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Longitudinal development of match performance in elite field hockey players training within a high-performance environment

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ABSTRACT

This study examined whether the performance characteristics of male university field hockey players were associated with undergraduate degree year of study. Fifty-two male university field hockey players (age 20.8 ± 2.4 years, stature 1.79 ± 0.06 m, body mass 75.8 ± 8.3 kg) were monitored over 85 matches played across four national league seasons in the UK (2018–2022) using 15 Hz Global Positioning System units and heart rate monitors. Total distance, high-speed running distance (≥15.5 km.h^{-1}), accelerations (≥2 m.s^{-1}), decelerations (≤ −2 m.s^{-1}), average heart rate and percentage of time spent at >85% of maximum heart rate were compared between 1st year, 2nd year and final year players across 1090 player-match files. Hierarchical linear modelling of performance characteristics (Match – level 1, Player – level 2), normalised to 70 min match time, found that the total and high-speed running distance covered by final year players was lower compared to 2nd year players (by 163 m and 127 m, respectively, both $p < 0.05$). With increased training experience in a high-performance programme, running performance required to perform optimally could be reduced in university players due to the high level of match performance achieved, development of game understanding and improved technical ability.

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GPS; team sport; talent identification; training load

Introduction

Upon completing education up to the age of 18 years, talented field hockey players may undertake an academic degree at university to prepare for a post-athletic career whilst continuing to play at club level and if selected, participate within junior international programmes (Defruyt et al., 2019). To accommodate dual careers in higher education and elite sport, some UK-based universities host high-performance centres that can provide professional support services (for example, strength and conditioning, sport science, physiotherapy) and structured training programmes around academic schedules to facilitate developmental pathways to world-class performance (Brown et al., 2015; MacNamara & Collins, 2010).

Accordingly, the Talent System (talent identification and development) pathway structured by Great Britain (GB) Hockey recognises the importance of university environments and prioritises the ‘Performance Development’ of future Olympic field hockey players around university ages (Great Britain Hockey, 2021). Notably, 87.5% of field hockey players who played at a previous Olympic Games had attended university (Aquilina, 2013). Key criteria for selection into the GB Elite Development Programme (EDP) from international age group hockey, which then subsequently feeds the Senior GB Programme, is the ability of players to cope with the performance demands of international matches and deliver repeated high-intensity performances across a tournament (Great Britain Hockey, 2023). Therefore, high-performance university environments may facilitate the development of the necessary technical, tactical, physical and mental attributes necessary for elite match performance, and subsequently influence the selection or transition of field hockey players from the Under-18 into the Under-21, EDP and Senior GB Programmes during their academic studies or post-university career (Great Britain Hockey, 2021). However, to the authors’ knowledge, there is no research investigating whether the match performance characteristics of university field hockey players differs between year of study and relatedly, with increased training experience within an elite performance environment.

The use of wearable tracking devices such as Global Positioning/Navigation Satellite Systems (GPS/GNSS)

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and heart rate monitors are commonplace in team sport and have enabled performance characteristics (such as, the distance covered in total and at high-speed, number of accelerations and decelerations performed, heart rate responses) of male international field hockey to be repeatedly examined across whole matches (McMahon & Kennedy, 2019; Morencos et al., 2018; Polglaze et al., 2018; White & MacFarlane, 2013), quarters of play (Ihsan et al., 2021; James et al., 2021) and 1–10 min moving average periods (Cunniffe et al., 2021; Delves et al., 2021). Previous studies have typically focused on establishing position-specific profiles to aid training prescription (D. H. Jennings et al., 2012; Lythe & Kilding, 2011; Polglaze et al., 2015), whilst recent research has tactically contextualised match performance with possession status and phase of play to improve our understanding of how performance characteristics are altered (Cunniffe et al., 2022, 2024). Interestingly, it has been found in research investigating matchplay in field hockey, soccer and rugby union that the distances covered at higher intensities can distinguish between playing standards; information that can inform the developmental strategies of sub-elite players (Bradley et al., 2013; Gabbett, 2013; D. H. Jennings et al., 2012).

However, the majority of studies examining international performance characteristics in field hockey have been limited to small sample sizes of players and matches monitored over one tournament or season. This is also a feature of the comparatively limited information available on the performance characteristics of male field hockey players competing at national level in the UK (Noblett et al., 2023; Sunderland & Edwards, 2017). For instance, Noblett et al. (2023) recently examined performance characteristics across position and quarters of play but only assessed 10 matches and 100 player-match files within one season. Further, the match performance data in the study could have been biased by contextual factors not related to the explanatory variables of focus (James, Gibson, et al., 2022). For example, factors such as match result, opposition ranking and air temperature have all been associated with performance characteristics in field hockey (James, Willmott, et al., 2022; D. Jennings et al., 2012; Vinson et al., 2018; White & MacFarlane, 2015). These contextual factors may explain the high between-match variability in performance characteristics recorded by field hockey players, with coefficient of variance (CV) ranging from 13% to 35% for characteristics such as high-speed and sprint running distance (Curran et al., 2022; Sunderland & Edwards, 2017). One way of addressing these issues could be to use multilevel analysis to account for a clustered dataset with differing numbers of match files within players and unequal sample sizes when assessing explanatory variables (Owen et al., 2022).

Summarising, there is a need to assess the performance characteristics of male university players across multiple seasons, and using multilevel models that account for contextual variables, to examine whether match performance is developed as players engage within high-performance university programmes. This research may provide a foundation to improve our understanding of talent identification and development pathways undertaken by elite field hockey players, and supplement the need for more longitudinal analysis of developing youth athletes.

Therefore, the aim of the current study was to examine whether the performance characteristics of male university field hockey players, competing at national level in the UK, were associated with undergraduate degree year of study. It was hypothesised that a higher match running output would be seen in older players at latter stages of their degree programme, and with increased training experience within a high-performance university environment.

Methods

Experimental approach to the problem

A longitudinal study design was used to examine whether the performance characteristics of male university field hockey players were associated with undergraduate degree year of study. All players were involved in a men's field hockey performance programme based at a university housing a high-performance centre. The programme provided players with a structured training schedule during the season including on-pitch training sessions (3–4 per week), competitive matches (1–2 per week), gym-based resistance sessions (1–2 per week), on-pitch conditioning sessions (0–1 per week) and return to play activities (when required). The programme was supported by professional services including hockey coaching, strength and conditioning, physiotherapy, sport science, performance analysis, nutrition, psychology and performance lifestyle coaching.

Performance characteristics were examined from matches played over four consecutive national leagues seasons in the UK from 2018 to 2022, with three seasons scheduled from September to March (2018–2019, 2019–2020, 2021–2022) and one shortened season scheduled from September to November due to the COVID-19 pandemic (2020–2021). All matches were played in two national league competitions, namely the England Hockey League Division One North (EHL) and the British Universities and Colleges Sport Hockey Premier North A League (BUCS). Matches were of 70 min duration, and structured as 2 × 35 min halves with a 10 min half-time interval (2018–2019 season) or as 2 × 2x 17.5 min quarters with 2 min quarter-time and a 7 min half-time interval (2019–2020 season onwards). Matches were played on artificial sand-based or water-based field hockey pitches under temperate conditions (temperature: 7.8 ± 3.1°C, range 3–19°C; relative humidity: 83 ± 9%, range 50–95%; mean ± standard deviation [SD]).

Participants

Fifty-two male field hockey players (age 20.8 ± 2.4 years, stature 1.79 ± 0.06 m, body mass 75.8 ± 8.3 kg) representing the 1st team of a national league field hockey club and studying an academic degree volunteered to participate in the study. Players competed for the team over a varying number of matches and seasons, constituting different playing squads for each season. The player and match characteristics from each season are presented in Table 1. Twenty-seven players (52% of total players) were selected and participated in junior international training camps or matches whilst playing for the university club at some stage, represented their country at Under-18 or Under-21 age groups and/or participated within the GB Elite Development Programme (EDP). Players were categorised in each season by their playing position (defenders, midfielders and forwards) and undergraduate degree year of study (1st year student, 2nd year student, final year [3rd year or 4th year] student; Table 1). Goalkeepers were excluded from the current study. A total of 1090 individual player-match files were collected from 85 matches after exclusion of partial or erroneous data. The minimum time on pitch required for a player-match file to be included was 25 min, consisting of at least 10 min per half or 5 min per quarter, as this was the shortest time considered for tactical rotation. Players were provided written and verbal communication of the aims, procedures and risks of the current research before opt-out consent was given prior to the commencement of the study. Ethical approval was granted by an institutional university ethics committee (Ref No: R19-PO19).

Procedures

Performance characteristics were quantified using 15 Hz GPS units (SPI HPU, GPSports, Canberra, Australia) and heart rate monitors (Polar Electro T31, Kempele, Finland). GPS units were switched on outside and kept stationary until GPS lock was obtained. Across the 85 matches examined, the number of connected satellites was 9 ± 1 (range 7–11) and horizontal dilution of precision was 0.48 ± 0.05 (range 0.40–0.61) which demonstrated acceptable signal quality (Malone et al., 2017). Each player wore a specialised, elasticated harness with a pocket designed to position the GPS unit on the upper back, between the scapulae and level with the upper thoracic region (T1 – T6). Players equipped themselves with their heart rate monitor which was positioned just below the sternum and secured in place by an elasticated chest strap onto their skin. Players inserted their GPS unit into their harness prior to starting the warm-up. During matches, heart rate data was continuously recorded and logged with the external data

Table 1. Player and match characteristics collected from playing squads representing a male university field hockey team across four consecutive national league seasons based in the United Kingdom (2018–2019, 2019–2020, 2020–2021, 2021–2022).

Season	2018–2019	2019–2020	2020–2021	2021–2022
Number of players (junior internationals)	22 (8)	22 (12)	23 (14)	23 (15)
Age (years)	21.5 ± 3.1	20.6 ± 3.2	20.5 ± 1.6	20.3 ± 1.5
Stature (m)	1.80 ± 0.07	1.79 ± 0.06	1.79 ± 0.06	1.80 ± 0.04
Body Mass (kg)	74.3 ± 6.3	74.9 ± 8.9	78.3 ± 9.3	75.9 ± 6.9
$30–15_{IFT}$ velocity (km.h^{-1})	*	21.2 ± 1.0	20.5 ± 0.9	20.7 ± 0.9
Positions	Def (n = 6) Mid (n = 8) For (n = 8)	Def (n = 7) Mid (n = 7) For (n = 8)	Def (n = 8) Mid (n = 7) For (n = 8)	Def (n = 8) Mid (n = 8) For (n = 7)
Undergraduate degree year of study	1st year (n = 7) 2nd year (n = 5) Final year (n = 10)	1st year (n = 8) 2nd year (n = 8) Final year (n = 6)	1st year (n = 6) 2nd year (n = 8) Final year (n = 9)	1st year (n = 8) 2nd year (n = 6) Final year (n = 9)
Number of matches (competitions)	28 (EHL = 16; BUCS = 12)	24 (EHL = 16; BUCS = 8)	5 (EHL = 5; BUCS = 0)	28 (EHL = 18; BUCS = 10)
Individual player-match files	251	353	71	415

$30–15_{IFT}$ = 30–15 intermittent fitness test. Def = defenders; Mid = midfielders; For = forwards; EHL = England Hockey League Division 1 North; BUCS = British Universities and Colleges Sport Premier North A League. * No 30–15 intermittent fitness test was carried out in the 2018–2019 season.

collected by the GPS units. Each player was assigned the same harness, GPS unit and heart rate monitor within-season to minimise interunit error.

GPS and heart rate data was downloaded and processed post-match using a laptop computer containing the manufacturer's GPS software package (GPSports Team AMS, v.R1 2019, Canberra, Australia). This version of the software package was used to analyse all player-match files. Each match file was split to only include time periods when a player was on the pitch during the match (rotations), as described by White and MacFarlane (2013). Data relating to time on pitch was then exported from the analysis software into customised Excel spreadsheets (Office 365, Microsoft Office, Redmond, WA). Time on pitch data were averaged or summated to calculate performance characteristics for the whole match within each match file.

The GPS and heart rate variables used to quantify the performance characteristics of players in the current study are defined in Table 2. The absolute high-speed running threshold chosen has been used in previous field hockey research (Polglaze et al., 2018; Sunderland & Edwards, 2017), based upon the original speed categories defined by Bangsbo et al. (1991) and adapted from the sport-specific GPS velocity zones calculated for male field hockey (Dwyer & Gabbett, 2012). Some variables were derived from maximum speed or maximum heart rate, which were individually determined and updated from the highest recorded value during within-season fitness testing or, if higher, a maximal within-season value during training sessions or matches.

Statistical analysis

The raw, descriptive GPS and heart rate data (relating to time on pitch) used to quantify match performance characteristics are presented as mean ± SD. Before inclusion in the modelling analysis (see detailed description below), absolute GPS characteristics were normalised to 70 min match time by dividing the actual performance characteristic value by time on pitch, and then multiplying by 70.

To account for the hierarchical dependency of the dataset (for example, different number of match files within players), multilevel modelling was used to examine whether the performance characteristics of university field hockey players were associated with undergraduate degree year of study. These models were interpreted after controlling for the following contextual variables: season (differences between the four seasons), international standard (differences between university players involved and not involved in junior

Table 2. The definitions of Global Positioning System (GPS) and heart rate variables used to quantify the match performance characteristics of players.

Performance Characteristic (units)	Definition
Total Distance (metres, m)	Overall volume of distance covered
Distance per minute (metres per minute, $m.min^{-1}$)	Total distance covered expressed relative to time spent on pitch
High-Speed Running Distance (metres, m)	Distance covered at a speed of ≥15.5 $km.h^{-1}$
High-Speed Running Distance% (%total distance)	High-speed running distance covered expressed relative to the total distance covered
Accelerations (number, n)	Number of increases in velocity performed > 2$m.s^{-2}$, quantified if lasting for a minimum time of >1 s
Accelerations per minute (number per minute, $n.min^{-1}$)	Number of accelerations expressed relative to time spent on pitch
Decelerations (number, n)	Number of decreases in velocity performed < −2 $m.s^{-2}$, quantified if lasting for a minimum time of >1 s
Decelerations per minute (number per minute, $n.min^{-1}$)	Number of decelerations expressed relative to time spent on pitch
Peak Speed (kilometres per hour, $km.h^{-1}$)	The highest speed achieved at a singular time point within the time spent on pitch.
Peak Speed% (%Maximum Speed)	The highest speed achieved expressed relative to the maximum speed recorded by the relevant player
Average Heart Rate (HR_{AVE}) (beats per minute, $b.min^{-1}$)	The mean heart rate recorded within the time spent on pitch
%Maximum Heart Rate	The mean heart rate recorded expressed relative to the maximum heart rate recorded by the relevant player
Peak Heart Rate (HR_{PEAK}) (beats per min, $b.min^{-1}$)	The highest heart rate recorded within the time spent on pitch
Peak Heart Rate% (HR_{PEAK}%) (%Maximum Heart Rate)	The highest heart rate recorded expressed relative to the maximum heart rate recorded by the relevant player.
Time spent at >85% of Maximum Heart Rate (minute)	Total time spent in a heart rate zone exceeding 85% of maximum heart rate
Percentage Time spent at >85% of Maximum Heart Rate (%)	Total time spent in a heart rate zone exceeding 85% of maximum heart rate expressed relative to time spent on pitch.

international programmes alongside the university programme), competition (differences between EHL and BUCS matches), opposition standard (differences between teams ranking lower than the university team [n = 53; 50 wins, 3 draws] and teams ranking higher than the university team in competitions [n = 32, 7 wins, 7 draws, 18 losses]) and playing position (differences between defenders, midfielders and forwards).

Specialist software (MLwiN v.3.05, Bristol, UK) was used to fit two-level random intercept models (match file [level 1; n = 1090] nested within player [level 2; n = 52]) to six dependent variables: total distance (m), high-speed running distance (m), accelerations (n), decelerations (n), percentage of maximal heart rate (%) and percentage time spent at >85% of maximum heart rate (%). First, a baseline model (model 1) was fitted giving the mean and standard error (SE) of the intercept (fixed component), the unexplained between-player and between-match file variance (random component) and the deviance value (−2*log-likelihood) that represented the goodness of the model fit. A series of fixed, explanatory variables were progressively added to create more complex models in the following order, comparing a chosen reference category with its other categories: season (model 2; 2018–2019 [reference] vs. 2019–2020 vs. 2020–2021 vs. 2021 – 2022); international standard (model 3; non-international players [reference] vs. international players); competition (model 4; EHL [reference] vs. BUCS); opposition standard (model 5; low ranked teams [reference] vs. high ranked teams), position (model 6; defenders [reference] vs. midfielders vs. forwards) and undergraduate degree year of study (model 7; 1st year [reference] vs. 2nd year vs. final year). After an explanatory variable was added to the model, significant differences ($p < 0.05$) between the categories of each explanatory variable included within the new model were interpreted using the Wald statistic (parameter estimate/SE; Singer & Willett, 2003). Residuals from each model were assessed for normality through graphical inspection of Q–Q plots and were found to be normally distributed. The magnitude of differences between the categories of undergraduate degree year of study were determined using an effect size (Cohen's d; difference between parameter estimates/pooled SD) and interpreted using the following thresholds: $d < 0.2$ = trivial, $0.2 \leq d < 0.5$ = small, $0.5 \leq d < 0.8$ = moderate and $d \geq 0.8$ = large (Cohen, 1969). Moderate to large effects were considered practically significant (Hopkins et al., 2009). To determine if the addition of an explanatory variable resulted in an improved overall model fit, it was necessary for the likelihood ratio test (deviance of model [as assessed by −2*log-likelihood] when explanatory variable was added – deviance of previous model) to show a reduction exceeding the critical value of a chi-squared distribution at the 5% level ($p < 0.05$).

Results

Performance characteristics (descriptive statistics)

The performance characteristics of male university players during national level matches played across

Table 3. Match performance characteristics (descriptive data) of male university field hockey players (n = 52; 1090 match files) presented across position and undergraduate degree year of study during 70 min matches played over four consecutive seasons (2018–2022).

	Mean ± SD						
		Position			Undergraduate Degree Year of Study		
	Team	Defenders	Midfielders	Forwards	1st year	2nd year	Final year
Time on pitch (min)	49.8 ± 10.0	59.2 ± 9.6	45.6 ± 6.7	44.4 ± 5.2	47.8 ± 9.8	50.4 ± 10.5	50.9 ± 9.6
Total distance (m)	6458 ± 921	7076 ± 852	6234 ± 841	6054 ± 715	6189 ± 941	6468 ± 792	6670 ± 931
Distance per minute (m.min^{-1})	132 ± 14	121 ± 14	137 ± 10	137 ± 11	131 ± 13	131 ± 17	133 ± 12
High-speed running distance (m)	1424 ± 390	1225 ± 427	1483 ± 298	1568 ± 354	1324 ± 351	1425 ± 435	1505 ± 370
High-speed running% (%total distance)	22.3 ± 5.7	17.3 ± 5.7	23.8 ± 3.3	25.8 ± 4.2	21.6 ± 5.4	22.2 ± 6.4	22.8 ± 5.5
Accelerations (n)	76 ± 16	72 ± 17	76 ± 14	80 ± 15	71 ± 14	75 ± 17	80 ± 16
Accelerations per minute (n.min^{-1})	1.57 ± 0.40	1.25 ± 0.34	1.67 ± 0.26	1.80 ± 0.35	1.53 ± 0.35	1.56 ± 0.42	1.62 ± 0.40
Decelerations (n)	77 ± 16	73 ± 17	79 ± 16	80 ± 15	72 ± 14	78 ± 18	81 ± 16
Decelerations per minute (n.min^{-1})	1.60 ± 0.40	1.26 ± 0.31	1.73 ± 0.30	1.82 ± 0.33	1.55 ± 0.38	1.61 ± 0.46	1.64 ± 0.37
Peak speed (km.h^{-1})	28.4 ± 1.7	27.9 ± 1.7	28.5 ± 1.6	28.7 ± 1.5	28.3 ± 1.6	28.4 ± 1.8	28.4 ± 1.6
Peak speed% (%Maximum speed)	87.1 ± 4.8	85.8 ± 5.0	88.0 ± 4.7	87.6 ± 4.5	88.0 ± 4.6	87.0 ± 4.9	86.5 ± 4.9
HR_{AVE} (b.min^{-1})	169 ± 10	168 ± 10	168 ± 11	169 ± 8	169 ± 10	168 ± 10	168 ± 9
%Maximum heart rate	83.6 ± 4.2	83.3 ± 4.5	83.4 ± 4.6	84.1 ± 3.2	83.3 ± 4.1	83.5 ± 4.0	83.9 ± 4.4
HR_{PEAK} (b.min^{-1})	194 ± 7	193 ± 7	194 ± 9	194 ± 6	195 ± 7	193 ± 8	193 ± 7
HR_{PEAK}% (%Maximum heart rate)	96.0 ± 2.4	95.9 ± 2.5	95.9 ± 2.4	96.1 ± 2.1	96.1 ± 2.2	95.7 ± 2.3	96.1 ± 2.5
Time spent > 85% HR_{MAX} (min)	28.1 ± 10.7	31.3 ± 13.9	25.6 ± 9.2	27.2 ± 6.8	26.7 ± 9.6	28.0 ± 10.7	29.2 ± 11.5
Percentage time > 85% HR_{MAX} (%)	57.1 ± 19.8	53.3 ± 22.9	56.5 ± 19.8	61.8 ± 14.9	56.8 ± 19.5	55.9 ± 19.2	58.1 ± 20.5

HR_{AVE} = average heart rate; HR_{PEAK} = peak heart rate; Time spent > 85% HR_{MAX} (min) = duration (min) of total time spent at a zone exceeding 85% of maximum heart rate; Percentage time > 85% HR_{MAX} (%) = percentage (%) of total time spent at a zone exceeding 85% of maximum heart rate. Variables are presented as mean ± SD.

four seasons are presented for the overall team, across position and across undergraduate degree year of study in Table 3. There were large differences in age between undergraduate degree year of study (1st year: 18.6 ± 0.5, 2nd year: 19.8 ± 0.4, Final year: 20.9 ± 1.5 years; $d \geq 1.00$).

Performance characteristics (multilevel models)

Multilevel models examining the main effects of season, international standard, competition, opposition ranking, position and undergraduate degree year of study on GPS and heart rate variables (model 7), normalised to 70 min match time, are presented in Table 4. Effect sizes and 95% confidence intervals examining the magnitude of differences between undergraduate degree year of study are presented in Figure 1.

Undergraduate degree year of study

The inclusion of undergraduate degree year of study as an explanatory variable suggests that the total distance covered by final year players was lower compared to 2nd year players (by 163 m; $p = 0.033$, $d = 0.22$) and 1st year players (by 192 m; $p = 0.055$, $d = 0.26$), although the latter was not statistically different (Table 4). The high-speed running distance covered by final year players was lower compared to 2nd year players (by 127 m; $p = 0.016$, $d = 0.25$). No differences between undergraduate

Table 4. Multilevel models examining the main effects of season, international standard, domestic competition, opposition ranking, position and undergraduate degree year of study on Global Positioning System (GPS) and heart rate variables normalised to 70 min match time (model 7).

Dependent Variable		Total Distance (m)	High-speed Running Distance (m)	Accelerations (n)	Decelerations (n)	%Maximum Heart Rate	Percentage time spent at > 85% HR_{MAX} (%)
		Mean (SE)					
Fixed Component							
Baseline	Intercept	8961 (131)	1809 (91)	98 (4)	99 (4)	84.2 (0.9)	60.3 (3.4)
Season	2019–2020	−322 (72)*	−212 (49)*	−2 (2)	+1 (2)	−0.5 (0.5)	−1.1 (2.0)
(Ref: 2018–2019)	2020–2021	−524 (113) *$^{\alpha}$	−299 (77)*	−8 (3)*$^{\alpha}$	−4 (3)	−1.8 (0.7)*$^{\alpha}$	−8.2 (3.0)*$^{\alpha}$
	2021–2022	+50 (127)$^{\alpha\ \beta}$	−94(89)$^{\beta}$	−4 (4)	+2 (4) $^{\beta}$	−2.2 (0.9)*$^{\alpha}$	−8.9 (3.4) *$^{\alpha}$
International Standard (Ref: Non-international)	International	−366 (190)*	−236 (62)*	−10 (3)*	−9 (3)*	−0.9 (0.6)	−7.2 (2.4)*
Domestic Competition (Ref: EHL)	BUCS	+140 (36)*	+98 (24)*	0 (1)	0 (1)	+0.1 (0.2)	+1.5 (1.0)
Opposition Ranking (Ref: Low Ranked)	High Ranked	−119 (35)*	−7 (24)	+3 (1)*	+1 (1)	+1.2 (0.2)*	+4.6 (1.0)*
Position	Midfielders	+1048 (107)*	+673 (74)*	+23 (3)*	+25 (3)*	+0.1 (0.7)	+5.4 (2.9)
(Ref: Defenders)	Forwards	+1018 (125) *	+844 (86)*^{M}	+34 (4)*^{M}	+30 (4)*^{M}	−0.2 (0.8)	+4.4 (3.3)
Undergraduate Year	2nd year	−29 (70)	+74 (48)	+1 (2)	−1 (2)	+0.3 (0.4)	0.0 (1.9)
of Study (Ref: 1st year)	Final year	−192 (100)^{2}	−53 (70)^{2}	+2 (3)	−2 (3)	+0.9 (0.7)	+1.9 (2.6)
Random Component							
	Between-player SD	522	371	18	17	3.6	13.3
	Between-file SD	526	354	14	15	3.0	13.6
Δ Deviance	Model 2	90	76	40	30	21.8	44.9
(From previous model)	Model 3	48	42	39	38	3.0	12.0
	Model 4	10	15	0	0	1.7	5.0
	Model 5	11	0	9	0	29.7	23.1
	Model 6	78	95	70	63	0.5	3.4
	Model 7	7	8	0	1	2.0	0.7

Significance = $p < 0.05$.* = Significant difference from reference category (Ref). $^{\alpha}$ = Significant difference from 2019–020 season. $^{\beta}$ = Significant difference from 2020–2021 season. ^{M} = Significant difference from midfielders. ^{2} = Significantly different from 2nd year. ꜝ = Significantly better model fit. SD – standard deviation (√variance). Percentage time spent at > 85% HR_{MAX} = percentage (%) of total time spent at a zone exceeding 85% of maximum heart rate.

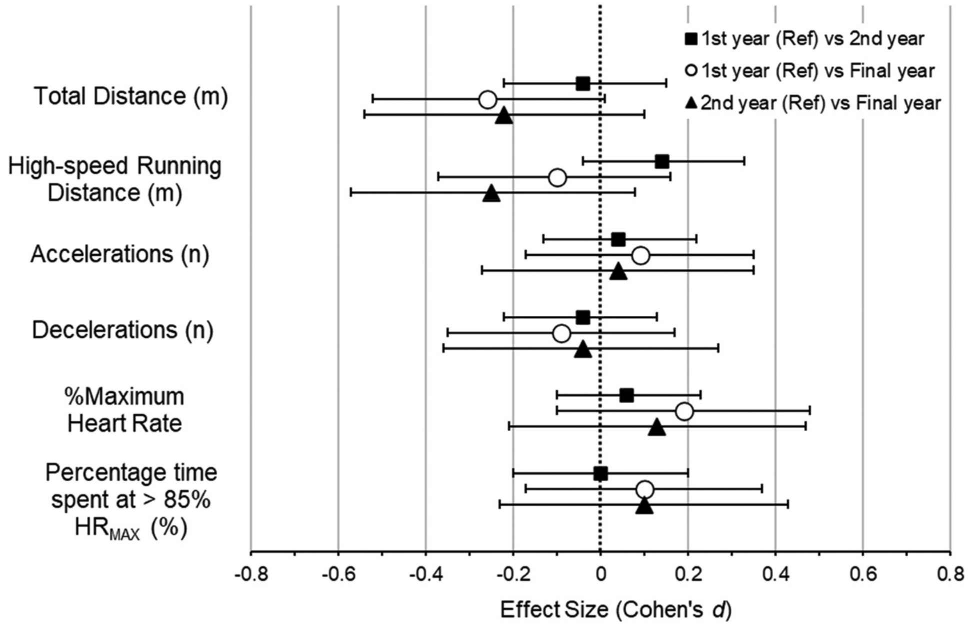

Figure 1. Effect size (Cohen's *d*) with 95% confidence intervals examining the magnitude of differences between the categories of undergraduate degree year of study on global positioning systems (GPS) and heart rate variables normalised to 70 min match time (model 7). Positive effect sizes indicate that the category compared to the reference category (ref) had a greater performance characteristic value. Negative effect sizes indicate that the category compared to the reference category had a lower performance characteristic value.

degree year of study were found for the number of accelerations and decelerations performed, the percentage of maximum heart rate maintained, and percentage of time spent at >85% of maximum heart rate ($p \geq 0.162$). The magnitude of differences between undergraduate degree year of study were trivial to small for the normalised GPS and heart rate variables studied ($d \leq 0.29$; Figure 1).

Contextual variables

The inclusion of season as an explanatory variable improved the model fit for all six performance characteristics (all $p < 0.001$). The total distance covered, number of accelerations performed, percentage of maximum heart rate maintained, and percentage of time spent at >85% of maximum heart rate were lower during matches played in the 2020–2021 season compared to the 2018–2019 and 2019–2020 seasons ($p \leq 0.025$).

The inclusion of international standard as an explanatory variable suggests that the total distance and high-speed running distance covered, the number of accelerations and decelerations performed, and the percentage of time spent at >85% of maximum heart rate were lower in matches played by university players involved in junior international programmes compared to non-international players (all $p < 0.01$).

The inclusion of competition as an explanatory variable suggests that the total distance and high-speed running distance covered were greater in matches played in BUCS matches compared to the EHL matches (both $p < 0.001$).

The inclusion of opposition ranking as an explanatory variable suggests that the total distance covered was lower, but the number of accelerations performed, percentage of maximum heart rate maintained, and percentage of time spent at >85% of maximum heart rate were greater in matches played against high ranked teams compared to low ranked teams (all $p < 0.001$).

The inclusion of position as an explanatory variable suggests that the total distance and high-speed running distance covered, and the number of accelerations and decelerations performed, were lower in matches played by defenders compared to midfielders and forwards (all $p < 0.001$). The high-speed running distance covered, and the number of accelerations and decelerations performed, were greater in matches played by forwards compared to midfielders (all $p < 0.01$).

Discussion

The current study examined whether the match performance characteristics of male field hockey players competing at national level in the UK were associated with undergraduate degree year of study. Rather than suggesting that match running output increases as players progress through university, as hypothesised, hierarchical linear modelling of performance characteristics found that the total distance and high-speed running distance covered by final year players was lower compared to 2nd year players (by 163 and 127 m respectively). The current findings also found no practical differences in performance characteristics between undergraduate degree year of study, and no association with the number of accelerations performed, number of decelerations performed, percentage of maximum heart rate maintained, and percentage of time spent at >85% of maximum heart rate by male university players.

The ages at which the Talent System pathway prioritises the development of future GB field hockey players coincides with the likelihood that these players are studying an academic degree at university (Great Britain Hockey, 2021). High-performance university programmes may contribute towards the development of match performance and influence player selection or transition through the pathway. However, in the current study, older male players with more training experience within a high-performance university programme demonstrated no practical differences in performance characteristics indicative of improvement (for example., higher external output with maintained or lower heart rate responses). In fact, the total distance covered by final year players were found to be lower by 2% compared to 1st and 2nd year players, whilst the high-speed running distance covered was lower by 7% compared to 2nd year players in national level matches. Research investigating the performance characteristics of field hockey players across typical undergraduate university ages (18–22 years) is limited, but the current findings contradict similar cross-sectional analysis employed by Vescovi (2016) who compared the Under-17 and Under-21 Canadian female international squads. The author found that Under-21 players covered 9% more distance per minute (Under-17: 103 ± 9 vs. Under-21: 112 ± 6 m.min^{-1}; $p = 0.024$) and 38% more high-speed running distance per minute (16.1–20.0 km.h^{-1}; Under-17: 371 ± 197 vs. Under-21: 511 ± 147 m.min^{-1}; $p = 0.003$), but also spent 21% less time at > 90% of maximum heart rate compared to Under-17 players (Under-17: 18.5 ± 9.1 vs. Under-21: 21. ± 6 min; $p = 0.036$). It was suggested that the accumulated training effect within collegiate and junior international environments enhanced the physical fitness of Under-21 players and enabled them to achieve a higher match output (Vescovi, 2016). In contrast, studies examining the performance characteristics of players within other team sports in the UK have found no improvement around university ages. Saward et al. (2016) modelled the match running performance of youth academy soccer players aged 8–18 years and found that initial age-related increases plateaued at 17.7 years for the total distance covered, whilst the high-speed running distance covered decreased after 16.1 years. It was suggested that the superior tactical and technical ability of older players decreased the requirement to perform at maximal physical capacity (Saward et al., 2016). Comparison of performance characteristics between adolescent age groups during national level rugby union matches used similar reasoning to explain why the total distance and high-speed running distance per minute covered by Under-20 players were lower by 10–25% compared to Under-18 players (Read et al., 2017). Despite match running characteristics being commonly examined by practitioners, recent research in soccer has not associated higher outputs with improvements in physical fitness, match success or player development (Byrkjedal et al., 2024; Oliva-Lozano et al., 2023). These findings underpin the narrative that running performance may be more a consequence of game context and tactical decisions, reinforcing the increasing emphasis on integrating physical and technical characteristics in applied practice (Bradley & Ade, 2018; Carling, 2013). Further, cognitive processes such as postural orientation (scanning) and anticipation are also found to be superiorly developed in skilled players, leading to effective decision making that can maximise the efficiency of controlled running outputs (Habekost et al., 2024). Relatedly, Great Britain Hockey (2021) use the term 'game understanding' which incorporates the awareness of tactics, formations and game context (for example, match score) that enhances the execution of technical actions, and this is a key criterion for selection into GB international programmes (Great Britain Hockey, 2023). An improved game understanding as players progress through university years and develop in a high-performance environment, despite potential concurrent improvements in physical characteristics, may reduce the running distances required to perform optimally in national level competition.

Examining the descriptive data of performance characteristics recorded by male university players at national level showed a comparably high level of performance to senior male internationals reported in previous studies (Table 3). The total distance and distance per minute covered by male university players in the current study was comparable to the 5500–7000 m and 117–131 m.min^{-1} covered in senior international matchplay, respectively (James et al., 2021; Lythe & Kilding, 2011; Polglaze et al., 2015, 2018; White & MacFarlane, 2013). The high-speed running distance covered and accelerations performed in the current study were similar to Australian male international players during a World League tournament as defined using the same thresholds, where these players covered 1156 ± 235 m (> 15.5 km.h^{-1}; 20.9% of total distance) and performed 69 ± 12 accelerations (> 2 m.s^{-2}; 1.5 ± 0.3 n.min^{-1}) during 70 min matches (Polglaze et al., 2018). The peak speed achieved, and percentage of maximum heart rate maintained, were also comparable with senior male international players who have previously recorded values of 26.2–27.3 km.h^{-1} and 84–86% during matchplay, respectively (Buglione et al., 2013; Lythe & Kilding, 2011; Morencos et al., 2018; White & MacFarlane, 2013). The high level of match performance achieved may reflect the high proportion of junior internationals attending university in the current study (52% of total players), reinforcing the suggestion that older players do not need to increase their physical output to perform at national level. Alternatively, the role of high-performance university programmes within the Talent System pathway may be to allow field hockey players to demonstrate a high level of performance consistently over a three to four year period. The periodisation strategies required to prepare university field hockey players for national level competition, typically consisting of longer playing rotations and 1–2 matches per week over an 8–9-month season, differ considerably to the demands of international tournaments where shorter in-match rotations are employed and 4–5 matches may be played across 7 days (Vescovi & Frayne, 2015). The ability to sustain repeated high-intensity performances across a tournament without accruing significant injury is a key criterion for selection into GB international programmes (Great Britain Hockey, 2023). In preparation for such demands, and unlike soccer that typically construct microcycles allowing players to recover the day after a match (Douchet et al., 2024), it is not atypical for field hockey players to train intensively on this day. This is despite the injury risk in field hockey players being 4–7 times higher when matches are played across consecutive days compared to matches played with a 3–7-day break in between (Mason et al., 2022). The current study highlights the importance to field hockey practitioners in understanding the training load requirements of national and international competition to facilitate the physical, tactical, technical and mental development of talented university players, in order to prepare them for this transition.

A strength of the current study was to associate undergraduate degree year of study with performance characteristics across a large dataset collected over multiple seasons, and using multilevel models that account for various contextual factors (Table 4). The current finding that defenders exhibit lower performance characteristics compared to midfielders and forwards is consistent with studies examining national and international field hockey matchplay (D. H. Jennings et al., 2012; Lythe & Kilding, 2011; Sunderland & Edwards, 2017). Regarding opposition standard, the current study found that male university players covered less total distance but performed more accelerations and attained higher heart rate responses against teams ranked in a higher league position. These findings contrast with field hockey studies finding that more total distance and high-speed running distance is covered by national level players against top ranked or mid ranked teams in a domestic national league (Vinson et al., 2018; White & MacFarlane, 2015), and by international players against higher ranked countries (James, Gibson, et al., 2022). Analysis of English Premier League soccer matches found that elite players performed less decelerations when out of possession against higher ranked opposition, another contrasting finding that highlights the need for more contextualised interpretation of performance characteristics in team sport (Morgans et al., 2025). Domestic competition was also associated with performance characteristics in the current study as male university players covered more total distance and high-speed running distance in BUCS matches (midweek university competition) compared to EHL matches (open-age weekend competition). This novel finding may reflect the frenetic, end-to-end matchplay of university competition where younger, fitter players are supported by bigger crowds and trusted to perform more man-to-man formation strategies. The current study has highlighted the influence of contextual factors which are important for practitioners working in field hockey, and other team sports, to account for when examining meaningful differences from performance characteristics data.

It is important to note the limitations of the current study. Data was collected from one national level team and high-performance university environment, therefore training programmes and match strategies may have limited generalisability. Comparison of performance characteristics between studies are limited by the varying manufacturers and device models of GPS units used that employ different sampling frequencies, processing methods and metric definitions (Scott et al., 2016). Modelling analyses were employed to compare between players at different stages of their undergraduate degree study due to the limited data collected across the COVID-19 affected 2020–2021 season. Future studies using longitudinal multilevel models (for example, latent growth models) to study within-player development and investigate the physical, match performance and technical characteristics, of both university and junior international field hockey players, may further increase the understanding of how talented players develop in high-performance environments.

Conclusion

The current study sought to determine whether undergraduate degree year of study was associated with the match performance characteristics of male university players competing at national level in the UK. Rather than suggesting that performance characteristics are increased as players progress through university, as hypothesised, the current findings found that final year players covered less total distance and high-speed running distance (normalised to 70 min match time) compared to 2nd year players. It was suggested that an improved game understanding and technical ability of university players, with increased experience training within a high-performance environment, may reduce the match running performance required to perform optimally at national level. The role of high-performance university environments may be to prepare players, a high proportion of which were junior internationals in the current study, to achieve high levels of match performance consistently for potential selection into senior international competition where shorter in-match rotations and between-match periods in tournament play are typical.

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Data availability statement

The data presented in this study are available on request from the corresponding author.

Institutional review board statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of LOUGHBOROUGH UNIVERSITY (Ref No: R19-PO19).

Informed consent statement

Informed consent (opted out) was obtained from all participants involved in the study.

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