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Match demands on officials and umpires across variations of lacrosse

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ABSTRACT

The physical demands on lacrosse officials throughout different variants of the game remain largely unknown. The purpose of this study was to quantify the match demands of officials in field lacrosse (FL), box lacrosse (BL) and sixes lacrosse (SL). Thirty officials (10 Females and 20 Males; 34.3 ± 8.2 years, 168.4 ± 13.2 cm, 73.4 ± 6.8 kg) were monitored during 96 competitive matches (33 FL matches, 39 SL matches and 24 BL matches) using 10 hz GPS microtechnology. Significant differences ($p < 0.001$, $\eta^2 > 0.11$) in physical demands were observed, with trivial to very large differences ($d = 0.19–6.99$) identified between different lacrosse variants. There was a moderate difference ($p = 0.01$, $\eta^2 = 0.05$) between quarters and variations. FL officials covered the greatest low intensity distances (≤5.5 m/s), while SL officials exhibited greater high-speed running (>5.5 m/s). BL and SL, both smaller variants, resulted in more frequent accelerations and decelerations in comparison to FL. These findings highlight that officials experience unique physical challenges depending on the variant, emphasising the need for tailored physical preparation strategies for each format, particularly for those aiming to officiate at the highest levels of competition.

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Field; box; sixes; match congestion; tournament

1. Introduction

Lacrosse is a traditional indigenous people's game and is seen as a key element of cultural identity and spiritual healing to Native Americans. The sport itself is regarded as the fastest sport on two feet (Steinhagen et al., 1998), it is a stick and ball invasion-based team sport where players use fast dynamic movements and stick manipulation, of their own stick or their opponents sticks, to score a goal against opponents. Recently, lacrosse has seen a rapid growth in global participation rates since the early 2000s, with the introduction of new variants contributing to the sports evolution. While variants and popularity have increased, there has been little attention on the evolving demands for a key figure within the sport – the match official.

Traditional field lacrosse (FL) consists of 10 vs.10 players, with a 23-player game day squad for men's lacrosse and 18-player game day squad for women's squads played on

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a pitch 91.4-m × 55-m for four 15- to 20-minute quarters, with matches frequently played at youth, club, collegiate and international competitive levels. Box lacrosse (BL), which is typically an indoor variant played within the confines of an ice hockey rink (61 m × 30 m) with 19 players in a match squad (up to 23 within international tournaments), but only 5 outfield players otherwise known as runners allowed to be on the field of play at any one time (offensive, transition and defensive players), played over four 15-minute quarters with BL using a 30-second shot clock. A new smaller-scale format, sixes lacrosse (SL) has been designed, involving 6 vs. 6 players consisting of one goalkeeper and five "outfield" players with no formal positions or position specific rules (e.g. offside rules in relation to each of the positions). SL uses rolling substitutes with unlimited interchanges, potentially changing intensity of match play. Matches are played over four 8-minute quarters on a 70-m × 36-m playing area, but with the addition of a 30-second shot clock consistent with BL, whereby a team must shoot or turn over possession within the designated timeframe. Recently, SL has received confirmation of its inclusion for the 34th edition of the summer Olympics. However, given it is less than one Olympic cycle (4 years) since the inception of SL, and at the same time SL inaugural appearance in the Olympics, there remains a limited amount of information available on the physical demands of international SL competition for athletes and officials.

As of December 2023, there were only 20 studies presenting the match demands on variants of lacrosse (Ripley et al., 2024a, 2024b). To date, no study has looked to observe the physical demands of match-play on match officials during any lacrosse variant. Currently, World Lacrosse have fitness testing protocols and standards for officials; however, these may not be appropriate for all variants of lacrosse given the different formats, pitch sizes, shot-clock inclusion and number of active players at a given time. Understanding the demands of lacrosse is essential information for practitioners and governing bodies working for optimal physical preparation of officials, especially those preparing for the highest levels of competition which is currently multi-sport events such as the Olympics and lacrosse World championship events. Therefore, the purpose of this study was to identify the match demands placed upon lacrosse officials across the variations of the sport, including SL which will help physical preparation requirements for officials who want to officiate at the highest level.

2. Materials and methods

2.1. Experimental approach to the problem

An observational design was used to quantify the physical demands of match-play on match officials across FL, BL and SL in competition wearing global positioning systems (GPS). GPS data were collected during competitive men's and women's matches across Europe including (Monte Gordo Portugal; Prague, Czech Republic; Macclesfield, England; Cardiff, Wales; Manchester, England; and London, England). There was a spread of game for each variation including both male and female officials, male and female players and at domestic and international level. All data were collected in outdoor arenas, including BL which also competes within indoor arenas (Supplementary material 1). A priori sample size estimation was performed, based off observations comparing between field and assistant football referees (Gomes et al., 2024), match type in the

Chinese football super league (Jiang et al., 2022) and Gaelic football championships (Brady et al., 2023), an alpha error probability of 0.05 and statistical power of 0.80 and three groups provided an estimated sample size between 9 and 36.

3. Participants

Thirty match officials (10 females and 20 males; 34.3 ± 8.2 years, 168.4 ± 13.2 cm, 73.4 ± 6.8 kg) participated within the present study, officiating 96 competitive matches (mean ± standard deviation (SD) of matches per official 3.4 ± 1.3, total number for each variation FL = 33 matches, SL = 39 matches and BL = 24 matches). A detailed description of all matches is presented in the supplementary material 1. All officials were World Lacrosse affiliated, selected for each competition and were injury free. Without prior knowledge of the match officials, physical profiles could not be accurately quantified; however, with the physical fitness standards outlined by World Lacrosse, it can be assumed that all officials were trained/developmental or above (tier 2) (McKay et al., 2022). This study was approved by the Ethics Review Board of University of Salford (ID number 0390) and conducted in accordance with the Declaration of Helsinki. All match officials provided written informed consent and were ensured the anonymity of data.

4. Procedures

4.1. Instrumentation

To collect locomotion data, GPS microtechnology sampling at 10 hz (Vector S7; Catapult Sports, Melbourne, Australia) was utilised. All match officials wore the GPS units within a fitted sports vest (Catapult Sports, Melbourne, Australia) with a pocket positioned between the scapulae to hold a microsensor, which included a 10-Hz GPS chip and 100-Hz triaxial accelerometer. The validity of GPS technology has been deemed acceptable for measuring movements associated with team sports competition (Beato et al., 2018; Delaney et al., 2019; Scott et al., 2016). GPS devices are deemed suitable for use within the sport of lacrosse, are regularly worn by athletes which is evident in previous studies (1). All GPS microsensors were activated 10 minutes before match preparation and acquired satellite reception, all officials were familiar with the equipment and protocols being conducted for data acquisition. The average and minimum number of satellites identified across the observation period was (17.6 ± 0.88) and the average horizontal dilution of precision across the observation period was (0.90 ± 0.12), which are in accordance with recommendations (J. J. Malone et al., 2017).

5. Movement demands

Sprint software (version 3.7.0; Catapult Sports) was used to manually identify the start and end of each match from GPS data following acquisition, with the start and end of each quarter being time matched. Thereafter, raw data from each match were exported into a custom designed spreadsheet (Microsoft, Redmond, Washington, U.S.A.) to process the variables for analysis. Speed zone thresholds and minimum time used to identify efforts were as per original proprietary software. Identification of the start and

end of each match and analysis of data were conducted by the lead author, NR, to ensure consistency.

Data collected during inter-quarter breaks or half-time break during each match were excluded from analysis. Furthermore, timeouts and stoppages were not accounted for due to the variability within their application across matches. Locomotive outcome measures include: total absolute distance (m), average speed (m/min) and absolute distances covered performing across different velocity thresholds, defined as: walking and jogging (<4 m/s), running (4–5.49 m/s), high-speed running (≥5.5 m/s). Maximum velocity (m/s) was also recorded and reported.

Triaxial accelerometers were used to detect the frequency (count) of accelerations (>2 $m \cdot s^2$) and decelerations (>2 $m \cdot s^2$). The various intensity and speed thresholds used required a 1-second minimum effort duration to record acceleration and deceleration counts, were in line with the manufacturers' recommended default settings and previous research in FL (Akiyama et al., 2019).

6. Statistical analyses

The Shapiro–Wilk test was applied to assess the data distribution. Descriptive statistics were calculated and are presented as the mean ± standard deviation for all variables (Tables 1 and 2).

A series of one-way analysis of variance (ANOVA) were performed as the aim of the study was to examine the effect of different lacrosse variations (FL, BL and SL) independently on the characteristics of the match demands for officials and not observe any interaction effect, while a repeated measures ANOVA was performed to examine the differences in average speed between quarters in lacrosse variations (FL, BL and SL) (quarters × lacrosse variations). Partial eta squared (η^2) was used to assess differences between variations and interpreted as trivial (0.00–0.09), small (0.01–0.59), moderate (0.06–0.13) and large (≥0.14).

Pairwise effect sizes were calculated using the Cohen's *d* method, providing a measure of the magnitude of the differences noted in each variable between lacrosse variations, and were interpreted as trivial (≤0.19), small (0.20–0.49), moderate (0.50–0.79), large (0.80–1.19) or very large (≥1.20) (Cohen, 1988), with associated 95% confidence intervals (95 CIs). All data were analysed within JASP (Version 0.18.2 [Computer software]) with calculations being bootstrapped to 10,000 samples, with statistical significance accepted at $p \leq 0.05$.

7. Results

Mean, standard deviation, minimum and maximum values for entire lacrosse matches are presented in Table 1, with distances covered in each quarter presented in Table 2. The average time (entire duration including stoppages in play and time-outs, excluding breaks between quarters) for matches was 78.22 ± 8.54 mins, 33.53 ± 1.05 mins and 67.67 ± 5.98 mins, for BL, FL and SL, respectively.

Significant and moderate-large main effects in lacrosse officials' locomotive demands were observed between lacrosse variations ($p < 0.001$, $\eta^2 > 0.11$). Large to very large differences ($d = 1.03$–6.99 (95 CI = 0.37 to 8.40)) were observed in total

Table 1. Descriptive data for locomotive and acceleration output during different lacrosse match variants.

	Total distance (m)			Average speed (m/min)			Running (4–5.5 m/s) (m)			High speed running (>5.5 m/s) (m)			Number of Accelerations (>2 m/s)			Number of Decelerations (>−2 m/s)		
	Box	Field	Sixes	Box	Field	Sixes	Box	Field	Sixes	Box	Field	Sixes	Box	Field	Sixes	Box	Field	Sixes
Mean	3,931.71	5,286.67	3,605.00	66.78	65.05	78.47	605.08	2,369.30	1,124.59	163.13	140.82	286.95	32.33	13.76	30.87	35.38	16.03	28.85
SD	368.95	261.89	327.11	6.58	5.30	6.68	120.26	357.85	198.52	37.61	33.67	63.46	5.85	3.57	7.16	5.97	4.86	5.54
Min	3,245.00	5,023.00	3,031.00	56.80	54.00	66.60	448.00	1,889.00	802.00	105.00	101.00	149.00	21.00	8.00	18.00	22.00	5.00	20.00
Max	4,831.00	6,066.00	4,280.00	86.20	82.10	95.80	984.00	2,978.00	1,614.00	230.00	225.00	432.00	44.00	23.00	48.00	48.00	25.00	48.00

SD = Standard deviation

Table 2. Average speed (m/min) presented across each quarter for each lacrosse variant.

	Box				Field				Sixes			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Mean	69.88	65.05	63.90	63.23	70.60	65.41	65.27	63.16	111.17	111.23	98.92	108.22
SD	9.44	8.59	8.54	7.45	6.88	6.95	6.43	4.93	16.82	16.52	17.48	18.79
Min	55.70	51.20	47.90	49.10	54.90	51.00	56.30	54.30	76.40	79.00	57.30	73.30
Max	88.90	82.20	83.00	83.40	89.50	87.50	80.60	79.20	145.10	143.50	132.00	141.00

Q1 = Quarter 1, Q2 = Quarter 2, Q3 = Quarter 3, Q4 = Quarter 4, SD = Standard deviation

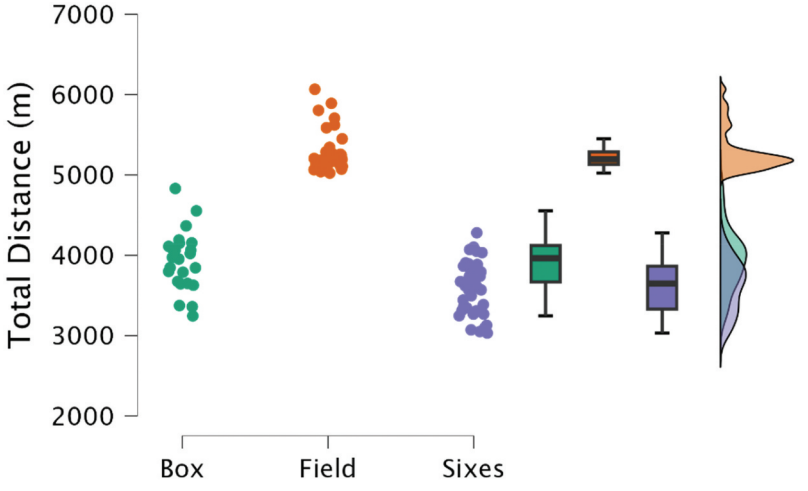

Figure 1. Comparison of total distance between lacrosse variations, with individual data points, box and whisker plots and distribution of data.

distance and running distance, with FL resulting in the greatest total and running distance (Figures 1 and 2). Average speed (m/min) presented small difference as observed between BL and FL ($d = 0.22$ (95 CI = −0.43 to 0.86)) with very large differences between SL when compared to BL and FL ($d = 2.04$–2.25 (95 CI = 1.31 to 2.96)) with SL having the greatest average speed. A small difference in high-speed running distance ($d = 0.46$ (95 CI = −0.20 to 1.12)) was observed between BL and FL, all other pairwise differences were very large ($d = 2.54$–2.99 (95 CI = 1.76 to 3.78)) (Figure 3). A trivial difference in maximal velocity was observed between BL and SL ($d = 0.19$ (95 CI = −0.44 to 0.83)), with a moderate difference in maximal velocity between BL and FL ($d = 0.59$ (95 CI = −0.07 to 1.26)) and a moderate difference in maximal velocity between FL and SL ($d = 0.79$ (95 CI = 0.19 to 1.38)). A small difference ($d = 0.25$ (95 CI = −0.38 to 0.89)) was observed for the number of accelerations between BL and SL, very large differences were found in the number of accelerations when BL and SL were compared to FL ($d = 2.95$–3.20 (95 CI = 2.16 to 4.06)). Large to very large difference were observed with decelerations across variations of lacrosse ($d = 1.13$–3.34 (95 CI = 0.46 to 4.23)), with FL having the lowest number of decelerations.

The repeated measures ANOVA identified a significant, yet moderate difference ($p = 0.003$, $\eta^2 = 0.07$, $F = 3.39$) between quarters and variations. Between lacrosse variations, trivial differences were observed between FL and BL between quarter 1

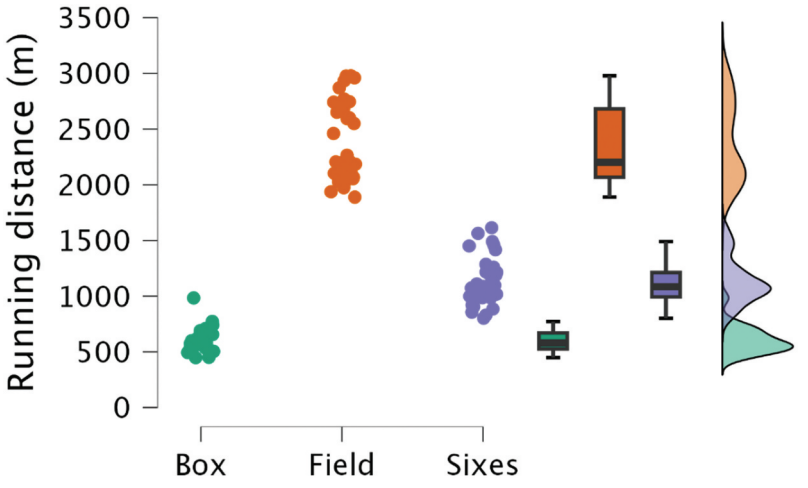

Figure 2. Comparison of running distance (4–5.5 m/s) between lacrosse variations, with individual data points, box and whisker plots and distribution of data.

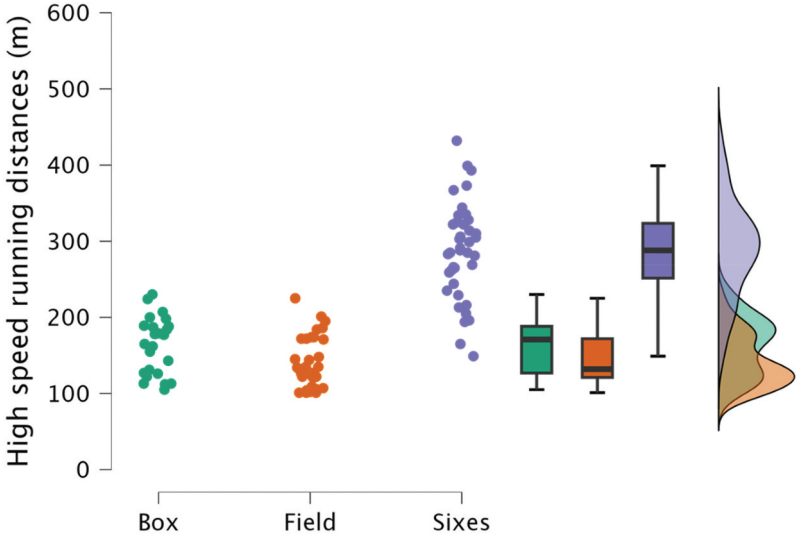

Figure 3. Comparison of high-speed running distance (>5.5 m/s) between lacrosse variations, with individual data points, box and whisker plots and distribution of data.

($d = 0.05$), quarter 2 ($d = 0.02$), quarter 3 ($d = 0.10$) and quarter 4 ($d = 0.09$). Greater average speed was observed within SL in comparison to FL and BL across all quarters (quarter 1 $d = 3.25$–3.30, quarter 2 d 3.67–3.69, quarter 3 $d = 2.67$–2.81, quarter 4 $d = 3.60$–3.61) (Figure 4). Trivial-moderate decreases ($d = 0.01$–0.55) in average speed were across all quarters for FL (Figure 4). Trivial-small differences ($d = 0.05$–0.49) were observed in average speed across all quarters for BL (Figure 4). Trivial-large differences ($d = 0.04$–0.98) were observed in average speed across all quarters for SL (Figure 4).

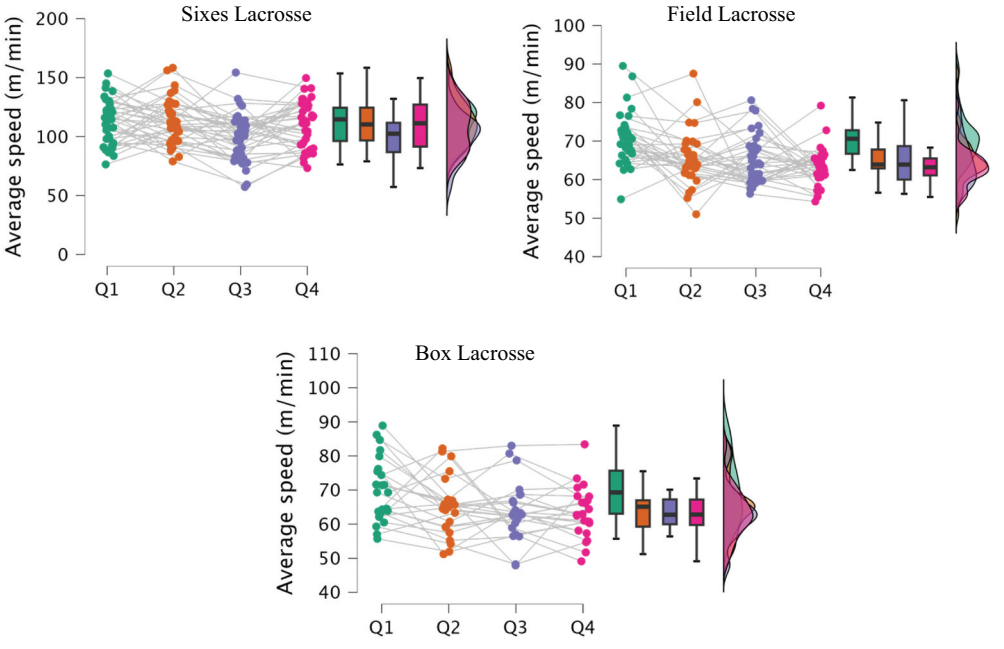

Figure 4. Distances covered in each quarter for each lacrosse variation with individual data points, box and whisker plots and distribution of data.

8. Discussion

The purpose of the present study was to quantify the physical match demands placed upon match officials across the different variations of lacrosse. Across the three variations, FL covered the greatest total and running distance (4–5.5 m/s), with SL having greater high-speed running (>5.5 m/s) and average speed (m/min). Smaller field of play variants (BL and SL) resulted in the greatest accelerations and decelerations greater than 2 m/s/s and −2 m/s/s in comparison to FL, with no difference between these variants. SL had the greatest average speed (m/min) across each of the quarters in comparison to BL and FL, with trivial differences observed between BL and FL. Trivial to large differences were observed across the lacrosse matches, with a decreasing average speed across matches, due to changes in field position such as single side and trail official, in addition to match constraints such as score and opposition. Understanding the physical match demands for lacrosse officials is essential information for practitioners and governing bodies working for optimal physical preparation of officials, especially those preparing for the highest levels of competition.

Field hockey matches are similar in design to FL with regards to pitch dimensions and style of play, the distances covered by match officials within field hockey are also similar to those presented within the present study for FL with distances of 5.90 ± 0.79 km and 5.99 ± 0.68 km covered within men's and women's field hockey, respectively (Spice et al., 2017). Contrastingly, soccer officials are exposed to greater external demands than FL, as international soccer officials cover up to 10 km (9,989.37 ± 780.71 m; 10218 ± 643 m; 10.07 km (9.20–11.49 km) within competitive matches (Castillo et al., 2018; Krustrup & Bangsbo, 2001; Mallo et al., 2009), with 1.67 km (range = 0.90–2.39 km) covered as high

intensity running (>4.1 m/s) (Krustrup & Bangsbo, 2001) and a distance of 1,920 ± 399 m covered at >5 m/s (Mallo et al., 2009). Similar to FL officials, elite rugby union officials cover an average distance of 6,825.9 m (range: 4,836.8–8,774.4 m) (Bester et al., 2019). The greater total distance values observed in larger field-based sports (e.g. soccer, rugby, field hockey) and FL in comparison to BL and SL are likely explained by the greater overall field space and greater duration than BL and SL, especially with contrasting quarter durations. Although the greater distances covered in soccer and rugby in comparison to field hockey and FL could be related to the overall field space officials are officiating, within field hockey and FL there are two and three match officials, respectively, covering predefined areas of the field whereas within soccer and rugby a single lead official is expected to cover the entire playing space. Moreover, as officials in SL, FL and BL, rotate roles across the match where they perform as a sole official on a single side or as two officials covering one side, further explaining the reduced distances covered in comparison to larger field sports such as soccer or rugby.

The present study is the first study to observe the physical match demands on lacrosse officials, including smaller variants (i.e. BL and SL). This makes it difficult to compare to known literature; however, a previous transition from a large team sport to a smaller sided team sport has already occurred and been successful, with rugby union and rugby sevens, which is consistent with the transition from FL to SL. Officials in international rugby sevens cover less total distance, but greater average speed (m/min) than what is observed within the present study for SL and BL, with total distances (and average speeds (m/min)) for international, professional, semi-professional and amateur rugby sevens, 1,865 ± 187 m (114.3 ± 10.1 m/min), 1,922 ± 182 m (118.4 ± 9.3 m/min), 1,819 ± 129 m (118.7 ± 8.8 m/min) and 1,653 ± 165 m (103.5 ± 8.0 m/min), respectively (Sant'anna et al., 2021). This is likely explained by the lower total duration (two × seven-minute halves vs. four × eight-minute quarters). International, professional, semi-professional rugby sevens officials performed significantly greater sprints and repeated high-intensity efforts and achieved greater maximal running velocities than amateur rugby sevens officials (Sant'anna et al., 2021). This highlights at increasing levels of competition, officials need to be able to cope with increasing levels of physical performance to match the demands (Sant'anna et al., 2021), especially for international preparation for world events and Olympics.

The smaller variants of lacrosse, not only result in the greater high-speed running and average speed they also result in a greater number of accelerations and decelerations in comparison the FL. This is likely related to the increased rate of turnovers in possession, requiring frequent and rapid changes of direction and moving between halves rapidly. Supporting this finding of greater frequency of accelerations in smaller style games, Castellano and Casamichana (2013) presented differences in acceleration between small sided games and matches within soccer players, where small sided games elicited twice the number of accelerations than competitive matches, with increases observed at all acceleration intensities. It is worth noting, however, that player locomotion and official locomotion are different within matches and the comparisons to small sided games should be made with caution, despite this there is currently no evidence observing differences in match officials between large and smaller sided games with similar rules but modified pitch sizes, highlighting the novelty of the present study. Similar to other team

sports (Harper et al., 2019), all variants of lacrosse elicit more decelerations than accelerations, with greatest number of accelerations and decelerations performed within BL and SL, emphasising the high rate in change in activity, especially when considering the reduced playing duration of SL. When comparing large field-based sports (e.g. soccer) to a smaller style team sport (e.g. basketball), the total frequency of activity changes in basketball is comparable to soccer (Taylor et al., 2017), even with the reduced playing duration. As SL has a similar playing style as basketball, with increased accelerations and deceleration across a shorter match duration, meaning the density of acceleration and deceleration activities is going to be greater, this has implications for physical preparation, tissue damage and neuromuscular fatigue (Harper & Kiely, 2018), this finding highlights the need for adequate physical preparation to cope with these demands.

Within the present study, there were trivial-large differences between quarters, but there was with a decreasing trend which could potentially related to contextual factors within the match (e.g. score line) or be indicative of fatigue although this requires further investigation. Similarly, no significant decreases in the distances covered across speed zones were observed between halves within rugby sevens referees (Suarez-Arrones et al., 2013), with consistent frequency, distance and duration of sprints and maximal speed between first and second halves (Suarez-Arrones et al., 2013). When comparing SL and BL to FL, the intensity of actions (average speed, high speed running, and frequency of higher intensity accelerations and decelerations (<-2 m/s/s and >2 m/s/s) are meaningfully greater. This could be explained by the smaller space to officiate, additionally, the rules in SL and BL result in a significantly greater changes in possession, highlighting the faster paced nature of these shorter style of games. As lacrosse is already described as the fastest sport on two feet (Steinhagen et al., 1998), these smaller variants are increasing the rate and intensity of actions that officials are required to perform. These data highlight that when larger field sports such as FL are transitioned to small-sided field sports such as SL, officials are exposed to high intensities which require a high level of physical fitness albeit at a lower overall volume. Within international SL, short international tournaments where officials could be covering a substantial number of matches (>3 matches) within a competition period (3–4 days), presenting a match congestion problem with high physical requirements and the potential injury concern with spike in volume (Gabbett, 2016; S. Malone et al., 2018; S. Malone et al., 2017a; S. Malone et al., 2017b).

The present study is not without limitations, external demands only provide some of the information on workload, further investigation is required in determining internal workloads (e.g. heart rate), this would provide practitioners a better understanding of the predominant energy system demands (i.e. aerobic or anaerobic) which would dictate training needs. Most of the observed fixtures included international matches and may not be representative of youth or collegiate lacrosse and therefore limits application for practitioners working with officials at this level. Furthermore, a next step requires the physical demands to be consider in relation to correct decisions and optimal positioning. Finally, match context, officiating experience and the sex of players have not been considered within the present study, as this can also have substantial impact on the demands placed on officials and the rule modifications in men's and women's lacrosse could also impact officials match demands.

Lacrosse officials can be exposed to varying demands dependent on the variant of lacrosse they are officiating, with similar demands observed in FL to soccer and rugby. Officiating in FL results in a greater volume of low intensity work performed by officials, while BL and SL have resulted in a greater volume of high intensity work (e.g. average speed, high speed running, accelerations and decelerations). This highlights that officials working with BL and SL require well developed aerobic and anaerobic qualities to cope with the demands of both smaller lacrosse variants, plus multiple matches within a congested period. Moreover, the increased frequency of decelerations in SL, with the current competition format (6–10 matches within a 3-day competition period), would also highlight a necessity for high levels of relative strength to cope with these demands. With the inaugural appearance of SL at Los Angeles Olympic Games in 2028, the physical preparation of SL referees will require similar consideration to rugby sevens, ensuring officials can cope with the unique demands on competition to maximise the sport competitiveness on the highest stage of competition.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data are available from reasonable request to the authors.

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