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The characteristics of within match play acceleration and deceleration activity in international hockey

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A B S T R A C T

This investigation identified the common characteristics of both acceleration and deceleration in senior male international field hockey matches. The aim was to identify these characteristics on a positional basis. The activity of 24 players across 10 matches was investigated. Each participant wore an individual GPS unit (STATSports APEX), operating at 10 Hz. Based on match data, we identified all acceleration and deceleration efforts. Additional information relating to that effort was extracted such as distance, magnitude and duration per effort, time between efforts. The largest proportion of acceleration (71%) and deceleration (61%) events were completed within a 3-3. 99m.s^{-1} range. There was a greater proportion of deceleration efforts (11%) than acceleration efforts (6%) observed at magnitudes >5m.s^{-1}. Up to 54% of all acceleration efforts were within a distance of 2-7m and 93% of deceleration efforts were ≤5m. Defenders completed acceleration efforts of a shorter distance (6.20m) as compared to both midfielders (7.59m) and forwards (7.54m), with no difference in magnitude identified. The parameters identified in this investigation can aid in the prescription and monitoring of training for international hockey players. In training, players should experience accelerations and decelerations of similar distances and magnitude to those experienced during match play. These data can be compared to training drill data to ensure players are being afforded the opportunity to complete efforts of similar magnitude and distance in the training environment. However, further investigation relating to the contextual environment in which these events are accumulated is warranted.

1. Introduction

The physical output profiles of international hockey players during match play have been established in a comprehensive manner. It is intermittent in nature with a large proportion of activity completed in low to moderate speed zones (64%) (James et al., 2021). Match play is interspersed with intense short periods of play presenting opportunities to reach maximal velocities of 8.75m/s and peak intensities of 199–223 metres per minute, achieved in 1-3 minutes, which is similar to results found in the Australian football (Casamichana et al., 2018; Cunniffe, Grainger, et al., 2021; Delaney et al., 2017; Delves et al., 2019; Johnston et al., 2020). High intensities are enabled in field hockey due to unlimited rotations (Linke & Lames, 2017), a four-quarter match format and the use of the "self-pass" (Tromp & Holmes, 2011) rule, however, fluctuations are apparent from quarter to quarter (Haro et al., 2021; Ihsan et al., 2017; Morencos et al., 2018) and within rotations (Linke & Lames, 2017; Lythe & Kilding, 2013).

Due to pitch constraints in field hockey, 230 m² per player compared to 320 m² in soccer (Olthof et al., 2018), hockey players reach high intensities through short, high magnitude acceleration efforts while accumulating limited max velocity efforts (Casamichana et al., 2018; Ihsan et al., 2017; Morencos et al., 2018). The ability to accelerate is a crucial physical characteristic of high-level field hockey players due to the emphasis on repeat sprint ability, for which acceleration plays a large role (Spencer et

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al., 2004). Repeat sprint ability has been widely investigated within field hockey. Spencer et al. have documented up to 17 occasions of at least 3 sprint efforts, with less than 20 seconds of recovery between efforts, per team in one match. However, the definition of sprinting utilised was "maximal effort with a greater extension of the lower leg during forward swing and a higher heel lift relative to striding". This reliance on identifying efforts visually, could cause high magnitude acceleration efforts to be mistakenly categorised as repeat sprint efforts, which in recent times, are more commonly identified using microtechnology to identify efforts that reach certain velocity thresholds. A further consideration in field hockey physical output profiling is that tournaments pose unique demands on players, with five matches played in seven days, typically reducing perceived wellness which impacts upon physical output (Ihsan et al., 2017). It has been established that accelerations and decelerations are major contributors to post-match muscle damage (Gastin et al., 2019) and may be a large contributor to the disturbed physiological and neuromuscular pattern displayed by players post-match and during a tournament (Beato & Drust, 2021; Harper & Kiely, 2018). This may be because high rates of force development are required for acceleration (di Prampero et al., 2005) and in contrast to constant velocity running, acceleration also demands greater neural activation of the muscles (Mero & Komi, 1987). As players change velocity, even when their velocity is low, athletes require a great deal of metabolic energy, not just during the most intense phases of the match (sprinting and high-speed running) (Osgnach et al., 2010) with frequent changes of velocity reported to have an increase metabolic cost of 6-20% even at low magnitudes (Seethapathi & Srinivasan, 2015). Furthermore, a correlation between post-match creatine kinase levels and the number of high intensity decelerations completed during match play in hockey has been established, potentially linked to the high eccentric demands of these actions (McMahon & Kennedy, 2021). Thus, there is a high potential for both accelerations and decelerations to cause a disturbed physiological state. This potentially disrupts the performance potential of a hockey player, highlighting the need to track these actions.

Each position within the team has a specific physical output profile – forwards and midfielders compete at higher relative intensities and complete more repeat sprint bouts than defenders, while additionally, fatigue patterns are also distinctly different between positions (Morencos et al., 2018). Morencos et al. (2018) have established that acceleration and deceleration may be the two metrics most sensitive to fatigue in field hockey, due to these metrics displaying a reduction in volume during competition while high speed running was maintained. This is important as a key aspect of field hockey physical performance is repeat performances in a short period of time. Consequently, tracking these variables may provide an insight into the fatigue levels of players. However, according to Harper and Kiely (2018) acceleration and deceleration efforts impose significantly different demands on the physiological systems of the body despite being viewed as equivalent loading parameters. This may be attributed to the magnitude, duration, and frequency of each type of action (Beato & Drust, 2021).

There is presently limited research regarding acceleration or deceleration efforts in field hockey despite the highly metabolically challenging and fatiguing nature of these efforts. Morencos et al. has established that fatigue is present across quarters in club level field hockey with moderate and high-intensity accelerations showing a decline (11.4 ± 3.9%) in later quarters (Morencos et al., 2018). The acceleration bands utilised were moderate 2-2.9m·s² and high >3m·s² which is consistent with the data proposed for acceleration bands in elite male field hockey (Dwyer & Gabbett, 2012). Chesher et al. (2019) have established the typical characteristics of deceleration efforts in elite field hockey. A peak magnitude of -13.6m/s² was noted alongside an average magnitude of -4.25-4.35m/s² across 5 matches. A -0.11m/s² decrement between halves was also identified (Chesher et al., 2019). However, these values refer to match play in elite international hockey, utilising two halves instead of four quarters. Currently, there are no available data relating to the typical distance per effort, the magnitude of efforts and the typical counts across positions in the current match format in international hockey. Identifying typical loading patterns for these two metrics may provide parameters for the monitoring of the accelerations and decelerations experienced by international field hockey teams relating to match play. These parameters can inform the national teams junior ages group physical development pathway physical training, by providing a benchmark for senior international level match play. Additionally, practitioners, at senior level can determine whether prescribed drills in training closely mimic the acceleration and deceleration demands of international matches with a consideration of playing position.

This investigation sets out to identify the acceleration and deceleration profile of elite field hockey players across positions in terms of frequency, duration, magnitude, and rest intervals in the updated match format of four quarters.

2. Methods

2.1. Participants

To be included in this investigation, players had to be an international hockey player and injury-free. Twenty-four players met the inclusion criteria and were split into four positions: defenders (mean relative to bodyweight back squat 1 repetition max (1RM) = 1.48, mean 5m time = 1.02 seconds), outside backs (1RM = 1.42, 5m time 1.02 seconds), midfielders (1RM = 1.36, 5m = 1.04 seconds), and forwards (1RM = 1.35, 5m = 1.03 seconds).

2.2. Apparatus

Each participant wore an individual GPS unit (STATSports APEX, firmware 2.50), operating at 10 Hz, for 10 international matches as part of their normal monitoring as members of the international field hockey squad. Institutional ethics approval was obtained from the Faculty of Research Ethics and Integrity committee (University College Dublin - LS – 17- 85) in accordance with the Helsinki Declaration. Before the commencement of the studies and monitoring of players, all participants provided written informed consent.

The reliability and validity of these units have previously been reported. They display a high level of validity in a team sport setting (Beato et al., 2018), as well as excellent inter and intra unit reliability (Beato & Keijzer, 2019). They report a small error of around 1– 2% compared to the criterion distances during 400-m, 128.5-m team sport-based circuit, 20-m trials, and maximal velocity (Beato et al., 2018). Crang et al. (2021) have stated these "devices generally possessed suitable reliability and consistency for threshold-based accelerations and decelerations". GPS data handling procedures, Horizontal Dilution of Precision and match details are as reported in Cunniffe et al. (2021) .

2.3. GPS Metrics

Accelerations were any effort that reached 3.0 m/s² for a minimum duration of 0.5 seconds while decelerations were noted as a reduction in velocity greater than 3.0 m/s² over a minimum duration of 0.5 seconds (Dwyer & Gabbett, 2012; Morencos et al., 2018; Romero-Moraleda et al., 2020). These efforts were derived solely from GPS data rather than the inertial sensors contained within the GPS units. Utilising the STATSports Apex Pro Series Software, all acceleration and deceleration efforts were identified and extracted alongside the following characteristics: the magnitude of the change of velocity during the effort, total effort duration, total effort distance and time since the last effort was completed. These are typical thresholds utilised in multiple investigations relating to accelerations and decelerations across multiple sports (Harper et al., 2019). By cross referencing the raw gps data with the timestamp within the match footage, the primary investigator was able to verify, or dismiss, potential outliers based on magnitude, duration, and distance.

2.4. Statistical Analysis

Linear mixed models (LMM) were utilised to examine the influence of position on the characteristics of acceleration and deceleration during match play. The approach used in the construction and use of LMMs replicates the approach previously reported by Cunniffe et al. (Cunniffe, Connor, et al., 2021; Cunniffe, Grainger, et al., 2021). The dependent variables were distance per effort, duration per effort, magnitude per effort and time between efforts.

3. Results

Table 1 outlines the mean number of acceleration and deceleration efforts completed across positions during an international match. There were no significant differences for the number of efforts completed between positions for either accelerations or decelerations ($p > 0.05$). Within positions, there was no significant difference identified between the number of accelerations ($p = 0.14$) and decelerations ($p = 0.74$) completed with and without accounting for time on pitch. Table 2 outlines the mean distance, duration, magnitude, and time since the last occurrence of each effort by high-intensity action type across positions.

No significant differences were identified between positions for magnitude per effort of either accelerations or decelerations ($p > 0.05$). Differences identified between positions regarding distance per effort can be found in Table 2. Regarding within position comparisons, accelerations were greater in distance but not magnitude per effort than decelerations for all positions ($p < 0.05$) (Table 2). There were no significant differences identified for time between efforts for between position comparison for either accelerations or decelerations type ($p > 0.05$).

Over half (54%) of acceleration efforts were between 2-7m long. 24% of acceleration efforts were between 10-20m in distance. 3% of accelerations were >20m with a max effort of 36m (Figure 1). Less than 1% of deceleration efforts were >10m. 93% of deceleration efforts were ≤5m (Figure 2). Figure 3 outlines the total percentage of efforts in each 1m.s² band for acceleration and deceleration efforts relative to magnitude. Figure 4 outlines similar data categorised by position. Figures 3 and 4 can be found in table format in the supplementary materials.

Table 1: Average, standard deviation (SD), median and range of acceleration and deceleration efforts during match play by position.

Position	Type	Count ± SD	Median	Range
Defender	Acceleration	46 ± 9	44	30 - 58
Defender	Deceleration	61 ± 8	64	45 - 73
Forward	Acceleration	57 ± 16	54	35 - 94
Forward	Deceleration	56 ± 23	47	30 - 112
Midfielder	Acceleration	52 ± 13	54	29 - 74
Midfielder	Deceleration	56 ± 12	57	30 - 74
Outside Back	Acceleration	54 ± 9	56	39 - 63
Outside Back	Deceleration	65 ± 19	65	40 - 101

Table 2: Average and standard deviation of distance per effort, magnitude per effort, duration per effort and the time between each occurrence by position.

Position	Type	Distance (m)	SD	ES	Magnitude (m.s2)	ES	SD	Duration (seconds)	SD	Time Between (seconds)	SD
Defender	Acceleration	6.20*†¥	4.62	1.23	3.70		0.61	2	1	23	16
Defender	Deceleration	2.17	1.46		-3.85*	0.22	0.73	2	1	20	16
Forward	Acceleration	7.54*	5.49	1.12	3.81		0.72	2	1	21	17
Forward	Deceleration	2.85	2.12		-3.99*	0.24	0.81	2	1	19	16
Midfielder	Acceleration	7.59*	5.43	1.20	3.78		0.68	2	1	21	16
Midfielder	Deceleration	2.77	1.94		-3.97*	0.26	0.80	2	1	20	15
Outside back	Acceleration	6.97*	5.27	1.19	3.76		0.71	2	1	21	16
Outside back	Deceleration	2.48	1.75		-3.95*	0.26	0.73	2	1	19	15

Note: *Significantly different to deceleration value within position. †Significantly different to midfielders. ¥ Significantly different to forwards. Effect sizes are for differences for within position comparisons for distance per effort and magnitude per effort.

4. Discussion

This investigation outlines the common features of both acceleration and deceleration activities in senior male international field hockey match play. The typical distance, duration, and magnitude per effort across positions have been established. Defenders completed accelerations which were of shorter distance per effort, but similar magnitude compared to midfielders and forwards highlighting the unique positional nature of acceleration demands. Accelerations were of longer distance while decelerations were of greater magnitude for all positions. The largest proportion of acceleration and deceleration events were completed in the 3-3. 99m.s^{-1} range. 54% of all acceleration efforts were completed within a distance of 2-7m. 93% of deceleration efforts were ≤5m. These findings provide a clearer understanding of how senior international field hockey players accumulate accelerations and decelerations in the revised, current match format and may inform the future training practices of elite hockey teams.

There was no significant difference in the number of either high-intensity actions completed between positions, despite having different tactical roles, which have been shown to influence movement patterns (Casamichana et al., 2018; Cunniffe, Grainger, et al., 2021; Morencos et al., 2018). This is especially noteworthy in relative terms given the different quantity of total time played by each position. The availability of unlimited rotations typically reduces the time forwards are active within a match as it has been shown that increased rest between on pitch stints may improve technical and physical performance (Lythe & Kilding, 2013). This in turn may lead to less absolute physical output and energy expenditure, therefore enabling higher intensity activity to occur. This may explain the findings of Morencos et al. (2018), who reported that forwards completed a greater number of accelerations per-minute, yet not in the present investigation. This may be due to the increased physical capacity of international level players compared to club level players (Jennings, 2012), investigated by Morencos et al. (2018) with international players across positions able to exhibit and maintain greater high-intensity activities. This is further evidenced by the findings of Chesher et al. (2019) who did not report any differences between positions for decelerations completed at international level.

Typically, in other field sports, players exhibit greater frequencies of high-intensity deceleration efforts compared to acceleration efforts (Harper et al., 2019) and Morencos et al. (2018) reported a higher frequency of deceleration efforts per minute in elite club level field hockey for both defenders and midfielders. In contrast, in this investigation, there was no disparity between the number of efforts of each high-intensity action within positions. This replicates the findings of Chesher et al. (2019). This potentially highlights the stability of acceleration and deceleration efforts as a marker for monitoring field hockey players output longitudinally and for performance analysis purposes. Additionally, how these efforts are accumulated is warranted as given the different tactical roles of each position they may be accumulated in different tactical context. An exploration of a field hockey players physical output within match phases such as counter-attacking or deep defending, may offer further insight into how accelerations and decelerations are accumulated and why there is no discrepancy between the number of efforts completed between positions.

Within position contrasts identified that deceleration activities exhibited greater magnitudes (small ES) compared to acceleration activities for all positions. Deceleration efforts may produce higher magnitude efforts as they are frequently unplanned and unpredictable, as often, they are in response to an opposition

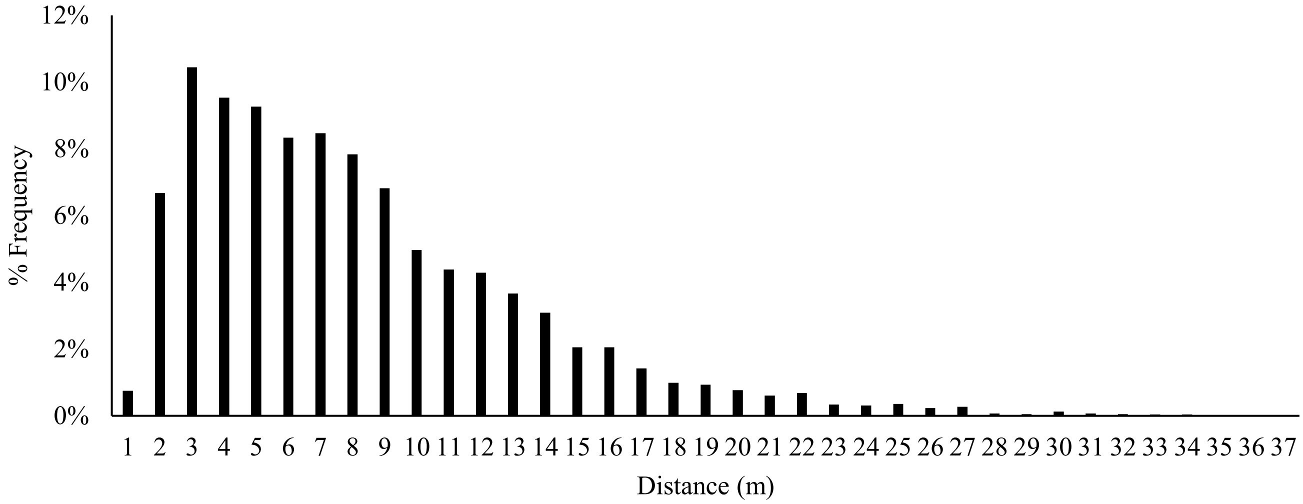

Figure 1: Percentage frequency of acceleration efforts by distance (m) across all players.

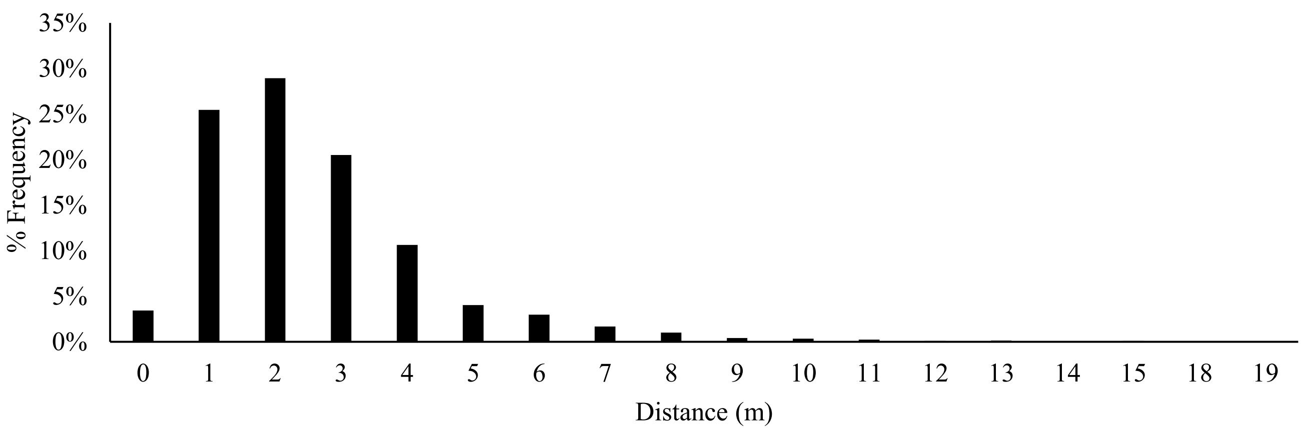

Figure 2: Percentage frequency of deceleration efforts by distance (m) across all players.

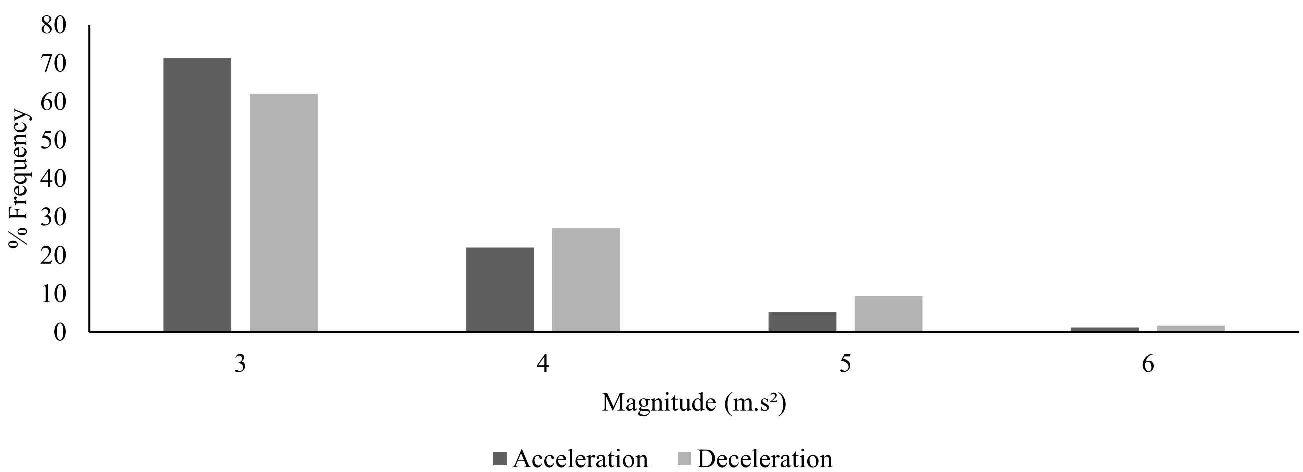

Figure 3: Percentage frequency of acceleration and decelerations by magnitude (m.s^{-2}).

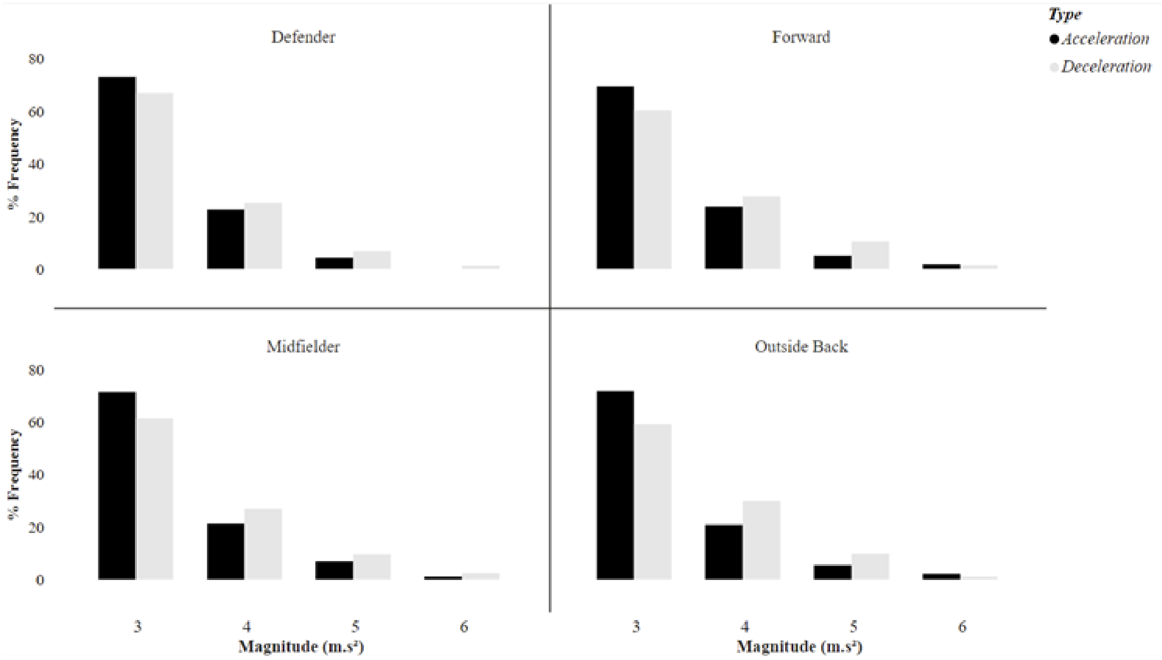

Figure 4: Percentage frequency of acceleration and decelerations by magnitude (m.s^{-2}) categorised by position.

players movement or change of direction (Cunniffe, Connor, et al., 2021). Unplanned changes of velocity or direction have been shown to have altered kinetic and kinematic patterns relative to planned movements which may be a contributory factor to the greater magnitude displayed (Brown et al., 2014). Further investigation is required to ascertain the phase of play that field hockey players accumulate the majority of deceleration efforts in. As such, this may provide further context for drill prescription regarding elements such as body orientation, angle of approach, and whether this is an on-ball or off-ball evasion event. Previous investigations (Morencos et al., 2018) have reported that forwards typically exhibit greater magnitudes when accelerating compared to decelerating, however, in this investigation this finding was not confirmed. This may highlight that forwards are starting to have a larger role in the defensive aspect of match play as it is assumed that deceleration events are linked to defensive actions when attempting to track the movements of opposition players. This requires further investigation with greater context added to the physical output data of field hockey players.

The mean deceleration magnitude in this paper is lower than the mean magnitude detected in the study of Chesher et al. (2019) for defenders, midfielders, and forwards. The average deceleration magnitudes across positions, in the investigation, can be categorised as low-intensity according to Chesher et al. (2019) however, they can be classified into the very high-intensity category suggested by Harper et al. (2019). 99% of the decelerations captured in this investigation can be placed in the low intensity bracket (-3--5.99m.s^2) range recommended by Chesher and colleagues (2019). At least 38% of deceleration efforts and 28% of acceleration efforts fall into the high-intensity categories recommended by Harper et al. for team sports (Harper et al., 2019; Harper & Kiely, 2018). Accordingly, the high volume of actions completed in high intensity categories may explain the cause of the decrement identified in output across match play in hockey (Haro et al., 2021; James et al., 2021; Morencos et al., 2018). Strategies should be put in place in order to prevent this fatigue while enhancing the players' capabilities, as it may provide a performance advantage particularly as the ability to deceleration has been identified as a key factor in change of direction performance in team sport (Lakomy & Haydon, 2004).

The maximal magnitude of deceleration is much lower in this investigation (-8.30m.s²) compared to the only other hockey investigation (-13.6m.s²) that provides a maximal value (Chesher et al., 2019). Additionally, a lower volume of deceleration activities was also found in the current investigation when compared to Chesher et al. (2019). This is potentially due to GPS units from different manufacturers utilised in each study. Thornton et al. have established substantial between differences between manufacturers for both accelerations and decelerations, within the same task, due to data processing approaches such as the filtering algorithms applied (Thornton et al., 2019). This is further substantiated by the findings of Crang et al. (2021) who highlighted, in particular, the variance between unit manufacturers for counts of acceleration and deceleration events during the same task. Both studies utilised GPS (10Hz) derived values and a similar minimum threshold of 3m.s^2, however, the match format (halves compared to quarters), differences in squad size (15 compared to 16) and differences between manufacturers data processing approaches make comparisons difficult.

Defenders complete less distance per acceleration effort than both midfielders and forwards, with close to 1m less reported per effort (small ES). This may reflect the different tactical roles demanded from each position with defenders playing closer to their own goal and exploring less of the pitch. Given that deceleration events frequently follow acceleration events, and that the magnitude of accelerations are similar for each position despite defenders achieving this magnitude in a shorter distance, defenders may require greater eccentric strength to ensure they have the capacity to repeatedly produce and sustain these efforts. In this cohort, as reported in the methods section, defenders have a higher 1 repetition max back squat, relative to their bodyweight, compared to other positions. Additionally, as deceleration events have been shown to reach a greater magnitude than acceleration events across positions field hockey players require a greater focus on their eccentric strength capacity (Harper & Kiely, 2018; Jones et al., 2017; Lakomy & Haydon, 2004; Sabido et al., 2017).

An increase in eccentric strength can have a dual impact on acceleration and deceleration performance as athletes with greater levels of eccentric strength are able to approach change of direction tasks/scenarios at higher velocities as they are better able to tolerate the greater ground reaction forces generated by a faster approach. This has been suggested by Jones and colleagues as a "'self-regulation' effect (i.e., a player approaches faster based on the deceleration load they know/feel they can tolerate)" (Jones et al., 2017). This may offer performance benefits due to the importance of change of direction in field hockey.

Over 90% of deceleration efforts are less than 5m in distance. This must be considered when prescribing training drills and drills targeted towards improving hockey specific deceleration capabilities. This is important as a field hockey athlete with high deceleration capabilities may have a performance advantage. For both activities, typical distance per effort can be deemed as short, however, events that fall outside the typical pattern must also be considered to ensure that players have been exposed to what can be considered "maximal" or greater than typical demands. Particularly, as longer distance acceleration efforts may be linked to sprint efforts and given the importance of acceleration to obtaining maximal velocity. Preparing players for the average demands of the sport may lead to injury and underperformance, while safely exposing players to demands beyond average values in a progressive manner may lower injury levels "likely through higher performance ability rendering typical match demands as being relatively lower for any given individual" (Gabbett, 2016). Thus, players should be afforded the opportunity to train acceleration over longer distances despite the abundance of shorter acceleration efforts within match play using the maximal values displayed in this investigation. Upton et al has reported that different strategies should be employed for training acceleration efforts over greater distance (>14m) with resisted efforts proving beneficial whereas assisted efforts were more beneficial for shorter distance efforts (<5m) (Upton, 2011). However, Spinks et al. (2007) reported that longer distance efforts, without resistance, were just as effective at improving acceleration velocity.

Completing high intensity acceleration and deceleration events have been linked with an increase in creatine kinase (Gastin et al., 2019). An increase in creatine kinase (+1 Z score) has been reported to decrease accelerations, decelerations, distance completed while completing these actions and maximal velocity by -4.3 ± 2.9%, -4.1 ± 2.9%, -3.1 ± 2.9%, and -4.6 ± 1.9% respectively (Malone et al., 2018). Thus, monitoring the frequency, magnitude and duration of acceleration and deceleration events could provide coaches with the useful information as to the physical status of their athletes for performance within a hockey tournament or the training environment. This is particularly important in field hockey as peak creatine kinase levels have been found at forty-eight hours post activity and typical hockey scheduling means that a second match occurs within this time period. Furthermore, Beato et al found meaningful differences in internal load variables between protocols which compared high magnitude accelerations versus lower magnitude acceleration during repeat sprint training (Beato & Drust, 2021). Higher peak heart rate and time spent at > 85% heart rate peak were noted alongside moderate differences were found in the muscular and cardiovascular rate of perceived exertion values reported (Beato & Drust, 2021). This highlights the higher perceived cardiovascular and muscular load required during maximal accelerations and the value in tracking and preparing for them in elite sport.

This investigation provides normative data for acceleration and deceleration efforts during international hockey matches. The typical magnitude, duration of and distance of each effort type (Table 2), have been established providing markers for the monitoring of hockey players. Training drill data can be compared to the data provided in this investigation to ensure players are exposed to acceleration and deceleration efforts similar to match exposure. Further investigation relating to the contextual environment in which these events are accumulated is warranted.

Conflict of Interest

The authors declare no conflict of interests.

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Supplementary Materials

Supplementary Table 1: Accelerations and decelerations categorised into velocity bands.

Type	Velocity (m.s²)	Percentage	Type	Velocity (m.s²)	Percentage
Deceleration	-3 – 3.99	62%	Acceleration	3 – 3.99	71%
Deceleration	-4-4.99	27%	Acceleration	4-4.99	22%
Deceleration	-5-5.99	9%	Acceleration	5-5.99	5%
Deceleration	-6-6.99	2%	Acceleration	6-6.99	1%

Supplementary Table 2: Accelerations and decelerations categorised into velocity bands by position.

Type	Velocity (m.s²)	Defender	Outside Back	Midfielder	Forward
Accelerations	3-3.99	73%	71.65%	71.28%	69.41%
Accelerations	4-4.99	23%	20.74%	21.16%	23.75%
Accelerations	5-5.99	4%	5.41%	6.85%	4.93%
Accelerations	6-6.99	0%	2.%	1.%	2%
Deceleration	-3-3.99	67%	59%	62%	60%
Deceleration	-4-4.99	25%	30%	27%	28%
Deceleration	-5-5.99	7%	10%	10%	10%
Deceleration	-6-6.99	1%	1.%	2%	1%
Deceleration	-7-7.99	0%	<0%	0%	1%