Journal of Strength and Conditioning Research Publish Ahead of Print
DOI: 10.1519/JSC.0000000000001818

Manuscript Type: Original Investigation

Manuscript Title: An Acceleration Profile of Elite Gaelic Football Match-Play

Running Title: Acceleration Demands of Elite Gaelic football

Martin Ryan,[1] Shane Malone,[1] Kieran Collins[1]

Author Affiliations

1. Gaelic Sports Research Centre, Institute of Tallaght, Tallaght, Dublin.

Corresponding author
Martin Ryan
c/o The Gaelic Sports Research Centre, Department of Science, Institute of Technology Tallaght, Tallaght, Dublin, Ireland.
Email: martinryan77@gmail.com

Word count : - 3213

Number of tables and figures 1 Table 4 Figures

ABSTRACT

The use of global positioning system (GPS) technology in Gaelic football is the primary source of quantifying game demands. The aim of the current study was to quantify the acceleration profile of elite Gaelic football. Thirty-six elite male Gaelic football players (Mean ± *SD*, age: 24 ± 6 years; height: 180 ± 7 cm; mass: 81 ± 7 kg) across five playing positions took part in a multiple study (*n* = 154 observations). Player movement was recorded during nineteen (*n* = 19) competitive games over 2 seasons using 4-Hz GPS (VXSport, New Zealand). The average total distance (m), high speed running distance (m; ≥17 $km \cdot h^{-1}$), very high speed running distance (m; ≥22 $km \cdot h^{-1}$) were recorded. Additionally the number (n), distance (m) and the duration of accelerations were quantified. Accelerations were subdivided into 14 equal parts of 5-minute epochs (E_1 = 0-5 min, E_2 = 5-10 min, E_3 = 10-15 min etc. Players performed 166 ± 41 accelerations. High speed running distance and very high speed running distance was 1563 ± 605 and 524 ± 190 m respectively. The mean acceleration distance was 267 ± 45 m distributed between 12 ± 5 accelerations per 5-minute epoch. The maximum acceleration epoch classified as the greatest distance covered accelerating during a predetermined 5-minute epoch was 296 ± 134 m. The PEAK epoch resulted in a significant reduction of acceleration distance covered in the period prior and/or in the subsequent epoch. An understanding of the acceleration profile in Gaelic football can inform the prescription of appropriate training regimen.

Keywords: GPS, Temporal Profile, Performance Analysis, Intermittent team sport

INTRODUCTION

Gaelic football is an intermittent high intensity invasion team sport with frequent bouts of high speed running interspersed with acceleration efforts. Previously work undertaken by McErlean, Cassidy and O'Donoghue (19) observed the global movements of players during match-play using time-motion analysis. This investigation observed that 18.9% ± 7.8% of match movement consisted of jogging with running equated to 7.8% ± 4.0% of overall movement. Interestingly this investigation found that the time spent soloing (carrying the ball) 1.1% ± 0.8% was associated with high-speed activity during match-play. More recently the movement demands during competitive league and championship match-play have been quantified using Global Positioning Systems (GPS) (15) providing coaches and practitioners with up to date information for the prescription and monitoring of player specific preparation programs.

The use of global positioning systems (GPS) technology in Gaelic football is the primary source of quantifying game demands (4,15,16,17). It is a method which is simple to use and unobtrusive to the players wearing the device and has seen considerable use in various intermittent field sports, most notably rugby league (8) and soccer (6). Recently Malone et al., (18) observed total distance and high speed running distance (HSRD) for senior male elite Gaelic football match-play 8889 ± 1448 m and 1596 ± 594 m respectively. A temporal profile examined by quarters saw reductions for total distance in the second (-4.1%), third (-5.9%) and fourth (-3.8%) quarters respectively. There was a significant reduction in HSRD in the second (-8.8%), third (-15.9%) and fourth (-19.8%) quarters when compared to the first quarter. While these studies provide valuable information for reporting the absolute demands per halves and quarters of match-play, they fail to account for the most intense running periods of match-play. Therefore it may be more beneficial to quantify the duration-specific match-play acceleration demands to more accurately prescribe and monitor training to better reflect the oscillating physiological responses that occur throughout match-play.

Previously, Varley and colleagues observed a significant variation in accelerated meters between five-minute predetermined time periods in Australian rules players [(26)]. However, it was unclear if this phenomenon is associated with player fatigue, pacing or other factor [(2)]. Additionally Delaney et al [(5)] reported a positional profile for acceleration demands within rugby league across subtle time-dependent periods. Temporal changes in relation to acceleration are potentially a more adaptable metric for the practitioner when compared to high speed running and sprint running [(1)] due to accelerated movements resulting in increased physiological cost when compared to high speed movements [(9,11)].

Previously acceleration over a 10 metres has been associated successful elite performance within Gaelic football players [(7)]. However, to date there is no up to date data on the acceleration profiles of elite Gaelic footballers during competitive match-play despite this action making up a significant amount of players movement profile. In summary, the above would suggest that a pre-defined epoch could be used to determine performance decline and movement demands of Gaelic football players. Therefore the aims of the current study was to: (1) determine the performance decline patterns by quantifying the duration-specific acceleration demands in pre-defined 5-minute epochs during elite Gaelic football match-play and (2) determine PEAK and recovery distances for acceleration based values during match- play. It was hypothesized that similar to other intermittent team sports Gaelic football players would experience decrements in acceleration performance as match-play progressed.

METHODS

Experimental approach to the problem

The current observational study was designed to quantify the acceleration profile of elite Gaelic football players. Player movement was recorded during nineteen matches over two seasons (February 2013 to September 2014) using individual 4-Hz GPS units (VXSport, New Zealand, Issue: 330a, Firmware: 4.01.1.0). The GPS unit (mass: 76g; 48mm x 20mm x 87mm) was secured in a harness and situated between the scapulas in the upper thoracic-spine region. The raw velocity state was analysed further by exporting the data to a customized Excel spreadsheet (Microsoft, Redmond, USA). The participants of the current study were competing at the highest level of competition (Division 1 of the National Football League and All Ireland Series). Thirty-six (n = 36) elite Gaelic football players were observed over two competitive seasons (n =19 games). A total of 154 individual samples were collected. Player data were included for analysis provided they met the following criteria: (1) the player completed the full duration of the game; (2) they played the same position throughout the game; (3) they were familiar with their playing position; and (4) added minutes of playing time were not included. All competitive matches took place between 14.00 and 20.00 hours. Temperatures during match-play ranged from 10 to 22°C. The GPS was used to determine specific running performance variables during elite Gaelic football match play. All players were advised to maintain their normal diet, with special emphasis being placed on the intake of fluids and carbohydrates. The above design allowed for the collection of longitudinal match-play data. This allowed for the identification of specific acceleration demands of match play and to discriminate across 14 equal predetermined 5-minute epochs.

Subjects

Following ethical approval by the local research ethics committee (Institute of Technology Tallaght, Dublin, Ireland) and informed consent, thirty-six male (Mean ± *SD*, age: 24 ± 6 years; height: 180 ± 7 cm; mass: 81 ± 7 kg) elite inter-county Gaelic footballers (8 full-backs, 10 half-backs, 4 midfielders, 6 half-forwards, 8 full-forwards) participated in the study. The senior level playing experience of the current squad was 8 ± 4 years. Playing experience within a Gaelic football context refers to the time a player is registered to the senior elite playing squad. Currently in Gaelic football, players can be released from elite squads to return to sub-elite competition where management deem appropriate [15]. All participants were informed of study requirements, the collection protocols, the risks involved and the equipment to be used. Prior to the commencement of the study all participants provided informed consent. The team participated in division 1 of the National Football League and All-Ireland series competitions for the duration of the study.

Acceleration and Acceleration Distance Analysis

Player movement was recorded during nineteen matches over two seasons using individual 4-Hz GPS units (VXSport, New Zealand, Issue: 330a, Firmware: 4.01.1.0). The GPS unit (mass: 76g; 48mm x 20mm x 87mm) was secured in a harness and situated between the scapulas in the upper thoracic-spine region. The device is lightweight and does not intrude on the performance of the player. Activation and satellite lock was established 15 minutes before game commencement [14]. The raw velocity state was analysed further by exporting the data to a customized Excel spreadsheet (Microsoft, Redmond, USA). The validity and reliability of this device has previously been communicated Specifically Malone et al. [17] report the VXSport GPS to be reliable during intermittent exercise. Test-retest (7 days apart) reliability was reported for total distance covered (m), maximum speed ($km \cdot h^{-1}$), and average speed ($km \cdot h^{-1}$). Systematic differences were examined using a paired t-test on the test-retest data and revealed no significant differences for the total distance covered (300.5 ± 3.3; 303.6 ± 5.6 m), maximum speed (23.9 ± 1.9; 24.1 ± 1.3 $km \cdot h^{-1}$), and average speed (10.2 ± 1.0; 10.2 ± 0.9 $km \cdot h^{-1}$). The typical error (TE ± 95% confidence interval [CI]) was 0.84 ± 0.3 for total distance covered, 0.75 ± 0.26 for maximum speed, and 0.55 ± 0.19 for average speed, respectively. The coefficient of variation (CV% ± 95% CI) was 1.0 ± 0.4 for the total distance covered, 4.2 ± 1.5 for maximum speed, and 4.4 ± 1.5 for average speed, respectively.

The variables of the number of accelerations performed (n), acceleration distance (m), duration of accelerations (s) and maximum acceleration ($km \cdot h^{-1}$) were quantified to assess the temporal profile of the sport. To investigate total match-play variation data were subdivided into 14 equal predetermined 5-minute epochs (0-5, 5-10 min etc.) and categorized as E_1, E_2, E_3 etc. Acceleration was categorized once a player changed speed by 2 $km \cdot h^{-1}$ within 1 second. The change was triggered over a minimum time of 2 seconds to differentiate from a player lunging or pivoting. Acceleration values for a player stopped once the player decelerated to <75% of maximum speed reached in the previous acceleration effort. The peak 5-minute value

(PEAK) for acceleration distance was identified and recorded. Distance covered in the previous 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 (x ¯ 45) [(1)].

Statistical Analysis

The assumptions of normality were verified prior to parametric statistical analysis with a Shapiro-Wilk test. A Bonferroni post hoc test was used to determine the source of any significant differences. The level of significance was set at $P \leq 0.05$ and all data were reported as mean ± SD with 95% CI (SPSS version 22, SPSS Inc. Chicago, USA). The difference between each 5-minute epoch was analysed using a repeated measures analysis of variance (0-5, 5-10, 10-15) for acceleration distance, the number of accelerations, maximum acceleration and duration of accelerations during match-play. Cohen's d effect sizes (ES) were calculated for all between-epoch differences. Effects were classified as trivial (0.0–0.2), small (0.21–0.5), moderate (0.51–0.8), and large (>0.81). Match-play periods of predefined 5-minute epochs (e.g. E_1 (0-5), E_2 (5-10), E_3 (10-15) were independent variables. The dependent variables across the range of analysis were high speed running ($\geq 17 km \cdot h^{-1}$) distance (m), very high speed running ($\geq 22 km \cdot h^{-1}$) distance (m), total number of accelerations (n), acceleration distance (m), acceleration duration (s) and maximum acceleration ($km \cdot h^{-1}$).

RESULTS

Gaelic football players performed (166 ± 41: 95% CI: 160-173) accelerations during match-play. High speed running distance and very high speed running distance was 1563 ± 605 and 524 ± 190 m respectively. The acceleration distance was (3739 ± 1172: 95% CI: 3531-3904). The mean accelerations during match-play was (12 ± 5: 95% CI: 11-13) accelerations. During the predetermined 5-minute epochs only four epochs showed a significant difference in the number of accelerations completed, E_1 and E_6 (p = .001, CI: 1, 2.7, ES: 0.38); E_1 and E_{11} (p = .00, CI: .6, 2.5, ES: 0.43); E_3 and E_{11} (p = .01, CI: .2, 1.8, ES: 0.36); E_7 and E_{11} (p = .05, CI: .02, 1.5, ES: 0.33). There is a consistency of accelerations undertaken by Gaelic football players during match-play and only small effect size for the majority of epochs when examining the number of accelerations performed versus 5-minute epochs. (Figure 1)

*** Insert figure 1 near here***

The mean acceleration distance observed during match-play was (267 ± 45 m: 95% CI: 247 – 284). The maximum acceleration distance was observed at E_1 (296 ± 135 m: 95% CI: 267 - 311). The lowest acceleration distance was observed during the latter stages of the second half at E_{11} (247 ± 121 m: 95% CI: 226 - 264). A temporal change of -16.6% was noted (p = .001, CI: 19.8, 66.4 m ES: 0.33) when comparing the lowest acceleration distance E_{11} (247 ± 121 m: 95% CI: 226 – 264) to the maximum E_1 (296 ± 135 m: 95% CI: 267 - 311).

*** Insert figure 2 near here***

Observed diminutions in acceleration distance highlighted a temporal change of -13% immediately after E_1 the max epoch and the subsequent epoch thereafter E_2 (258 ± 120 m: 95% CI: 239 - 277) (p = .01, CI: 7, 52.3 m ES: 0.23). A significant difference in acceleration distance between the maximum E_1 and the following epochs was observed E_2; E_4; E_5; E_6; E_9; E_{11}; E_{14} (p < .04, CI: .1, 66.4 m ES: 0.19 – 0.33). A significant difference between the lowest epoch, E_{11} and epochs E_3; E_5; E_7; E_8; E_{10}; E_{12}; E_{13} was also observed (p < .03, CI: 2.3, 53.2 m ES: 0.17 – 0.23). The penultimate epoch before the half time break saw a significant difference in acceleration distance between E_6 and E_3; E_7; E_8; E_{10} (p < .03, CI: 1.9, 48.6 m ES: 0.19 – 0.20) (Figure 2).

*** Insert figure 3 near here***

The mean epoch acceleration duration (s) during match-play was (77.8 ± 33.2 s: 95% CI: 76.4 – 79.3). In accordance with the observations of acceleration distance max epoch (E_1), the epoch with the most time spent accelerating was also E_1 (82.8 ± 36.3 s: 95% CI: 76.5 – 87.6). The percentage differences, against the mean acceleration duration did not fluctuate greatly across match-play when examined using 5-minute epochs and in general highlights a consistency across game time. E_{11} (72.9 ± 32.4 s: 95% CI: 67.8 – 78) was observed as being -6% and E_1 +5% respectively versus match-play mean of acceleration duration (Figure 3). A significance difference was observed for acceleration duration for E_1 and E_{11} (p = .001, CI: 2.3, 15.9 s, ES: 0.26). Significant difference was observed between epoch E_1 and E_2; E_4; E_6; E_9 (p < .03, CI: .6, 15.9 s, ES: 0.20 – 0.26) . Significant difference was observed between epoch E_2 and E_8 (p = .04, CI: .02, 13.7 s, ES: 0.07). Significant difference was observed between epoch E_{11} and E_3; E_7; E_{10}; E_{13} ($p < .03$, CI: 1.5, 14.1 s, ES: 0.20 – 0.26).

*** Insert figure 4 near here***

Maximum acceleration (km·h^{-1}) mean across total match-play was (24.7 ± .5 km·h^{-1}: 95% CI: 24.3 – 25.2). Significant difference was observed between the initial epoch E_1 and the following epochs E_5; E_6; E_9; E_{10}; E_{13}; E_{14} ($p < .05$, CI: .02, 2.1 km.h^{-1}, ES: 0.17 - 0.27). Significant difference was observed between epoch E_6 and E_2; E_3; E_7 ($p < .01$, CI: .03, 1.6 km·h^{-1}, ES: 0.00 – 0.24). Significant difference was observed between the last epoch E_{14} and E_3; E_4; E_7; E_8 ($p < .05$, CI: .04, 1.7 km·h^{-1}, ES: 0.18 – 0.26). The maximum acceleration saw the initial epoch E_1 (25.4 ± .5 km·h^{-1}: 95% CI: 24.7 – 26.2) to be greater than all other epochs E_2 – E_{14} (Figure 4).

*** Insert figure 5 near here***

Mean percentage change from $\bar{x}$ 45 at 5_{PRE} , PEAK, 5_{POST} and 10_{POST} for acceleration distance (m) was observed. Significant difference was observed for PEAK and $\bar{x}$ 45; 5_{PRE}; 5_{POST}; 10_{POST} ($p < .001$, CI: 117, 193 m, ES: 1.38 – 1.75) (Figure 5). A significant difference was observed from 5_{PRE} and 5_{POST} ($p = .02$, CI: 4, 56 m, ES: .30). PEAK acceleration distance was observed at 159 % of $\bar{x}$ 45 with 5_{PRE} 92 %, 5_{POST} 105 % and 10_{POST} 107 % respectively.

DISCUSSION

The aim of the current study determine the running performance patterns of elite Gaelic football players with special reference to accelerated running by quantifying the duration-specific acceleration demands across pre-defined 5-minute epochs during match-play. Additionally, we aimed to determine PEAK and recovery distances for acceleration based values during match- play. The main finding of the study was that temporal changes in acceleration distance exist during predetermined 5-minute epochs with pronounced decrements in performance as match-play progresses for both PEAK and recovery based accelerated running variables.

Our observations show a reduction in acceleration demands of elite Gaelic football players as match play progressed, these findings are in agreement with previously observed decrements across match-play quarters in Gaelic football, and similar to observations in both soccer and rugby league cohorts [13,16,23,25]. It is unclear if the cyclical nature of the peak-trough occurrence of acceleration distance in Gaelic football is related to glycogen depletion, training status, pacing or tactical elements of the game. The study observed a significant difference between PEAK and 5_{PRE}, 5_{POST} and 10_{POST} ($p < .01$) while also noting large percentage changes at PEAK 159 %, 5_{PRE} 92 %, 5_{POST} 105 % and 10_{POST} 107 % above the non specific playing position mean of $\bar{x}$ 45 respectively. The +5% temporal change in acceleration distance for 5_{POST} following PEAK above $\bar{x}$ 45 only precedes an -8% decline at 5_{PRE} (Figure 5). Further to this recovery distance was +7% for 10_{POST} above $\bar{x}$ 45. This observation may be related to intra-cellular interactions that help maintain excitation–contraction coupling resulting in minimum spikes of peripheral fatigue as seen in soccer [9]. However, Gaelic football players in our study did not express the same decline in performance as their soccer counterparts [1]. While the game interactions can affect movement demands in many team spots, notable unique differences such as frees, sidelines and scores can affect tempo and pace of Gaelic football match-play. Our study suggests that PEAK acceleration distance and the recovery distances of PRE and POST efforts can assist to accurately reflect the difference in physiological response that occur over time. Therefore these measures may be utilized by coaches to best prepare for inter-change strategies for Gaelic football players based on these based on these specific acceleration variables.

The acceleration profile of elite Gaelic football players highlights the ability of players to sustain acceleration efforts throughout the game. The peak effort was 13 ± 5 accelerations in E_1 to a low of 11 ± 5 accelerations in E_9 (Figure 1). The current data suggest limited variability in accelerations between epochs, with only five epochs showing significant difference ($p \leq 0.05$). We observed that the number of accelerations performed per epoch has a limited effect on the temporal change in that variable. The results for accelerations performed during match-play demonstrates that Gaelic football is a sport that places a high demand on both the aerobic oxidative and anaerobic glycolytic energy systems [12]. The study data show a consistency of acceleration efforts that Gaelic football players need to attain to compete during match-play. Running programs such as repeat sprint and sprint interval training as well as specific strength and conditioning programs designed to train these energetic pathways may provide coaches with a valuable method of training the acceleration profile required during match-play. Future investigations should aim to assess the utility of such programs in aiding match play acceleration profiles in Gaelic football cohorts

The variations of acceleration distance across epochs in the current investigation are similar to previous observations of temporal change seen in premier league soccer [3]. The study noted a 20% decline in the first 15-minute period versus the last 15-minute period in high intensity running. Earlier work conducted by Mohr and colleagues [21] found that immediately after the most intense 5-minute period, a 12% reduction in high intensity running was evident. The consecutive percentage differences for acceleration distance completed during match-play from epoch E_1 to E_{14} range between -13% to +7%. Acceleration distances only increased consecutively in two separate time periods, 25-35 min and 50-60 min respectively. All other (n=10) epochs maintained the peak-trough cycle however this data may be heavily influenced by the parameters of an intermittent sport such as playing position, individual differences and individual player interactions. Malone et al. [18] observed a decrement in high speed running distance when comparing match-play by quarters. A small to moderate effect size was noted for high speed running distance during the second (ES = 0.45), third (ES = 0.78) and fourth (ES = 1.23) quarters of play when compared to the first quarter (p = 0.005). A similar profile is evident in the current study with a decrement in acceleration distance as the game progresses. Studies by Mohr, Krustrup and Bangsbo [20,21] using time-motion analysis and performance measures [13] during match-play in soccer observed that fatigue or reduced performance seems to occur at three different stages in the game: (1) after short-term intense periods in both halves; (2) in the initial phase of the second half; and (3) towards the end of the game.

The current study examined the overall changes in acceleration distance and observed that players do not exceed a value of more than 17% and no less than -10% against the mean during match-play (see Figure 2). Furthermore, Akenhead et al.[1]

reported that high acceleration (H_{ACC}) capability is acutely compromised during match-play. Using the 5-minute epoch methodology, decrements in performance hypothesized as fatigue were supported by the findings that H_{ACC} performance following peak was approximately 10% lower than mean values.

Maximal acceleration is an important player characteristic as it allows players to beat opposition to the ball and accelerate away from opposition in attacking and defensive situations. Figure 4 depicts the Maximum acceleration (km·h^{-1}) mean across total match-play (24.7 ± .5 km·h^{-1}). A significant difference but trivial to small effect size was noted across all epochs (ES: 0.00 - 0.24). The initial epoch E_1 contained the maximum acceleration (25.4 ± .5 km·h^{-1}) value above all other epochs E_2 – E_{14} (ES: 0.17 - 0.27) (Figure 4). Since little variation in mean maximum acceleration across epochs was observed, mean maximum acceleration may be viewed as a constant performance variable with any significant change possibly indicative of fatigue. The lack of variability across epoch is not surprising and is possibly indicative of the match-play nuances of Gaelic football where strong positional lines govern player-running patterns. The size of the pitch, the high number of players on a team, playing style and the heavy contact that ensues when soloing the ball may be justifiable factors that restrain acceleration velocity [16,18].

Future research should focus on the individualization of acceleration distance across rolling epochs that would support practitioners in creating a match – specific training stimuli ensuring that a sufficient acceleration stimulus is met at training. Furthermore there is a need for the identification of a rolling average based acceleration profile for Gaelic football across moving averages of 1 to 10 minutes in duration [5]. Studies have noted that the pace of match-play has a significantly different modulation when seen minute by minute, allowing practitioners to identify some unique "temporal patterns" of match-play [10]. Such typical modulations of the matches were found to be significant and consistent, with reductions in performance suggested as transient fatigue however this may only be relatable to the sport of Rugby sevens or high volume running such as Australian Rules football. There is a need to undertake a task analysis of Gaelic football and juxtapose the demands upon the task. Game components such as collisions, tackling and blocking with general contested play have a high physical demand on a player however they were not part of this study. These in-game demands could have an overall physical effect on a player and possibly impact the temporal changes in acceleration distances and decision-making processes.

PRACTICAL APPLICATIONS

The quantification of acceleration distance represents a unique method to assess the temporal change in running performance during Gaelic football match-play. After the initial epoch E_1 a notable performance decline of mean acceleration distance in subsequent epochs of up to 17% was observed. This reduction in acceleration distance may be related to player capacity to maintain work rate, pacing or adaptions to playing structure. The lowest acceleration distance covered during match-play was E_{11} and it is advised that before this point that game intervention of moving players from position or the introduction of substitutes may be warranted. The observation of acceleration distance in tandem with a defined epoch can therefore be used within training environments as a strategic metric to monitor players. Coaches should be aware of the required acceleration demands placed on players and aim to overload players within specific drills to these demands. Acceleration training demands within the same context can be used to expose players to the required acceleration distances to improve players' capacity to complete these demands within match-play environments. During In-season competition, coaches may be reluctant to administer testing protocols of Gaelic players. The availability of PEAK values and subsequent recovery times and distances against the mean may be an alternative to tracking performance decrements and define match readiness. This objective test is environment driven and caters for the unaccountable physiological markers of pacing, opposition standard and fatigue.

ACKNOWLEDGEMENTS

No sources of funding were provided to complete the current investigation. The author wishes to express no conflict of interest. We would like to thank all the players and management for their time and commitment during the data collection process.

REFERENCES

1. Akenhead, R, Hayes, PR, Thompson, KG, and French, D. Diminutions of acceleration and deceleration output during professional football match-play. *J. Sci. Med. Sport* 16: 556–561, 2013.

2. Aughey, RJ. Australian football player work rate: evidence of fatigue and pacing? *Int J Sports Physiol Perform*. 5: 395-405, 2010.

3. Buchheit, M, Allen, A, Poon, TK, Mondonutti, M, Gregson, W, and Di Salvo, V. Integrating different tracking systems in football: multiple camera semi-automatic system, local positioning measurement and GPS technologies. *J Sports Sci*. 32 (20): 1844 – 1857, 2014.

4. Collins, DK, Solan, B, and Doran, D, A. A preliminary investigation into high intensity activity during elite Gaelic football match-play. *J Sport Ther* 6:1, 2013.

5. Delaney, JA, Duthie, GM, Thornton, HR, Scott, TJ, Gay, D and Dascombe, BJ. Acceleration-Based Running Intensities of Professional Rugby League Match-Play. *Int J Sports Physiol Perform.* 2015. 10.1123/ijspp.2015-0424

6. Di Salvo, V, Gregson, W, Atkinson, G, Torduff, P, and Drust, B. Analysis of high intensity activity in Premier league soccer. *Int J Sports Med*. 30 (3): 205-12, 2009.

7. Doran, D.A., Donnelly, J.P. and Reilly, T. Kinanthropometric and performance characteristics of Gaelic games players, in in Reilly, T., (ed.) Kinanthropometry VIII, London: Routledge, 181-191 (2003).

8. Gabbett, TJ, Polley, C, Dwyer, DB, Kearney, S, and Corvo, A. Influence of field position and phase of play on the physical demands of match-play in professional rugby league forwards. *J. Sci. Med. Sport* 17 (5): 556-61, 2014.

9. Gaudino, P, Iaia, F.M., Alberti, G, Strudwick, A.J., Atkinson, G and Gregson, W. Monitoring Training in Elite Soccer Players: Systematic Bias between Running Speed and Metabolic Power Data. *Int J Sports Med* 34(11):963-968. 2013

10. Granatelli, G, Gabbett, T, Briotti, G, Padulo, J, Buglione, A, D'Ottavio, S, and Ruscello, B. Match Analysis and Temporal Patterns of Fatigue in Rugby Sevens. *J Strength Cond Res*. doi: 10.1519/JSC.0b013e31829d23c3 [Epub ahead of print]

11. Hodgson C, Akenhead R and Thomas K. Time-motion analysis od acceleration demands of 4v4 small-sided soccer games played on different pitch sizes. *Hum Mov Sci* 33:25-35. 2014

12. Keane, S, Reilly, T, and Hughes, M. Analysis of work rates in Gaelic football. *Aust. J. Sci. Med. Sport* 25 (4): 100–102, 1993.

13. Krustrup P, Mohr M, Steensberg, A, Bencke, J, Kjaer, M, and Bangsbo, J. Muscle and blood metabolites during a soccer game: implications for sprint performance. *Med Sci Sports Exerc*. 38(6): 1165–1174, 2006.

14. Maddison, R, and Ni Mhurchu, C. Global positioning system: A new opportunity in physical activity measurement. *Int J of Behav. Nutr. Phys. Act.* 6: 73, 2009.

15. Malone, S, Solan, B, and Collins, K. The Positional Match Running Performance of Elite Gaelic Football. *J Strength Cond Res* 30(8): 2292-2298, 2016.

16. Malone, S, Solan, B, Collins, K, and Doran, D. The metabolic and estimated energetic demands of Elite Gaelic football match play. *J Sports Med Phys Fitness*. 2016. [Epub ahead of print]

17. Malone, S, Collins, DK, McRobert, AP, Morton, J, and Doran, DA. Accuracy and reliability of VXsport global positioning system in intermittent activity. Presented at: *The 19th Annual Congress of the European College of Sport Science,* 5th July 2014; Amsterdam

18. Malone, S, Solan, B, Collins, K. The running performance of elite Gaelic football match-play. *J Strength Cond Res*. [Epub ahead of print]. doi: 10.1519/JSC.0000000000001477 2016.

19. McEerlan, CA, Cassidy J, and O'Donoghue, PG. Time-motion analysis of gender and positional effects on work-rate in elite Gaelic football competition. *J Hum Mov Stud* 38: 269–286, 2000.

20. Mohr, M, Krustrup, P, and Bangsbo, J. Fatigue in soccer: a brief review. *J Sports Sci* 23(6): 593-9, 2005.

21. Mohr, M, Krustrup, P, and Bangsbo, J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21(7): 519-28, 2003.

22. O'Donoghue, P, and King, S. Activity profile of men's Gaelic football. In T. Reilly (Ed.), Science and football V. Oxford, UK: Routledge. 2000 pp.207-213.

23. Rampinini, E, Impellizzeri, FM, Castagna, C, Coutts, AJ, and Wisloff, U. Technical performance during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. J. Sci. Med. Sport 12: 227-233, 2009.

24. Reilly, T, and Collins, K. Science and the Gaelic Sports; Gaelic football and Hurling. *Euro J Sports Sci* 8 (5) pp. 231-240, 2008.

25. Sirotic, AC, Knowles, H, Catterick, C, and Coutts, AJ. Positional match demands of elite rugby league competition. *J Strength Cond Res* 25: 3076–3087, 2011.

26. Varley, MC, Elias, GP, and Aughey, RJ. Current match-analysis techniques' underestimation of intense periods of high-velocity running. *Int. J. Sports Physiol. Perform.* 7: 183-185, 2012

FIGURE CAPTIONS

FIGURE 1 – The number of accelerations across 5-minute epochs during elite Gaelic football match-play. Data presented as mean ± SD.

Significant difference $p<0.05$ of the number of accelerations performed during 5-minute epochs (E_1 to E_{14}). Significant difference between epoch E_1 and E_6 (a) p = .00, CI: 1, 2.7, ES: 0.38 (0.5 - 1.2); E_{11} (b) p = .00, CI: .6, 2.5, ES: 0.43 (0.5 - 1.3). Significant difference between epoch E_3 and E_{11} (c) p = .01, CI: .2, 1.8, ES: 0.36 (0.6 - 1.3). Significant difference between epoch E_7 and E_{11} (d) p = .05, CI: -.02, 1.5, ES: 0.33 (0.07 - 0.52).

FIGURE 2 – The acceleration distance (m) across 5-minute epochs during elite Gaelic football match-play. Data presented as mean ± SD.

Significant difference $p<0.05$ of acceleration distance (m) during 5-minute epochs (E_1 to E_{14}). Significant difference was observed between epoch E_1 and E_2 (a) p = .01, CI: 7, 52.3 m ES: 0.23 (0.0 - 0.45); E_4 (b) p = .00, CI: 9.2, 51.7 m ES: 0.24 (0.01 - 0.46); E_5 (c) p = .04, CI: .1, 43.9 m ES: 0.17 (0.06 - 0.39); E_6 (d) p = .00, CI: 17.3, 58.9 m ES: 0.30 (0.07 - 0.52); E_9 (e) p = .02, CI: 3.8, 46.1 m ES: 0.19 (0.04 - 0.41); E_{11} (g) p = .00, CI: 19.8, 66.4 m ES: 0.33 (0.11 - 0.56); E_{14} (f) p = .00, CI: 8.9, 55.3 m ES: 0.27 (0.04 - 0.49). Significant difference was observed between epoch E_{11} and E_3 (h) p = .00, CI: 7.3, 49.2 m ES: 0.23 (0.01 - 0.47); E_5 (i) p = .03, CI: 2.3, 39.8 m ES: 0.17 (0.07 - 0.47); E_7 (j) p = .00, CI: 6.5, 44.0 m ES: 0.22 (0.02 - 0.46); E_8 (k) p = .01, CI: -5.5, -53.2 m ES: 0.22 (0.02 - 0.46); E_{10} (l) p = .00, CI: 10.1, 45.4 m ES: 0.23 (0.0 - 0.47); E_{13} (m) p = .01, CI: 5.7, 41.4 m ES: 0.21 (0.04 - 0.44). Significant difference was observed between epoch E_3 and E_6 (n) p = .02, CI: 3.6, 42.9 m ES: 0.20 (0.04 - 0.43). Significant difference was observed between epoch E_6 and E_7 (o) p = .03, CI: 2.1, 39.3 m

ES: 0.20 (0.07 - 0.42); E_8 (p) p = .02, CI: 1.9, 48.6 m ES: 0.20 (0.06 - 0.43); E_{10} (q) p = .1, CI: 2.3, 41.6 m ES: 0.20 (0.05 - 0.43)*

FIGURE 3 – The acceleration duration (s) across 5-minute epochs during elite Gaelic football match-play. Data presented as mean ± SD.

Significant difference p<0.05 of acceleration duration (s) during 5-minute epochs (E_1 to E_{14}). Significant difference was observed between epoch E_1 and E_2 (a) p = .03, CI: .6, 13.3 s, ES: 0.20 (0.16 - 0.56) ; E_4 (b) p = .04, CI: .1, 12.5 s, ES: 0.20 (0.18 - 0.55) ; E_6 (c) p = .03, CI: .5, 13.0 s, ES: 0.20 (0.17 - 0.21); E_9 (d) p = .04, CI: .02, 13.7 s, ES: 0.20 (0.17 - 0.21) ; E_{11} (e) p = .00, CI: 2.3, 15.9 s, ES: 0.26 (0.10 - 0.63). Significant difference was observed between epoch E_2 and E_8 (f) p = .04, CI: .02, 13.7 s, ES: 0.07 (0.3 - 0.45). Significant difference was observed between epoch E_{11} and E_3 (g) p = .03, CI: .54,13.0 s, ES: 0.20 (0.18 - 0.58);E_7 (h) p = .01, CI: 1.7,13.2 s, ES: 0.23 (0.15 - 0.61); E_{10} (i) p = .01, CI: 1.5,14.1 s, ES: 0.23 (0.15 - 0.61):E_{13} (j) p = .00, CI: -2.1,-14.1 s, ES: 0.26 (0.12 - 0.64).

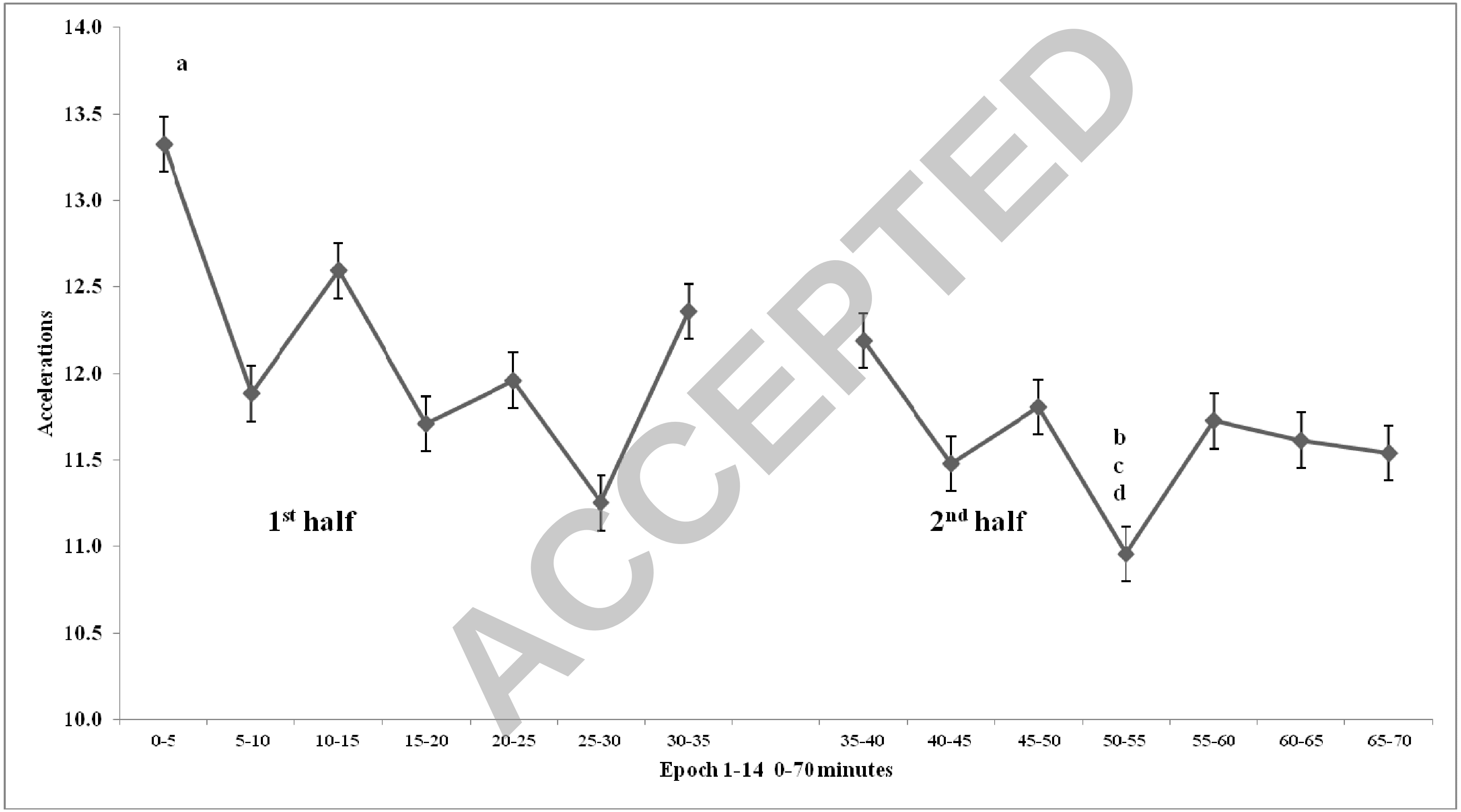
FIGURE 4 – The maximum acceleration ($km \cdot h^{-1}$) across 5-minute epochs during elite Gaelic football match-play. Data presented as mean ± SD.

Significant difference p<0.05 of Maximum acceleration ($km \cdot h^{-1}$) during 5-minute epochs (E_1 to E_{14}). Significant difference was observed between epoch E_1 and E_5 (a) p = .03, CI: .7, 1.6 $km \cdot h^{-1}$, ES: 0.17 (0.8 - 1.1); E_6 (b) p = .00, CI: 0.6, 2.1 $km \cdot h^{-1}$, ES: 0.28 (0.7 - 1.2) ; E_9 (c) p = .05, CI: .02, 1.8 $km \cdot h^{-1}$, ES: 0.18 (0.8 - 1.1); E_{10} (d) p = .02, CI: .1, 1.7 $km \cdot h^{-1}$, ES: 0.19 (0.8 - 1.1); E_{13} (e) p = .02, CI: .1, -1.8 $km \cdot h^{-1}$, ES: 0.19 (0.07 - 1.1); E_{14} (f) p = .00, CI: .4, 2.2 $km \cdot h^{-1}$, ES: 0.27 (0.7 - 1.2). Significant difference was observed between epoch E_2 and E_6 (g) p = .00, CI: .4, 1.8 $km \cdot h^{-1}$, ES: 0.24 (0.7 - 1.2). Significant difference was observed between epoch E_3 and E_6 (h) p = .01, CI: .2, 1.6 $km \cdot h^{-1}$, ES: 0.22 (0.8 - 1.2). Significant difference was observed between epoch E_6 and E_7 (i) p = .05, CI: .03, 1.6 $km \cdot h^{-1}$, ES: 0.20 (0.7 - 1.2). Significant difference was observed between epoch E_{14} and E_3 (j) p = .03, CI: .9, 1.7 $km \cdot h^{-1}$, ES: 0.22 (0.7 - 1.2); E4 (k) p = .00, CI: 0.4, 1.2 $km \cdot h^{-1}$, ES: 0.26 (0.7 - 1.2); E_7 (l) p = .05, CI: .1, 1.5 $km \cdot h^{-1}$, ES: 0.18 (0.8 - 1.1); E_8 (m) p = .05, CI: .1, 1.7 $km \cdot h^{-1}$, ES: 0.18 (0.8 - 1.2).

FIGURE 5 – The acceleration distance (m) across PEAK 5-minute epochs during elite Gaelic football match-play. Data presented as mean ± SD.

Mean percentage change from $\bar{x}$ 45 at 5_{PRE}, PEAK, 5_{POST} and 10_{POST} for Acceleration distance (m). Significant difference $p<0.05$ was observed from PEAK and 5_{PRE} (a) p = .00, CI: 165, 193 m, ES: 1.75 (1.45 - 2.0); 5_{POST} (b) p = .00, CI: 137, 162 m, ES: 1.4 (1.45 - 2.0); 10_{POST} (c) p = .00, CI: 117, 160 m, ES: 1.25 (1.45 - 2.0). Significantly difference $p<0.05$ from $\bar{x}$ 45 and PEAK (d) p = .00, CI: 129, 186 m, ES: 1.38 (1.1 - 1.65). Significantly different $p<0.05$ from 5_{PRE} and 5_{POST} (e) p = .02, CI: 4, 56 m, ES: .30 (.04 - .53).

1 **FIGURE 1**


14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
Accelerations
a
b
c
d
1st half
2nd half
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
Epoch 1-14 0-70 minutes
ACCEPTED

2

FIGURE 2

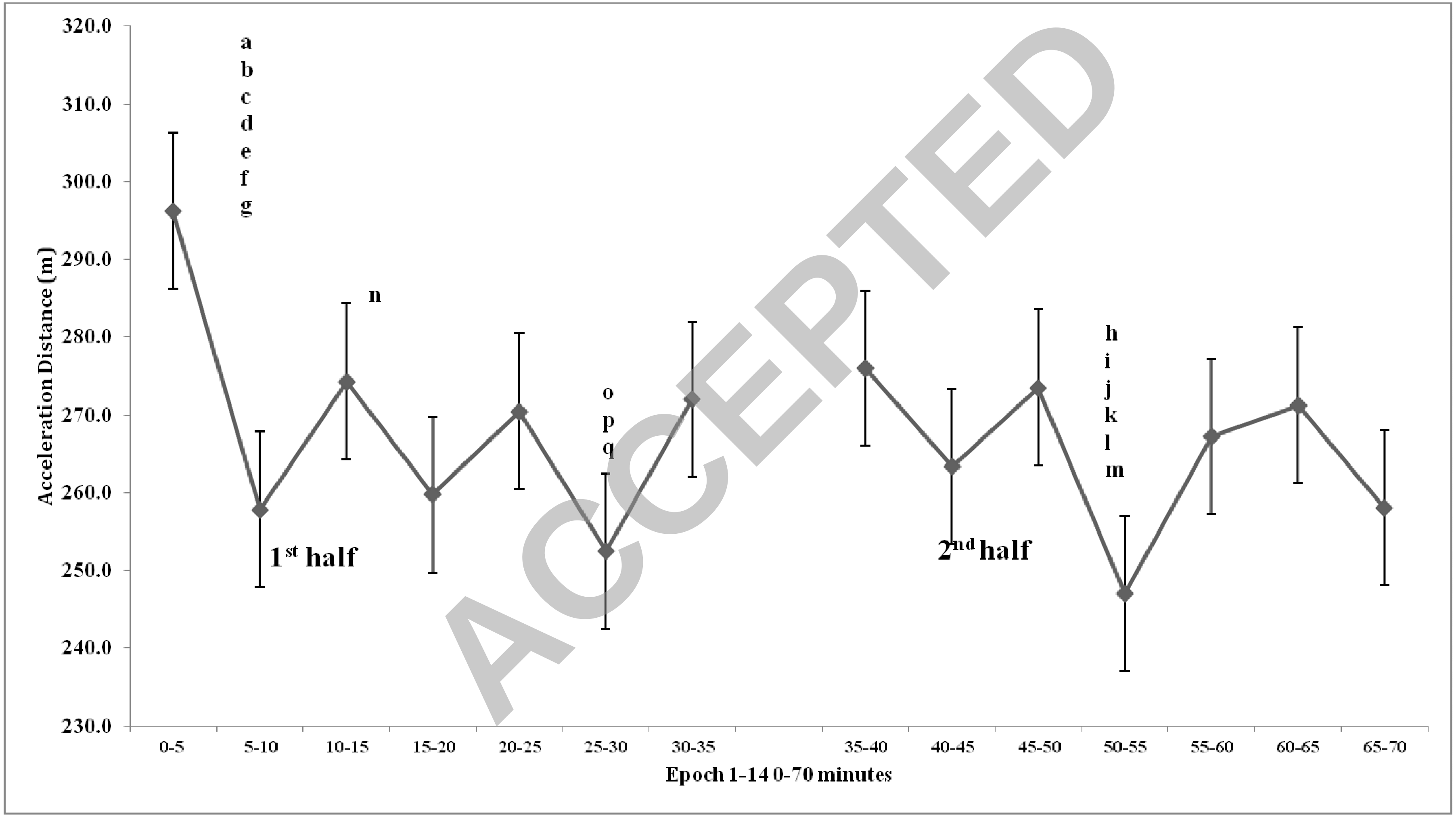

320.0
310.0
300.0
290.0
280.0
270.0
260.0
250.0
240.0
230.0
Acceleration Distance (m)
a b c d e f g
n
o p q
h i j k l m
1st half
2nd half
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
Epoch 1-14 0-70 minutes
ACCEPTED

FIGURE 3

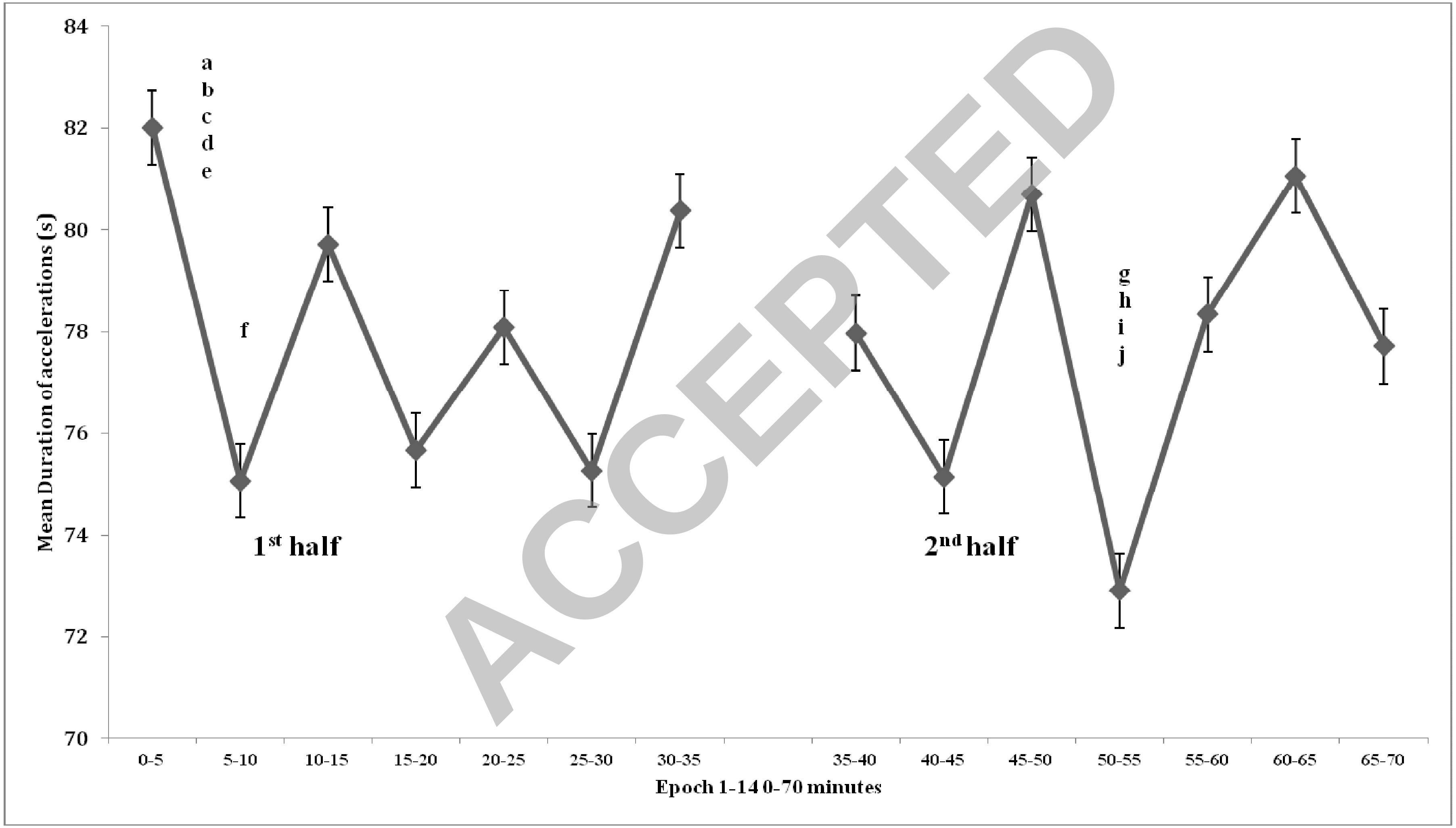
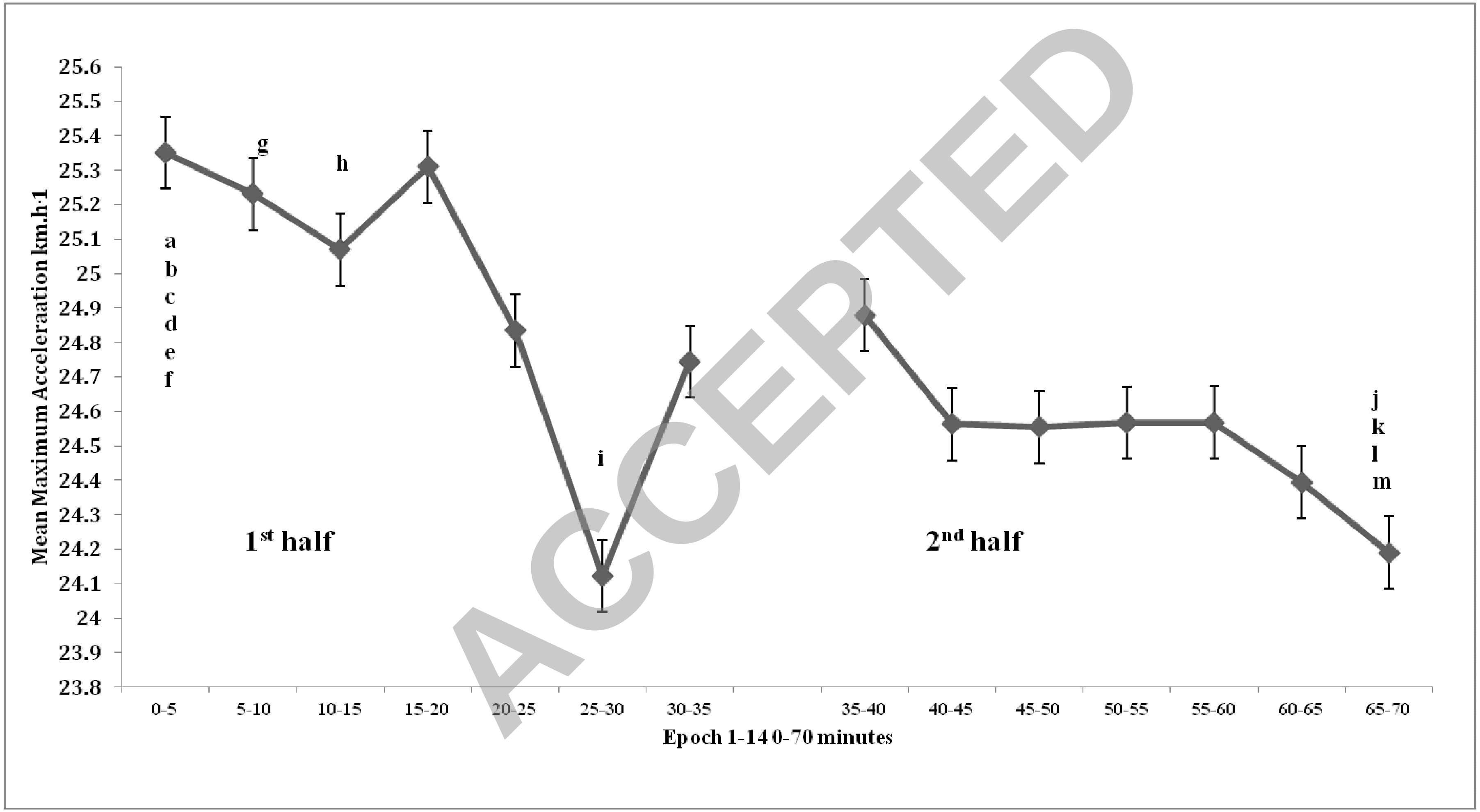
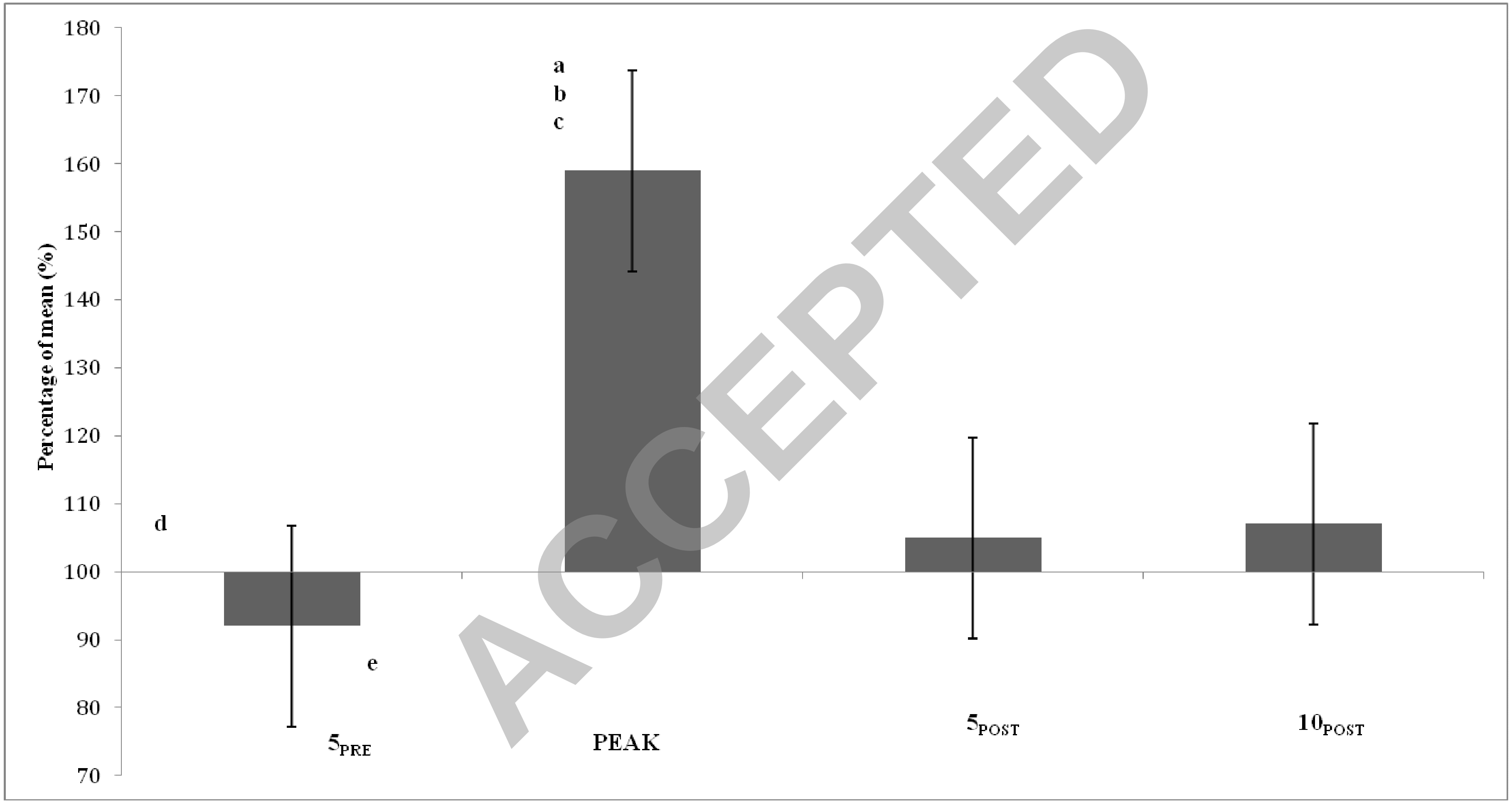

84
82
80
78
76
74
72
70
Mean Duration of accelerations (s)
a
b
c
d
e
f
g
h
i
j
1st half
2nd half
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
Epoch 1-14 0-70 minutes

FIGURE 4



Mean Maximum Acceleraation km.h·1
25.6
25.5
25.4
25.3
25.2
25.1
25
24.9
24.8
24.7
24.6
24.5
24.4
24.3
24.2
24.1
24
23.9
23.8
a
b
c
d
e
f
g
h
i
j
k
l
m
1st half
2nd half
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
Epoch 1-14 0-70 minutes

9 **FIGURE 5**


180
170
160
150
140
130
120
110
100
90
80
70
Percentage of mean (%)
a
b
c
d
e
5PRE
PEAK
5POST
10POST

10