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Comparison of In-game External Load Metrics Among Positions and Between Halves for Division I Collegiate Women's Lacrosse Athletes

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ABSTRACT

External load has become a common metric for coaches to track the activity profiles of athletes during training and competition. The advent of wearable technology has made external load monitoring accessible for more coaches. The purpose of this study was to compare positional (attack, midfield, and defense) and game (first half to second) external loads. An NCAA Division I women's lacrosse team was recruited to wear triaxal accelerometers and GPS units during five non-conference games during the 2020 regular season. The external load metrics evaluated for this study included total distance, sprint distance (> 19 km·hr^{-1}), number of power plays (> 3 m·s^{-2}), top speed, and PlayerLoad. Significance was set at $p < 0.05$. No significant differences among positions were observed for full game measures ($p > 0.05$). A significant main effect for time was observed for sprint distance (midfield; $p < 0.001$) and power plays (midfield; $p < 0.001$ and defense; $p = 0.004$). While no significant differences occurred for activity profiles among positions, high-intensity efforts (sprint distance and power plays) were significantly less in the second half, likely due to fatigue. Coaches and sports scientists can use this information to manage in-game fatigue through tactics such as strategic substitutions and time-outs, thus preserving the intensity of the activity profiles late in the game.

Keywords: Wearables, Catapult, microtechnology, load monitoring

INTRODUCTION

Originally a sport created by Native Americans, Lacrosse has a long history but did not experience widespread participation rates until recently (12). Part of the rise in popularity has been through an increased international presence (14). As "the fastest game on two feet", lacrosse is characterized by frequent and repeated sprint efforts throughout the 30-minute halves that make up regulation time in college women's lacrosse (5). These repeated sprint efforts and general speed associated with the sport have contributed to its growing appeal. Athletes transition the ball between offensive and defensive sides of the field throughout the game, with a 90-second shot clock maintaining a relatively rapid game pace. The structure of the game makes the physiological demands of lacrosse similar to sports like basketball and soccer, but with unique aspects that make the investigation of lacrosse important for the continued growth of the sport (10).

Traditionally, athletes have been evaluated using a comprehensive testing battery to gauge their physiological level of preparedness for competition, based on a needs analysis for the sport (12). The assessment of physical performance characteristics of an athlete can be used to compare athletes, identify strengths and weaknesses, set training goals, and monitor training progression. For example, a testing battery conducted on NCAA Division III women's lacrosse athletes reported higher squat strength in defenders compared to midfielders and higher peak and mean power output during Wingate anaerobic power testing for attackers compared to the other positions (16). Furthermore, Sell et al. found that NCAA Division I male lacrosse starters were significantly faster for speed (20- and 40-yard sprints) and agility (3 cone drill) assessments compared to non-starters, despite similarities in aerobic fitness (1.5-mile run) levels (24). Thus, testing batteries are useful tools for comparative purposes, yet fail to directly measure the on-field expression of physical fitness through external load metrics, which may differ by position and/or the playing status of the athlete.

Some differences in physiological preparedness can be observed in the conflicting testing results for the same sport across different levels of competition. Generally, the level of competition has a positive relationship with physiological preparedness (23). However, this is not always the case. Interestingly, a two-time defending NCAA Division III national championship women's lacrosse team had lower vertical jump heights and power output compared to female club lacrosse players (16,17). This difference may be due to technical and tactical considerations where highly skilled athletes can meet a maximal threshold of physical readiness that prepares them for the sport, beyond which there are diminishing returns in positive transfer with continued increases in basic fitness measures. Thus, testing fitness alone may be inadequate for determining the exact in-game demands placed on athletes. When comparing different positions on the same team Lockie et al. reported differences in speed and agility in favor of field players over goalies (17). Alternatively, when goalies were excluded from the analysis, Vescovi et al. did not observe any differences in fitness for any field players (25). When performing lacrosse-specific conditioning using small-sided games, the physiological responses measured via heart rate were more dependent on the pattern of play—intermittent compared to continuous—than based on positional breakdowns (14). Therefore, it would appear that fitness is more a function of a team's conditioning practices rather than specific preparation for the sport, opening up the need for in-game monitoring of external load measures in addition to baseline physiological testing.

External load monitoring is a fairly new technology, increasing in popularity over the past 10-15 years as the technology has improved and the costs have become more affordable. It has been applied in sports such as soccer, field hockey, and men's and women's lacrosse (1,9,19,23). Soccer and field hockey appear to have similar physiological demands to lacrosse, but they are not identical. In a recent study on in-game external load monitoring for female lacrosse athletes, Calder et al. reported decreases in relative speed, acceleration, and metabolic power from the first half to the second, as well as positional differences for the women's collegiate lacrosse players they analyzed that were largely consistent with prior work (6,9,15). One could therioize these changes can be attributed to fatigue accumulated throughout the game. However, more data to comprehensively evaluate the in-game external load for collegiate women's lacrosse athletes is necessary, specifically when compared between halves.

In addition, team-based physiological monitoring and assessment are connected with the expression of physiological attributes during competitions (2), but previous literature has also indicated that position-specific breakdown of in-game external load may provide a more robust means of quantifying the specific programming needs for each position (19). For example, male lacrosse midfielders covered less total distance compared to other field positions, yet more distance was covered at sprint speed (21). Positional comparisons of international women's lacrosse athletes reported less total distance by midfielders with significantly more total distance covered by defenders (15). Overall, ample evidence exists to support the conclusion that there are positional differences in the expression of physiological attributes during competition (1,9,15,21). A physiological foundation is necessary to support the expression of fitness for in-game performance, but the absolute expression tends to vary based on position.

Positional differences may, in part, influence the extent of fatigue based on variations in the expression of fitness during competition. Integrating the importance of specific physiological foundations to make sure athletes are directly prepared for the external loads expected during competition is the complementary part of connecting physiology and performance. For example, Castagna and colleagues reported a positive relationship ($r = 0.77$, $p < 0.001$) between performance on the Yo-yo Intermittent Recovery Test and the volume of high-intensity activity during experimental games (7). Similarly, in female field hockey players, there were simultaneously high physiological and match load demands (19). However, these differences were not always proportional. While defenders covered significantly greater total distance, midfielders had significantly higher sprint distances, yet defenders still maintained more total minutes above 85% of peak heart rate. Therefore, a certain physiological threshold is necessary to be able to sustain high-intensity activity throughout a game, yet the exact expression of fitness is different among positions, making a detailed analysis of external load a relevant pursuit. Thus, the aim of the present study adds to the available literature on women's lacrosse by assessing a position-by-time comparison of external load metrics during collegiate competition, adding to the available data with an analysis of total load, power play count, and sprint distance.

METHODS

Experimental Approach to the Problem

To evaluate external load, athletes were fitted with wearable microtechnology devices designed to track a variety of metrics, such as total distance, sprint distance, top speed, power play count, and the proprietary measure of cumulative load: PlayerLoad.Total distance and sprint distances were dependent variables selected to evaluate the volume of work completed. Top speed and power plays were selected as markers of peak intensity and frequency of high-intensity efforts, respectively. PlayerLoad was selected to summarize total load from a combination of the volume and intensity of work completed over the selected timeframes. The first independent variable selected was position, with goalies excluded due to the noted difference in positional requirements. The second independent variable selected was time, with the comparison happening between the first half and second half of play to align with standard timekeeping practice for women's lacrosse.

Subjects

Eleven NCAA Division I female lacrosse players (age 19.8 ± 1.2 years, height 164.42 ± 7.89 cm, weight 61.87 ± 8.2 kg) were included as participants. A total of 36 athletes rostered on the women's lacrosse team were eligible participants but only athletes who played more than 50% of each half were included in the data analysis, which effectively limited the analysis to starters. Each athlete was healthy and cleared for athletic participation by the athletic trainer assigned to the team. The study was approved by the University's Institutional Review Board (IRB-FY19-20-113) and informed consent was obtained from each athlete. External load metrics were originally collected for athletic purposes as a normal part of the athlete monitoring protocols for the team, so the research was approved as an archival analysis.

Procedures

Playertek wearable sensors (Catapult Sports, Melbourne, Australia) were used for data collection. Each athlete was fitted with a custom garment, resembling a sports bra, which housed these small pods (84 mm x 42 mm x 21 mm, 42 g) in a pouch, located between the shoulder blades. The GPS sampling rate for these devices is 10 Hz with an inertial sampling of 400 Hz. This technology has been previously validated in both laboratory and field testing (4).

Before each competition, athletes were instructed to turn on their GPS sensors within 15 minutes of the beginning of the game. The sensor collected data continuously throughout the game. After the game ended, athletes switched off their sensor and turned them in to a team representative for raw upload via the software syncing program provided by the manufacturer. The online software was used to separate the athletes based on position (midfield, attack, defense). Based on timestamps, the data were cropped to only include regulation time, including the removal of half time to separate the data into first and second halves. This protocol was repeated for each of the five regular-season, non-conference games that occurred at the beginning of the season. The entirety of the season was not assessed due to COVID-19 restrictions.

Each of the competitions analyzed were afternoon games held on turf fields. Standard tapering practices were in place to reduce workload in the practice before the game (ex. a walk-through). The pre-game meal was scheduled 2-4 hours prior to the start of each game with energy waffles (150 kcal, 21 g CHO, 1 g PRO, 7 g FAT) available to the athletes as a pre-game snack and between halves. Standard instructions were in place for the athletes to get 7-8 hours of sleep each night and maintain regular hydration practices throughout the day.

Statistical Analysis

To assess position by time interactions, a 3 x 2 mixed model analysis of variance (ANOVA) with repeated measures was used for each of the dependent variables: Position (attack, midfield, defense) × Half (First vs. Second). Statistical significance was set a priori at $p < 0.05$. Dependent variables analyzed for this study included total distance, sprint distance (> 19 $km \cdot hr^{-1}$), number of power plays (> 3 $m \cdot s^{-2}$), top speed, and PlayerLoad. Post-hoc pairwise comparisons utilizing Bonferonni corrections were used to determine any significant one-way ANOVAs to reduce the chance of inflating type I error. Due to the relatively small sample size, partial eta squared effect sizes were also calculated to provide insights into the practical meaningfulness of the measures. Small effect sizes were defined as greater than or equal to 0.01 but less than 0.06, moderate as 0.06 to less than 0.14, and 0.14 and greater as large (22). Whole game data were analyzed using one-way ANOVAs, with Cohen's d calculated to provide practical meaningfulness; these effect sizes were classified as small ($0.2 < d < 0.5$), medium ($0.5 < d < 0.8$), large ($0.8 < d < 1.3$) and very large ($d > 1.3$).

RESULTS

The average values for all dependent variables, separated by position and half, are displayed in Table 1. No significant between-group differences were observed ($p > 0.05$) for any variables. A main effect for time was observed for both sprint distance ($F = 15.87$, $p < 0.001$, $\eta_p^2 = 0.27$) and power plays ($F = 36.9$, $p < 0.001$, $\eta_p^2 = 0.468$). There was a significant decline in sprint distance from the first half to the second half for midfielders ($p < 0.001$, $d = 1.34$), a non-significant, but trending decline in defenders ($p = 0.058$, $d = 0.69$), and no significant difference for attackers ($p = 0.343$, $d = 0.24$). A significant decline in the number of power plays was observed from the first half to the second half for midfielders ($p < 0.001$, $d = 0.99$) and defenders ($p = 0.004$, $d = 1.23$), but not attackers ($p = 0.078$, $d = 0.47$).

Table 1. Game Data Comparison between Halves and Among Positions

	Total Distance (meters) M (SD)	Sprint Distance (meters > 18 km·hr^{-1}) M (SD)	Top Speed (km·hr^{-1}) M (SD)	Power Plays (count) M (SD)	PlayerLoad (AU) M (SD)
Attack					
1st Half	4158.37 (499.11)	406.81 (162.27)	25.04 (2.20)	31.06 (7.61)	200.55 (28.58)
2nd Half	4109.84 (663.84)	355.23 (162.48)	25.18 (1.93)	26.88 (7.35)	197.21 (33.99)
Midfield					
1st Half	4239.15 (1098.96)	509.35 (140.48)	25.87 (2.02)	30.32 (8.06)	199.87 (44.14)
2nd Half	4256.84 (1072.80)	395.73 (148.74)*	25.46 (1.60)	25.16 (7.26)*	200.65 (40.93)
Defense					
1st Half	4573. (334.04)	437.10 (178.84)	25.26 (1.12)	33.30 (10.46)	196.42 (15.99)
2nd Half	4213.90 (998.16)	284.28 (125.99)	25.56 (1.36)	19.70 (7.67)*	184.41 (42.55)
Total					
1st Half	4284.73 (792.13)	456.84 (160.57)	25.44 (1.93)	31.24 (8.37)	199.34 (33.62)
2nd Half	4195.03 (910.62)	356.56 (152.15)*	25.38 (1.65)	24.56 (7.71)*	195.82 (38.60)

M=Mean, SD=Standard deviation, AU=arbitrary units
*significantly different than 1st half ($p < 0.05$)

Table 2. Game Data According to Player Position

	Total Distance (meters) M (SD)	Sprint Distance (meters > 18 km·hr^{-1}) M (SD)	Top Speed (km·hr^{-1}) M (SD)	Power Plays (count) M (SD)	PlayerLoad (AU) M (SD)
Attack	8268.2 (1026.4)	762.0 (247.0)	25.8 (1.8)	57.9 (12.1)	397.8 (57.7)
Midfield	8620.3 (2074.0)	912.4 (282.7)	26.2 (1.7)	55.8 (14.8)	401.8 (83.8)
Defense	8787.4 (1026.5)	721.4 (214.5)	26.0 (1.2)	53.0 (14.6)	380.8 (43.2)
Total	8530.3 (1527.4)	814.3 (263.8)	26.0 (1.6)	55.9 (13.6)	395.6 (66.3)

M=Mean, SD=Standard deviation, AU=arbitrary units

Positional comparisons were also made for whole game data (Table 2). No significant between-group differences were observed for any dependent variables ($p > 0.05$). Despite the lack of statistical significance, there was a moderate effect for total distance between attack and defense ($d = 0.51$), compared to the small effect between midfield and attack ($d = 0.21$), and the negligible effect between defense and midfield ($d = 0.09$). Similarly, sprint distance was not significantly different among positions, but there were moderate effect sizes for differences between midfield and attack ($d = 0.56$), and midfield and defense ($d = 0.73$). No significant differences or effect sizes greater than small were observed between positions for top speed, power plays, or PlayerLoad.

DISCUSSION

A relatively small number of studies have been published on the in-game external load monitoring of female lacrosse athletes (9,15). The current study adds to the available literature specifically related to women's lacrosse by including a within-game comparison of the first half to the second for sprint distance and power plays. The athletes were assessed on the in-game external load metrics of total distance, sprint distance, power plays, top speed, and PlayerLoad.

Consistent with both men's and women's lacrosse, the current sample of women's lacrosse players displayed a decline in intensity late in games (1,6,21). A significant drop-off from the first half to the second was apparent in the high-intensity efforts of sprint distance for midfield and power plays for both midfield and defense. The likely explanation for this decline is the obvious fatigue resulting from repeated, high-intensity sprint efforts (6). However, the top speed was not different from the first half to the second, which could also indicate self-regulation in what has been defined as "sparing behavior" (7). Under conditions of fatigue, athletes may manage their high-intensity efforts so that more relative time is spent at lower intensities, thus preserving total distance and maximum-intensity efforts (i.e. top speed). The ability of an athlete to self-manage their fatigue is beneficial in terms of economy of effort and high-intensity effort prioritization, but strategic substitutions or time-outs can also be used by coaches to regulate the external load of athletes, particularly for midfielders. In agreement with previous research, monitoring load across positions and time on the field may allow for more appropriate athlete preparation and substitution strategies (3).

Positional differences in total distance and sprint distance have been previously reported for both men's lacrosse and women's lacrosse (1,6,9,15,21). In the present study, no significant differences were observed among positions. Part of this discrepancy in the literature might be explained by coaching strategy and style of play (13). Lacrosse is a game that allows free substitution, often used most effectively through the midfield lines because this position tends to cover more of the field and be more integral in transitioning the ball between the offensive and defensive sides of the field. If the midfielders are substituted, the result is individual players will play fewer minutes and, therefore, cover less distance (21). Strategic substitutions provide valuable passive recovery time to preserve the intensity of effort late in the game. Alternatively, if the midfielders are not substituted as frequently, they can have a similar activity profile to the other positions, though it is more likely to precipitate a decline in intensity throughout the game, as was apparent for power plays and sprint distance.

Another important breakdown for external load is the relative contributions of sprint distance to total distance (13). In one sample, while not significantly different, defenders covered nearly 60% more distance in the fastest speed zone compared to midfielders (15). In another sample, collegiate women's lacrosse athletes had slightly different positional differences. Midfielders covered the greatest total distance, with the greatest percent of that distance covered at high-intensity speeds, which differs from the high-intensity speed density reported by Hamlet and colleagues (9,13). In a different sample of collegiate women's lacrosse players, defenders covered the greatest total distance, midfielders had the greatest speed and metabolic power per minute of playing time and differed from attackers on several intensity-based measures (6). In the present study, midfield had the highest percentage of total distance covered at sprint speed (12% for the first half and 9.3% for the second half compared to the defense's 9.6% and 6.8%, respectively). Yet, the defense had the greatest decline in relative intensity with the percent of distance covered at sprint speed falling 29.4% compared to the decrease of 22.6% for midfielders. Understanding proportional contributions—not only among positions but also between specific teams—increases the understanding of a volume compared to an intensity dominant position (13).

Knowing the in-game external load provides a practical standard of performance that coaches need to use to prepare athletes for competition. Positional or individual averages can be used to develop more precise training programs designed to target the volume and proportional intensity of efforts. Not every training session should replicate a game, but enough volume and intensity should be programmed for athletes to adequately prepare them for the rigors of competition without unnecessary fatigue (13). PlayerLoad, in particular, can be used to monitor the overall training load on an athlete, which can be important for managing long-term fatigue and injury risk (3).

Activity profile data can also be used to monitor an athlete's ability to return to play following an injury or an extended period without an adequate training stimulus (9). An athlete may be able to participate in drills during practice, but unless the external load of the drills can be directly compared to the external load requirements of competition, the athlete may not be adequately prepared to re-enter competition in the context of a full game, risking re-injury after a substantial change in load. It is important for an athlete to progressively increase their load such that a game-like load can be experienced in a practice setting, thus demonstrating the athlete's full recovery from injury.

Another area of application for activity profiling could be the connection with wellness variables. In an analysis of a women's collegiate lacrosse team, Crouch's group reported significant increases in external load scores with increased wellness scores (8). When athletes reported better sleep, energy, stress management, and muscular readiness, their total distance, high-speed distance, and athlete loads were proportionally higher. Therefore, it is reasonable to infer that reductions in external load over time may be indicative of poor habits outside of practice time, alerting coaches to certain wellness behaviors that were not measured in this sample, yet may need to be addressed throughout a season.

The data from the present analysis were abbreviated by the premature conclusion of the season due to COVID-19. As such, only non-conference games were included in the analysis, which may influence the overall intensity of effort. However, in another study with Division I female lacrosse athletes, the conference season analysis showed similar results to the present study for total distance and maximum velocity. Furthermore, Devine et al. reported consistent external load throughout a competitive NCAA DI women's lacrosse season, except for speed, which increased in proximity to the postseason (9). The inherent value of the game might influence some external load metrics when a particular game carries more weight (i.e. conference games or post-season competition), but most metrics appear to remain consistent throughout a full competitive season. Similarly, Fields and colleagues monitored internal load metrics throughout a 13-week competitive season and saw some variations across the season but no maladaptive trends to indicate overtraining (11). Thus, it is reasonable to assume that subsequent games likely would have had similar profiles to the ones analyzed for this study.

Another possible limitation is the relatively small sample size. Due to only 11 players (excluding the goalie) on the field at a time, increasing the in-game sample size is challenging. The stochastic nature of in-game performance as well as the diversity of fitness attributes within the same sport creates the context for inter-athlete variations, which may have more influence over a smaller sample. In the future, multi-team trials might be considered to increase statistical power (13). Alternatively, Sausaman and colleagues had a strong design by collecting data throughout four consecutive seasons, effectively increasing the number of data points being analyzed (23).

Future research should also investigate the connections between external load and hard endpoints that determine game outcomes such as assists, shots on goal, and ground ball percentage (20). With further analysis, it may be possible to make connections from one game to another to evaluate the relative value of each external load metric, which can then inform training decisions for the most important characteristics to target when programming strength and conditioning sessions.

CONCLUSION

In-game external load monitoring is an emerging practice in the field of sports science. Accurately representing the in-game demands athletes face has far-reaching implications for load monitoring to reduce the risk of injury and maximize preparatory training and conditioning. Relatively little has been published on lacrosse, but this study adds information on the in-game demands of women's college lacrosse athletes. Specifically, we found that midfielders tend to have higher intensity efforts that decline significantly from the first half to the second half. Coaches can use this information to tailor their preparatory conditioning strategies to the known in-game demands.

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