Original research

Diminutions of acceleration and deceleration output during professional football match play

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ABSTRACT

Objectives: This study examined distances covered at low (1–2 m s \(^{-2}\)), moderate (2–3 m s \(^{-2}\)) and high (>3 m s \(^{-2}\)) acceleration \(\text{HACC, MACC, and HACC respectively}\) and deceleration \(\text{LDEC, MDEC, and HDEC respectively}\) during competitive football games. Temporal and transient patterns of acceleration and deceleration were also examined.

Design: Observational, repeated measures.

Methods: Thirty-six professional male footballers were monitored using a 10Hz non-differential global positioning system (NdGPS). Match data was organised into six 15 min periods (P1: 1–15 min, P2: 16–30 min, P3: 31–45 min, P4: 46–60 min, P5: 61–75 min, and P6: 76–90 min) for analysis of temporal patterns, and into eighteen 5 min periods for analysis of transient patterns. ANOVA with Bonferroni post hoc tests were used to identify significant \((p<0.05)\) differences between periods.

Results: Distance covered at \(\text{LACC, MACC, HACC, LDEC, MDEC, and HDEC was 424 ± 75 m, 242 ± 25 m, 178 ± 38 m, 365 ± 54 m, 210 ± 23 m and 162 ± 29 m respectively. Between period decrements ranged from 8.0% to 13.2% from P1 to P3, 9.2% to 16.3% from P4 to P6, and from 14.9% to 21.0% from P1 to P6. Following PEAK \(\text{HACC, and HDEC performance following PEAK was approximately 10% lower than mean values}.\)

Conclusions: Time-dependent reductions in distances covered suggest that acceleration and deceleration capability are acutely compromised during match play. Further, the occurrence of transient fatigue may be supported by the findings that \(\text{HACC and HDEC performance following PEAK was approximately 10% lower than mean values}.\)

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1. Introduction

Professional association football is a high-intensity intermittent team sport. \(^1\) Out-field players cover approximately 9–12 km at a mean intensity of approximately 80–90% maximal heart rate and 70% \(\text{VO}_{2}\) \(_{max}.\) \(^3\) Players also perform numerous high-intensity activities including sprinting, jumping, kicking and changing direction. \(^2\) When studying the physical demands of match play, gross locomotion is often categorised using several speed “thresholds”, ranging from motionless standing to maximal sprinting. \(^5\) This method however, neglects frequent actions such as acceleration and deceleration. \(^6\) Speed threshold measurements in isolation ignore that, even at low absolute speeds, acceleration, and therefore metabolic demand can still be maximal.

Elite and non-elite players have been suggested to exhibit signs of temporary fatigue during match play. \(^1\) Following the peak 5 min period of high speed running (>15 km h\(^{-1}\)), physical performance in the subsequent 5 min period was found to be reduced by 12% \((p<0.05)\) compared to mean 5 min values. \(^9\) Furthermore, Bradley et al. \(^10\) reported a 6–8% \((p<0.05)\) reduction in high-intensity (>19.8 km h) distance following a peak 5 min period. However the same trend cannot be assumed for accelerations and decelerations during football as this has not previously been studied. Certainly, acceleration is a pre-cursor to high speed running \(^11\) and requires high rates of force development. It is however a distinct quality \(^11\) requiring greater neural activation to the working muscles compared to constant speed sprinting. \(^13\) To date only a study by Osgnach et al. \(^12\) has described the sum total of accelerations and decelerations during football match play. However, temporal patterns were not reported in this study. Recently, the use of non-differential global positioning satellite technology (NdGPS) based time-motion analysis has become commonplace within team sports. Although early 1- and 5 Hz systems may have been unsuitable for the measurement of changes of speed, \(^5\) recent advances in chipset technology and an increased sampling rate (10Hz) allow for a greater level of

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accuracy and reliability when measuring discrete movements over short distances.\(^6,14\)

To the best of our knowledge there are no publications describing the effect of playing time on accelerations and decelerations in football, or whether acceleration or deceleration output is compromised following the peak period of activity. The primary aim of the study was to describe the distances covered at total, low, moderate and high acceleration (\(T_{ACC}\), >1 m s\(^{-2}\); \(L_{ACC}\), 1–2 m s\(^{-2}\); \(M_{ACC}\), 2–3 m s\(^{-2}\); \(H_{ACC}\), >3 m s\(^{-2}\)) and deceleration (\(T_{DEC}\), <−1 m s\(^{-2}\); \(L_{DEC}\), −1 to −2 m s\(^{-2}\); \(M_{DEC}\), −2 to −3 m s\(^{-2}\); \(H_{DEC}\), <−3 m s\(^{-2}\)) during competitive games. The current classifications were chosen as appropriate arbitrary demarcations during match play based on previous data (unpublished). Although maximal accelerations may be as high as 6 m s\(^{-2}\),\(^11\) such rates are fleeting and only achieved from stationary or low speed starts, which occur less infrequently than higher speed rolling starts in football match play. A secondary aim was to examine the temporal patterns of acceleration and deceleration during match play. It was hypothesised that there would be a time-dependent reduction in acceleration and deceleration variables throughout a match. Furthermore it was also considered that following the peak period of \(H_{ACC}\) and \(H_{DEC}\) performance in the subsequent 5 min period would be reduced.

2. Methods

NdGPS sampling at 10 Hz (MinimaxX, Catapult Innovations, Canberra, ACT, Australia) was used to conduct time-motion analysis during 18 competitive English Premier Reserve League matches in the 2010–2011 season. All matches were played on outdoor natural grass pitches (105 m × 68 m) in accordance with English Football Association rules. All teams utilised a 4–4–2 formation.

Thirty-six outfield professional male football players participated in the study, including players with under-21 and full-international caps. Their age, height, body mass and body fat percentage were 19.3 ± 0.5 years, 77.9 ± 7.4 kg, 1.83 ± 0.05 m, and 8.6 ± 1.7%, respectively. Participants were given full details of the study procedures and provided written consent to participate. All experimental procedures received approval from the Institutional Ethics Review Board at Northumbria University.

Fifteen minutes prior to the commencement of warm-up NdGPS units were switched on and placed outdoors. Immediately prior to warm-up each starting player (\(n = 10\)) was fitted with an NdGPS unit worn in tight-fitting vests to reduce movement artefact.\(^15\)

Data were downloaded and each 45 min half was split into nine 5 min periods using the manufacturers’ software (Logan Plus v4.5, Catapult Innovations, Canberra, ACT, Australia). Only the first forty-five minutes of each half was included for analysis. Raw data for \(L_{ACC}\), \(M_{ACC}\), \(H_{ACC}\), \(T_{DEC}\), \(L_{DEC}\), \(M_{DEC}\), and \(H_{DEC}\) were exported to Microsoft Excel. Total distance (m\(^{-1}\)), high speed (>5.8 m s\(^{-2}\), HSR) and sprint (>6.78 m s\(^{-2}\), SPD) distance data were also exported.

Player data were included for analysis provided they met the following criteria: (i) the player completed the full duration of the game; (ii) they did not suffer an injury during the game; (iii) they played the same position throughout the game; (iv) they were familiar with their playing position; and (v) the first half of the game had no more than two added minutes of playing time. Application of the inclusion criteria yielded data sets for 36 separate players; central defenders [CD] (\(n = 8\)), wide defenders [WD] (\(n = 8\)), central midfielders [CM] (\(n = 8\)), wide midfielders [WM] (\(n = 6\)) and forwards [F] (\(n = 6\)).

To investigate whole-game temporal patterns, data were organised into three 5 min periods per half (0–15 min [P1], 16–30 min [P2], 31–45 min [P3], 46–60 min [P4], 61–75 min [P5], and 76–90 min [P6]). The peak 5 min value (PEAK) for \(H_{ACC}\) and \(H_{DEC}\) was identified and recorded. Distance covered in the preceding 5 min (\(5\_PRE\)), subsequent 5 min (\(5\_POST\)) and following 10 min (\(10\_POST\)) were also recorded. Values for \(5\_PRE\), \(5\_POST\) and \(10\_POST\) were then expressed as a percentage relative to the mean 5 min value of the half in which it occurred (x45). Total ball-in-play (BIP) time was also analysed for each 15 min period. Video based analysis was conducted by an experienced video analyst.

Data were tested for normality using a Shapiro–Wilk test, all data shown to be normally distributed (\(p > 0.05\)). Between-period differences in \(T_{ACC}\), \(L_{ACC}\), \(M_{ACC}\), \(H_{ACC}\), \(T_{DEC}\), \(L_{DEC}\), \(M_{DEC}\), \(H_{DEC}\) and BIP were tested for using a repeated-measures one-way ANOVA with a post hoc Bonferroni test (significance accepted at \(p < 0.05\)). Between-half differences were tested for using a t-test. Statistical analyses were conducted in SPSS 15.0 for Windows (SPSS, Inc., Chicago, IL). Cohen’s effect sizes (ES) and 95% confidence intervals (CI) were calculated for all between-period differences. Effects were classified as trivial (0.0–0.2), small (0.2–0.5), moderate (0.5–0.8), and large (>0.8). Descriptive statistics are mean ± SD unless otherwise stated.

3. Results

Mean ± SD and ranges for time-motion parameters during the first and second halves of match play are presented in Table 1. A significant main time effect was found for \(T_{ACC}\) (\(d f = 5, F_2 = 10.3, p < 0.01\)), \(L_{ACC}\) (\(d f = 5, F_2 = 8.1, p < 0.01\)) and \(M_{ACC}\) (\(d f = 5, F_2 = 8.1, p < 0.01\)). Post hoc comparison (Fig. 1A–D) showed P1 to be greater than P3, P5 and P6 (\(p < 0.01\); CI: 6.0, 49.6 m; ES: 0.67–1.51). P2 and P4 were greater than P6 (\(p < 0.01\); CI: 3.2, 34.9 m; ES: 0.60–0.94). For \(L_{ACC}\) P1 was greater than P3, P5 and P6 (\(p < 0.01\); CI: 2.3, 30.1 m; ES: 0.47–1.31). P2 was greater than P6 (\(p < 0.01\); CI: 1.9, 23.0 m; ES:

![Table 1](https://example.com/table1.png)

**Table 1** Distance covered in defined speed, acceleration and deceleration thresholds during elite match play.

<table>
<thead>
<tr>
<th>Parameter (m)</th>
<th>First half (45-min)</th>
<th>Second half (45-min)</th>
<th>Match total (90-min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPD</td>
<td>94 ± 58 [0–221]</td>
<td>100 ± 56 [0–262]</td>
<td>194 ± 101 [0–450]</td>
</tr>
<tr>
<td>(T_{ACC})</td>
<td>532 ± 47 [398–632]</td>
<td>492 ± 51 [409–596]</td>
<td>1022 ± 89 [813–1163]</td>
</tr>
<tr>
<td>(T_{DEC})</td>
<td>466 ± 42 [351–546]</td>
<td>434 ± 46 [351–516]</td>
<td>899 ± 80 [734–1018]</td>
</tr>
<tr>
<td>(L_{DEC})</td>
<td>191 ± 30 [118–245]</td>
<td>175 ± 29 [110–244]</td>
<td>365 ± 54 [231–479]</td>
</tr>
<tr>
<td>(H_{DEC})</td>
<td>84 ± 17 [54–125]</td>
<td>87 ± 15 [46–118]</td>
<td>162 ± 29 [103–225]</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± SD [range]. TD, total distance. HSR, high speed running distance (>5.8 m s\(^{-1}\)). SPD, sprint distance (>6.78 m s\(^{-1}\)). \(T_{ACC}\), total acceleration (>1 m s\(^{-2}\)); \(L_{ACC}\), low acceleration (1–2 m s\(^{-2}\)); \(M_{ACC}\), moderate acceleration (2–3 m s\(^{-2}\)); \(H_{ACC}\), high acceleration (>3 m s\(^{-2}\)); \(T_{DEC}\), total deceleration (>−1 m s\(^{-2}\)); \(L_{DEC}\), low deceleration (−1 to −2 m s\(^{-2}\)); \(M_{DEC}\), moderate deceleration (−2 to −3 m s\(^{-2}\)); \(H_{DEC}\), high deceleration (>−3 m s\(^{-2}\)).

\(^*\) Significantly lower than first half (\(p < 0.05\)).
0.66–0.86). For $M_{ACC}$ P1 was greater than P3, P5 and P6 ($p < 0.01$, CI: 1.2, 14.5 m, ES: 0.81–1.36). P2 and P4 were greater than P6 ($p = 0.04$, CI: 0.1, 9.9 m, ES: 0.73–0.77). $H_{ACC}$ did not exhibit a significant main time effect (df=5, $F_2 = 2.0$, $p = 0.08$). However P1 and P4 were greater than P6 with a moderate effect (CI: –1.3, 10.0 m, ES: 0.61).

Similar results were found for deceleration (Fig. 1E–H). Significant main time effects were found for $T_{DEC}$ (df=5, $F_2 = 8.5$, $p < 0.01$),
were lower than \( x45 \) (\( p < 0.02, \text{ CI: 3.6, 19.2 m, ES: 0.59–0.87} \)). Additionally, \( 10\text{POST} \) was shown to be significantly greater than \( 5\text{POST} \) (\( p = 0.03, \text{ CI: 3.4, 23.6 m, ES: 0.36} \)).

Mean \( \pm SD \) number of connected satellites during data collection was \( 13 \pm 1 \), and horizontal dilution of position was \( 0.8 \pm 0.1 \), both of which are within the required ranges for accurate measurement. Analysis of BIP demonstrated no significant time-dependent reductions in ball-in-play time, with the greatest decrease being 6% from \( P1 \) to \( P6 \) (\( p = 1.0 \)).

4. Discussion

The current study is the first to use 10Hz GPS technology to describe temporal patterns of acceleration and deceleration distance during football match play. On average 18% of total distance covered is done so whilst accelerating or decelerating at a rate greater than 1 m s\(^{-2}\). Further, 7.5%, 4.3% and 3.3% of total distance is covered at 1–2 m s\(^{-2}\), 2–3 m s\(^{-2}\) and >3 m s\(^{-2}\) respectively. In agreement with our hypothesis, our data also provide support for the occurrence of time-dependent and transient reductions in acceleration and deceleration output (Figs. 1 and 2).

Observed diminutions in acceleration and deceleration distance ranged from 8.0% to 13.2% from \( P1 \) to \( P3 \), 9.2% to 16.3% from \( P4 \) to \( P6 \), and from 14.9% to 21.0% from \( P1 \) to \( P6 \) (\( ES: 0.62–1.51 \)). \( P1 \) consistently contained the highest values, which may be due to tactical enforcements made by coaches resulting in game tempo being elevated in the initial stages of the game.\(^{16} \) It may also be contributed to by the preceding period of rest following pre-game warm-up. This period of approximately ten minutes of passive recovery facilitates re-synthesis of ATP, clearance of inorganic phosphates, restoration of intracellular pH, conversion of lactate to pyruvate, and restoration of effenter nerve membrane potential.\(^{17,18} \) Combined with the possible occurrence of post-activation potentiation, a residual elevation in VO\(_2\) kinetics,\(^{19} \) intact glycogen reserves, and the motivation to gain an initial advantage, the initial minutes of a match may be predisposed to a higher work rate.

Despite between-half reductions in acceleration and deceleration performance, there was little difference between first and second half HSR and SPD (Table 1) which may be attributed to a pacing strategy. However it may also be reasonable to assume that if acceleration output is reduced, a player would take longer to reach any given speed, and may therefore be required to run further, thus covering a greater distance at high speed. This may also explain the often reported second half increase in distance covered at low speed such as walking, as greater rest periods may be required.

Following PEAK \( H_{\text{ACC}} \) (148% of mean), \( H_{\text{ACC}} \) performed at \( 5\text{POST} \) was on average 10.4% lower than mean values. At \( 10\text{POST} \) \( H_{\text{ACC}} \) had recovered to 99.9% of the mean value. This trend is similar to that reported for high speed running by Mohr et al.\(^{5} \) and Bradley et al.\(^{15} \) Krustup et al.\(^{20} \) argued that following 5 min of intense football match play perturbations in creatine phosphate, inosine monophosphate, hydrogen ion and intracellular potassium concentration compromise excitation–contraction coupling resulting in peripheral fatigue.

It may be reasonable to suggest that exercise-induced homeostatic perturbations are partially responsible for the significant 11.4% reduction of \( H_{\text{DEC}} \) at \( 5\text{POST} \) following PEAK \( H_{\text{DEC}} \). However the possible consequences for performance may be different for deceleration. Eccentric force production and regulation is required for deceleration as the hip, knee and ankle extensors work eccentrically to increase braking forces.\(^{21} \) Failure of the working muscles to produce the required force at the appropriate times may lead to compromised physical performance during change of direction and an increased risk of injury.\(^{21} \) Rahnama et al.\(^{17} \) showed that concentric and eccentric peak torque of the knee extensors was

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**Fig. 2.** Mean (±SD) percentage change from \( x45 \) at \( 5\text{PRE} \), PEAK, \( 5\text{POST} \) and \( 10\text{POST} \) for \( H_{\text{ACC}} \) (A), and \( H_{\text{DEC}} \) (B). Significantly (\( p < 0.05 \)) different from \( x45 \) (*), PEAK (\( * \)), \( 5\text{PRE} \) (\( * \)) and +5 min (#).
significantly reduced following football match-play, suggesting that acceleration and deceleration performance would be compromised as a result. Fatigue characteristics are however muscle specific\textsuperscript{22} and the current understanding of fatigue characteristics of the synergistic muscle groups responsible for decelerating is limited. The current study provides a strong rationale for future research to examine such responses.

Observed reductions in $H_{\text{ACC}}$ and $H_{\text{DEC}}$ following PEAK appear to persist for approximately 5 min, although predictors of the magnitude and duration of any temporary fatigue remain to be fully elucidated and are likely highly individual. The large range of values for PEAK $H_{\text{ACC}}$ and PEAK $H_{\text{DEC}}$ across the sample (121–221\% of mean) is likely due to the intermittent nature of the game, playing position and individual differences. Individual variations in muscle fibre-type distribution, strength, training status and proportional contribution from metabolic pathways are likely factors. Further research is needed in quantifying the determinants of magnitude of this fatigue. Profiling athletes’ maximum voluntary activation or rate of force development, repeat sprint ability and aerobic capacity may provide useful measures in determining an athletes’ predisposition to transient peripheral fatigue. However, our data (unpublished) suggest that intra-reliability of $H_{\text{ACC}}$ and $H_{\text{DEC}}$ during match play (CV = 12–25\%) may be a more sensitive measure than high speed (CV = 25–45\%) and sprint (CV = 30–47.5\%) distance.

Our finding that acceleration and deceleration output exhibited time-dependent reductions from the start to the end of a game (ES $> 1.0$) provides football-specific support for previous studies which have demonstrated reductions in determinants of accelerations and decelerations based on GPS activity\textsuperscript{17,23-26} and repeat sprint activity.\textsuperscript{27,28} A recent study by Bradley et al.\textsuperscript{29} suggested that acceleration capacity was not reduced by match play in the same way as distance covered during high-intensity running (>14.4 km h\textsuperscript{-1}, 3.88 m s\textsuperscript{-1}). This suggestion was made following analysis of the number of discrete acceleration efforts in the first vs. second half, and in the first compared to final 15 min period of the game. Although the exact mechanisms are not fully understood, reductions in central neural drive and increases in peripheral fatigue have been shown to reduce the rate of force development (RFD) and maximal force production compared to baseline levels.\textsuperscript{17,24} Indeed, as a consequence of football match-play and repeat-sprint protocols, sprint performance, jump performance and RFD have all been shown to be reduced.\textsuperscript{17,24} The current study provides further evidence that acceleration and deceleration capacity are attenuated during football match-play.

When interpreting the current findings, a number of limitations should be considered. Physical demands of professional match play are known to be position specific.\textsuperscript{4} Despite using participants from two football clubs, sample size was insufficient for differentiation of position specific acceleration and deceleration demands. This situation is difficult to overcome as clubs often have only 3–5 players in each playing position, with yet fewer playing regularly. A further consideration is the validity and accuracy of 10 Hz GPS technology for measuring peak effort changes in speed. Recently however, it has been established that the 10 Hz system used provides sufficient accuracy to quantify the acceleration and deceleration phases in team sports.\textsuperscript{8}

5. Conclusion

In conclusion, this study is the first to describe the temporal and transient patterns of acceleration and deceleration during professional football match play. Time dependent reductions in acceleration and deceleration output may provide further support for the occurrence of fatigue during match play. The presence of transient reductions in $H_{\text{ACC}}$ and $H_{\text{DEC}}$ following periods of peak activity suggest that a players’ capacity to perform required actions may be transiently compromised during match play.

6. Practical implications

- With 18\% of total distance covered being whilst accelerating or decelerating at $> 1$ m s\textsuperscript{-2}, the current data highlights the importance of both eccentric and concentric conditioning to football performance.
- Practitioners may use the published data to design and prescribe appropriate match-specific training stimuli, ensuring a sufficient acceleration and deceleration stimulus is included.
- As the reliability of acceleration and deceleration output appears to be greater than that of high speed and sprint running, practitioners may wish to explore the use of these measures as performance monitoring variables.

Conflicts of interest

None declared.

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References


