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Original research

Deceleration characteristics of elite Australian male field hockey players during an Olympic tournament

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ABSTRACT

Objectives: This study described the deceleration efforts of the Australian men's field hockey team during the 2016 Olympics by categorising efforts into 'bands' of intensity; and comparing the deceleration intensity and frequency by player position, game period and opponent.
Design: Descriptive retrospective analysis.
Methods: Global positioning system sensors (MinimaxX S4, Catapult Sports Pty. Ltd., Melbourne, Australia; 10 Hz) were worn by 15 male field hockey players during six games of the 2016 Olympic tournament.
Results: There were 8998 individual deceleration efforts ($\leq -3\ ms^{-2}$) performed over the tournament with the most intense effort measured at $-13.6\ ms^{-2}$. Deceleration intensity 'bands' were calculated using Receiver Operator Characteristic (ROC) curves as low intensity = -3 to $-5.99\ ms^{-2}$; medium intensity = -6 to $-8.99\ ms^{-2}$; high intensity = -9 to $-11.99\ ms^{-2}$; and, very high intensity = $<-12\ ms^{-2}$. There were no significantly different decelerations between field positions but decelerations performed within game period one were more intense than game period two ($-0.11 \pm 0.01\ ms^{-2}$, $p < 0.001$). Deceleration efforts were more frequent in game period one than two [$X^2(3, N = 8997) = 12.00$, $p = 0.007$].
Conclusions: Decelerations are common in elite field hockey and very high intensities are present. These findings, in conjunction with other metrics can be used as a tool to monitor the load associated with training and match play in field hockey.

Practical implications

- As very intense decelerations were identified in elite field hockey, it is recommended coaches develop players for this demand.
- Practitioners may wish to consider the suggested classification of decelerations into mathematically valid bands (as shown in this study) when investigating the work performed by their athletes or team throughout training or games.
- The first period of the game is the most demanding in elite men's field hockey in terms of deceleration work; however, further investigation is warranted to explore the significance of this finding.

1. Introduction

At the elite level, field hockey is characterised by periods of low intensity activity (113 ± 51 s; standing, walking and jogging) interspersed with short (3.3 ± 1.9 s) sprint efforts at high velocity (maximum $8.75\ ms^{-1}$).[1–3] Numerous studies have examined the movement demands of elite field hockey players during international games,[1,3,4] and have primarily focussed on reports of total distance and high speed running as performance indicators. The act of achieving a high velocity and then decelerating quickly to change direction, is an equally important component of performance.[5,6] Due to the highly intense, 'stop-start' nature of field hockey, repetitive deceleration efforts are required, particularly at the elite level.[7] These repetitive deceleration efforts increase the neuromuscular and metabolic demands imposed on players throughout a match.[5,8,9] Therefore it is important to improve our understanding of decelerations in a field hockey match.

Deceleration is the act of partially or completely slowing the body's centre of mass and is used in sport to cause a change

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in direction of movement, avoid collision or make a skilful manoeuvre.[6] When decelerating, athletes typically use several shortened gait cycles to rapidly absorb the forces involved by eccentrically contracting lower-body muscles.[6] While it is clear competent deceleration ability is critical to the game of field hockey, decelerations are also associated with exercise induced muscle damage[6,10] and a quicker rate of fatigue development.[7] Lakomy and Haydon[7] showed faster performance decrements (occurring in sprint 2 rather than sprint 4 of a 6 sprint test) in repeat sprint times when elite male field hockey players (n = 18) were forced to decelerate to a complete stop (over 6 m) after a 40 m sprint (5.82 ± 0.54 s) rather than decelerate slowly to a jog (over 20 m) and then to a stop before the next sprint.[7] Furthermore, female field hockey players have been shown to be at significantly higher risk of injury in the second half of the game compared to the first, suggesting fatigue may be linked to increased injury risk.[11] Therefore, developing a method of classifying and describing deceleration, could advance load monitoring and fatigue management of athletes.[12]

Wearable sensors are commonly used in sport to quantify the movement of athletes.[13] These devices may provide a means of describing the deceleration demands of field hockey, as previously demonstrated by studies in soccer[14] and rugby union.[15] Wearable sensor technology can comprise of a: global positioning system (GPS); accelerometer; heart rate sensors; magnetometer; and, gyroscope, although the GPS component is the most commonly utilised.[13] This component of the sensor provides detailed and precise (0.7% standard error) information of an athlete's movements.[13] There is agreement in the literature regarding the ability of early GPS units (5 Hz) to measure total distance (2% typical error measurement; TEM) and medium to low velocities with acceptable accuracy (4.3% TEM).[16] However, Jennings et al.[17] have shown that when quantifying the distance of a 10 m sprint task, the TEM associated with 1 Hz and 5 Hz wearable sensors was 32.4 ± 6.9% and 30.9 ± 5.8%, respectively. With the introduction of GPS units that sample at or above 10 Hz and allow integration of data from the inbuilt triaxial accelerometer,[3] GPS is now deemed to be an adequate tool to measure deceleration (coefficient of variation = 11.3 ± 0.44%, r = 0.98).[5,18]

Akenhead et al.[14] classified the deceleration of 36 professional male soccer players using 10 Hz non-differential GPS (MinimaxX, Catapult Innovations, Canberra, ACT, Australia). Deceleration intensity bands of low (−1 to −2 ms^{-2}), medium (−2 to −3 ms^{-2}) and high intensity decelerations (<–3 ms^{-2}) were arbitrarily selected. Similarly, Owen, Venter, Du Toit and Kraak[15] quantified (SPI HPU, GPSports Systems®, Canberra, Australia; 15 Hz) the number of decelerations and distance covered within three deceleration bands by 33 elite male rugby union players from a single squad during 14 matches of a major international club competition (15-team Super Rugby competition). This analysis was only performed over the first half of each match and separated decelerations occurring in collisions from decelerations due to eccentric contractions of lower-body muscles (non-collision decelerations). The non-collision decelerations were then classified in to arbitrary bands of light (−1 to −1.99 ms^{-2}), moderate (−2 to −2.99 ms^{-2}) and heavy intensity (−3 to −5.99 ms^{-2}).[15] In contrast, the categorisation of decelerations has yet to be applied in field hockey, a sport where repeated deceleration ability is critical.[7] Therefore, the aims of this study were to: describe the decelerations of elite male field hockey players during Olympic competition using 10 Hz GPS; classify these movements into distinct categories; and, compare the deceleration intensity and frequency of efforts between different player positions, opponents and game periods.

2. Methods

This study was a retrospective analysis of data from the men's Australian Field Hockey team over eight days in the 2016 Summer Olympic games (n = 6 games). Data were gathered from 15 male players [27.3 ± 8.51 years old, 170 ± 84 caps (number of international games), 179.6 ± 5.98 cm, 75.9 ± 6.67 kg]. All players remained in the same position throughout each game (5 forwards, 5 midfielders and 5 defenders). The GPS data for each player were collected from a wearable sensor (MinimaxX S4, Catapult Sports Pty. Ltd., Melbourne, Australia; 10 Hz) contained within a chest harness and situated between the scapulae. All GPS data were collected and stored by Hockey Australia staff and provided to the research team in a de-identified form. Data were excluded from analysis if; the wearable sensor stopped collecting data for any reason, or an athlete did not participate in the entire game. Ethical approval to analyse the de-identified data was obtained from the Curtin University Human Research Ethics Committee (RDH 24-16).

Data were extracted using manufacturer supplied software (Catapult Sprint, Version 5.1, Catapult Sports Pty. Ltd., Melbourne, Australia) and exported to a customised spreadsheet (Microsoft Excel, Version 14.5.8, 2011, Microsoft Corporation; Redmond, Washington). Individual deceleration efforts were identified and separated from other decelerations based on average sprint durations reported in the literature.[1,2] Deceleration efforts with peak intensities between zero and −3 ms^{-2} were removed from the study as particular attention was intended to be directed towards rapid decelerations which have been shown to induce fatigue.[7,10,14] Non-genuine peak decelerations (defined as decelerations that did not occur through self-effort, such as a fall or collision) were verified from televised video footage by an investigator (SC); manually marked in match analysis software (Sportscode, Version 11.1.4, HUDL, Agile Sports Technologies, Inc., Lincoln, Nebraska); cross-referenced against the timestamp; reviewed and excluded. Further, any decelerations that occurred when a player was absent from the field were omitted from the analyses.

In order to categorise decelerations into bands, all peaks of deceleration efforts were allocated into bins of −1 ms^{-2}, and plotted in a histogram to show the frequency within each bin. The frequency was then transformed ($\log_{10}$) to highlight the less frequent but greater peak intensity decelerations. Deceleration bands were estimated from the frequency distribution in accordance with the aforementioned ranges. To check the accuracy of the estimated ranges of deceleration, coordinates of Receiver Operator Characteristic (ROC) curves were used to calculate the sensitivity and specificity of all data points.[19,20] Sensitivity and specificity are terms that are used in medical diagnostics to evaluate the ability of a test to detect the true disease state of a patient.[19] Sensitivity refers to the percentage of true positive outcomes, while specificity refers to the percentage of true negative outcomes.[19] To precisely determine the cut-off between each band, the Youden Index (J) was calculated (J = 'sensitivity + specificity − 1').[21] The Youden Index is an assessment of each data point as the placement for a cut-off so that the maximum amount of true positive values are placed within a category, while preventing the maximum amount of true negatives from being placed in the same category.[21] Values for the Youden Index range from 1 to −1, whereby a value of 1 or −1 indicates a perfect cut-off.[21]

In order to examine the effect of player position, game period (period 1 = quarter 1 + quarter 2; period 2 = quarter 3 + quarter 4) and opponent on deceleration intensity, multilevel censored (Tobit) regression models with random player intercepts were performed and results summarised using back-transformed marginal means and their 95% confidence intervals. Tobit regression models were selected due to the censored nature of the outcome data. Cohen's D was also calculated to describe effect size differences. Player

Table 1
Mean and 95% CI (mean) for the effects of player position, game period and opponent on deceleration intensity (ms^{-2}).

		Mean deceleration	95% CI mean deceleration	p-Value	Cohen's D
Opponent	Spain	−4.35	−4.43, −4.28		
	Belgium	−4.28	−4.36, −4.21	0.084	−1.18
	New Zealand	−4.25	−4.33, −4.17	0.023	−1.14
	Great Britain	−4.25	−4.35, −4.20	0.055	−1.17
	Brazil	−4.27	−4.35, −4.20	0.059	−1.09
	The Netherlands	-4.27	-4.32, −4.17	0.012	−1.17
Position	Defence	−4.24	−4.33, −4.15		
	Forward	−4.30	−4.39, −4.21	0.341	−1.00
	Midfield	−4.30	−4.39, −4.21	0.332	−1.01
Period	1	−4.33	−4.39, −4.27		
	2	−4.22	−4.28, −4.17	<0.001	−1.44

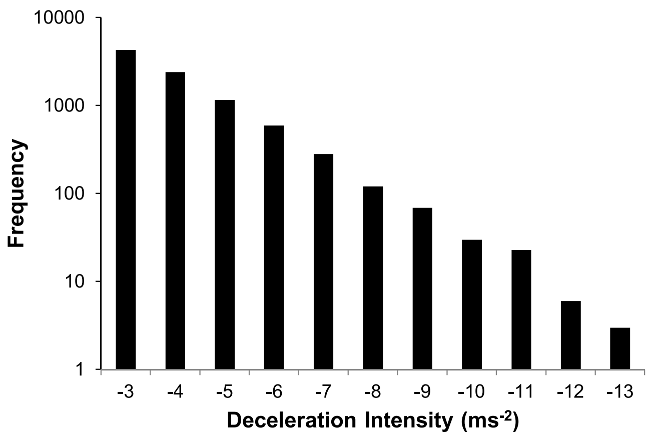

Fig. 1. The frequency of deceleration efforts, grouped by every $-1\ ms^{-2}$, performed by every player for every game.

characteristics of height, mass and number of caps were checked for significance in the models. Frequencies distributions of banded deceleration efforts within the three comparison groups (player position, game period and opponent) were compared using Chi squared tests. Statistical analysis was conducted using SPSS version 24.0 (Armonk, NY) and Stata 15 (Stata Statistical Software; StataCorp LP, College Station, Texas). All hypothesis tests were 2-sided, and *p*-values of <0.05 were considered statistically significant.

3. Results

The mean number of satellites available to each GPS unit was 11 ± 0.59 and a mean horizontal dilution of precision (HDOP) of 0.88 ± 0.03.[22] Overall, there were a total of 8998 deceleration efforts $\leq -3\ ms^{-2}$ performed over the tournament with the most intense deceleration measuring $-13.6\ ms^{-2}$. Based on the exclusion criteria, two data sets were removed from a total of 90 data sets, as the wearable sensor did not begin sampling at the start of the game (Fig. 1).

By observing the frequency distribution, the deceleration bands were estimated and placed into the following groups: band 1 (low intensity) = −3 to $-5.99\ ms^{-2}$; band 2 (medium intensity) = −6 to $-8.99\ ms^{-2}$; band 3 (high intensity) = −9 to $-11.99\ ms^{-2}$; and, band 4 (very high intensity) = <−12 ms^{-2}. The Youden Index calculations show the optimum placement of the cut-offs between each band to be[21]: Band 1–2 (deceleration cut-off = 6.01 ms^{-2}; sensitivity = 0; specificity = 0.017; $J = -0.983$); Band 2–3 (deceleration cut-off = $-8.99\ ms^{-2}$; sensitivity = 0; specificity = 0; $J = -1$); and Band 3–4 (deceleration cut-off = $-11.97\ ms^{-2}$; sensitivity = 0; specificity = 0; $J = -1$).

The multilevel censored regression model showed a significant within game period effect (Table 1), with mean deceleration intensity in game period one significantly greater than game period two ($p = <0.001$). Mean deceleration effort was significantly lower in the game against Spain compared to the games against New Zealand ($p = 0.023$) and The Netherlands ($p = 0.012$) but there were no significant differences against any other opposition teams. There were no significant differences in deceleration effort between field positions and no covariate effects were evident for player characteristics.

There were significant differences between deceleration frequency bands and game periods [X^2 (3, N = 8998) = 12.00, p = 0.007]. A greater number of deceleration efforts occurred during game period one, the majority of which came from the medium (59.3%) and the very high (55.6%) intensity bands. The results also show that 87.5% of all deceleration efforts occurred at low intensity, 11.1% occurred at medium intensity, 1.4% occurred at high intensity and 0.1% of efforts occurred at very high intensity. No significant relationship was found between deceleration frequency and playing position, or deceleration frequency and opponent (Table 2).

4. Discussion

The aim of this study was to describe the decelerations of elite male field hockey players during competition using 10 Hz GPS; classify these movements into distinct categories; and, compare the deceleration intensity and frequency of efforts between different player positions, opponents and game periods. The results of this study show that decelerations are commonplace in elite field hockey (102 ± 19.78 deceleration efforts/player/game; Forward = 492, Midfield = 523, Defence = 485 deceleration efforts/game; less than $-3\ ms^{-2}$) and occur at intensities up to $-13.6\ ms^{-2}$. The frequency of decelerations vary from previous reports of female soccer players (430 ± 125 deceleration efforts/player/game)[23] and male rugby players (82 ± 6.7 deceleration efforts/player/half).[15] The differences in deceleration characteristics between this study and previous research are likely due to two reasons. Firstly, the different constraints of the sports would have placed specific demands on the athletes, which may have caused decelerations to occur differently; secondly, the methodologies and intensity thresholds used to classify decelerations and detect when a deceleration occurs were different between the previous and present studies. While the present investigation adopted a statistical approach to classify decelerations, Akenhead et al.[14] used arbitrary bands based on unpublished data and Owen, et al.[15] used manufacturer determined acceleration and deceleration ranges, whereby a 'heavy' deceleration would be equivalent to a medium deceleration in the present study.

The presence of mathematical modelling to identify precise band cut-offs may give the classifications of decelerations in the present study more validity compared to previous investigations.

Table 2
Frequency distributions and comparisons between opponent, position and period groups.

Band:		1 (Low) n = 7872 n (%)	2 n = 995 n (%)	3 n = 122 n (%)	4 n = 9 n (%)	p-Value
Opponent	BEL	1442 (18.3)	191 (19.2)	29 (23.8)	3 (33.3)	0.362
	ESP	1381 (17.5)	193 (19.4)	22 (18.0)	0 (0.0)	
	NZ	1118 (14.2)	136 (13.7)	23 (18.9)	2 (22.2)	
	GBR	1407 (17.9)	161 (16.2)	20 (16.4)	0 (0.0)	
	BRA	1300 (16.5)	168 (16.9)	14 (11.5)	2 (22.2)	
	NED	1224 (15.5)	146 (14.7)	14 (11.5)	2 (22.2)	
Position	Def	2556 (32.5)	313 (31.5)	40 (32.8)	1 (11.1)	0.616
	For	2593 (32.9)	315 (31.7)	39 (32.0)	3 (33.3)	
	Mid	2723 (34.6)	367 (36.9)	43 (35.2)	5 (55.6)	
Period	1	4228 (53.7)	590 (59.3)	61 (50.0)	5 (55.6)	0.007
	2	3644 (46.3)	405 (40.7)	61 (50.0)	4 (44.4)	

For example, if the bands suggested in the previous literature[14,15] were applied in this study, a large proportion of decelerations (-6 to $-12\,ms^{-2}$; 1117 efforts or 12.4%) may have been incorrectly classified. The results from the specificity and sensitivity analysis suggest all bands estimated were precise for the data set analysed ($J = -0.983$ to -1). Although these results show the construct and content validity of the approach, these bands do however, need to be correlated with environmentally appropriate data (such as player fatigue, measures of muscle damage, soreness or injury) in order to enhance it's utility and validity.

In this study, significant differences in deceleration intensity between game period one and two were detected (average deceleration intensity in period one > period two; Table 1) and frequency (53.7% of deceleration efforts occur in period one and 46.3% in period two). Differences between game periods have also been reported where hockey players completed greater total distance in period one compared to period two (4.8% more, 198 m).[1] Furthermore when national female field hockey games were split into quarters rather than halves, players performed significantly less moderate intensity distance in quarters three and four than quarter one (Q1: 350 ± 61 m, Q3: 310 ± 63 m, Q4: 305 ± 79 m); and there was a significant decrease in high intensity distance from the first quarter to the second and third (Q1: 117 ± 36 m, Q2: 97 ± 30 m, Q3: 111 ± 32 m).[24] It is however, not clear whether these differences were tactical or due to fatigue.[24]

The Cohen's D values calculated in Table 1 show that although the absolute difference of deceleration intensity for within group comparisons (player, position and period) are small, they all have effect sizes of >0.8 or <−0.8 emphasising the significance of these differences and highlights the importance of utilising GPS as a load monitoring tool in field hockey.[25] However, whilst the quantification of decelerations in field hockey is useful knowledge, correlating this data to performance or injury metrics could provide a deeper insight into player demands and load management.

This investigation showed differences in deceleration frequency occurred in the low and medium deceleration bands, whereas the deceleration frequency in the high and very high band were identical. There were no significant differences found for deceleration intensity or frequency between playing position which is contrary to previous field hockey time-motion studies that showed positional differences in total distance covered and high-speed running.[3,4,8] In previous studies, midfield players completed more total distance (700 m and 170 m per player/game, respectively)[3,8] and high-speed running distance (820 m and 288 m per player/game, respectively)[3,4] than defenders. The homogeneity of the participants, being highly elite athletes that completed similar physical training may be the likely cause for this lack of difference. Further investigation examining athletes of different skill levels as well as playing styles is warranted to confirm the relationship between deceleration intensity and frequency on playing position and opponent.

The accuracy of GPS indices can be influenced by the number of satellites available to connect to the GPS units, and the HDOP, a measurement of satellite geometry.[22] The number of satellites (11 ± 0.59) available to connect to the GPS units were higher and HDOP (0.88 ± 0.03) lower (and therefore more accurate) than previous research.[22,26,27] The present study is an isolated analysis of decelerations in field hockey, however, it may be useful to consider decelerations in the context of other actions that occur in a hockey game (e.g. high-speed running or accelerations) as decelerations rarely occur in an isolated manner under match circumstances. Therefore, an analysis such as this could prove insightful in the future. Lastly, previous research has supported the use of 10 Hz GPS to measure high-speed velocity, acceleration and deceleration with sufficient accuracy with coefficients of variation of up to 11% being reported.[5] Investigators have started using accelerometers (already housed in the wearable sensors used in this study) to measure sporting movement demands[28] and future investigations may choose to adopt this approach.

5. Conclusion

The present study found that decelerations are commonplace in male field hockey, and accurately determined cut-offs for low (-3 and $-5.99\,ms^{-2}$); medium (-6 to $-8.99\,ms^{-2}$); high (-9 to $-11.99\,ms^{-2}$); and, very high ($\leq -12\,ms^{-2}$) decelerations. Whilst differences in intensity and frequency between playing position, game period and opponent were displayed, the practical relevance warrants further investigation. A greater number of low and medium decelerations were performed during the first period compared to the second, however, high and very high decelerations occur at the same frequency in period one and two. Overall, the results of this study will inform future research which will enable coaches to monitor the load of their athletes during training and matches, ultimately providing advancements in performance analysis.

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