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ORIGINAL ARTICLE

Physical demands of female collegiate lacrosse competition: whole-match and peak periods analysis

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Abstract
Background The use of Global Positioning Systems (GPS) has provided Sports Scientists with the ability to investigate locomotive behavior in sport. With Lacrosse being the fastest growing sport in the USA, there is no GPS analysis available, in current literature, for female lacrosse competition.
Aims This study aims to quantify the external outputs of women's collegiate lacrosse competition and determine any positional differences.
Methods Activity profiles were obtained, via GPS, from 14 players across 7 NCAA division-1 conference games. Total distance covered (metres), maximum velocity (m s^{-1}), speed (m min^{-1}), acceleration (m s^{-2}), and metabolic power (P_{MET}; W kg^{-1}) were used to establish outputs throughout both periods of match-play. Peak values were obtained, by using a moving-average approach for durations lasting 1–10 min, for speed (m min^{-1}), acceleration (m s^{-2}), and metabolic power (P_{MET}; W kg^{-1}).
Results Defenders covered more distance throughout a whole match play, compared to their positional counterparts (Effect size [ES] range = 0.69–1.17). All positions showed a decrease in the second half, compared to the first half, for speed, acceleration, and metabolic power (ES = 0.87, 0.64, and 0.86, respectively). The only positional difference between moving-average durations was at the 8, 9 and 10-min markers for average acceleration, where defenders were greater than attackers (ES range = 0.72 – 0.76).
Conclusions This study presented a construction of the whole-period outputs as well as peak intensities for women's collegiate lacrosse competition, that can provide coaches with the knowledge to assist with prescribing appropriate training drills to prepare for game-demands.

Keywords Racquet sports · Acceleration · Global positioning systems · Speed · Physical performance

Abbreviations
GPS Global positioning systems
P_{MET} Metabolic power

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Introduction

As the fastest growing sport in the United States, women's collegiate lacrosse has increased participation rates by 67% since 2006 [1]. Regulated female collegiate lacrosse games feature 12 players; 1 goalkeeper and 11 outfield players. Played on the same size field as soccer (110–120 yards long; 60–70 yards wide), the women's collegiate game is divided into two 30-min halves, with unlimited interchange. Comparably, the men's game played at the collegiate level consists of only 10 players with four 15-min periods of play.

Often regarded as the "fastest sport on two feet", female lacrosse players require a high degree of linear sprint speed, lower body power, aerobic and anaerobic capacities, and the ability to decelerate and re-accelerate to meet the demands of the game [1–4]. Female lacrosse players competing at the top collegiate division have demonstrated superior athletics attributes compared to lower divisions [5]. Thus, highlighting the importance of physical development for success in elite lacrosse competition.

In addition to the aforementioned physical qualities of lacrosse players, notational analysis of the movements of players during training and match-play have provided further information on the physiological requirements of the game [1, 6, 7]. Moreover, understanding of the movement demands of competition, in multiple football codes, have assisted in the development of specific training drills to mimic the peak intensities of competition [8–12]. The only study examining the movement profiles of male lacrosse players found that the speed, Player Load™, and a number of acceleration and deceleration efforts significantly reduced in the final quarter compared to the first quarter, amongst all positional groups (midfielders, attackers, defenders) [13]. Due to differences in player rotations, the average playing time for each positional group varied (midfielders: 36 min; attackers: 48 min; and defenders: 59 min). The activity profiles indicated some differences within positional groups, such as total distance covered, speed, and a number of accelerations and deceleration efforts. More specifically, total distance covered, per match, was highest for the defenders (4427 ± 1198 m) compared to both midfielders (3591 ± 1180 m) and attackers (4038 ± 884 m). However, these differences were largely based on the duration players were on the field, with average speeds indicating higher work rates for midfielders (100 ± 11 m min^{-1}) compared to attackers (87 ± 14 m min^{-1}) and defenders (79 ± 14 m min^{-1}). Presently there is no information regarding the running intensities of women's lacrosse [1].

The use of the moving average has been shown to be superior in quantifying the peak running intensities in team sports [9, 10, 14]. Briefly, the moving average finds the peak running speed or acceleration (derived from GPS data) for a given time-period using data collected during competition. The peak running intensities have been quantified in soccer [10], AFL [12], rugby league [11], and rugby sevens [15]. By establishing the peak intensities of match play across a range of durations, coaches have a reference "intensity" from which to prescribe training drills. This allows coaches and practitioners to design drills ranging in intensity from below to above peak game intensity. Moreover, specific drills can be designed that focus on higher speed activities, while others can be more focused to change of direction, thus increasing the acceleration and deceleration demands of the players.

The aim of this study is to quantify the activity profile for women's collegiate lacrosse during conference match play using GPS. Furthermore, using the moving average technique, the peak intensities for speed, acceleration and metabolic power will be established for each position (midfielders, attackers, defenders). It is hypothesized that midfielders result in greater overall distances as well as peak intensities, due to the lack of field restrictions during match-play.

Methods

Participants

GPS data were collected during the 2017 Atlantic Coast Conference season (NCAA Division 1) for one female lacrosse team, to establish the positional (midfielders, attackers, and defenders) activity profiles and peak intensities throughout match-play of women's lacrosse.

Fourteen female outfield lacrosse players from one team were monitored during match-play via GPS (Optimeye S5, Catapult Sports, Melbourne, Australia). The data collection was part of the organization's Sports Performance department's monitoring protocol. Players wore the same GPS across the entirety of the season to minimize between-unit variation [16]. Data from seven conference games (Atlantic Coast Conference) were collected for analysis. A standardized conference match consists of two 30-min halves. Subjects who participated in more than 75% of match play were selected for data collection. A total of 20 data files were omitted due to lack of match play (< 75% of game time). Players were categorized by positional group (n = number of observations): midfielders ($n = 32$), defenders ($n = 19$), and attackers ($n = 21$). Deidentified data were provided, and all parties involved were informed of the benefits and risks associated with the analysis. The study was approved by the Australian Catholic University Human Research Ethics Committee (Ethics Register Number: 2017-323 N).

Design

An observational research design was selected to obtain the match running demands of women's collegiate lacrosse players. The data was collected via a portable GPS unit, with a sampling rate of 10 Hz (Optimeye S5, Catapult Sports, Melbourne, Australia). GPS units were worn in a standardized vest provided by the GPS company, where the unit is positioned in the center of the upper back to prevent noise in data. The validity and reliability of running patterns in field-based sports, including total distance, peak speeds, and high-speed running, have been examined thoroughly in recent years [17, 18]. The validity of using Metabolic Power (P_{MET}) for a stable measurement of determining locomotor load has been shown to be a valid marker [19]. The use of P_{MET} accounts for acceleration and velocity-based running, thus, was selected as an appropriate measure for quantifying the global running intensity of women's collegiate lacrosse competition.

Procedures

Upon completion of each game, data were downloaded using specialist GPS software (Openfield, Catapult Innovations, Australia) before being extracted as individual data files. Individual data files were then analyzed using R Statistical Software (R.3.3, R foundation for Statistical Computing) for further analysis. A total of 72 individual match files were collected. Each file included full match time, and stoppages (after goals and resets in play). Extra time and time spent on the bench were omitted from the data collection. The average total match duration was 112 ± 13, 119 ± 9, and 114 ± 10 min for midfielders, defenders and attackers respectively. The analytical approach allowed multiple variables, including speed (m min^{-1}), acceleration (m s^{-2}) and P_{MET} (W kg^{-1}), to be examined over moving average durations. Moving average durations were investigated over ten different times (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 min), with the corresponding maximum value identified for each duration. Data were collected for all three variables (speed, acceleration, P_{MET}) across every moving average duration, then separated by position to complete comparisons. In addition to the peak running intensities, the overall activity profile data, including distance (meters), maximum velocity (m s^{-1}), speed (m min^{-1}), acceleration (m s^{-2}) and P_{MET} (W kg^{-1}), was established for each position and for each half of the game.

Statistical analysis

Multiple linear mixed models were assembled to appropriately examine differences between position, and periods of play. Standardized differences with interpretation of change determined by effect size (ES) and their associated 90% CI were assessed, with thresholds set as: < 0.20, trivial; 0.20–0.60, small; 0.60–1.20, moderate; 1.20–2.0, large; and > 2.0, very large [20]. Pairwise comparisons were made, provided by the least-squares mean test, to appropriately draw comparisons between groups [21]. Although the magnitude-based network approach has been recently scrutinized, this method has still shown to be valid and robust in representing the levels of uncertainty with qualitative categories of probability [22, 23]. The 90% CI was deemed an appropriate default level, as opposed to any other CI limits, due to the appropriateness of practical application based on the results obtained [20]. Furthermore, when examining monitoring strategies in team sports, CI are typically set at 90% making comparisons between research feasible as well as limiting the possibility of misleading readers to imprecise practical decision making [24, 25]. Differences were considered substantial if they were determined at least *likely* (> 75% likelihood of change) of exceeding the smallest worthwhile difference (SWD; calculated as 0.2 × the between-subject standard deviation (SD)). All statistical analyses were performed using a customized spreadsheet (Microsoft Excel; Microsoft, Redmond, USA), and the R statistical software (R.3.3, R foundation for Statistical Computing).

Results

Figure 1 illustrates the activity profiles of female collegiate lacrosse players across 7 conference games, grouped by position. Attackers covered greater distance (ES = 0.55; 90% CI 0.06–1.05) in the first half compared to the second half of play (Table 1). Whilst speed, acceleration, and metabolic power (P_{MET}) were greater in the first half compared to the second half, for all positional groups (ES = 0.42–0.81, 0.10–1.23).

When comparing positional groups, the defenders' group covered greater distance than both attackers (ES = 1.17; 0.55–1.78) and midfielders (ES = 0.69; 0.21–1.17). The midfielders had greater speed (ES = 0.74; 0.21–1.27) and P_{MET} (ES = 0.74; 0.23–1.24) in the second half compared to the attackers. However, midfielders had higher P_{MET} (ES = 0.71; 0.15–1.26 and acceleration (ES = 1.15; 0.64–1.65) compared to the attackers' group, in total match-play. Both midfielders' (1st half; ES = 0.88; 0.36–1.40, 2nd half; ES = 0.98; 0.52–1.44) and defenders' (1st half; ES = 0.82; 0.37–1.28, 2nd half; ES = 0.82; 0.36–1.29) groups had greater acceleration across both periods of play, compared to the attackers' group (Table 1).

The results of main effects derived from the mixed-model analysis for positional groups for speed, acceleration/deceleration and metabolic power were used for comparisons. Defenders exhibited a *likely* greater average acceleration in the 8-min (ES = 0.72; 0.26–1.19), 9-min (ES = 0.76; 0.28–1.24) and 10-min (ES = 0.72; 0.28–1.16) moving averages, compared to attackers (Table 2). There were no substantial differences between any positional group across any moving average duration for relative distance and metabolic power.

Discussion

The purpose of this study was to investigate the match activity profile as well as peak running intensities throughout female collegiate lacrosse competition. To the author's knowledge, this is the first study to objectively quantify female lacrosse match-play using GPS technology. The findings from this study highlight the main differences in external outputs, derived from GPS, between different positional groups. This study found defenders covered the greatest distance compared to their fellow attackers (ES = 1.17) and midfielders (ES = 0.69). Furthermore, speed, acceleration,

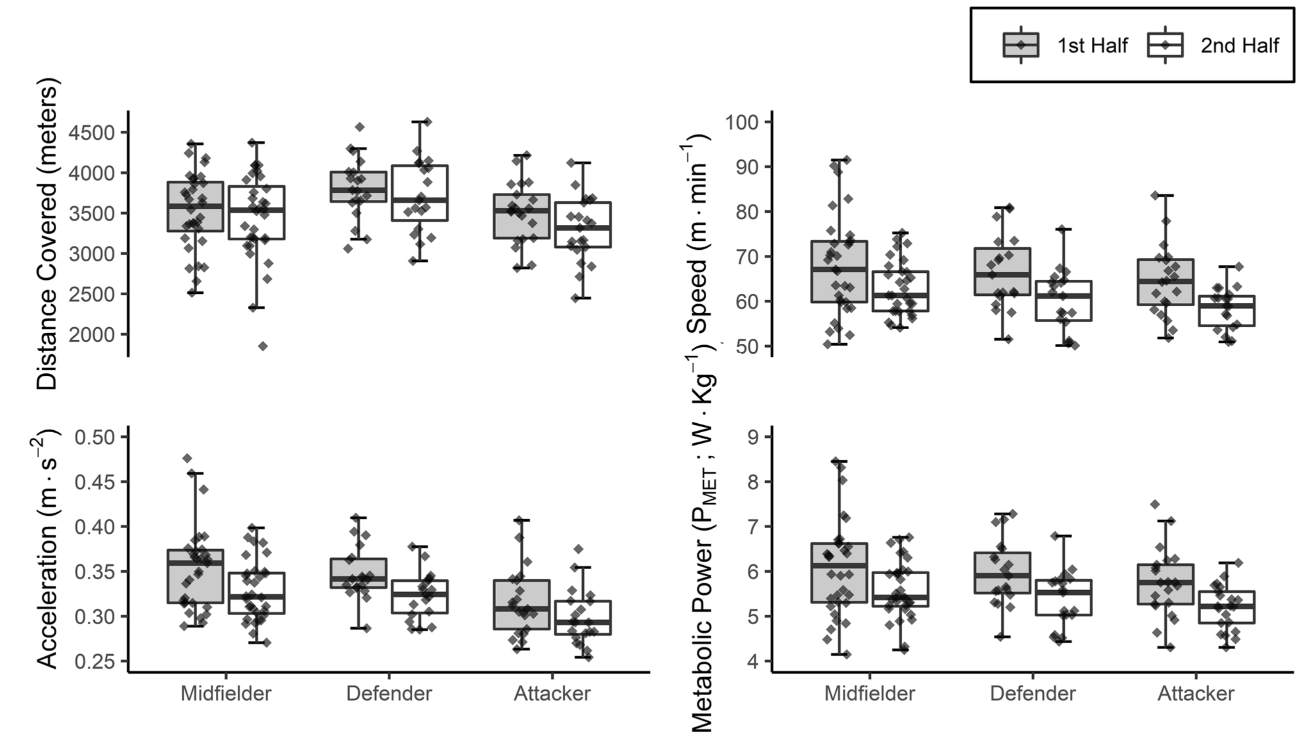

Fig. 1 Boxplots, including individual data points, of match activity variables for each position group during female collegiate lacrosse competition. The box plot represents the median, interquartile ranges and 90% confidence limits of the group values ($n = 72$)

Table 1 Match activity profile of different positions during a female collegiate conference season

		Midfielders Mean ± SD	Attackers Mean ± SD	Defenders Mean ± SD	All Mean ± SD	Defenders vs Attackers ES ± CI	Midfielders vs Attackers ES ± CI	Defenders vs Midfielders ES ± CI
Distance covered (metres)	First half	3527 ± 476	3511 ± 375[d]	3804 ± 385[ab]	3596 ± 438	0.75 ± 0.52[e]	0.04 ± 0.50	0.57 ± 0.42[e]
	Second half	3444 ± 542	3295 ± 403	3713 ± 455[ab]	3472 ± 502	1.00 ± 0.55[e]	0.36 ± 0.52	0.48 ± 0.43[e]
	Match	6972 ± 770	6806 ± 586	7517 ± 786[ab]	7067 ± 769	1.17 ± 0.61[e]	0.27 ± 0.51	0.69 ± 0.48[e]
Max velocity ($m \cdot s^{-1}$)	First half	7.2 ± 0.6	7.3 ± 0.9	7.2 ± 0.4	7.2 ± 0.6	0.16 ± 0.40	0.17 ± 0.62	0.07 ± 0.39
	Second half	7.1 ± 0.6	7.2 ± 0.8	7.0 ± 0.4	7.1 ± 0.6	0.21 ± 0.41	0.21 ± 0.58	0.09 ± 0.40
	Match	7.4 ± 0.6	7.5 ± 0.9	7.3 ± 0.3	7.4 ± 0.6	0.18 ± 0.38	0.19 ± 0.65	0.10 ± 0.36
Speed ($m \cdot min^{-1}$)	First half	67.2 ± 11.6[d]	63.7 ± 8.7[d]	66.6 ± 8.3[d]	66.0 ± 10.0[d]	0.32 ± 0.50	0.39 ± 0.52	0.05 ± 0.39
	Second half	61.6 ± 7.4[b]	57.4 ± 5.3	60.0 ± 6.9	60.0 ± 6.9	0.47 ± 0.60[e]	0.74 ± 0.53[e]	0.20 ± 0.46
	Match	64.5 ± 8.6	60.5 ± 5.7	63.2 ± 6.4	63.0 ± 7.4	0.45 ± 0.55[e]	0.68 ± 0.55[e]	0.15 ± 0.40
Acceleration ($m \cdot s^{-2}$)	First half	0.35 ± 0.05[bd]	0.32 ± 0.04[d]	0.35 ± 0.03[bd]	0.34 ± 0.44[d]	0.82 ± 0.46[e]	0.88 ± 0.52[e]	0.04 ± 0.36
	Second half	0.33 ± 0.03[b]	0.30 ± 0.03	0.32 ± 0.03[b]	0.32 ± 0.34	0.82 ± 0.46[e]	0.98 ± 0.46[e]	0.16 ± 0.41
	Match	0.34 ± 0.04[b]	0.31 ± 0.03	0.34 ± 0.02[b]	0.33 ± 0.03	0.98 ± 0.46[e]	1.15 ± 0.50[e]	0.14 ± 0.38
Metabolic power (P_{met}; $W \cdot kg^{-1}$)	First half	6.1 ± 1.1[d]	5.7 ± 0.8[d]	6.0 ± 0.7[d]	6.0 ± 0.9[d]	0.29 ± 0.50	0.42 ± 0.53	0.09 ± 0.39
	Second half	5.6 ± 0.6[b]	5.2 ± 0.5	5.4 ± 0.6	5.4 ± 0.6	0.35 ± 0.59	0.74 ± 0.51[e]	0.31 ± 0.47
	Match	5.8 ± 0.8[b]	5.5 ± 0.5	5.7 ± 0.6	5.7 ± 0.7	0.37 ± 0.55	0.71 ± 0.55[e]	0.23 ± 0.41

($n = 72$; mean ± SD)

[a] = greater than midfielders; [b] = greater than attackers; [c] = greater than defenders, [d] = greater than second half. [e] = Observed difference > 75% likelihood of being greater than the smallest worthwhile change (calculated as 0.2 × between-subject SD). ES ± CI = effect size ± 90% confidence intervals

Table 2 Peak running intensities of female collegiate lacrosse players (mean ± SD)

	Speed (m min^{-1})			Acceleration (m s^{-2})			P_{MET} (W kg^{-1})		
	Midfielders	Attackers	Defenders	Midfielders	Attackers	Defenders	Midfielders	Attackers	Defenders
1	177 ± 14	183 ± 15	178 ± 12	0.80 ± 0.05	0.80 ± 0.05	0.81 ± 0.05	16.1 ± 1.3	16.7 ± 1.2	16.4 ± 1.1
2	143 ± 15	141 ± 12	143 ± 13	0.65 ± 0.05	0.65 ± 0.05	0.65 ± 0.04	12.9 ± 1.3	12.9 ± 1.0	12.9 ± 1.2
3	125 ± 13	123 ± 11	128 ± 14	0.59 ± 0.05	0.59 ± 0.04	0.60 ± 0.04	11.3 ± 1.1	11.2 ± 0.9	11.5 ± 1.2
4	115 ± 12	111 ± 9	116 ± 4	0.54 ± 0.04	0.54 ± 0.04	0.56 ± 0.04	10.3 ± 1.1	10.1 ± 0.8	10.4 ± 1.2
5	106 ± 11	102 ± 9	107 ± 11	0.52 ± 0.04	0.51 ± 0.04	0.52 ± 0.03	9.6 ± 1.0	9.3 ± 0.8	9.6 ± 0.9
6	101 ± 12	98 ± 8	102 ± 11	0.50 ± 0.04	0.48 ± 0.04	0.50 ± 0.03	9.1 ± 1.1	8.9 ± 0.7	9.2 ± 1.0
7	98 ± 12	94 ± 8	96 ± 11	0.48 ± 0.04	0.46 ± 0.04	0.48 ± 0.03	8.8 ± 1.1	8.5 ± 0.7	8.7 ± 0.9
8	94 ± 13	91 ± 9	95 ± 11	0.47 ± 0.05	0.45 ± 0.04	0.48 ± 0.03[b]	8.5 ± 1.2	8.3 ± 0.7	8.5 ± 0.9
9	92 ± 13	90 ± 9	94 ± 11	0.46 ± 0.05	0.44 ± 0.04	0.47 ± 0.03[b]	8.3 ± 1.2	8.2 ± 0.8	8.4 ± 1.0
10	89 ± 12	87 ± 7	91 ± 11	0.45 ± 0.05	0.43 ± 0.04	0.46 ± 0.03[b]	8.0 ± 1.1	7.9 ± 0.7	8.1 ± 0.9

P_{MET} = Metabolic Power

[a] = greater than midfielders; [b] = greater than attackers; [c] = greater than defenders. All observed differences are > 75% likelihood of being greater than the smallest worthwhile change (calculated as 0.2 × between-subject SD)

and P_{MET} all indicated a substantial decrease in the second half, when compared to the first half, for all positional groups, indicating a decrement in running intensity throughout match-play.

Similarly to previous research on men's lacrosse [13], there was a reduction in running intensity (quantified using speed, acceleration, and P_{MET}) over the course of the match. Although the sample size is small, there is the notion of a decrease in running intensity throughout match-play, possibly due to an onset of fatigue. Sprint and acceleration efforts (n min^{-1}) throughout thhhe first and second halves of match-play have been quantified in Australian football, soccer and rugby league [26]. All three sports highlighted a substantial decrease in the second half compared to the first half and it has been suggested that the observed decrement in running efforts was due to an onset of fatigue and perhaps a lack of opportunity for players to experience passive recovery [26, 27]. These findings add support to the use of conditioning practices to prepare lacrosse athletes for the volume of running undertaken during competitive match play. Identifying peak intensities throughout match-play can provide coaches and practitioners with guidance to prescribing drills to overload certain physical capacities [14]. Specifically, varying the number of players involved, the size and shape of the pitch, and duration of specific drills can result in different physiological responses [28].

Previous literature investigating activity profiles in football suggest that running intensities, including speed and acceleration, differ between positions and studies, due to tactical and coaching strategies [10, 29]. Therefore, it's imperative for readers to acknowledge multiple variables associated with the subjects within the study such as the sample size, and varied tactical approaches amongst teams. In this study, defenders showed a greater total distance covered compared to their positional counterparts. However, when investigating the peak average speed players achieved over different durations, midfielders displayed greater outputs compared to defenders, in all 3 metrics. Peak average speeds, across a 1-min moving average, have been quantified in rugby league and union, Australian football and soccer [8–10, 12]. The two codes of rugby (union and league) showed comparable peak average speeds across their positional groups (154–175 m min^{-1} and 154–172 m min^{-1}, respectively) [8, 9]. Whereas, Australian football and soccer showed a greater average peak speed, for multiple positions, in a 1-min moving average [10, 12]. Soccer players ranged from 173 to 196 m min^{-1}, whilst Australian football players ranged 199–223 m min^{-1}. Positional groups in this current study exhibited an average peak speed of 177–183 m min^{-1}, which is more than both rugby codes, but less than Australian football players. However, the peak speeds of the investigated lacrosse players were comparable to professional soccer players [10]. These peak game speeds can be used in monitoring and prescribing training drills. For example, if a small-sided lacrosse game was prescribed during training for a 2-min bout, and the midfielders resulted in an average speed of 120 m min^{-1}, they would be physically outputting less than their average 2-min peak speed in a game (145 ± 15 m min^{-1}). If coaches wish to increase the intensity of this small-sided game, they could potentially provide a task constraint or manipulate the size of the playing area [30].

The secondary aim of this current study was to investigate the peak average acceleration achieved over different durations (1- to 10-min moving averages) during women's collegiate lacrosse competition. Similar to other sports, the peak running speed for 1 min was ~ 180 m min^{-1} or 3 m s^{-1}. This speed would hardly be classified as "high-intensity" and highlights the importance of quantifying the acceleration and deceleration that occurs in team sports. The present study investigated accelerations and decelerations as a cumulative metric for the moving average approach. By calculating the rate of change in all directions, acceleration/deceleration represents the total multi-directional load on the athlete, and therefore, appropriate to justify positional external outputs in lacrosse competition. Similar to other sports, there was a noticeable decrease in peak average acceleration as moving average duration increased [8–12]. Specifically, Australian Football players (0.95–1.05 m s^{-2}) showed a greater 1-min peak acceleration compared to soccer players (0.79–0.96 m s^{-2}) and international rugby players (0.87–1.01 m s^{-2}). The current research showed a lower peak acceleration across all positions (0.80–0.81 m s^{-2}) compared to the sports previously mentioned. This may be due to gender differences as well as the positional area restrictions in women's lacrosse. However, with the new addition of the 90-s possession clock, there has been a greater emphasis on the transition of play. Therefore, acceleration and deceleration qualities are imperative attributes for high-level lacrosse players. Given the time constraint (90-s shot clock) to transition offensively, there is a greater demand for defenders to increase acceleration towards the opponent's goal. Hence, the overall acceleration output for defenders (0.34 ± 0.02 m s^{-2}) was greater when compared to attackers (0.31 ± 0.03 m s^{-2}) in the whole-period analysis (Table 1). These results suggest that although defenders cover more distance compared to other positions, due to greater time on the field, midfielders held a higher running intensity when on the field. Furthermore, the restraining lines that are in place to determine whether a player is offside may possibly restrict potential accelerative patterns and velocity exposures.

Players in this current study, exhibited an average peak P_{MET}, in a 1-min moving average duration, of 16.1–16.7 W kg^{-1} across all positional groups. Although the validity of using P_{MET}, via GPS, has been questioned in football [31], it has been observed that absolute power outputs (W kg^{-1}), including maximal and mean, were higher in men's lacrosse players compared to elite men's soccer. In professional soccer, a central midfielder has an average metabolic power (P_{MET}) of 8.4 ± 1.2 W kg^{-1} throughout a match [32]. However, when investigating average metabolic power in a 1-min moving average window, male soccer players resulted in an average peak P_{MET} of 16.1–18.3 W kg^{-1}, which seems somewhat comparable to this current study [10]. Similarly, rugby league players demonstrated an average peak P_{MET} of 16.4–18.1 W kg^{-1} [11]. On the contrary, Australian Football showed a higher average peak P_{MET} of 17.8–20.8 W kg^{-1} [12]. Although weight and gender differ between studies, the relative measure of P_{MET} may give coaches and practitioners a relatively accurate measure of overall energy cost throughout a unit of time [14]. Due to the importance of maximal and mean power outputs being physiological characteristics needed for lacrosse, it is deemed necessary to investigate the P_{MET} outputs for estimating energy cost throughout women's lacrosse match play [1, 2].

This investigation has shown some significant differences amongst positional external outputs. Match activity profiles indicated a decrement in relative metrics from the first half to the second half of match-play, potentially resulting from an onset of fatigue. The findings suggested that defenders covered more distance throughout the game compared to their positional counterparts. Attackers had the lowest average acceleration in the first half compared to attackers and defenders. The peak 1-min moving average was found to be well in excess of the average match demands. It is essential to note that this research was conducted using one team, across one season. This data does not represent all playing styles of women's lacrosse, but merely represents the findings across the high-level collegiate competition. Therefore, peak running intensities may differ for positional groups and competition levels if tactical strategies differ. Fitness capacities as well as coaching techniques may alter the rate of decrement in running intensities throughout match-play. It is recommended that practitioners investigate the between-period decrement of running intensities as well as peak-intensities from match-play to help prescribe training sessions. By developing individual and positional profiles of peak intensities throughout match-play, practitioners can ensure their players are training at, or above, "game-like" intensity. Therefore, physically preparing their players for the demands of competition, as well as improving fitness capacities. It is suggested that with efficient, game-like training, athletes will postpone the onset of fatigue, and potentially minimizing the physical output drop-off between whole-periods of match-play.

Conclusions

External outputs during match-play (obtained via GPS) can aid practitioners in prescribing training volumes and intensities in preparation for competition. The results from this study highlight the external loads from both periods of match-play in elite lacrosse competition. Coaches and practitioners can use the results from this study to prescribe intensities for lacrosse drills ranging between 1 and 10 min. Altering variables associated with training drills, such as time, dimensions and constraints, can aid coaches in achieving 'match-like' intensities from their positional groups. Lacrosse players should develop all physical qualities, including high-speed running as well as resistance training, to build the foundational requirements to mitigate the risk of injury, as well as preparing for game demands [2]. It is suggested that individual training programs are designed to meet the positional demands of the game.

Complaince with ethical standards

Conflict of interest No potential conflict of interest was reported by the authors.

Ethical approval The study was approved by the Australian Catholic University Human Research Ethics Committee (Ethics Register Number: 2017-323 N).

Informed consent Deidentified data were provided, and all parties involved were informed of the benefits and risks associated with the analysis.

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