Activity Profile of High-Level Australian Lacrosse Players

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Abstract

Polley, CS, Cormack, SJ, Gabbett, TJ, and Polglaze, T. Activity profile of high-level Australian lacrosse players. *J Strength Cond Res* 29(1): 126–136, 2015–Despite lacrosse being one of the fastest growing team sports in the world, there is a paucity of information detailing the activity profile of high-level players. Microtechnology systems (global positioning systems and accelerometers) provide the opportunity to obtain detailed information on the activity profile in lacrosse. Therefore, this study aimed to analyze the activity profile of lacrosse match-play using microtechnology. Activity profile variables assessed relative to minutes of playing time included relative distance (meter per minute), distance spent standing (0–0.1 $m \cdot min^{-1}$), walking (0.2–1.7 $m \cdot min^{-1}$), jogging (1.8–3.2 $m \cdot min^{-1}$), running (3.3–5.6 $m \cdot min^{-1}$), sprinting ($\geq$5.7 $m \cdot min^{-1}$), number of high, moderate, low accelerations and decelerations, and player load (PL per minute), calculated as the square root of the sum of the squared instantaneous rate of change in acceleration in 3 vectors (medio-lateral, anterior-posterior, and vertical). Activity was recorded from 14 lacrosse players over 4 matches during a national tournament. Players were separated into positions of attack, midfield, or defense. Differences (effect size [ES] $\pm$ 90% confidence interval) between positions and periods of play were considered likely positive when there was $\geq$75% likelihood of the difference exceeding an ES threshold of 0.2. Midfielders had likely covered higher (mean $\pm$ *SD*) meters per minute (100 $\pm$ 11) compared with attackers (87 $\pm$ 14; ES = 0.89 $\pm$ 1.04) and defenders (79 $\pm$ 14; ES = 1.54 $\pm$ 0.94) and more moderate and high accelerations and decelerations. Almost all variables across positions were reduced in quarter 4 compared with quarter 1. Coaches should accommodate for positional differences when preparing lacrosse players for competition.

Key Words global positioning systems, match-play, analysis, performance, positional differences, tournament

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Introduction

Originating in North America in the 15th century, lacrosse has enjoyed substantial growth over the past decade (7,24) and seen a 150% increase in participation since 2002 (18). Considered one of the fastest field-based invasion games (7,28,32), match-play is characterized by intermittent high-intensity activity, collisions, and rapid changes of direction (15,28). Matches comprise 4 quarters of 15-minute (National Collegiate Athletic Association) or 20-minute duration (Federation of International Lacrosse). Teams consist of 1 goal keeper and 9 field players divided into 3 positional groups (midfield $n = 3$, attack $n = 3$, and defense $n = 3$) with unlimited interchange allowable. Midfielders generally cover the entire playing field, whereas attackers and defenders usually remain in their respective halves (15). Considering the positional restrictions placed upon the team, potential exists for differences in the activity profile of match-play between positions and between quarters.

Despite minimal research examining the activity profile of lacrosse (25,30), an abundance of activity profile research exists in other field-based team sports (e.g., soccer, rugby league, hockey, and Australian football) (3,9,21). Much of this recent work has been made possible by the advent of microtechnology including global positioning systems (GPS) and accelerometers (19). This technology has enabled the quantification of gross-fatiguing movements and locomotor patterns (4,6,14). Specifically, analysis commonly includes the determination of positional differences (3,21) and differences between periods of match-play (1,9,23,26,29).

In Australian football, relative distance (first half: 137.8 $m \cdot min^{-1}$ vs. second half: 132.3 $m \cdot min^{-1}$) and low-speed activity (first half: 97.7 $m \cdot min^{-1}$ vs. second half: 95.2 $m \cdot min^{-1}$) are shown to be significantly reduced in the second half of matches when compared with the first (23), whereas total distance (TD) and high-intensity running (HIR) are significantly reduced after the first quarter (9). Similarly, in rugby league, HIR and very HIR expressed relative to game time have been shown to significantly reduce in the fourth quarter compared with the first. Relative distance was also reduced in both the second (96.1 $\pm$ 12 $m \cdot min^{-1}$) and fourth quarters (95.5 $\pm$ 13.2 $m \cdot min^{-1}$) when compared with the first (100.7 $\pm$ 8.1 $m \cdot min^{-1}$) (29). Additionally, it has been noted that maximal

Table 1. Match activity profile of different positional groups during a national lacrosse tournament (n = 51; mean ± *SD*).*

	Midfield Mean ± *SD*	Attack Mean ± *SD*	Defense Mean ± *SD*	Midfield vs. attack ES ± CI	Midfield vs. defense ES ± CI	Attack vs. defense ES ± CI
Playing time (min)	36.15 ± 13.16	48.18 ± 14:29†	59.03 ± 20:07†	−0.82 ± 0.96	−1.14 ± 0.93	−0.43 ± 1.02
Relative distance ($m \cdot min^{-1}$)	100 ± 11‡§	87 ± 14	79 ± 14	0.89 ± 1.04	1.54 ± 0.94	0.53 ± 1.03
Relative PL ($PL \cdot min^{-1}$)	9.9 ± 1.5‡§	8.2 ± 2.1	7.6 ± 2.7	0.83 ± 1.07	1.04 ± 0.98	0.27 ± 1.02
Stand ($m \cdot min^{-1}$)	3.1 ± 2.1	3.6 ± 1.9	3.1 ± 1.1	−0.38 ± 0.92	−0.21 ± 0.87	0.24 ± 1.05
Walk ($m \cdot min^{-1}$)	28.8 ± 3.1	29.1 ± 3.4	32.4 ± 4.8†‡	−0.08 ± 1.01	−0.78 ± 0.94	−0.67 ± 1.01
Jog ($m \cdot min^{-1}$)	28.8 ± 4.5‡§	25.0 ± 5.2§	19.8 ± 2.4	0.70 ± 1.04	2.48 ± 0.90	1.02 ± 1.10
Run ($m \cdot min^{-1}$)	31.7 ± 5.8‡§	25.9 ± 6.4§	20.3 ± 13.3	0.80 ± 1.04	1.28 ± 0.97	0.75 ± 0.99
Sprint ($m \cdot min^{-1}$)	5.4 ± 1.8‡§	3.4 ± 1.7	3.5 ± 4.4	1.12 ± 1.04	1.03 ± 1.00	0.38 ± 1.00
Dec_{HI} ($no \cdot min^{-1}$)	0.7 ± 0.2‡§	0.5 ± 0.1	0.5 ± 0.2	0.59 ± 0.94	0.66 ± 0.92	0.16 ± 1.01
Dec_{MO} ($no \cdot min^{-1}$)	2.7 ± 0.3‡§	2.2 ± 0.3	2.1 ± 0.5	1.75 ± 1.04	1.54 ± 0.98	0.23 ± 1.00
Dec_{LO} ($no \cdot min^{-1}$)	18.5 ± 1.2	18.4 ± 2.1	19.2 ± 2.0	0.09 ± 1.07	−0.36 ± 0.96	−0.37 ± 1.03
Acc_{HI} ($no \cdot min^{-1}$)	0.7 ± 0.2‡§	0.5 ± 0.2	0.5 ± 0.2	0.95 ± 1.01	0.76 ± 0.94	−0.11 ± 1.02
Acc_{MO} ($no \cdot min^{-1}$)	3.0 ± 0.4‡§	2.5 ± 0.5§	2.1 ± 0.4	1.00 ± 1.04	2.11 ± 0.93	0.89 ± 1.03
Acc_{LO} ($no \cdot min^{-1}$)	25.4 ± 2.2	25.6 ± 2.7	26.6 ± 2.5	−0.08 ± 1.01	−0.46 ± 0.92	−0.35 ± 1.03

*Stand = 0–0.2 $m \cdot s^{-1}$; walk = 0.2–1.8 $m \cdot s^{-1}$; jog = 1.8–3.3 $m \cdot s^{-1}$; run = 3.3–5.7 $m \cdot s^{-1}$; sprint = >5.7 $m \cdot s^{-1}$; Dec_{HI} = ≥−2.78 $m \cdot s^{-2}$; Dec_{MO} = −2.78 to −1.11 $m \cdot s^{-2}$; Dec_{LO} = −1.11 to 0 $m \cdot s^{-2}$; Acc_{HI} = ≥2.78 $m \cdot s^{-2}$; Acc_{MO} = 1.11–2.78 $m \cdot s^{-2}$; Acc_{LO} = 0–1.1 $m \cdot s^{-2}$; ES ± 90% CI = effect size ± 90% confidence interval. Differences (ES ± 90% CI) were considered likely positive when there was more than a 75% likelihood of the difference exceeding an ES threshold of 0.2.

†A ≥75% likely positive difference from midfield.

‡A ≥75% likely positive difference from attack.

§A ≥75% likely positive difference from defense.

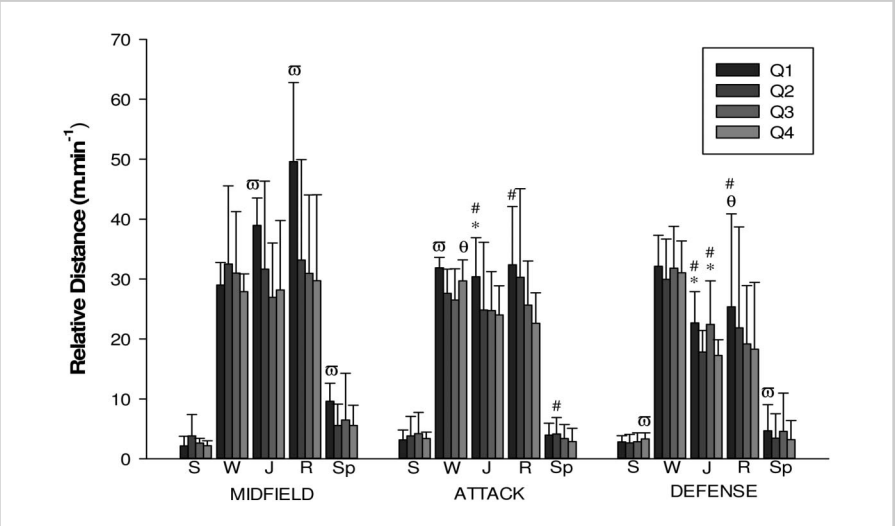

Figure 1. The relative mean ± *SD* comparisons for velocity within positions. Differences (ES ± 90% CI) were considered likely positive when there was more than a 75% likelihood of the difference exceeding an ES threshold of 0.2. ES = effect size; CI = confidence interval; Q1 = quarter 1; Q2 = quarter 2; Q3 = quarter 3; Q4 = quarter 4; S = stand; W = walk; J = jog; R = run; Sp = sprint; ϖ indicates ≥75% likely positive difference from all quarters; * indicates ≥75% likely positive difference from Q2; θ indicates ≥75% likely positive difference from Q3; # indicates ≥75% likely positive difference from Q4.

accelerations in Australian football and decelerations in rugby league were reduced in the latter part of matches indicative of fatigue (1,26).

To date, only 2 studies using video-based time motion analysis (TMA) exist on the activity profile of lacrosse (25,30). Compared with other team ball sports, lacrosse exhibited the second longest duration of high-velocity movements (lacrosse, 1.05 ± 0.60 s; soccer, 1.33 ± 0.86 s; field hockey, 0.96 ± 0.5 s; handball, 0.67 ± 0.36 s; basketball, 0.64 ± 0.37 s) and recorded a high-average speed of 5.25 ± 1.06 $m \cdot min^{-1}$ (30). When compared by position, midfielders played less game time (53%) but had covered higher relative distance (133 $m \cdot min^{-1}$) and a greater contribution of running (18%) and sprinting (7%) than attackers (97 $m \cdot min^{-1}$; 10% and 4%, respectively) (25). Although a basic knowledge of the movement performed by lacrosse players exists, no detailed activity profile has been conducted with objective analysis between positions or quarters of match-play. Furthermore, the use of video-based TMA used in these previous studies has numerous limitations including poor-to-moderate reliability as opposed to GPS (12,27). Therefore, the aim of this study was to quantify the activity profile of top level Australian lacrosse players in match-play using GPS and associated microtechnology.

Methods

Experimental Approach to the Problem

The activity profile patterns of lacrosse match-play were measured using microtechnology devices (GPS and accelerometers). Data were collected from outfield players in 1 team during 4 matches of a National Championship tournament. Matches were 80 minutes in duration (4 × 20-minute quarters) played on consecutive days. Similar to previous studies, players were required to have played at least 50% of game time compared with their positional average to be included in data analysis (1,9). Players were classified as midfield, attack, and defense for positional comparisons.

Subjects

Fifteen male lacrosse players from a state team participating in the National Championships provided data for this study. All participants were outfield players (goalkeepers were excluded) and played in each match of the tournament. Before the commencement of the study, participants were provided with a written description outlining the purposes, procedures, benefits, and risks associated with the study. Written informed consent was then obtained from all participants. The study was approved by the Australian Catholic University Human Research Ethics Committee.

Procedures

Microtechnology Device. Activity profile data were collected using MinimaxX, GPS units (Catapult Innovations, Team S4, Melbourne, Australia), sampling at 10 Hz, that also contained triaxial accelerometers (KXP94; Kionix, New York, NY, USA) sampling at 100 Hz. Accelerometers measured the magnitude and frequency of movement in 3 planes (anterior-posterior, medio-lateral, and vertical) reported as player load (PL) (5). Player load is calculated as the square root of the sum of the squared instantaneous rate of change in acceleration in each of the 3 vectors (4). A high validity and reliability for MinimaxX 10 Hz GPS and accelerometers (coefficient of variation [CV] <2%) has previously been reported (4,8,33). The microtechnology device used in this study (88 × 50 × 19 mm) was positioned between the scapulae in a custom built harness worn under playing attire. Participants had previously worn the same units in competition and each player was assigned the same device in each match to minimize potential error (20).

Activity Profile Data. Players were divided into 3 positional groups (midfield, attack, and defense) for comparison. Variables were expressed per minute of playing time and

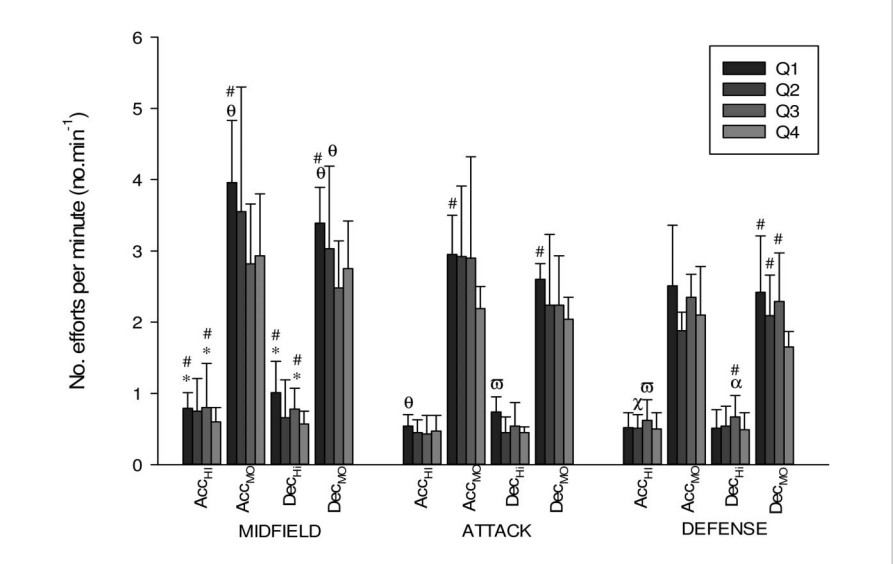

Figure 2. The relative mean ± *SD* comparisons of accelerations and decelerations within positions. Differences (ES ± 90% CI) were considered likely positive when there was more than a 75% likelihood of the difference exceeding an ES threshold of 0.2. ES = effect size; CI = confidence interval; Q1 = quarter 1; Q2 = quarter 2; Q3 = quarter 3; Q4 = quarter 4; Acc_{HI} = high accelerations (≥2.78 m·s^{-2}); Acc_{MO} = moderate accelerations (1.11–2.78 m·s^{-2}); Dec_{HI} = high decelerations (≥−2.78 m·s^{-2}); Dec_{MO} = moderate decelerations (−2.78 to −1.11 m·s^{-2}); ϖ indicates ≥75% likely positive difference from all quarters; α indicates ≥75% likely positive difference from Q1; * indicates ≥75% likely positive difference from Q2; θ indicates ≥75% likely positive difference from Q3; # indicates ≥75% likely positive difference from Q4; χ indicates trivial difference from Q4.

included relative distance (meter per minute) and relative PL (PL per minute). Velocity categories included stand (0–0.1 m·s^{-1}), walk (0.2–1.7 m·s^{-1}), jog (1.8–3.2 m·s^{-1}), run (3.3–5.6 m·s^{-1}), and sprint (≥5.7 m·s^{-1}) (13). The number of accelerations and decelerations per minute was recorded and categorized as high accelerations (Acc_{HI} no·min^{-1}, ≥2.78 m·s^{-2}), moderate accelerations (Acc_{MO} no·min^{-1}, 1.11–2.78 m·s^{-2}), low accelerations (Acc_{LO} no·min^{-1}, 0–1.11 m·s^{-2}) and high decelerations (Dec_{HI} no·min^{-1}, ≥−2.78 m·s^{-2}), moderate decelerations (Dec_{MO} no·min^{-1}, −2.78 to −1.11 m·s^{-2}), low decelerations (Dec_{LO} no·min^{-1}, −1.11 to 0 m·s^{-2}). The velocity ranges in this study are based on the velocity distribution curves of team sport athletes (13). Maximal accelerations of ≥2.78 m·s^{-2} were used as described previously (1). Overall position data were calculated as the mean of all 4 tournament matches. Data were analyzed from a total of 51 samples (midfield, $n = 18$; attack, $n = 15$; and defense, $n = 18$).

Statistical Analyses

Descriptive data relative to playing time is presented as mean ± *SD*. Data were log transformed to reduce bias due to nonuniformity of error and analyzed using the effect size (ES) statistic ±90% confidence interval (CI). Comparisons between positions (midfield vs. attack, midfield vs. defense, and attack vs. defense) and comparisons within positions between quarters (e.g., midfield quarter 1 vs. midfield quarter 2) were assessed and mean differences in activity profile variables analyzed using customized spreadsheets (16,17). Differences (ES ± 90% CI) were considered likely positive or negative when there was more than a 75% likelihood of the difference exceeding an ES threshold of 0.2 (16). Differences with less certainty were considered trivial, and where the 90% CI crossed boundaries of likely positive and negative, the difference was considered unclear (16).

Results

Match Activity Profile

The mean ± *SD* absolute distances per match for positions were as follows: midfield, 3591 ± 1180 m; attack, 4038 ± 884 m; and defense, 4427 ± 1198 m. The mean ± *SD* absolute PL per match for positions were as follows: midfield, 348 ± 98 au; attack, 380 ± 91 au; and defense, 409 ± 100 au. Total mean ± *SD* absolute distances for each of the velocity ranges were as follows: (a) stand–midfield: 127 ± 113 m, attack: 189 ± 114 m, and defense: 194 ± 100 m; (b) walk–midfield: 1061 ± 383 m, attack: 1385 ± 366 m, and defense: 1991 ± 854 m; (c) jog–midfield: 1065 ± 387 m, attack: 1150 ± 261 m, defense: 1130 ± 342 m; (d) run–midfield: 1138 ± 332 m, attack: 1170 ± 286 m, and defense: 968 ± 219 m; and (e) sprint–midfield: 200 ± 89 m, attack: 143 ± 63 m, and defense: 139 ± 95 m. Differences in playing time, relative distances covered in various locomotor categories, and relative number of accelerations and decelerations between positions are shown in Table 1.

Quarter Comparisons: Midfield

Figures 1–3 display the relative mean ± *SD* for all activity profile variables per quarter and the likelihood (≥75% likely) that differences exist between quarters within the respective positional groups. Midfielders produced the highest meters per minute in quarter 1 compared with all other quarters (ES = 1.95 ± 0.91 [Q2]; 2.61 ± 0.90 [Q3]; 2.03 ± 0.97 [Q4]) and the highest PL per minute in quarter 1 compared with all other quarters (ES = 1.95 ± 0.92 [Q2]; 2.00 ± 1.00 [Q3]; 1.74 ± 0.93 [Q4]) (Figure 3). However, there were no clear differences in distances covered standing (0–0.1 m·s^{-1}) and walking by midfielders throughout a match. Midfielders covered greater meters per minute in the following locomotor categories in quarter 1 in comparison with all other quarters: jog (ES = 0.72 ± 0.86 [Q2]; 0.95 ± 0.51 [Q3]; 0.92 ±

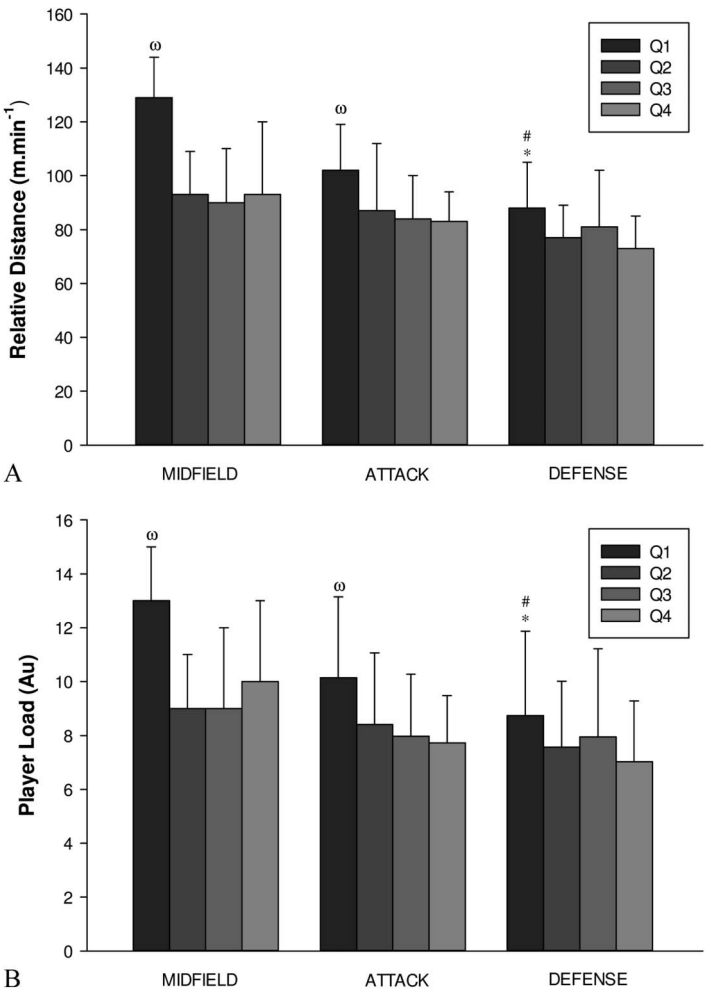

Figure 3. Relative distance (meter per minute) (A) and relative PL (PL per minute) (B) comparisons between quarters by position. Differences (ES ± 90% CI) were considered likely positive or when there was more than a 75% likelihood of the difference exceeding an ES threshold of 0.2. ES = effect size; CI = confidence interval; Q1 = quarter 1; Q2 = quarter 2; Q3 = quarter 3; Q4 = quarter 4; ϖ indicates ≥75% likely positive difference from all quarters; * indicates ≥75% likely positive difference from Q2; # indicates ≥75% likely positive difference from Q4.

0.72 [Q4]), run (ES = 1.07 ± 0.99 [Q2]; 1.14 ± 0.50 [Q3]; 1.31 ± 0.60 [Q4]), and sprint (ES = 0.92 ± 1.01 [Q2]; 0.90 ± 0.93 [Q3]; 1.13 ± 0.72 [Q4]) (Figure 1). The highest number of Dec_{HI} no·min^{-1} and Acc_{HI} no·min^{-1} occurred in quarter 1 and was reduced in quarters 2 (ES = −0.77 ± 0.90; −0.30 ± 0.98) and quarter 4 (ES = −0.69 ± 0.47; −0.55 ± 0.58). Similarly, the respective number of Dec_{HI} no·min^{-1} and Acc_{HI} no·min^{-1} was higher in quarter 3 and reduced in quarter 2 (ES = −0.47 ± 0.69; −0.34 ± 1.37) and quarter 4 (ES = −0.39 ± 0.46; −0.43 ± 0.57). Furthermore, Acc_{MO} no·min^{-1} was highest in quarter 1 and reduced in quarters 3 (ES = −0.92 ± 0.66) and 4 (ES = −0.83 ± 0.49). Similarly, Dec_{MO} no·min^{-1} also reduced in quarters 3 (ES = −1.04 ± 0.71) and 4 (ES = −0.69 ± 0.72) compared with quarter 1 and was also reduced in quarter 3 when compared with quarter 2 (ES = −0.53 ± 0.76). The difference in Acc_{LO} no·min^{-1} and Dec_{LO} no·min^{-1} between all quarters was unclear (Figure 2).

Quarter Comparisons: Attack

The highest meter per minute (ES = 0.58 ± 0.74 [Q2]; 0.65 ± 0.70 [Q3]; 0.68 ± 0.34 [Q4]) and PL per minute (ES = 0.47 ± 0.56 [Q2]; 0.58 ± 0.67 [Q3]; 0.63 ± 0.39 [Q4]) occurred in quarter 1 when compared with all other quarters (Figure 3). Attackers also performed the highest amount of walk meter per minute in quarter 1 in comparison with all other quarters (ES = 1.02 ± 0.81 [Q2]; 1.34 ± 1.17 [Q3]; 0.50 ± 0.51 [Q4]) as well as a greater amount of walk meter per minute in quarter 4 when compared with quarter 3 (ES = 0.84 ± 1.08). The highest amount of jog meter per minute was observed in quarter 1 and reduced in quarters 2 (ES = −0.57 ± 0.78) and 4 (ES = −0.48 ± 0.19) with amounts of run meter per minute similarly highest in quarter 1 but only reduced in quarter 4 (ES = −0.59 ± 0.54). Sprint meter per minute was highest for attackers in quarter 2 and reduced in quarter 4 (ES = −0.73 ± 1.35) (Figure 1). The number of Dec_{HI} no·min^{-1} was highest in quarter 1 and reduced in all subsequent quarters (ES = −1.13 ± 0.71 [Q2]; −1.05 ± 1.51 [Q3]; −0.95 ± 0.79 [Q4]), whereas Acc_{HI} no·min^{-1} was highest in quarter 1 but only reduced in quarter 3 (ES = −0.55 ± 0.72). Similarly, Dec_{LO} no·min^{-1} was greatest in quarter 1 and reduced in comparison with all quarters (ES = −0.73 ± 0.85 [Q2]; −0.83 ± 0.67 [Q3]; −0.38 ± 0.27 [Q4]) with the subsequent Acc_{LO} no·min^{-1} highest in quarter 1 but only reduced in quarters 2 (ES = −0.63 ± 0.85) and 4 (ES = −0.74 ± 0.93). Acc_{MO} no·min^{-1} and Dec_{MO} no·min^{-1} were highest in quarter 1 and reduced in quarter 4 (ES = −0.88 ± 0.72; −0.54 ± 0.38) (Figure 2). There was no clear change in standing between quarters.

Table 2. Midfield vs. attack positional comparison between quarters of a national lacrosse tournament.*

	Q1		Q2		Q3		Q4	
Midfield vs. attack	ES ± CI	Qual	ES ± CI	Qual	ES ± CI	Qual	ES ± CI	Qual
Relative distance ($m \cdot s^{-1}$)	1.45 ± 1.04	Likely positive	0.29 ± 1.04	Unclear	0.25 ± 0.95	Unclear	0.37 ± 0.88	Unclear
Relative PL ($PL \cdot min^{-1}$)	0.95 ± 1.07	Likely positive	0.34 ± 1.07	Unclear	0.39 ± 0.95	Unclear	0.70 ± 0.95	Likely positive
Stand ($m \cdot s^{-1}$)	−0.71 ± 0.92	Likely negative	−0.23 ± 0.91	Unclear	−0.47 ± 1.06	Unclear	−1.13 ± 0.92	Likely negative
Walk ($m \cdot s^{-1}$)	−0.88 ± 0.87	Likely negative	0.28 ± 0.87	Unclear	0.28 ± 0.88	Unclear	−0.52 ± 0.98	Unclear
Jog ($m \cdot s^{-1}$)	1.03 ± −0.95	Likely positive	0.40 ± 0.96	Unclear	0.19 ± 0.95	Unclear	0.25 ± 0.88	Unclear
Run ($m \cdot s^{-1}$)	1.25 ± 1.04	Likely positive	0.16 ± 0.98	Unclear	0.40 ± 0.93	Unclear	0.44 ± 0.87	Unclear
Sprint ($m \cdot s^{-1}$)	1.89 ± 1.07	Likely positive	0.60 ± 0.97	Likely positive	0.66 ± 1.01	Likely positive	0.80 ± 1.01	Likely positive
Dec_{HI} ($no \cdot min^{-1}$)	0.56 ± 0.90	Likely positive	0.32 ± 0.90	Unclear	0.66 ± 1.12	Likely positive	0.64 ± 0.87	Likely positive
Dec_{MO} ($no \cdot min^{-1}$)	2.00 ± 0.90	Likely positive	0.67 ± 1.04	Likely positive	0.31 ± 1.04	Unclear	1.28 ± 0.91	Likely positive
Dec_{LO} ($no \cdot min^{-1}$)	−0.34 ± 0.93	Unclear	0.27 ± 0.89	Unclear	0.83 ± 0.98	Likely positive	−0.11 ± 1.00	Unclear
Acc_{HI} ($no \cdot min^{-1}$)	1.04 ± 0.99	Likely positive	0.70 ± 0.93	Likely positive	1.36 ± 1.01	Likely positive	0.51 ± 0.98	Unclear
Acc_{MO} ($no \cdot min^{-1}$)	1.34 ± 0.95	Likely positive	0.36 ± 0.93	Unclear	0.06 ± 1.07	Unclear	0.96 ± 0.87	Likely positive
Acc_{LO} ($no \cdot min^{-1}$)	−0.02 ± 0.93	Unclear	0.23 ± 0.86	Unclear	0.63 ± 0.96	Likely positive	−0.45 ± 1.04	Unclear

*$PL \cdot min^{-1}$ = player load per minute; stand = 0–0.2 $m \cdot s^{-1}$; walk = 0.2–1.8 $m \cdot s^{-1}$; jog = 1.8–3.3 $m \cdot s^{-1}$; run = 3.3–5.7 $m \cdot s^{-1}$; sprint = >5.7 $m \cdot s^{-1}$; Dec_{HI} = ≥ −2.78 $m \cdot s^{-2}$; Dec_{MO} = −2.78 to −1.11 $m \cdot s^{-2}$; Dec_{LO} = −1.11 to 0 $m \cdot s^{-2}$; Acc_{HI} = ≥2.78 $m \cdot s^{-2}$; Acc_{MO} = 1.11–2.78 $m \cdot s^{-2}$; Acc_{LO} = 0–1.1 $m \cdot s^{-2}$; ES ± 90% CI = effect size ±90% confidence interval; Qual = qualitative outcome. Differences (ES ± 90% CI) were considered likely positive or when there was more than a 75% likelihood of the difference exceeding an ES threshold of 0.2.

Table 3. Midfield vs. defense positional comparison between quarters of a national lacrosse tournament.*

	Q1		Q2		Q3		Q4	
Midfield vs. defense	ES ± CI	Qual	ES ± CI	Qual	ES ± CI	Qual	ES ± CI	Qual
Relative distance ($m \cdot s^{-1}$)	2.29 ± 0.96	Likely positive	1.04 ± 0.89	Likely positive	0.43 ± 0.91	Unclear	0.88 ± 0.86	Likely positive
Relative PL ($PL \cdot min^{-1}$)	0.95 ± 1.07	Likely positive	0.77 ± 0.96	Likely positive	0.43 ± 0.92	Unclear	0.99 ± 0.91	Likely positive
Stand ($m \cdot s^{-1}$)	−0.69 ± 0.86	Likely negative	−0.02 ± 0.86	Unclear	0.00 ± 0.96	Unclear	−1.14 ± 0.88	Likely negative
Walk ($m \cdot s^{-1}$)	−0.59 ± 0.93	Likely negative	0.08 ± 0.86	Unclear	−0.18 ± 0.87	Unclear	−0.63 ± 0.96	Likely negative
Jog ($m \cdot s^{-1}$)	1.23 ± 1.07	Likely positive	1.08 ± 0.86	Likely positive	0.49 ± 0.90	Unclear	1.14 ± 0.85	Likely positive
Run ($m \cdot s^{-1}$)	1.67 ± 0.96	Likely positive	0.82 ± 0.93	Likely positive	1.04 ± 0.93	Likely positive	0.93 ± 0.91	Likely positive
Sprint ($m \cdot s^{-1}$)	1.38 ± 0.97	Likely positive	0.98 ± 0.95	Likely positive	0.66 ± 0.96	Likely positive	0.79 ± 0.95	Likely positive
Dec_{HI} ($no \cdot min^{-1}$)	1.30 ± 0.91	Likely positive	0.05 ± 0.86	Unclear	0.39 ± 0.93	Unclear	0.43 ± 0.93	Unclear
Dec_{MO} ($no \cdot min^{-1}$)	1.37 ± 0.98	Likely positive	0.96 ± 0.89	Likely positive	0.25 ± 0.90	Unclear	2.31 ± 0.86	Likely positive
Dec_{LO} ($no \cdot min^{-1}$)	−0.08 ± 0.92	Unclear	0.23 ± 0.86	Unclear	0.22 ± 0.95	Unclear	−0.12 ± 0.93	Unclear
Acc_{HI} ($no \cdot min^{-1}$)	1.14 ± 0.89	Likely positive	0.51 ± 0.87	Unclear	0.72 ± 0.93	Likely positive	0.38 ± 0.90	Unclear
Acc_{MO} ($no \cdot min^{-1}$)	1.58 ± 0.94	Likely positive	1.54 ± 0.86	Likely positive	0.56 ± 0.86	Likely positive	1.02 ± 0.90	Likely positive
Acc_{LO} ($no \cdot min^{-1}$)	−0.05 ± 0.90	Unclear	0.22 ± 0.86	Unclear	0.32 ± 0.92	Unclear	−0.46 ± 0.93	Unclear

*$PL \cdot min^{-1}$ = player load per minute; stand = 0–0.2 $m \cdot s^{-1}$; walk = 0.2–1.8 $m \cdot s^{-1}$; jog = 1.8–3.3 $m \cdot s^{-1}$; run = 3.3–5.7 $m \cdot s^{-1}$; sprint = > 5.7 $m \cdot s^{-1}$; Dec_{HI} = ≥ −2.78 $m \cdot s^{-2}$; Dec_{MO} = −2.78 to −1.11 $m \cdot s^{-2}$; Dec_{LO} = −1.11 to 0 $m \cdot s^{-2}$; Acc_{HI} = ≥2.78 $m \cdot s^{-2}$; Acc_{MO} = 1.11–2.78 $m \cdot s^{-2}$; Acc_{LO} = 0–1.1 $m \cdot s^{-2}$; ES ± 90% CI = effect size ±90% confidence interval; Qual = qualitative outcome. Differences (ES ± 90% CI) were considered likely positive or when there was more than a 75% likelihood of the difference exceeding an ES threshold of 0.2.

Table 4. Attack vs. defense positional comparison between quarters of a national lacrosse tournament.*

	Q1		Q2		Q3		Q4	
Attack vs. defense	ES ± CI	Qual	ES ± CI	Qual	ES ± CI	Qual	ES ± CI	Qual
Relative distance ($m \cdot s^{-1}$)	0.76 ± 1.03	Likely positive	0.41 ± 1.09	Unclear	0.21 ± 1.02	Unclear	0.79 ± 1.03	Likely positive
Relative PL ($PL \cdot min^{-1}$)	0.44 ± 1.02	Unclear	0.29 ± 1.03	Unclear	0.08 ± 1.02	Unclear	0.37 ± 1.02	Unclear
Stand ($m \cdot s^{-1}$)	0.12 ± 1.07	Unclear	0.30 ± 1.05	Unclear	0.43 ± 1.05	Unclear	0.02 ± 1.03	Unclear
Walk ($m \cdot s^{-1}$)	0.01 ± 0.98	Unclear	−0.33 ± 1.01	Unclear	−0.66 ± 1.02	Likely negative	−0.24 ± 1.00	Unclear
Jog ($m \cdot s^{-1}$)	1.11 ± 1.03	Likely positive	0.58 ± 1.08	Unclear	0.32 ± 1.03	Unclear	1.50 ± 1.04	Likely positive
Run ($m \cdot s^{-1}$)	0.66 ± 1.01	Likely positive	0.65 ± 1.02	Likely positive	0.79 ± 0.99	Likely positive	0.72 ± 0.99	Likely positive
Sprint ($m \cdot s^{-1}$)	0.02 ± 1.00	Unclear	0.55 ± 0.99	Unclear	0.10 ± 1.01	Unclear	0.06 ± 1.02	Unclear
Dec_{HI} ($no \cdot min^{-1}$)	0.98 ± 0.99	Likely positive	−0.38 ± 1.03	Unclear	−0.43 ± 1.09	Unclear	0.00 ± 0.99	Unclear
Dec_{MO} ($no \cdot min^{-1}$)	0.42 ± 1.01	Unclear	0.02 ± 1.09	Unclear	−0.13 ± 1.07	Unclear	1.36 ± 1.03	Likely positive
Dec_{LO} ($no \cdot min^{-1}$)	0.22 ± 1.01	Unclear	−0.06 ± 1.03	Unclear	−0.45 ± 1.01	Unclear	−0.02 ± 1.02	Unclear
Acc_{HI} ($no \cdot min^{-1}$)	0.13 ± 1.03	Unclear	−0.29 ± 1.05	Unclear	−0.75 ± 1.05	Likely positive	−0.13 ± 1.03	Unclear
Acc_{MO} ($no \cdot min^{-1}$)	0.65 ± 0.99	Likely positive	1.34 ± 1.08	Likely positive	0.27 ± 1.11	Unclear	0.27 ± 1.00	Unclear
Acc_{LO} ($no \cdot min^{-1}$)	−0.3 ± 1.02	Unclear	0.00 ± 1.02	Unclear	−0.25 ± 1.02	Unclear	0.06 ± 1.05	Unclear

*$PL \cdot min^{-1}$ = player load per minute; stand = 0–0.2 $m \cdot s^{-1}$; walk = 0.2–1.8 $m \cdot s^{-1}$; jog = 1.8–3.3 $m \cdot s^{-1}$; run = 3.3–5.7 $m \cdot s^{-1}$; sprint = > 5.7 $m \cdot s^{-1}$; $Dec_{HI} = \geq -2.78$ $m \cdot s^{-2}$; $Dec_{MO} = -2.78$ to -1.11 $m \cdot s^{-2}$; $Dec_{LO} = -1.11$ to 0 $m \cdot s^{-2}$; $Acc_{HI} = \geq 2.78$ $m \cdot s^{-2}$; $Acc_{MO} = 1.11$–2.78 $m \cdot s^{-2}$; $Acc_{LO} = 0$–1.1 $m \cdot s^{-2}$; ES ± 90% CI = effect size ±90% confidence interval; Qual = qualitative outcome. Differences (ES ± 90% CI) were considered likely positive when there was more than a 75% likelihood of the difference exceeding an ES threshold of 0.2.

Quarter Comparisons: Defense

Similar to midfielders and attackers, meter per minute and PL per minute were highest in quarter 1. However, both were only reduced in quarters 2 (ES = −0.63 ± 0.45; −0.33 ± 0.28) and quarter 4 (ES = −0.89 ± 0.38; −0.51 ± 0.35) with differences between quarters 1 and 3 considered unclear (Figure 1). The contribution of sprint meter per minute was highest for defenders in quarter 1 compared with all other quarters (ES = 0.42 ± 0.57 [Q2]; 0.44 ± 0.66 [Q3]; 0.51 ± 0.72 [Q4]), whereas stand meter per minute seemed greatest in quarter 4 compared with all other quarters (ES = 0.34 ± 0.30 [Q1]; 0.56 ± 0.63 [Q2]; 0.43 ± 0.65 [Q3]). Jog meter per minute values were highest in quarters 1 and 3 but reduced in quarters 2 (ES = −0.86 ± 1.16; −0.76 ± 1.31) and 4 (ES = −0.94 ± 0.56; −0.85 ± 0.71). Additionally, run meter per minute was highest in quarter 1 and reduced after half time in quarters 3 (ES = −0.39 ± 0.48) and 4 (ES = −0.48 ± 0.29). The difference in walking between quarters was unclear (Figure 1). Acc_{HI} no·min^{-1} was greatest in quarter 3 compared with all other quarters (ES = 0.37 ± 0.44 [Q1]; 0.42 ± 0.45 [Q2]; 0.48 ± 0.32 [Q4]) with trivial differences existing between quarters 2 and 4 (ES = 0.06 ± 0.24). Similarly, Dec_{HI} no·min^{-1} was greatest in quarter 3 compared with quarters 1 (ES = 0.51 ± 0.51) and 4 (ES = 0.56 ± 0.47). In contrast, both Acc_{LO} no·min^{-1} and Dec_{LO} no·min^{-1} were highest in quarter 1 and reduced in quarter 2, respectively (ES = −0.53 ± 0.68; −0.58 ± 0.59). Acc_{MO} no·min^{-1} were highest in quarters 1 and 3 and reduced in quarters 2 (ES = −0.84 ± 1.10; −0.75 ± 0.62) and 4 (ES = −0.47 ± 0.67; −0.47 ± 0.67). The number of Dec_{MO} no·min^{-1} was lowest in quarter 4 compared with all other quarters (ES = −1.02 ± 0.49 [Q1]; −0.62 ± 0.66 [Q2]; −0.90 ± 0.51 [Q3]) (Figure 2).

Quarter Comparisons Between Positions

The mean ± *SD* of all activity profile variables by position are shown in Figures 1–3. Likely differences in activity profile variables are illustrated between midfield and attack (Table 2), midfield and defense (Table 3), and attack and defense (Table 4). Midfielders performed more sprinting when compared with attackers across all quarters (ES = 1.89 ± 1.07 [Q1]; 0.60 ± 0.97 [Q2]; 0.66 ± 1.01 [Q3]; Q4 0.80 ± 1.01) (Table 2) and performed more sprinting (ES = 1.38 ± 0.97 [Q1]; 0.98 ± 0.95 [Q2]; 0.66 ± 0.96 [Q3]; 0.79 ± 0.95 [Q4]) and running (ES = 1.67 ± 0.96 [Q1]; 0.82 ± 0.93 [Q2]; 1.04 ± 0.93 [Q3]; 0.93 ± 0.91 [Q4]) than defenders (Table 3). Likely differences were also observed in a range of accelerations and decelerations across quarters with the greatest magnitude observed with high accelerations and decelerations. Both attackers and defenders performed greater amounts of standing and walking when compared with midfielders with differences between attackers and defenders unclear.

Discussion

This is the first study to objectively quantify lacrosse matchplay using GPS and associated microtechnology. Our findings demonstrate that midfielders exhibited the greatest activity per minute of playing time (100 m·s^{-1}) and greater contributions of jog meter per minute, run meter per minute, and sprint meter per minute in comparison with attackers and defenders. Furthermore, it was established that midfielders performed a greater number of Acc_{MO} no·min^{-1}, Acc_{HI} no·min^{-1}, and Dec_{HI} no·min^{-1} per match relative to playing time and exhibited higher PL per minute values. Defenders played the greatest amount of field time (~59 minutes) and had similar activity profiles to attackers.

The present findings are in contrast to the only other TMA study of lacrosse (25). Previous research determined that midfielders covered greater relative distance compared with attackers and exhibited greater contributions from jogging, running, and sprinting to TD. However, despite the similarities in the relative contributions of jogging, running, and sprinting, values in this study (attack: TD = 4038 m, 87 m·s^{-1}; midfield: TD = 3591 m, 100 m·s^{-1}) were considerably lower than those reported previously (attack: TD = 10,906 m, 97 m·s^{-1}; midfield: TD = 7429 m, 133 m·s^{-1}) (25). The disparity in absolute results may be explained by the shorter matches (20- vs. 25-minute quarters) and reduced playing time of participants in this study (midfield, ~36 minutes; attack, ~48 minutes) as opposed to percentage of time spent on the field for midfield (53%) and attack (100%) in previous studies. Although it is not clear why relative intensity was lower in this study particularly given it was a higher level of competition, it is possible that the differences in methodology in each study and the measurement error of subjective interpretation in video TMA could account for the large variations in results (12,27).

A novel aspect of this investigation is the analysis of the activity profile between positions by quarter. It is evident from other field sports that differences can exist due to the various roles required by position (6,26,34). In many sports (e.g., Australian football and soccer), midfielders are required to cover the entire field and provide support to both defending and attacking players (6,10). Differences in the activity profiles between lacrosse positions might therefore be expected (10). This was observed in this study as midfielders had a likely higher activity profile and likely positive differences in a number of activity profile variables when compared with both attackers and defenders. Despite this, numerous differences between positions in quarter 1 became unclear in quarters 2 and 3, respectively. It is possible that due to the higher early activity of midfielders in quarter 1, they may reduce their activity profile to a greater extent than attackers and defenders, thus reducing the likelihood of a clear difference in activity profiles between positions (9). Interestingly, the likely differences that occurred in quarter 1 reappeared in quarter 4. It is possible that a combination of several factors may account for this. First, the lower total game time for midfielders (~36 minutes) may allow the maintenance of their activity profile later in matches (23), whereas the higher game time for attackers (~48 minutes) and defenders (~59 minutes) may

induce fatigue and subsequent reductions in their activity profile (1,9,26). Furthermore, consideration must be given to the score and tactics of the match as the activity profile for attackers and defenders may be somewhat dependent on positional restrictions, the location of the ball, and the amount of time spent actively involved in match-play (11,22).

As stated previously, it seems evident that first half activity affects second half activity in team sport (9,26), with high-intensity activity shown to decrease in the latter stages of matches (1,11,22,26). In this investigation, a number of activity profile variables across all positions were reduced in the latter part of matches. Future research could be directed to investigate whether fatigue, physical capacity, or number of interchanges has a relationship with the magnitude of change within positions, similar to research conducted in Australian football (23). It is noted that frequent rotations allowing for recovery may help resynthesize phosphocreatine in preparation for high-intensity efforts (23). Because of the high-intensity intermittent nature of lacrosse and frequency of interchange, it is possible that the physical capacity of players and an effective interchange strategy may influence these findings (23).

A limitation of previous TMA techniques is that the assessment of brief high-intensity activities such as accelerations and decelerations has been difficult (2,19). Higher sample rate (i.e., 10 Hz) GPS units have now improved the accuracy of measurement of these activities (33). In this study, both the number of high and moderate accelerations and decelerations per minute for midfielders and attackers were reduced toward the end of the game. These findings concur with those in rugby and Australian football that determined maximal decelerations and accelerations were reduced in the latter part of matches (2,26). Reasons for this seem unclear but could include the higher physiological cost of these activities (31), fatigue (1,9), and match context. Interestingly, although and in contrast to other positions, defenders performed their highest number of maximal accelerations and decelerations in quarter 3. The precise mechanism for this is difficult to determine but may be related to match situation including score.

Practical Applications

These findings suggest that differences in activity profile exist both within matches and between positions in high-level Australian lacrosse players. As activity profiles are somewhat position dependent, this should be considered when prescribing conditioning sessions. Coaches should be aware of the greater meter per minute, PL per minute and relative contribution to locomotion from high-intensity movement for midfielders, and the reduction in the activity profile in all positions after the first quarter. Furthermore, players with higher meter per minute, PL per minute, and greater amounts of Acc_{HI} no·min^{-1} and Dec_{HI} no·min^{-1} may require periods of longer recovery and efficient interchange strategies to maintain higher intensity activity (23). It is recommended that individualized programs be developed to suit the specific positional and tactical requirements of lacrosse.

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