Positional differences in peak intensity periods in Swedish elite football

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Abstract

Introduction: Football players cover around 8-13 kilometres of running in different speeds in a match. However, the reporting of the sum or average of total distance covered fail to give an accurate picture of the most physically intense and demanding periods in matches, called “peak periods”. These periods have shown to cause temporary fatigue to the players, also known as “transient fatigue”. By gaining more information and knowledge about the peak intensity periods and how they affect players, coaches could train players to meet the physiological demands of elite football matches in a more accurate and effective manner.

Aim: The aim of this study was to gain a better understanding of positional differences in peak periods in elite football and how they affect the players in terms of fatigue.

Method: This study analysed peak intense periods as well as transient fatigue effects of 37 players from two male teams playing in 45 Swedish first division matches. Position specific analysis was conducted, based on the positions central defender (CD), external defender (ED), central midfielder (CM), wide midfielder (WM) and striker (ST), as well as a merged positional comparison between the central (CEN) positions (CD+CM+ST) and lateral (LAT) positions (ED+WM). The data was acquired through Catapult Vector x7 10 Hz GPS devices. Five-minute rolling periods and the variable “PEAK” was used and stands for the sum of distance of the variables “High intensity running”, “High speed running”, “Sprinting”, “Acceleration” and “Deceleration”. The difference between playing positions was analysed using a two-way mixed ANOVA with repeated measures and an independent t-test was used for the merged positional analysis.

Results: There was a significant difference in peak, post and mean distance between the positions overall. The magnitude of the peak periods was greatest for WM and ED. The magnitude was lowest for CD. The results were similar for the post and mean distances. In terms of transient fatigue in meters, WM and ED displayed the highest values. The peak, post and mean values as well as transient fatigue in meters were significantly higher for LAT players compared to CEN players.

Conclusion: There are differences in peak periods between positions in the Swedish first division, with CD position standing out as the least demanding. Lateral positions have higher magnitude of peak periods overall compared to central positions, as well as higher transient fatigue values.
# Table of contents

1. Introduction ........................................................................................................................................ 5
2. Aim and research question .................................................................................................................. 7
3. Method ................................................................................................................................................ 8
   3.1 Participants ...................................................................................................................................... 8
   3.2 Match analysis procedures .............................................................................................................. 8
   3.3 Data analysis ................................................................................................................................... 9
   3.4 Ethical considerations ...................................................................................................................... 10
   3.5 Statistical analysis .......................................................................................................................... 10
4. Results .................................................................................................................................................. 11
5. Discussion ............................................................................................................................................ 13
   5.1 Result discussion .............................................................................................................................. 13
   5.2 Methodological discussion ............................................................................................................. 14
6. Conclusion .......................................................................................................................................... 15
Reference list ........................................................................................................................................... 16
1. Introduction

Football is an intermittent sport involving many physical components such as running, changes of direction, jumping and landing (Stølen et al., 2005). In general, players cover around 8-13 kilometres of running in different speeds in a match (Akenhead et al., 2013; Bradley & Noakes, 2013; Di Salvo et al., 2009; Mohr et al., 2008). However, the reporting of the sum or average of total distance covered fail to give an accurate picture of the most physically intense and demanding periods in matches, called “peak periods” (Bradley & Noakes, 2013; Mernagh et al., 2021; Novak et al., 2021). Peak periods are short, intense passages of play where the external and internal load is at its highest level for the player (Whitehead et al., 2018). These periods have shown to cause temporary fatigue to the players, also known as “transient fatigue” (Akenhead et al., 2013; Bradley et al., 2009; Bradley & Noakes, 2013; Fransson et al., 2017; Mohr et al., 2003). Therefore, it is important to understand these intensive periods and to increase the knowledge regarding the extent to which players experience fatigue during such moments. This is especially critical given that recent studies have demonstrated that the number of high intensity runs and sprints performed by players have increased within the last few years, whilst the total running distance has not (Barnes et al., 2014; Bradley et al., 2009).

There have been some previous studies concerning positional differences in peak periods in football, for instance Di Mascio and Bradley (2013), who investigated 100 players in 20 matches in the English Premier League, demonstrated that central defenders (CD) cover the least amount of high intensity running meters in five-minute periods. Further, Bradley et al. (2009) also analysed 370 players from 28 matches in Premier League and established that wingers (WG) had the highest numbers in intensity running in five-minute periods and CD the lowest. Fransson et al. (2017) analysed positional differences as well for 360 Premier League players, with the results that CD covered fewest meters in the peak period, the five minutes immediately following the peak period (post-peak) and match mean distances.
The above-mentioned studies have also seen significant differences between the most intense periods and transient fatigue effects for playing positions. Bradley et al. (2009) noticed a decline in high intensity running during the post-peak period while Di Mascio and Bradley (2013) and Fransson et al. (2017) reported significant differences in high intensity running in the post-peak periods compared to the match average. Collectively, their findings suggest players experience transient fatigue in periods immediately following the peak period. The ability to accelerate and decelerate also deteriorated after a peak period of five minutes for players overall, in a study by Akenhead et al. (2013).

There are many factors that can affect the intensity of peak periods. One factor is the team’s playing formation (Bradley et al., 2011). Novak et al. (2021) also bring up the fact that peak periods may give different players different internal responses to the same amount of physical action. Therefore, Baptista et al. (2019) cast about for more individual specificity in the creation of training drills. Mohr et al. (2012) also suggest that peak period values can vary depending on the weather and temperature. In their study, Mohr et al. (2012) demonstrated a reduction in total distance and high intensity running whilst playing in hotter temperature, although peak sprinting speed increased. Another factor worth mentioning is that a pacing strategy from an individual player or the team as a whole can affect the magnitude of the peak periods (Bradley & Noakes, 2013). There is also a match-to-match variability to consider, according to Carling et al. (2016).

There seem to be a lack of consensus considering how to best define and calculate peak periods (Novak et al., 2021). One dilemma is deciding the length of the peak period. The longer the peak period time frame, the lower values in terms of intensity there usually is in football (Whitehead et al., 2018). The reason for this being, for instance, the ball out of play factor, meaning that the level of physical intensity decreases when the ball goes out of play (Mernagh et al., 2021). Five minutes is the most studied length of peak periods, and previous studies have used either predetermined periods or rolling periods as a method to calculate these periods. Predetermined periods are when time periods are fixed, for example minute 0-5, 5-10, 10-15 etcetera. Via the rolling periods method, moving averages of any five-minute period in a match is being analysed at a given rate depending on the GPS (Global Positioning
System) device. If using a 10 Hz GPS device, this means there will be 10 speed samples for every second (Whitehead et al., 2018). Varley et al. (2012) claim that rolling periods is a better way to analyse peak period data as the predetermined periods are not as accurate and may underestimate the load of the players up to ~20%. This is something that Mernagh et al. (2021) as well as the systematic review of Whitehead et al. (2018) also acknowledge.

By gaining more information and knowledge about the peak intensity periods and how they affect players in terms of physiological and metabolic responses, coaches could train players to meet the physiological demands of elite football matches in a more accurate and effective manner. This would ensure that players are fit enough to cope with the peak periods they encounter during competition, in effect, putting them at a lesser risk of injury (Mernagh et al., 2021; Novak et al., 2021).

Another important factor in gaining knowledge about the peak periods and how to train accordingly is that it lowers the difference in fitness levels between starting and non-starting players. Knowing what the physiological demands of matches feature, coaches can deliver programmes and training sessions for non-starting players that replicate their individual in-match demands. Having peak period data based on playing position will help the coaches even further by informing their decisions regarding designing and implementing training protocols.

This study is intent on bringing more knowledge to the subject of positional differences in peak intensity periods in elite football in general and in Swedish football. This is particularly relevant as there are no previous studies conducted regarding peak periods and transient fatigue effects in Swedish football. Furthermore, this study implemented a collective multivariate approach towards identifying the peak period, which has not been previously reported.

2. Aim and research question

The aim of this study was to gain a better understanding of positional differences in the most intensive periods (peak periods) in elite football and how they affect the players in terms of
fatigue. The aim was intended to be met by analysing and comparing the magnitude of peak periods of players from two Swedish first division teams and furthermore investigating and comparing the transient fatigue effects between the playing positions.

Research question:

- What are the differences in peak periods and transient fatigue levels between playing positions in two Swedish first division teams?

3. Method

3.1 Participants

This is a quantitative retrospective study analysing five-minute peak intense periods, post-peak periods and mean peak distance as well as transient fatigue effects of players from two male teams playing in the Swedish first division. The data was collected from 37 players from 45 professional competitive matches. Position specific analysis was conducted, based on the outfield positions central defender (CD), external defender (ED), central midfielder (CM), wide midfielder (WM) and striker (ST), as well as a merged positional comparison between the central (CEN) positions (CD+CM+ST) and lateral (LAT) positions (ED+WM). Goalkeepers were excluded due to their unique physical requirements. If a player played in different positions during different matches, the values of the player from that position in that particular match was registered. For instance, if a player normally plays as a ST and in one match plays as a WM, the player was accounted for as a WM in the data collection from that match. Only players that played a minimum of 90 minutes of the match were included in the study, thus explaining the total number of observations (280) in this study.

3.2 Match analysis procedures

Both teams were using Catapult Vector x7 10 Hz (Catapult Innovations, Melbourne, Australia) GPS (Global Positioning System) devices during the matches, from which the data was obtained. GPS is a commonly used system by elite sport teams, receiving signals via satellites. The signals are then converted into data which can be analysed through for example a computer or tablet device. The system has improved its accuracy over the years and units
with 10 Hz has been proven to have good validity and reliability (Scott et al, 2016). Best accuracy is when the GPS sensor is used outdoors in an open-space setting, which has been the case for these two teams. Other practical factors that need to be considered when using a GPS device and collecting data is that the sensor is placed in a tight socket on the upper back region, between the scapulae, of the player to get a good signal and avoiding any additional movement of the sensor, hence prohibiting registration of invalid data. Moreover, to prohibit invalid data, it is of significance that each player continuously wears the same sensor as there may be some differences between the sensors (Malone et al., 2017).

3.3 Data analysis

Five-minute peak period, post-peak period and mean data were analysed using a customised Microsoft Excel spreadsheet from the downloaded GPS data. Transient fatigue was calculated as the difference (in meters and percentage) between the five-minute post-peak period compared to the five-minute mean distance.

To analyse the different activity periods, the variable “PEAK” was used and incorporates the sum of distance of the variables including “High intensity running” (15-19.79 km/h), “High speed running” (19.8-25.19 km/h), “Sprinting” (> 25.2 km/h), “Acceleration” (> 3m/s\(^2\)) and “Deceleration” (< -3m/s\(^2\)). Hence, \text{PEAK} = \text{sum of (HIR+HSR+SPR+ACC3+DEC3)}\) distances in meters, making this an analysis of multiple variables within one variable. The benefit of this method is that it captures multiple variables concurrently as opposed to analysing the magnitude of each variable separately. Thus, a more dynamic peak period is captured composed of both kinematic (velocity) and mechanical (acceleration/deceleration) load.

The peak period is the five-minute period with the largest “PEAK” distance, the post period is the five-minute “PEAK” distance immediately following the peak period and mean distance is the average five-minute “PEAK” distance of the match (minus the period with the largest “PEAK”). Furthermore, the Transient fatigue is the difference in distance between the post-peak period and the mean (Fransson et al., 2017; Mohr et al., 2012).
The speed thresholds used in this study are similar to those previously reported by Di Mascio and Bradley (2013) and Rampini et al. (2007), and the acceleration/deceleration variables similar to those previously reported by Akenhead et al. (2013).

Five-minute rolling periods were used because of its superiority in terms of accuracy compared to predetermined periods, making sure valuable information does not get overlooked. As a 10 Hz GPS device was used by the teams, this means 3000 data points for the five-minute moving average analysis for each player in every match, contributing to the power of the method of this study. Five minutes for peak, post and mean periods were chosen for several reasons. Firstly because of the reason that a significant relationship has been seen between the YoYo Intermittent Recovery Test Level 2 test levels and distance covered in five-minute periods during matches (Bangsbo et al., 2008; Mohr et al., 2016). Moreover, there is a strong correlation between short, intense periods of play and the sum of Na+–K+ ATPase protein, which has proven to be an important factor for delaying fatigue in peak periods (Mohr & Iaia, 2014). Lastly, peak periods have shown to cause decrements in physical performance for over five minutes (Fransson et al., 2017).

3.4 Ethical considerations

The individual data was received from fitness coaches and sport scientists from the two different teams and then anonymised before analysis, to assure confidentiality. No letter of consent was needed from the individual players due to the fact that the ability to retrieve player data is seen as a condition of their employment (Winter & Maughan, 2009).

The data was saved inside a password-locked computer, which was stored and locked in a safe place during the whole process of this study. Only the author of this thesis had access to the computer.

3.5 Statistical analysis

The data analysis was conducted in IBM SPSS Statistics version 28.0. Data was tested for normality using the Shapiro-Wilks test and found to be normally distributed. The difference between playing positions was analysed using a two-way mixed ANOVA with repeated
measures and an independent t-test was used for the merged positional analysis. Significance level was set at P-value < 0.05. Where there were significant differences, Bonferroni post-hoc tests were used to identify differences between specific factors. The magnitude of difference was tested between teams and positions for peak, post, mean and transient fatigue levels using Cohen’s d effect size (ES) according to the following criteria: 0.0-0.2: trivial, 0.2-0.5: small, 0.5-0.8: moderate and >0.8: large (Cohen, 1988).

4. Results

There was a significant difference in peak, post and mean distance between the positions overall (P < 0.05).

The magnitude of the peak periods was greatest for players in the WM and ED positions, followed by CM and ST, respectively. The magnitude was lowest for CD. The results were similar for the post and mean distances (see Table 1).

There was significant difference between CD and every other position in peak and mean distance (P < 0.05, ES: 1.0-1.9). A significance in difference was also found in post-peak distance between CD and every other position except for ST (P < 0.05, ES: 0.7). Moreover, there was a significant difference between ED and CM for peak and mean distance (P < 0.05, ES: 0.6) and in the post distance (P < 0.05, ES: 0.1). A significant difference was also observed when comparing peak and mean distance for WM-ST (P < 0.05, ES: 0.9) and between ED-ST and CM-WM for the same variables (P < 0.05, ES: 0.5-0.7).

Furthermore, there were a significant difference in decrease between post and mean distances for all positions except CD and CM (P < 0.05). In terms of transient fatigue in meters, ED and WM displayed the highest values and CM and CD the lowest (see Table 1). Significant differences were found between CD-WM, CD-ED and ED-CM (P < 0.05, ES: 0.4-0.5).
Table 1. Values of peak, post, mean and transient fatigue for positions

<table>
<thead>
<tr>
<th>Position</th>
<th>Peak</th>
<th>Post</th>
<th>Mean</th>
<th>Transient fatigue (%)</th>
<th>Transient fatigue (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM (n = 76)</td>
<td>238,1 ± 46,8</td>
<td>97,7 ± 41,9</td>
<td>107,4 ± 22,9</td>
<td>-8,9 % ± 35 %</td>
<td>-9,6 ± 36,8</td>
</tr>
<tr>
<td></td>
<td>*#β</td>
<td>*#</td>
<td>*β</td>
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</tr>
<tr>
<td>CD (n = 82)</td>
<td>185,9 ± 40,3</td>
<td>69,4 ± 43</td>
<td>76,9 ± 20,6</td>
<td>-9,7 % ± 42,2 %</td>
<td>-7,3 ± 31,5</td>
</tr>
<tr>
<td>ST (n = 20)</td>
<td>229 ± 41,1</td>
<td>87,2 ± 27</td>
<td>105,5 ± 20</td>
<td>-17,3 % ± 27,1 %</td>
<td>-18,3 ± 28,8</td>
</tr>
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<td></td>
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<tr>
<td>ED (n = 67)</td>
<td>265,5 ± 52,1</td>
<td>98,2 ± 36,6</td>
<td>122,2 ± 27,3</td>
<td>-19,6 % ± 28,2 %</td>
<td>-23,9 ± 34,8</td>
</tr>
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<td>*#α</td>
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<tr>
<td>WM (n = 35)</td>
<td>267,2 ± 43,3</td>
<td>102,5 ± 48,1</td>
<td>124,9 ± 24,6</td>
<td>-17,9 % ± 34,7 %</td>
<td>-22,4 ± 40,5</td>
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<td>*βμ</td>
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</tbody>
</table>

Distance covered during peak five-minute period (Peak), the five-minute period directly after the peak (Post), five-minute whole match average (Mean) and transient fatigue measured in percent and meters for each position. Data are means ± SD. * indicates significant difference from CD. # indicates significant difference between ED and CM. α indicates significant difference between ED and ST. β indicates significant difference between CM and WM. μ indicates significant difference between WM and ST. Significance level is P < 0.05.

Merging the positions into CEN and LAT, the peak, post and mean values as well as transient fatigue in meters were significantly higher for lateral players compared to central (P < 0.05, ES: 0.4-1.1, see Table 2).

Table 2. Values of peak, post, mean and transient fatigue for CEN and LAT positions

<table>
<thead>
<tr>
<th>Position</th>
<th>Peak</th>
<th>Post</th>
<th>Mean</th>
<th>Transient fatigue (%)</th>
<th>Transient fatigue (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEN (n = 178)</td>
<td>212,6 ± 50</td>
<td>83,5 ± 42,9</td>
<td>93 ± 26,2</td>
<td>-11,8 % ± 37,8 %</td>
<td>-9,5 ± 33,6</td>
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<tr>
<td>LAT (n = 102)</td>
<td>266,1 ± 49,1</td>
<td>99,7 ± 40,8</td>
<td>122,8 ± 25,7</td>
<td>-18 % ± 30,5 %</td>
<td>-23,1 ± 36,7</td>
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</table>

Distance covered during peak five-minute period (Peak), the five-minute period directly after the peak (Post), five-minute whole match average (Mean) and transient fatigue measured in percent and meters for central (CEN) and lateral (LAT) positions. Data are means ± SD. * indicates significant difference between CEN and LAT. Significance level is P < 0.05.
5. Discussion

The aim of this study was to gain a better understanding of positional differences in the most intensive periods (peak periods), through comparing the peak, post-peak and mean periods across different playing positions of two Swedish first division teams, as well as investigating the transient fatigue effects between them.

5.1 Result discussion

The result of this study indicates differences in peak periods between playing positions, suggesting that in Swedish elite football players experience different physiological strains based on their playing position. Furthermore, every position except CD and CM showed significant signs of fatigue after the peak periods, comparing the difference in distance covered between post-peak and mean match. These findings support the results of previous studies claiming that fatigue occurs after peak periods (Akenhead et al., 2013; Bradley et al., 2009; Di Mascio & Bradley, 2013; Fransson et al., 2017).

CD and CM showed the lowest transient fatigue levels, in contrast to ED and WM who showed the highest levels, indicating that the peak period of ED and WM may affect them more than the peak period of CD and CM.

CD had the lowest magnitude in peak, post and mean distance. This result is in alignment with the studies of Bradley et al. (2009), Bradley et al. (2011), Di Mascio and Bradley (2013) and Fransson et al. (2017). There was a significant difference between CD and every other position for these three variables, except for post distance compared to ST, where no significant difference was found, explaining that the match demands of the players in the CD position are the lowest.

The LAT players covered significantly more distance than the CEN players in peak, post and mean. A likely reason as to why the LAT players have significantly higher values is because they, due to the nature of a football match, have more open space to run at compared to players playing in the central parts of the pitch. Furthermore, LAT demonstrates higher
transient fatigue numbers, suggesting that their match demands cause a greater level of fatigue compared to CEN players.

What is interesting is that there were significant differences in peak, post and mean distances within the CEN category, showing that CD have lower physical strains in matches compared to players playing in the CM and ST positions.

5.2 Methodological discussion

From one perspective, the use of five minutes as the length of the peak periods may be seen as too long. Situations resulting in an underestimation of the magnitude of the peak intensity may occur in a five-minute period during a match, such as stoppages in play. The length of the peak periods, however, was chosen because of the correlations to the YoYo Intermittent Recovery Level 2 test, the role of Na+-K+ ATPase protein in short, intense activities as well as the transient fatigue effects after peak periods, which have been shown to last over five minutes. Another factor worth mentioning is that it might not be practical to replicate peak periods in training sessions if they are too short.

The data analysis in this study was performed using a rolling periods method, which is superior in accuracy compared to predetermined periods and hence limiting the risk of underestimating the peak period values.

As this study is only limited to 37 players and two teams, conclusions should be made with caution as the data from the teams included in this study may differentiate from other teams in Swedish and international elite football.

The author of this study did not collect the data personally, which means there may be a certain level of insecurity if there were any possible errors in any of the data. Furthermore, the author cannot ensure that the GPS sensor of every player was used correctly and that the players only used the same sensor in all the matches.
A limitation of the measurements of the player’s peak period data is that it only considers the external load of the players. To get a broader and more precise data, to see how much stress is placed on the individual players’ body during the peak distances, internal load should be taken into consideration, for example via heart rate measurements. I believe this is an approach worth adopting since there seem to be individual variability in internal load for the same external load (Novak et al., 2021). This should be of extra importance for coaches to look at when training their players for peak period adaptations.

Furthermore, except from the possible inter-variability in positions, there are some possible confounders to acknowledge when presenting results of peak period data, mentioned earlier in this study. These confounders may be the team’s playing formation (Bradley et al., 2011), temperature (Mohr et al., 2012), pacing strategies (Bradley & Noakes, 2013) or match-to-match variability (Carling et al., 2016). Other possible confounders may be match score, level of opposition and playing surface, to name a few. All these factors could potentially result in either higher or lower magnitude of peak distance.

Future research should focus on increasing knowledge in the area of the most physically intense periods for football players and furthermore give practical guidance for team coaches and players. Individual differences should be taken into consideration, which underpins requirements for future research to include internal load data in the analysis of how peak periods affect players during competition.

6. Conclusion

In conclusion, this study concludes that there are differences in peak periods between positions in the Swedish first division. There were differences overall, but mainly CD position standing out as the least demanding in terms of peak periods, which supports findings from earlier studies comparing positional differences in the English Premier League. Lateral positions have higher magnitude of peak periods overall compared to central positions, as well as higher transient fatigue values.


