-motion analysis based on video footage, visual tracking devices or time in heart rate zones. While this has provided a general insight into game demands for sports such the Australian Football League (AFL) (Norton 1999), it has been unable to accurately capture the workload players experience, largely due to the limitations and inaccuracies of determining speed and distance. AFL coaches and conditioning staff understand that AFL is a high intensity, intermittent exercise, involving large running distances, numerous accelerations and decelerations, and high speed intervals during periods of continuous running. However, the quantification of these demands for individual positions during the full course of a game (including off-ball periods) is something that has not been extensively assessed across the sport, despite being recognised as an important aspect in the early AFL literature (McKeon, 1978).

Previously, Pyke and Smith (1975) reported a total running distance of a midfielder at 13km for an entire game, and a defender covering 5km in half a game. Following this Hahn et al (1979) reported state level midfielders covering 8km, comprising 145 sprints totalling ~2.8km. More recently, total running distances have been reported at 20km per game (Woodam & Pyke, 1991). This increased amount of running compared to previous reports could be a result of the changing demands, tactics and intensity of the modern game. Burgess and Naughton (2004) also reported average total running distances to be 16.6km during the 2002 and 2003 season with an average speed of 9 $km{\cdot}hr^{-1}$ with 52 maximum sprint efforts per game. In contrast to this, they reported elite under 18 footballers who covered 11km with an average speed of 7 $km{\cdot}hr^{-1}$ comprising only 30 maximal efforts.

The most recent and complete attempt to define the movement patterns of modern AFL positions was completed by Dawson et al. (2004) from data collected in the season of 2000. A brief summary of the major findings of Dawson's research is of relevance.
The total distance for midfielders was found to be ~17km, full forwards and fullbacks 13.6km, half forwards and half backs ~16km. Forwards and backs completed the greatest number of sprints (30 per game). High intensity movements totalled 208 for midfielders during a game, with fast running and sprinting representing only 4.4% and 6.3% of the total movement time.

Although this information provides valuable insight to the gross movements of various positions and had possible training benefits, the data does not distinguish the characteristics that comprise the demands of the running profile of elite AFL footballers.

It does highlight that the total running distances between positions are not that dissimilar, and the reported 20km would seem atypical, but not impossible during a game.

The introduction and use of Global Positioning Systems (GPS) in field based sports has now allowed full game movements, along with player and positional demands to be monitored and assessed. With this introduction, and the upcoming release of accelerometers, performance analysis has become an area of interest for sports scientists and conditioning coaches. While research into the use of GPS in sport is still limited, two studies have reported on the accuracy of GPS units (Schutz, 2000; Witte, 2004).

The aims of this current investigation were to provide novel information with respect to the demands of AFL through the use of technology new to team sports. These include:

- Characterisation of the running profile of modern AFL footballers
- Assess several positional demands of elite AFL football
- Quantify modern day AFL player workloads within those positions
- Develop a greater understanding of training requirements based on game demands
- Provide practical outcomes that will assist conditioning staff prepare players

Methods

Elite AFL footballers (n=52) from eight of the sixteen AFL clubs were tracked using GPS (GPSports, Canberra, Australia) during the home and away games of the 2005 AFL season. Players were assigned to three major positional groups being forwards, midfielders and defenders as reported by their respective clubs. GPS Units were fitted to the upper back using a purpose built supportive harness. Analysis was restricted to three players in five games for each team throughout the season. In total, 90 game files were captured.

The GPS units captured data at 1 Hz throughout the duration of each game, and recorded speed, altitude, heart rate, latitude, and longitude. Where no satellites were found by the GPS unit during the course of the game, data for this period was omitted. It was the responsibility of each participating club to fit the unit during their selected games, and download the data to PC (GPSports Analysis Software V1.6). Data was then sent via email to the researchers. All game data was then exported to Microsoft Excel, where it was imported to custom built GPS analysis software (Sports Tracker Analysis v1.0, FitSense Australia). All GPS game data was stored with accompanying data for each player. This data was made up of individual player game possession statistics (kicks, handballs, marks, and total possessions), player position, game score, team, opposition, venue, playing duration and date. All playing time was analysed. Non-playing periods (quarter breaks, and interchange periods) were omitted from the analysed data.

All game files were analysed using a number of steady state and intermittent variables. These included:

- Total distance
- Average speed
- Exertion index
- Exertion index per minute
- Time spent in speed zones
- Number of surges over specified speeds

- Longest continuous time above specified speeds
- Maximal speed
- Average work to rest ratio
- Acceleration / deceleration profile

A brief explanation of each variable is outlined in Attachment A.

Statistical measures

Statistical analysis was performed using the SPSS software package (v13.0). A Pearson two tailed correlation was used to assess the relationship between variables with a significance of $p<0.01$. Comparisons of variables between positions was performed using a one-way ANOVA, with a significance level of $p<0.05$. Where significant differences were established a Bonferroni post hoc comparison was used.

GPS Accuracy

The accuracy of the GPSports units has been stated by the manufacturer to be 99% accurate in continuous straight line running, and 96-97% accurate when in a team sport situation with rapid changes of speed and direction (GPSports, 2005). Witte (2004) determined that the straight line accuracy from a generic GPS unit was slightly less than this, with only half of the recorded values being within 0.2 m/s of the actual speed based on the data captured. This report concluded ‘GPS data loggers are therefore accurate for the determination of speed over-ground in biomechanical and energetic studies performed on relatively straight courses’. However, this report also stated that errors increase on circular paths, especially those with small radii of curvature, due to a tendency to underestimate speed (Witte, 2004). The demands and speed of AFL with rapid changes in speed and direction may lead to important data points, such as changes in direction being missed by GPS due to the 1Hz sampling rate.

GPS accuracy is also dependant on the number of satellites detected. The number of satellites present at each 1 second sample was therefore recorded. During periods where no satellites were detected, data was eliminated from research to ensure accuracy.

Results

After screening the data, several files were short in duration and not representative of full game demands and therefore these files were removed, leaving only files with a playing time of greater than 80 minutes. This left a total of 80 files collected from 48 players for analysis.

The 80 analysed games files were captured by eight AFL clubs; this was made up of the following number of files per playing positions:

- Forwards (n=14)
- Midfielders (n=35)
- Defenders (n=31)

Files were collected across the following grounds:

- AAMI Stadium, Adelaide (n=17)
- GABBA, Brisbane (n=3)
- Melbourne Cricket Ground, Melbourne (n=29)
- Sydney Cricket Ground, Sydney (n=11)
- Skilled Stadium, Geelong (n=2)
- Subiaco Oval, Perth (n=18)

The range of satellites detected during data collection at any one time varied from 1 to 10, both during single games and between games.

Work

Average work load data is displayed in Table 1, and individual positional work load data is shown in Table 2. The spread of exertion index is illustrated in Figure 1. The exertion index showed moderate correlations with the average work to rest ratio (0.68, $p<0.01$) and average speed (0.70, $p<0.01$), and a strong correlation with total distance (0.94, $p<0.01$). Exertion index also correlated ($p<0.01$) with time in all speed zones between 8 $km \cdot hr^{-1}$ and above 25 $km \cdot hr^{-1}$. Exertion index also had a strong correlation with steady state running time above 8 $km \cdot hr^{-1}$ (0.93, $p<0.01$). A significant difference ($p<0.05$) in the exertion index was evident between midfielders and forwards, and midfielders and defenders.

Higher work rates were evident for midfielders, displaying a greater exertion index (Figure 3) and exertion index per minute than forwards and defenders. The difference between the mean values for exertion index between positions showed midfielders completing on average 15% more work than forwards, and 10% more work than defenders.

No correlation existed between exertion index and possessions for any individual playing position. However, exertion index did correlate with possessions across all playing positions (0.30, $p<0.01$).

The spread of exertion index per minute is shown in Figure 2. A significant difference ($p<0.05$) was only shown between midfielders and forwards. A significant difference (p<0.05) was also evident for the average work to rest ratio between midfielders and forwards, and midfielders and defenders.

Midfielders were more efficient than both forwards (15.9%) and defenders (27.6%). A correlation existed (0.30, p<0.01) between possessions and exertion index for all positions as shown in Figure 4. The relationship between exertion index and possessions for individual positions is shown in Figure 5 (forwards), Figure 6 (midfielders), and Figure 7 (defenders).

Work Variable	**Mean Values** (n=80 files)
Total Distance (km)	12.45 ± 1.65
Average Speed (km·hr^{-1})	6.76 ± 0.67
Total Time (min)	111:01 ± 13:50
Average Work to Rest	1:2.2
Exertion Index	120.98 ± 20.44
Exertion Index per Minute	1.10 ± 0.18
Efficiency (Exertion Index per Possession)	8.23 ± 3.35
Max Speed (km·hr^{-1})	30.25 ± 1.89

Table 1. Averages of all players for work variables (mean ± SD).

Work Variable	**Forwards** (n=14)	**Midfielders** (n=35)	**Defenders** (n=31)
Total Distance (km)	11.95 ± 1.93	12.93 ± 3.70	12.12 ± 2.13
Average Speed (km·hr^{-1})	6.49 ± 0.67	6.98 ± 0.75	6.64 ± 0.67
Total Time (min)	110:36 ± 15:08	111:48 ± 32:12	110:18 ± 19:40
Average Work to Rest	1:2.6	1:2.0*	1:2.3
Exertion Index	111.6 ± 22.98	128.6 ± 38.14*	116.6 ± 23.41
Exertion Index per Minute	1.01 ± 0.19	1.16 ± 0.16$^{\#}$	1.07 ± 0.18
Efficiency (Exertion Index per Possession)	8.32 ± 3.08	7.33 ± 2.77	9.22 ± 3.83
ax Speed (km·hr^{-1})	30.4 ± 1.59	30.2 ± 2.36	30.3 ± 1.49

Table 2. Average values for work variables by position (mean ± SD). * = Significantly different from forwards and defenders. # = Significantly different from forwards.

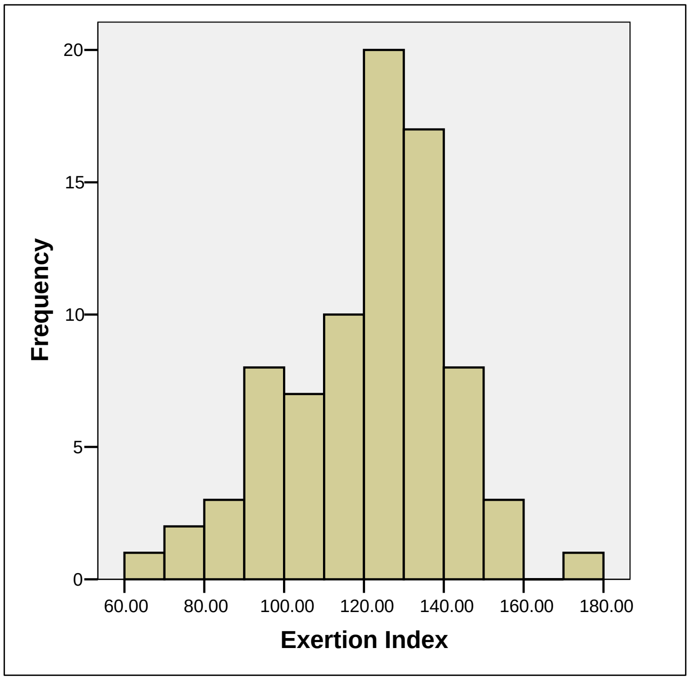

Figure 3: Histogram representing Exertion Index per Minute across all positions.

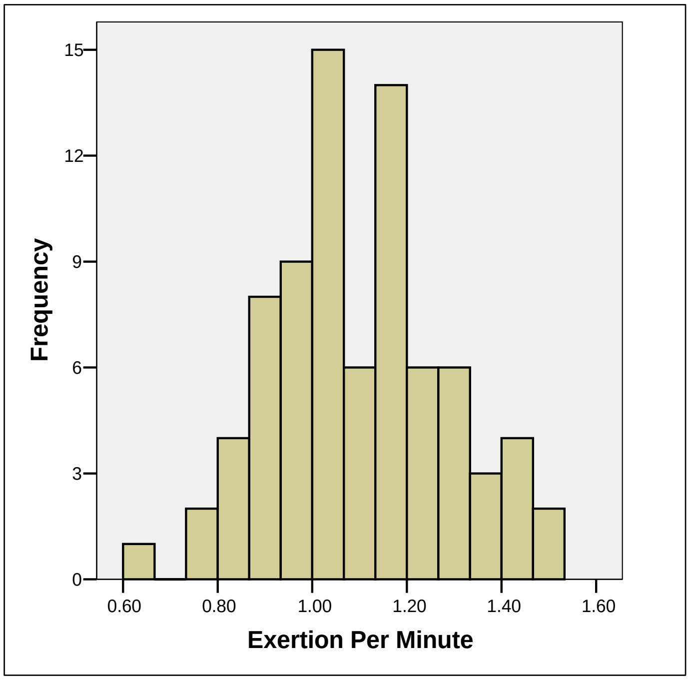

Figure 3: Histogram representing total Exertion Index across all positions.

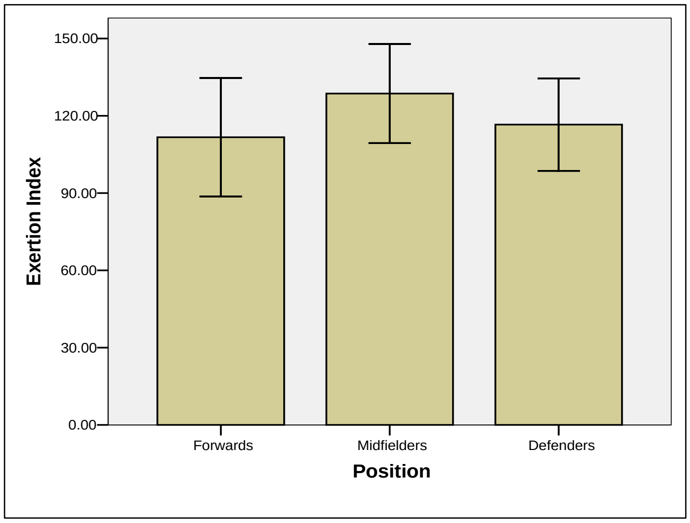

Figure 3: Bar Graph representing the Exertion Index for individual positions. Values are mean ± SD.

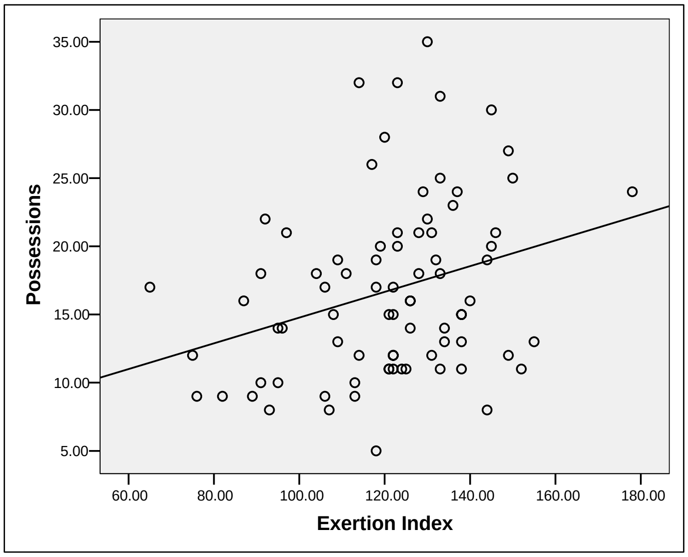

Figure 8: Scatter plot representing player efficiency (Exertion Index v. Possessions) across all positions.

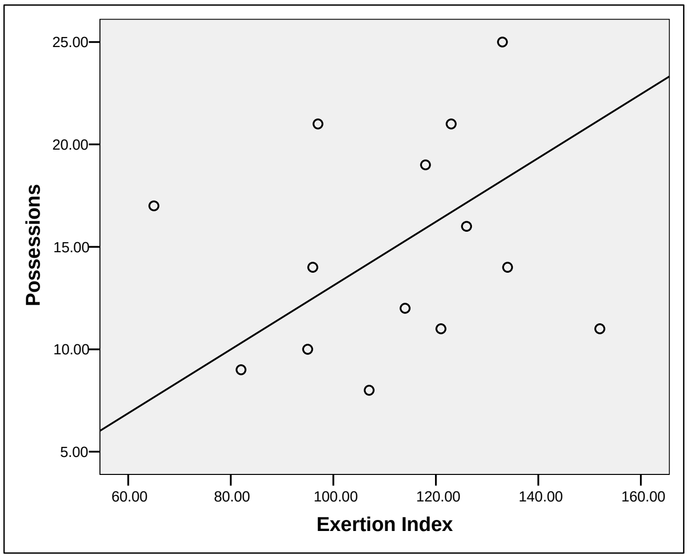

Figure 8: Scatter plot representation of efficiency (Exertion Index v. Possessions) for players competing in the forward position.

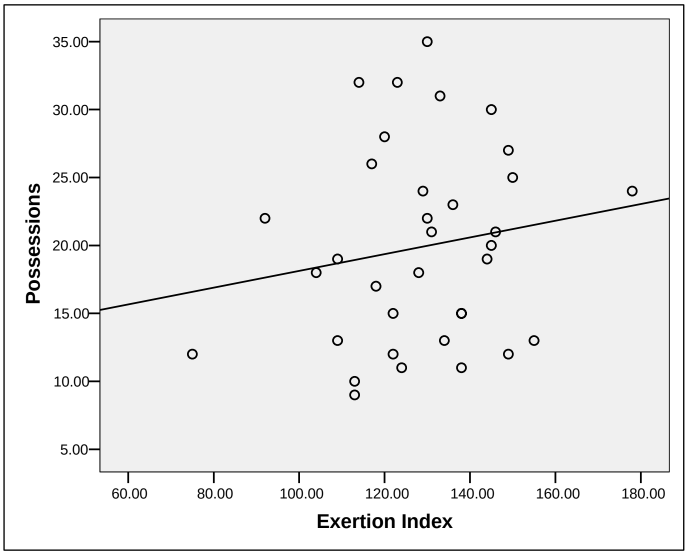

Figure 8: Scatter plot representation of efficiency (Exertion Index v. Possessions) for players competing in midfield positions.

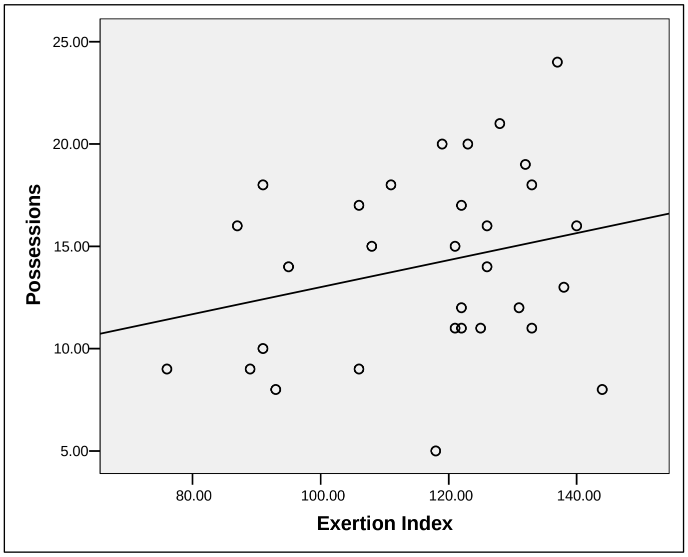

Figure 8: Scatter plot representation of efficiency (Exertion Index v. Possessions) for players competing in the defender position.

Intermittent Profile

Variable	**Mean Values** (n=80)
Surges Below 5 km·hr^{-1}	365.15 ± 52.28
Surges Above 14 km·hr^{-1}	110.85 ± 24.66
Surges Above 16 km·hr^{-1}	77.31 ± 18.62
Surges Above 18 km·hr^{-1}	88.61 ± 20.20
Accelerations Over 4 km·hr^{-1} in 1sec	240.83 ± 43.15
Accelerations Over 10 km·hr^{-1} in 1sec	10.03 ± 4.35
Decelerations Over 4 km·hr^{-1} in 1sec	227.96 ± 42.58
Decelerations Over 10 km·hr^{-1} in 1sec	15.76 ± 5.30
LCT Under 5 km·hr^{-1} (min)	1:35 ± 0:44
LCT Over 13 km·hr^{-1} (sec)	21.59 ± 4.05
LCT Over 15 km·hr^{-1} (sec)	17.04 ± 3.18
LCT Over 17 km·hr^{-1} (sec)	14.31 ± 2.72
LCT Over 20 km·hr^{-1} (sec)	11.08 ± 2.80
Steady State Time Above 8 km·hr^{-1} (min)	22:38 ± 4:49

Table 3. All positional averages for game intermittent profile (mean ± SD).

Average acceleration data, surges above speeds and longest continuous time (LCT) is shown for all positions in Table 3, and by individual playing position in Table 4. Midfielders spent a significantly greater amount of time undertaking steady state running above 8 km·hr^{-1} than other positions. This was 5:21(27%) and 3:46 (18%) greater than forwards and defenders respectively.

Although not significant (NS), forwards had a greater number of instances than both midfielders and defenders in the speed band below 5 km·hr^{-1}. Midfielders entered all high speed zones on a greater number of occasions than both forwards and defenders (NS). The greatest difference (NS) was most evident for surges above 14 km·hr^{-1}, where midfielders entered the band on average 17 and 11 times more than forwards more than defenders respectively.

Forwards entered low speed zones on a greater number of occasions than other positions, but spent shorter continuous periods at these low speeds than other positions. Forwards spent 12 seconds (14%) less than midfielders and 18 seconds (21%) less than defenders, below 5 km·hr^{-1} in any one continuous period.

Variable	**Forwards** (n=14)	**Midfielders** (n=35)	**Defenders** (n=31)
Surges Below 5 km·hr^{-1}	377.6 ± 74.44	361.3 ± 105.56	363.8 ± 63.95
Surges Above 14 km·hr^{-1}	101.4 ± 34.30	118.0 ± 37.42	107.1 ± 24.57
Surges Above 16 km·hr^{-1}	71.1 ± 27.57	81.5 ± 25.14	75.4 ± 17.96
Surges Above 18 km·hr^{-1}	80.1 ± 25.57	93.6 ± 29.12	86.8 ± 20.88
Accelerations Over 4 km·hr^{-1} in 1sec	227.7 ± 59.98	247.4 ±71.16	239.4 ± 51.06
Accelerations Over 10 km·hr^{-1} in 1sec	10.9 ± 5.54	10.3 ± 4.40	9.3 ± 4.77
Decelerations Over 4 km·hr^{-1} in 1sec	217.4 ± 63.84	230.3 ± 67.85	230.1 ± 49.69
Decelerations Over 10 km·hr^{-1} in 1sec	15.1 ± 5.32	16.0 ± 6.69	15.8 ± 5.43
LCT Under 5 km·hr^{-1} (min)	1:24 ± 0:37	1:36 ± 0:50	1:42 ± 0:37
LCT Over 13 km·hr^{-1} (sec)	21.2 ± 4.22	22.3 ± 4.68	21.3 ± 3.63
LCT Over 15 km·hr^{-1} (sec)	16.6 ± 2.73	17.5 ± 2.97	16.7 ± 3.65
LCT Over 17 km·hr^{-1} (sec)	14.3 ± 2.97	14.6 ± 2.20	14.0 ± 2.85
LCT Over 20 km·hr^{-1} (sec)	10.6 ± 2.69	11.6 ± 2.68	10.7 ± 3.10
Steady State Time Above 8 km·hr^{-1} (min)	19:41 ± 4:56	25:02 ± 7:44*	21:16 ± 4:46

Table 4. Average intermittent profile values by position (mean ± SD). * = Significantly different from forwards and defenders ($p<0.05$).

Midfielders completed longer continuous efforts above 20 km·hr^{-1} than both forwards (9.4%) and defenders (8.4%) (NS).

Defenders spent the longest continuous time walking (below 5 km·hr^{-1}). This was 8.3% and 21.4% more than midfielders and forwards respectively (NS).

Midfielders completed a greater number of moderate accelerations (increase of speed of more than 4 km·hr^{-1} in 1 second) than both forwards (8.7%) and defenders (3.3%) (NS). Both midfielders and defenders completed on average 13 more moderate decelerations per game than forwards (NS).

A similar number of rapid accelerations (speed change greater than 10 km·hr^{-1} in 1 second) and decelerations were evident across all positions (NS).

Time in Speed Zones

Time Zone	**Mean Values** (n=80 files)
Time Under 6 km·hr^{-1} (min)	66:28 ± 11:93
Time Under 8 km·hr^{-1} (min)	76:46 ± 12:35
Time 8-10 km·hr^{-1} (min)	7:27 ± 1:35
Time 10-12 km·hr^{-1} (min)	7:41 ± 1:43
Time 12-14 km·hr^{-1} (min)	6:19 ± 1:30
Time 14-16 km·hr^{-1} (min)	4:32 ± 1:05
Time 16-18 km·hr^{-1} (min)	2:50 ± 0:43
Time Over 18 km·hr^{-1} (min)	5:24 ± 1:31
Time Over 25 km·hr^{-1} (sec)	35.53 ± 17.12

Table 5. All positional averages for time spent in speed zones (mean ± SD).

Time Zone	**Forward** (n=14)	**Midfielders** (n=35)	**Defenders** (n=31)
Time Under 6 km·hr^{-1} (min)	69:40 ± 10:56	64:20 ± 20:05	67:25 ± 14:53
Time Under 8 km·hr^{-1} (min)	80:05 ± 12:26	74:44 ± 22:49	77:34 ± 16:26
Time 8-10 km·hr^{-1} (min)	6:52 ± 1:47	7:49 ± 2:25	7:18 ± 1:49
Time 10-12 km·hr^{-1} (min)	6:41 ± 1:47	8:23 ± 2:43*	7:20 ± 1:41
Time 12-14 km·hr^{-1} (min)	5:34 ± 1:31	7:04 ± 2:25*	5:49 ± 1:17
Time 14-16 km·hr^{-1} (min)	4:05 ± 1:13	4:56 ± 1:38#	4:19 ± 1:02
Time 16-18 km·hr^{-1} (min)	2:34 ± 0:51	3:02 ± 0:58	2:44 ± 0:43
Time Over 18 km·hr^{-1} (min)	4:43 ± 1:30	5:51 ± 2:02#	5:17 ± 1:31
Time Over 25 km·hr^{-1} (sec)	34.6 ± 15.27	35.6 ± 19.78	35.9 ± 16.72

Table 6. Average values for time spent in speed zones by position (mean ± SD).
* = Significantly different from forwards and defenders ($p<0.05$). # = Significantly different from forwards ($p<0.05$).

Table 5 shows the time spent in speed zones for all positions. Individual position data is displayed in Table 6. The distribution of time spent in speed zones for all positions is shown in Figure 8, and by position in Figure 9. On average, midfielders spent less time (6 minutes and 3 minutes) below 8 km·hr^{-1} than both defenders and forwards respectively (NS). There was no significant difference in the amount of time spent above 25km·hr^{-1} across all positions. Midfielders had a significant difference ($p<0.05$) in time spent between 10 and 12 km·hr^{-1}, and 12 to 14 km·hr^{-1} compared to both forwards and defenders. A significant difference ($p<0.05$) was also evident between midfielders and forwards for time spent in speed zones 14 to 16 km·hr^{-1} and over 18 km·hr^{-1}.

Time spent below 8 km·hr^{-1} had an inverse correlation with exertion index per minute (-0.69, $p<0.01$) and LCT time over 15 (-0.29, $p<0.01$) and 17 km·hr^{-1} (-0.34, $p<0.01$).

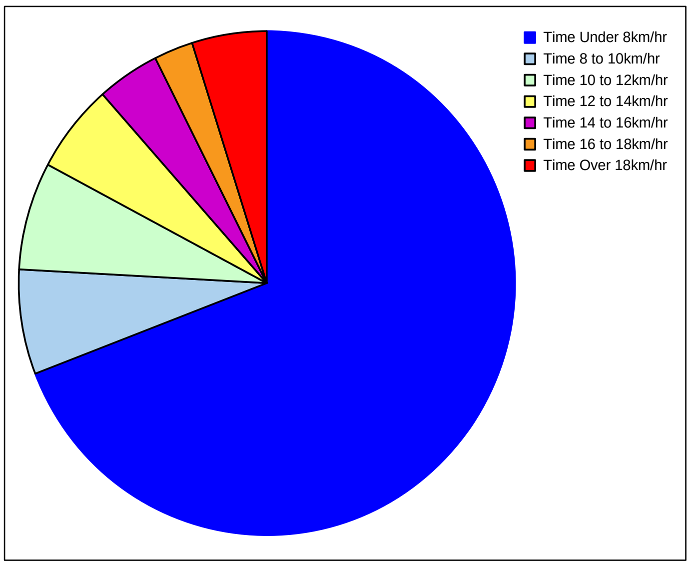

Figure 8. Pie Chart representing the Time Spent in Speed Zones across all positions.

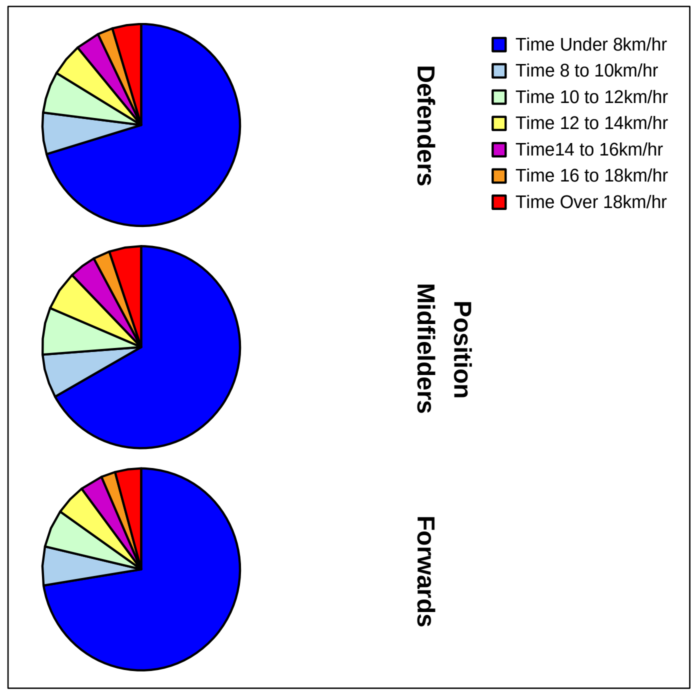

Figure 9. Pie Chart showing the distribution of Time Spent in Speed Zones across positions.

Discussion

Work

Actual playing time was similar between positions, with only 1:15 (min:sec) mean difference across all positions for the data collected.

Work to rest ratios

The average work to rest ratio across all positions is 1:2.2, indicating that for every one minute of running there will be 2:12 (min:sec) of rest, which may be at very slow running speeds, walking, or stationary. This highlights the large amount of recovery time available during an AFL game. It also shows that less than 1/3 of total playing time requires high levels of intense activity, yet it is these key periods of intensity that can determine the outcome of a game. This has practical training implications showing that it may be more important to represent game intensities for short periods in training, rather than attempting to replicate average game demands for extended periods. This ensures that players have the capacity to compete during these high intensity periods, and recover effectively before the next contest.

Exertion

Exertion index showed a strong correlation with other key variables including work to rest ratio, distance, average speed, and time in intermediate speed zones. These correlations indicate that the exertion index model developed here is a good measure of overall work in AFL, as it correlates with all key playing demand measures. The ability to combine all these stress measures into one variable provides an easier overall assessment of game and training demand. This exertion measure appears to provide a simple measure of overall game load.

While the overall workload and total exertion index provide an indication of total strain on the body, exertion index per minute provides a relative measure of intensity. The large standard deviation in this measure shows that game intensity varies greatly. This variation is likely due to varying positional demands, quality of opposition, individual fitness, and individual playing characteristics. This is useful information as it relates to the intermittent high intensity profile of the game; players can not expect to play each week based on average or expected demands, as any given game can elicit a wide variation in playing demands.

In terms of efficiency, there is a moderate relationship between increased work rate and obtaining more possessions. Intuitively, coaches and players would know that a higher work rate will elicit a greater return in possessions. Players can be assured that working harder during play will result in a greater likelihood that they will obtain more possessions. However, it should be recognised that possessions may also be dependent on the quality of the opposition, or the size and condition of the ground.

Distance

The average distance covered in the games across all positions was 12.5km ±1.7km. This is in contradiction to previous reports that have stated running distances of some players were found to be upwards of 20km a game. Although these large distances may have occurred in the past, they would appear to be atypical of a modern AFL game. The shorter distances recorded (12-13km) may be due to the higher rotational strategy applied to ensure that a high work rate is maintained during actual playing time. This indicates that while the absolute distance covered in modern day AFL may be lower than previously assessed, the intensity during on field playing periods may in actual fact be increasing as the game, and capacity of players develops.

Intermittent Profile

Maximum sprint speed was similar across forwards defenders and midfielders. Maximum speed showed a moderate correlation with accelerations and decelerations over 10 $km \cdot hr^{-1}$ in a 1 second period. Maximum sprint speed also correlates to the amount of time spent over 18 $km \cdot hr^{-1}$ and 25 $km \cdot hr^{-1}$, and also to the number of surges above 18 $km \cdot hr^{-1}$. This indicates that fast players not only have the ability to accelerate rapidly on numerous occasions, but can sustain higher speeds for extended periods. A high frequency of moderate and rapid accelerations was accompanied by a high frequency of decelerations. The consequence of these decelerations for this playing cohort is that it may create greater eccentric muscular load; this may be due to rapid planned stops, and also collisions or acute changes in direction. Based on this information it is likely that faster players may actually suffer more post-game muscular and general fatigue, increasing their risk of injury and prolonging their recovery.

Time in speed zones

The results highlight that if players spend more time in the low non-running speeds, the likelihood of sustaining longer efforts within the moderate to high speed zones may be less. Despite the increased period of rest, these players do not appear to be completing longer intensity efforts. This highlights one area where forwards may be able to significantly increase overall work load, increasing their chance of possessions and scoring opportunities.

Comparison between positions

Work

Work to rest ratios

As anticipated, midfielders have the least rest of all positions, with a work to rest ratio of 1:2.0, followed by defenders (1:2.3) and forwards (1:2.6). This is to be expected due to the continuous running profile exhibited by midfielders.

Exertion

The total exertion index shows that overall a midfielder's work rate is higher for approximately the same amount of playing time compared to both forwards and defenders. Interestingly, when exertion is expressed dependant on playing time (exertion index per minute), a significant difference was only seen between midfielders and forwards. While the difference between mean values for exertion index showed midfielders having an average 15% and 10% greater work rate than forwards and defenders respectively, the large standard deviation in exertion index across all positional data (20.1-29.7%) indicates that game demands may be just as much based on individual player fitness and playing styles. This highlights the substantial differences in training requirements between positions and even individuals.

The similarity in work rate between forwards and defenders may be due to defenders having to chase their direct opponents and assist team-mates in other contests in their area. It was previously believed that a defenders position was more static than other positions, with longer periods of rest and stationary time. The novel finding that defenders have a similar relative exertion index to midfielders has implication for the preparation of players competing in defensive positions.

When possessions are expressed relative to the total exertion count as a measure of efficiency, midfielders are more efficient as they obtain a possession for every 6.5 units of work, due to greater exposure to the ball. Forwards will obtain a possession for every 7.5 units and defenders every 8.3 units. This indicates that as midfielders are exposed to the ball more frequently, they require a greater absolute work rate. Therefore, the ability to undertake higher workloads and obtain a greater amount of possessions may indicate a controlling effect on the game. A greater number of midfielder possessions may ensure that the ball is delivered into the forward line, but this does not directly lead to scoring opportunities. Therefore it may be important to consider the work rate of forwards; if forwards can increase their work rate resulting in an additional possessions, this may create a direct scoring opportunity. Additionally, other positions will have to work up to 28% harder than midfielders for each possession.

Distance

Surprisingly, there is little difference in the total distance covered per game between midfielders, defenders and forwards. Midfielders will cover approximately 13 km during and game, which is approximately 1000 meters, (8.2%) and 800 meters (6.7%), further than defenders and forwards respectively. These distances are covered within approximately the same playing time for each position. The similarity of these running distances across positions possibly reflects the diverse running requirements of all players regardless of position. The fast running, modern game requires all players regardless of position, to have the ability to run long distances, at various intensities, and complete these demands on a weekly basis. Despite the similarity in distance covered, the difference in exertion index shows that midfielders complete a substantially greater amount of running at higher intensities throughout the game, resulting in a higher game demand.

Intermittent Profile

Midfielders spent a significantly greater amount of time undertaking steady state running above 8 $km \cdot hr^{-1}$ than both forwards and defenders. This difference appears to characterise midfielders and highlights one of the major differences between positions. This may also affect midfielder training requirements, with game specific drills including high intensity periods separated by steady state running periods for recovery.

A small difference in the average number of accelerations and decelerations was evident between positions; however the large standard deviation of these variables once again indicates that these game variables may be influenced more by individual playing styles than playing position.

Time in speed zones

All players spend a large amount of time under 8 $km \cdot hr^{-1}$; this may be at a slow jog or walking pace. Midfielders have the highest workloads, and this extra work is accounted for by spending greater amounts of time in all speeds zones above 8 $km \cdot hr^{-1}$, particularly between 8 and 14 $km \cdot hr^{-1}$. This defines their continuous running characteristics of high volume at moderate speeds, with frequent surges into higher speeds. This also confirms the findings that midfielders spend significantly more time running at steady state intensities above 8 $km \cdot hr^{-1}$. This indicates that midfielders have less low intensity recovery time, and are required to spend a greater amount of time at intermediate intensities.

Despite a greater amount of time in the low speed zones, and a greater number of surges into the lower speed zones, forwards spend shorter periods below 5 $km \cdot hr^{-1}$. Forwards entered low speed zones on a greater number of occasions than other positions, but spent shorter continuous periods at these low speeds than other positions. Forwards spent 12 seconds (14%) less than midfielders and 18 seconds (21%) less than defenders, below 5 $km \cdot hr^{-1}$ in any one continuous period. This shows that forwards have shorter, more frequent walking periods than the other positions.

General

One of the striking outcomes from this investigation was the similarity across the three positions for many general work variables. Previously it had been considered that midfielders cover the greatest distance during games, however these results confirm that in the modern game where players are required to have greater utility, the distance covered is similar regardless of position. The average speed, which is also similar across positions, was lower than previously described by other researchers. However, when the data is scrutinised more closely it is the nature of the work that midfielders undertake and the greater exertion required that separates the midfield demands from other positions. Despite the probable higher fitness levels of most midfielders, it is likely that midfielders will need more frequent substitutions than forwards and defenders in order to ensure game intensity remains high. This requirement is confirmed as this is a tactic used by AFL clubs at present in order to maintain the high work rate of midfielders.

The relationship between possessions and work load means that if a player drops intensity levels, fewer possessions will generally result. This also lends to the idea of fitter forwards having the ability to make a greater impact during the later part of the game when their opponent is perhaps fatigued. Possessions by forwards lead to an increased scoring opportunity. While forwards are less efficient than midfielders, a relationship between possessions and exertion index is still evident. The efficiency of forwards indicates that if a player in this position can complete 7.5% more work throughout the game, they will get an average of one more possession per game.

The lack of a relationship between time spent walking (time below 6 $km \cdot hr^{-1}$) and the number of possessions emphasises that it is the high intensity periods of a game that often determine the outcome, regardless of the amount of recovery time. This also leads to practical training implications. Training should not try and replicate overall game intensity. Game specific training drills should attempt to replicate the short high intensity periods that can determine game outcomes.

The large amount of accelerations and decelerations throughout the game may be affected by both position and individual playing characteristics. While time spent in speed zones provides an indication of game intensity, the player demands throughout a game are very dependant on the intermittent nature of the game. On average, 241 moderate accelerations were evident. While this level of acceleration is by no means maximal, it may have occurred within any speed zone. Therefore, a change in speed of 4 $km \cdot hr^{-1}$ at moderate to high speed can be highly demanding on the body and must therefore be specifically trained. These types of demands can be difficult to replicate, so it is important to ensure these demands are met in training by including accelerations beginning from a range of low to high starting speeds.

In order to maximise training it is important to know individual playing demands. As shown, this is influenced by position and individual playing characteristics. Players can be grouped accordingly, and provided with specific training drills that replicate the individual demands they will experience during a game. One method of breaking a team into training sub-groups may be to base these groups on overall workload, and intermittent game demands. This is outlined in Figure 10 where four distinguishable training groups may be determined based on the quadrant in which their playing characteristics fall. This will ensure players are preparing for the key positional and game demands experienced in competition. It may also allow players who require specific improvements to be identified and monitored through stages of preparation.

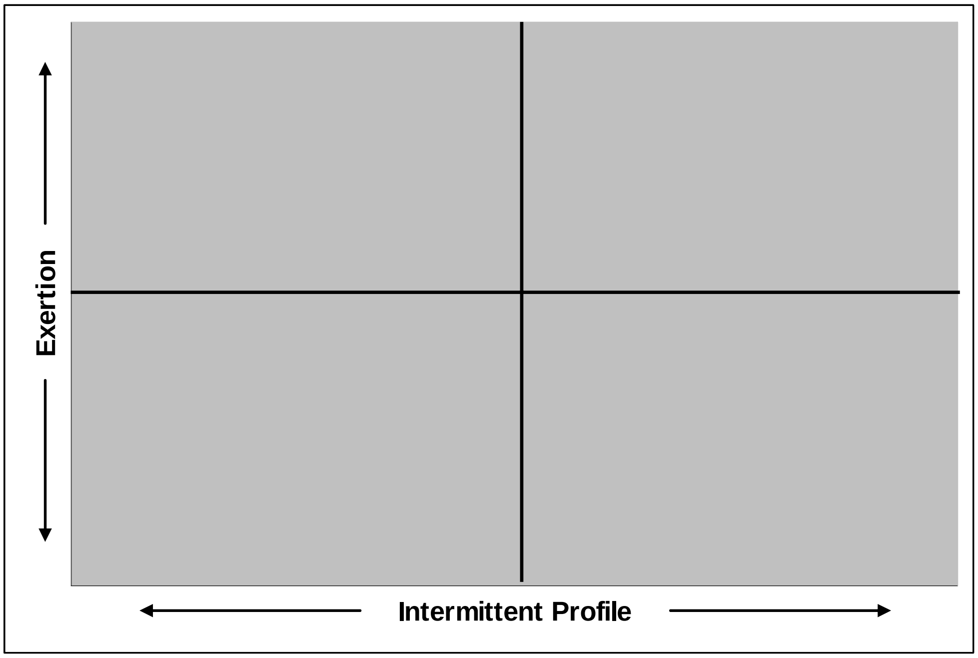

Figure 10 – Intermittent Profile v Exertion - Sub-group quadrant for training purposes.

While game specificity is obviously a key component of game preparation, the total game volume (as measured by playing duration and distance covered) shows the importance of aerobic endurance. While improved aerobic capacity may not improve performance in key intensity periods, it can have an impact on subsequent high intensity periods through the restoration of energy stores during the high volume of lower intensity. Specific training to replicate the repetitive high intensity anaerobic-based work periods, underpinned by periods of slow running to facilitate aerobic development and recovery may reduce the rate of fatigue during the game, and also improve post-game recovery. The intermittency of the game profile also affects post-game fatigue and recovery. Repeated accelerations result in neuromuscular fatigue while repeated decelerations cause muscle damage through eccentric loading. These game related measures may influence the type of post-game recovery undertaken, and the number of recovery days between the game and next training session. Rapid repeated decelerations can also impair repeat sprint performance. This has been shown recently by Lakomy, (2004) who concluded that reduced sprint performance and increased fatigue would result from approximately 11 repeated rapid post-sprint decelerations. While this magnitude of deceleration does not occur with repetitive frequency in an AFL game, the high frequency of moderate decelerations and accelerations will induce fatigue, and substantially impair performance.

The correlations between exertion index and a large range of other variables, indicates that overall game demands, and therefore fatigue, may be able to be obtained from this one measure of load. Relationships existed with both steady state running demands, and intermittent game demands.

Conclusion

This report aimed to identify the utility of GPS systems to understand the demands of modern AFL football and characterise the workloads of players in three major positional roles. Previously it had been considered that midfielders cover the greatest distance during games, however these results confirm that the distance covered is similar regardless of position. However, the nature of the work that midfielders undertakes, and the greater exertion required, separates the midfield playing demands from other positions. This is characterised by greater continual running, more frequent surges in to high speed zones and a greater number of accelerations.

We have determined that defenders have a similar relative exertion index to midfielders, which has implications for the preparation of players competing in defensive positions. Players who exhibit greater work loads will generally receive more possessions throughout a game, and an exertion index can be utilised to understand both individual and positional demands.

From the large amount of data obtained, it is obvious that GPS systems will provide vast amounts of information if the output is analysed in detail. Although this may serve to only overanalyse the game demands, important characteristics and relationships are evident and therefore the data must be scrutinised carefully.

Coaches and administrators of AFL clubs must now realise that the technology is available to assist in better preparation of their players. Not having this technology and information would be a serious disadvantage if competing against another club who had utilised and prepared players based on exact knowledge of specific positional, individual, and game demands.

GPS systems will not only define the movements of players in certain positions, but will characterise those movements into various speed zones. The information describes the similarity between positions, the large number of accelerations and decelerations, and the affect this may have on fatigue, injury and recovery. A measure of exertion can be derived to understand individual responses, and the need for specific preparation of not only senior players in certain positions, but also developing junior players for the demands of senior AFL football.

Future Directions

Performance analysis has shown its value as a practical training tool, with GPS tracking being the most effective means of player tracking to date for outdoor team sports. With combined accelerometer/GPS units currently entering the market, a greater number of possibilities arise from player tracking. These units offer a range of potential benefits; improved data capture resolution, greater accuracy, 3D movement analysis, more sensitive monitoring, and the possibility of measuring player collisions.

The value of greater volume and resolution of data capture through the use of accelerometer units capturing at up to 250 Hz has the potential to provide practical outcomes, however in order to translate this volume of data into meaningful output, methods of data management and analysis need to be improved at the club level. Investigation has indicated that GPS data analysis and feedback is not being maximised currently. Until the full potential of 1Hz data capture is exploited, greater resolution may provide no more practical outcomes.

The implementation of player tracking can also be further enhanced. Tracking players during a greater number of games will provide further insight into the variability of demands between games and individual players. If used on a large scale, this type of measurement also has the potential to monitor the load each player undertakes during a game, and thus how post-game training and recovery should be adapted. The ability to use tracking devices on a weekly basis in games will utilise their full potential.

Player tracking also has many possibilities from a training perspective. The ability to assess individual training drills, and determine their demands allows an objective assessment to be made of training drills and their relation to the total training load. Additionally, training drill specificity can then be assessed for their relevance to game demands. Such benefits have been highlighted from previous research comparing game and training demands (Dawson, 2004). Understanding the demands of senior grade AFL, also allows assessments of developmental players to be undertaken to determine if these players are capable of meeting the requirements of senior grade AFL.

This research project has led to a greater understanding of the demands of senior grade AFL, setting reference ranges for work rates, and types of work undertaken by players in the modern game. The findings of this report also highlight possible areas for further investigation, including an understanding of the acceleration and change of direction profile during games, and the incidence and severity of player collisions.

The possibility of using tracking devices in games on a weekly basis throughout the season would also allow workload, fitness, and performance to be monitored during the full course of the season. Trends may appear regarding these measurements over the course of the 22-week home and away season. This has implications on season performance, finals preparation, injury prevention, management strategies, recovery, and conditioning programs. Regularity of player tracking would also allow for an investigation to be undertaken regarding possible player performance differences in home and away fixtures. This would also allow adequate data to be captured to assess the position demands of different grounds.

Attachment A: GPS Analysis Definitions

Work

Total Distance: Measures the total distance travelled during the playing period. Measured in kilometres.

Average Speed: Total distance divided by total playing duration in hours. Measured in $km \cdot hr^{-1}$.

Total Time: The total on field playing duration. Measured in minutes.

Work to Rest Ratio: The average work to rest ratio is based on total times of work and rest. Work is anything above 8 $km \cdot hr^{-1}$, and rest is time below 8 $km \cdot hr^{-1}$. This ratio provides an overall summary of session work completed.

Exertion Index: Exertion index is a quantifiable level of physical load. This measure allows a relationship to be drawn between game load, fatigue, and the total load between players. The exertion index used to assess GPS data in this project was based on the sum of a weighted instantaneous speed, a weighted accumulated speed over 10 seconds, and a weighted accumulated speed over 60 seconds. This ensures both short sharp efforts, and long sustained efforts are analysed equally. The weighting is based on a polynomial relationship in which high speeds achieve a higher exertion value than lower speeds. Exertion index is measured in arbitrary units.

Exertion Index per Minute: This is a measure of game intensity. It is determined by dividing exertion index by playing time.

Efficiency: A measure of the work requirements for game involvement and game impact. Measured by dividing exertion index by total number of possessions.

Maximal Speed: The maximal speed reached for a one second sample period. This is likely to be lower than the actual maximal speed achieved by the player due to the sampling rate and resolution of the GPS system.

Acceleration Profile

Surges above/below a Specified Speed (# times >/< x $km \cdot hr^{-1}$): The number of times the player goes from below (above) this speed to above (below) this speed. Gives an indication to the intermittent nature of the session, and the intensity at which speed peaks occur.

Number of Accelerations (Acceleration > x $km \cdot hr^{-1}$ in 1sec): The number of times the speed increases by more than x $km \cdot hr^{-1}$in a 1 second time period. This gives an indication as to the accelerations undertaken and how frequently these occur. Accelerations are characterised into moderate (4 $km \cdot hr^{-1}$) and rapid (10 $km \cdot hr^{-1}$).

Number of decelerations (deceleration > *x* km·hr^{-1} in 1sec): The number of times the speed decreases by more than *x* km·hr^{-1} in a 1 second time period. This gives an indication as to the decelerations required and how frequently these occur. Decelerations are characterised into moderate (4 km·hr^{-1}) and rapid (10 km·hr^{-1}).

Longest Continuous Time above a Specified Speed (LCT > *x* km·hr^{-1}): The longest period of time the player stays above this speed, without dropping below this speed. Time is recorded even when the player enters a higher speed zone. Provides an indication of the longest continuous effort at varying speeds.

Time at steady state > 8 km·hr^{-1} (Steady State Intensity Time): Any time at a speed above 8 km·hr^{-1} where the players' velocity does not alter by more than 1.5 km·hr^{-1}within a 1 sec sample period. This gives an indication of time spent at continual running speeds.

<u>Time In Speed Zones</u>

Speed Zones (*x – y* km·hr^{-1}): Time spent between the speeds of *x* and *y* km·hr^{-1}. Provides information on the dispersion of speed throughout the session.

References

Blair, T. and Carlyon, P. *The physics of footy*. The Bulletin, March, 2005.

Burgess, D. and Naughton, G. *Quantifying the gap between under 18 and senior AFL football*. J Sci Med Sport. 2003. 6:525.

Dawson B, Hopkinson R, Appleby B, Stewart G, Roberts C. *Player movement patterns and game activities in the Australian Football League.* J Sci Med Sport. 2004 Sep; 7 (3): 278-91

Dawson B, Hopkinson R, Appleby B, Stewart G, Roberts C. *Comparison of training activities and game demands in the Australian Football League.* J Sci Med Sport. 2004 Sep; 7 (3): 292-301.

GPSports. 2005. http://www.gpsports.com/support/faq/index.php

Hahn, A., Taylor, N., Hunt, B., Woodhouse, T., Shultz, G. *Physiological relationships between training activities and match play in Australian Football rovers*. Sports Coach. 1979. 3(3): 3-8.

Lakomy, J., Haydon, D. *The effects of enforced, rapid deceleration on performance in a multiple sprint test.* J Str Con Res. 2004, 18 (3), 579-583

McKeon, M. *Overtraining in Australian Rules football*. 1978

Norton KI, Craig, NP, Olds TS. *The Evolution of Australian Football.* J Sci Med Sport. 1999 Dec; 2 (4): 389-404

Pyke, F. and Smith, R. *Football: the scientific way*. Perth, The University of Western Australia Press. 1975.

Schutz Y, Herren R. *Assessment of speed of human locomotion using a differential satellite global positioning system.* Med Sci Sports Exerc. 2000 Mar;32(3):642-6.

Witte TH, Wilson AM. *Accuracy of non-differential GPS for the determination of speed over ground*. J Biomech. 2004 Dec;37(12):1891-8.

Witte TH, Wilson AM. *Accuracy of WAAS-enabled GPS for the determination of position and speed over ground.* J Biomech. 2005 Aug;38(8):1717-22.

Woodman, L. and Pyke, F. *Periodisation of Australian Football training*. Sports Coach, April, 1991. 32-39.