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Research Article

Physical Activity Profiles of Male International Field Hockey Players are Greater in the Olympic Games versus other Competitions -

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ABSTRACT

Purpose: The purpose of this study was to compare the GPS-derived physical activity profiles of an Olympic Games versus other in-season international hockey tournaments.

Methods: 10Hz GPS units were used to assess the activity profiles (Total Distance: TD; High Speed Running Distance: HSR; Sprint Distance: SD & Max Velocity: MV) of outfield players in a men's international hockey squad. Data was collected during the 2016 Rio Olympic Games (OG), an Olympic Games qualifying tournament (World League 3; WL3) and a regular in-season competitive tournament (6 Nations: 6N).

Results: There were significant differences (p <0.05, mod ES) between defenders versus midfielders/forwards pooled across tournaments in all running variables. There were significant (p <0.05, small ES) differences between OG and 6N in TD, HSR, SD and MV, and between OG and WL3 in HSR. There were significant positional x competition interactions for TD between defenders and forwards between 6N/WL3 compared to OG.

Conclusions: Competition level (i.e. OG, WL3 and 6N) can affect the physical demands of hockey even within the same playing level (i.e. international). Therefore, development of different physical capacity levels of players and periodization of training may be warranted to prepare for specific events.

Keywords: Elite; GPS; Competition

INTRODUCTION

The preparation of elite athletes is concerned with developing the appropriate physical, mental, tactical and technical qualities or capacities necessary to compete at the highest levels of competition. When possible, these aspects are developed off data to reflect the demands of performance to help devise appropriate training strategies. In terms of physical capacity, international hockey has been shown to be a high-intensity intermittent sport [1-3] characterised by high-intensity efforts superimposed on predominantly low-intensity running. Amongst many other factors, it has previously been established that level of playing or competition can affect the running demands in various sports including soccer [4], Australian football [5] and hockey [6]. For example in hockey, Jennings et al. [6] demonstrated that male international players completed more high speed running across defense, midfield and strikers than national level athletes. Whilst such information is important to delineate the differences in physical demands placed on players at different levels, there is evidence to suggest that within the same level of play (e.g. elite level play), competition or tournament scenarios can also be a further factor in determining the physical activity demands of play. Aughey [5] found in elite Australian Football players, that the total distance, high speed running distance and maximal accelerations were significantly greater during Grand Finals matches versus regular season matches. In a similar fashion, Higham et al. [7] demonstrated that in international Rugby Sevens athletes, there were significant differences in distance covered at high velocity, number of accelerations and number of decelerations in international sevens matches versus domestic sevens matches, with international matches placing increased demands on the athletes. These studies illustrate that within the same level of playing, even at the elite level, that not all competition demands are equal.

Within the international hockey calendar, there are two quadrennial major events - the World Cup and the Summer Olympic Games, which are separated by two-year periods. Other tournaments within the annual international hockey calendar include major competition qualifying events and competitive standalone tournaments. Competing in tournaments that afford opportunities for major event qualification, and indeed the major event itself, there is the possibility that the physical demands of play may be altered compared to competitive standalone tournaments in international hockey. The main aim of the current study is to quantify and compare the team physical activity demands of a major event tournament (2016 Rio Summer Olympic Games, OG), an Olympic Games qualifying tournament (World League 3, WL3) and a typical standalone competitive tournament (6 Nations, 6N). A secondary aim is to compare the within positional demands across the tournaments.

METHODS

Participants

20 elite international male hockey players (Age 26 ± 3 years, mass 81.6 ± 4.4 kg) participated in the study. Players were members of a national team in the competition-phase of the annual plan, and therefore in relative peak condition and free from injury during data collection. Each participant gave written and informed consent, with the study approved by the Ulster University ethics committee and conforms to the principles of the Declaration of Helsinki. Data collected was part of the routine squad performance profiling and monitoring.

METHODOLOGY

Match data

International match player activity profiles were analysed in three tournaments. Tournament 1 (World League 3: WL3) was played in July of 2015 with 6 matches analysed. Tournament 2 (The 6 Nations: 6N) was played in June of 2016 and was a competitive tournament in the international calendar with 5 matches. Tournament 3 (Olympic Games: OG) was played in August of 2016, and consisted of data from the 5 matches of the 2016 Rio Olympic Games. World League 3 consisted of playing against teams ranked in the range of 1-31, the 6 Nations teams were ranked 3-11 and in the Olympic Games, teams were ranked 2-15 in the world at the time of play. World League 3 and 6 Nations had 16 outfield players (i.e. normal international hockey allowance), whereas the rules of the Olympic Games dictates only 15 outfield players. Profiles of all outfield players were analysed in every match. When a player had played less than 30% of the total match time, the data was not included in the analysis as to not add undue variation in more complete activity profiles. A player's total pitch time heavily dictates the amount of physical activity they can undertake [3], so when comparing the absolute differences in physical activity profiles across 3 tournaments, low playing time would impact

on the mean, standard deviation and range of the data. This variation has the potential to mask true differences between activity profiles. 30% was chosen as it was a naturally occurring 'cut-off' likely due to the coaches' player rotation preferences. This resulted in 73 out of a possible 75 individual profiles analysed in OG, 77 out of 80 in 6N, and 71 out of 90 in WL3. Therefore a total of 221 individual profiles were analysed.

GPS equipment

The Catapult Sports OptimEye S5 10Hz GPS system (Catapult Innovations, Melbourne, Australia) was used for all match data collection. The validity and reliability of this system's running metrics has not been published in a peer-reviewed journal thus far, however these are the next generation GPS units from Catapult Minimax 10Hz GPS units, whose validity and reliability has been verified previously [8,9]. The validity of these units for assessing maximum velocity has been reported previously [10]. Each GPS unit was turned on and left idle for 10 minutes pitch-side to allow location of satellites as per manufacturer's recommendations. Following confirmation of satellite connection, each unit was placed in the manufacturer's specific bib with a neoprene pouch for minimising extraneous unit movement, held approximately between the players' scapulas. Players had been wearing the bibs and units routinely for several months before data collection and were fully familiarised with the equipment. GPS data was sampled at 10Hz.

GPS analyses

All GPS data was downloaded using a Catapult Sports multi-unit docking station and was analysed using Catapult Sprint version 5.1.7 software (Catapult Innovations, Melbourne, Australia). The start and stop times of each quarter, as well as substitutions entry/ exit were identified in real-time by the same observer. Match Duration (MD) is the total amount of time each player spent on the pitch in real-time. Before generation of raw data reports, verification of substitution accuracy was done by interrogation of the raw velocity trace of each individual player against pitch mapping in the software. Simultaneously, Horizontal Dilution of Precision (HDOP) and satellite number was analysed to ensure GPS data quality. The mean HDOP for the games analysed were 0.73 ± 0.02, 0.71 ± 0.01 and 0.73 ± 0.03 for WL3, 6N and OG respectively with no significant difference between tournaments (One-way ANOVA, p >0.05). The mean satellite number for the games analysed were 16 ± 1, 16 ± 1 and 14 ± 2 for WL3, 6N and OG respectively with no significant difference between tournaments (One-way ANOVA, p >0.05). Therefore, GPS quality was deemed as excellent according to manufacturer's guidelines across each tournament. The same standardised 2 velocity bands were standardised between tournaments and used to deifine Low Speed Running (LSR, ≤ 14.99kph), High Speed Running (HSR, 15-22.99kph) and sprinting (Sprint velocity, ≥ 23kph).

Environmental conditions

Environmental temperatures were recorded live at each game using a handheld environmental meter (Kestrel 5200, Nielson-Kellerman, USA). Temperature readings were taken at the beginning, half-time and end of each match, with the average of the 3 readings used as the match temperature. WL3 matches were played in Antwerp, Belgium, 6N matches were played in Valencia, Spain and OG matches were played in Rio de Janeiro, Brazil. There was no significant difference between average match temperatures between WL3 (28 ± 3°C), 6N ((27 ± 2°C)) and OG ((27 ± 4°C)) games (One-way ANOVA, p >0.05)

Statistical analyses

A mixed model ANOVA with the between-subject factors of competition (primary outcome; 3 levels) and player position (secondary outcome; 3 levels) was used to compare the physical demands of the sport. Statistical significance was set a priori at p < 0.05. The effect size for the main effects and the interaction was estimated by calculating partial eta squared values (η_p^2), with 0.01, 0.06 and 0.14 used to denote small, moderate and large effects sizes, respectively [11,12]. To reduce type I error rates, Fisher's Least Squared Differences (LSD) contrasts were involved in each comparison [13]. All statistical calculations were performed using the open source software programme JASP (Version 0.8.5.1).

RESULTS

Competition comparison

There was a main effect of competition for all variables, including total distance ($F_{(2,210)}$ = 4.6; p = 0.011, η_p^2 = 0.04), high speed running distance ($F_{(2,210)}$ = 4.1; p = 0.019, η_p^2 = 0.04), sprint distance ($F_{(2,210)}$ = 4.6; p = 0.011, η_p^2 = 0.04), match duration ($F_{(2,210)}$ = 3.8; p = 0.024, η_p^2 = 0.04), and max velocity ($F_{(2,210)}$ = 3.8; p = 0.023, η_p^2 = 0.04). Pairwise comparisons revealed that OG matches had higher (Figure 1, p <0.05) values for total distance (ES 0.50, CI 0.17 to 0.83), high speed distance (ES 0.36, CI 0.03 to 0.68), sprint distance (ES 0.43, CI 0.10 to 0.76) and maximum velocity relative to 6N matches (ES 0.46, CI 0.13 to 0.79, figure 2). OG matches has also higher sprint distance than WL3 matches (ES 0.36, CI 0.03 to 0.70, and figure 1). Match duration for 6N matches (47.8 ± 9.5 mins) was lower than OG (50.8 ± 9.8 mins) and WL3 (50.2 ± 13.6 mins) matches. Less high-speed distance (p <0.05) was covered in WL3 (ES 0.40, CI 0.07 to 0.73) matches compared to OG matches (Figure 1). The interaction between playing position and the level of competition was significant for total distance ($F_{(2,210)}$ = 5.6; p < 0.001, η_p^2 = 0.10) and match duration ($F_{(2,210)}$ = 6.0; p < 0.001, η_p^2 = 0.10). Pairwise comparisons revealed that defenders covered less total distance in 6N matches, when compared to the other competition formats. Forwards covered less distance in WL3 matches when compared to the other competition formats. Pairwise comparisons revealed that defenders had lower match durations in 6N matches compared to the other competition formats. Midfielders have lower match duration in 6N matches compared to WL3 and vice-versa for forwards (Table 1).

Positional comparison

The factorial ANOVA results revealed a main effect for position in total distance ($F_{(2,210)}$ = 15.6; p < 0.001, η_p^2 = 0.13), match duration ($F_{(2,210)}$ = 41.8; p < 0.001, η_p^2 = 0.29), high speed running distance ($F_{(2,210)}$ = 20,0; p < 0.001, η_p^2 = 0.16), sprint distance ($F_{(2,210)}$ = 28.5; p < 0.001, η_p^2 = 0.21), and max velocity ($F_{(2,210)}$ = 9.8; p < 0.001, η_p^2 = 0.09). Pairwise comparisons revealed that defenders covered the most total distance and played the longest. However, they covered less high speed distance, sprint distance and achieved lower max velocity values, relative to both forwards and midfielders. Pairwise comparisons revealed that forwards covered less total distance and sprint distance than midfielders (Table 2). Pairwise comparisons of playing position across each tournament have not been presented as they are not a focus of the current study.

DISCUSSION

The current study aimed to investigate whether the level of competition within international hockey had an effect on the running

demands of the players. The findings of the current study show that in each of the variables analysed, the Olympic Games had significantly different physical activity demands than either a regular in-season tournament and or an Olympic Games qualifying tournament.

Previous research across elite level sports have shown that there are various factors that can influence the physical running demands of athletes. These include periods within a game (i.e. halves and quarters), scoreline, tactical formation, team ranking, fatigue, situational influences, rule changes and playing level [3,14-19]. For example in hockey, Jennings et al. [6] demonstrated that male international players completed more high speed running across defense, midfield and strikers than national level athletes. However, a much less investigated potential influence on physical activity profiles is the level of competition within the same playing level. Aughey [5] demonstrated that in Australian Rules football players, the total distance, high speed running distance and maximal accelerations were significantly greater during Grand Finals matches versus regular season matches. Higham and colleagues [7] showed that in international rugby sevens, athletes completed significantly greater distance at high velocity, and had a greater number of accelerations and decelerations in international versus domestic sevens matches. In the current study, we compared the match running demands during three distinctly different tournament scenarios. The Olympic Games is arguably the most important event, in terms of representation or success, within each quadrennial cycle in international hockey, with only the World Cup of a similar standing. This is the first study in the literature to report the running demands of an international hockey team in an Olympic Games, therefore presenting novel data. Our results indicate that competing in an Olympic Games induced greater running demands in total distance, high speed running distance, sprint distance and maximal velocity compared to a regular tournament, and also greater high intensity distance than an Olympic qualifying tournament. It would be tempting to suggest that in each of tournaments that the level of opponent may be reduced in the two other tournament scenarios compared to the Olympic Games simply by competition stature and likely perceived quality of opponent, and that this may account for some of the physical activity differences. This is especially in the light of evidence from rugby league [20], international rugby sevens [17] and soccer [21] that suggests team and opponent ranking can effect physical performances. In the current study WL3 consisted of playing against teams ranked in the range of 1-31, 6 Nations teams were ranked 3-11 and in the Olympic Games, teams were ranked 2-15 in the world at the time of play. It

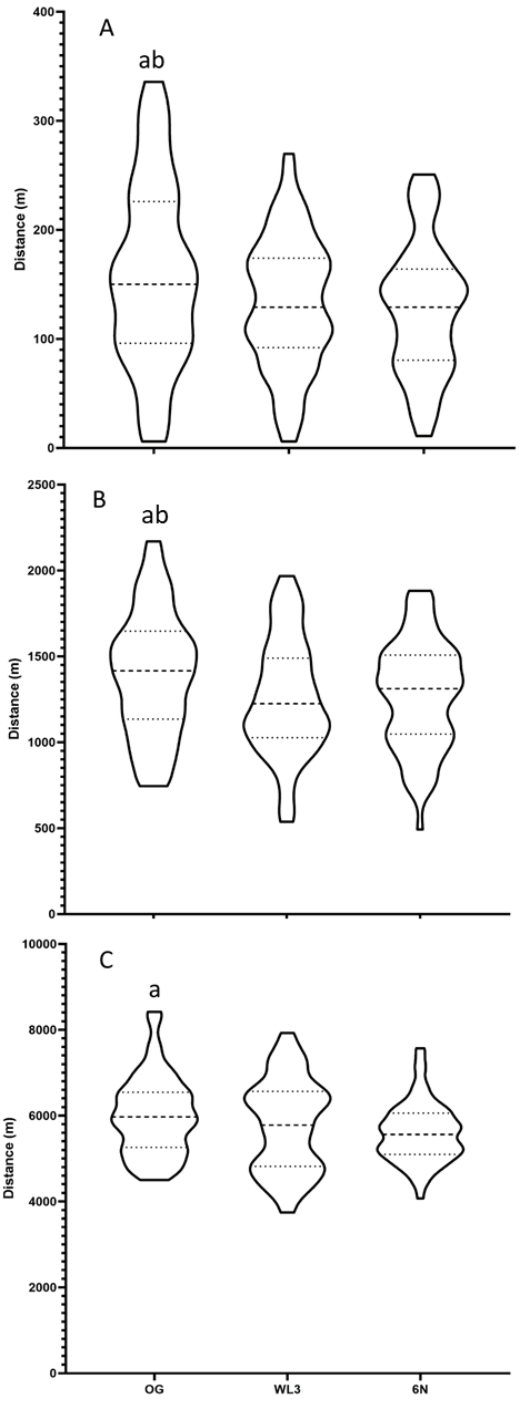

Figure 1: Comparisons of distances covered by players in (A) sprint distance, (B) high speed running distance, and (C) total distance. OG: Olympic Games; WL3: World League 3; 6N: 6 Nations. Data are mean ± S.D. a significantly different than 6 Nations (p <0.05), b significantly different than World League 3 (p <0.05), c significantly different to Olympic Games (p <0.05).

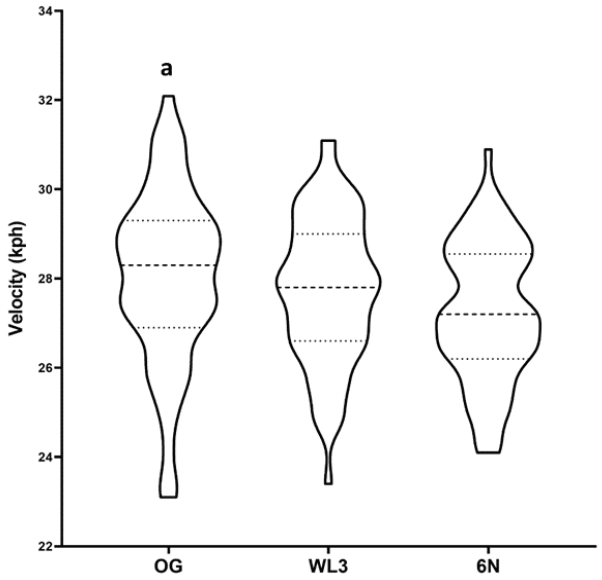

Figure 2: Comparison of maximum velocity of players in OG: Olympic Games; WL3: World League 3; 6N: 6 Nations. Data are mean ± S.D. *a* significantly different than 6 Nations (p <.05)

Table 1: Physical demand by position, according to the level of competition.

		6 Nations mean ± SD	League 3 mean ± SD	Olympics mean ± SD	6 Nations *vs* League 3 ES (95% CI)	Olympics *vs* 6 Nations ES (95% CI)	Olympics *vs* League 3 ES (95% CI)
Total Distance (m)	Defender	5582 ± 691	6586 ± 877	6496 ± 1079	-1.30* (-1.92 to -0.67)	1.04* (0.45 to 1.61)	-0.09 (-0.69 to 0.51)
	Midfielder	5577 ± 681	5829 ± 1044	5926 ± 636	-0.28 (-0.86 to 0.29)	0.53 (-0.05 to 1.10)	0.11 (-0.45 to 0.67)
	Forward	5650 ± 733	5134 ± 773	5606 ± 795	0.68* (0.12 to 1.24)	-0.06 (-0.62 to 0.51)	0.60* (0.03 to 1.17)
Match Duration (mins)	Defender	51.5 ± 9.6	62.9 ± 10.6	59.3 ± 9.1	-1.14* (-1.75 to -0.52)	0.84* (0.26 to 1.40)	-0.37 (-0.97 to 0.24)
	Midfielder	44.0 ± 7.	50.0 ± 13.8	47.7 ± 8.0	-0.54 (-1.12 to 0.05)	0.48 (-0.10 to 1.05)	-0.21 (-0.77 to 0.35)
	Forward	47.1 ± 9.7	41.0 ± 6.1	45.7 ± 6.4	0.76* (0.19 to 1.32)	-0.16 (-0.73 to 0.41)	0.77* (0.18 to 1.34)
High Speed Distance (m)	Defender	1051 ± 283	1090 ± 373	1244 ± 451	-0.12 (-0.69 to 0.45)	0.53 (-0.03 to 1.08)	0.37 (-0.24 to 0.97)
	Midfielder	1439 ± 199	1381 ± 350	1516 ± 207	0.20 (-0.37 to 0.77)	0.38 (-0.20 to 0.95)	0.47 (-0.10 to 1.04)
	Forward	1394 ± 284	1274 ± 250	1422 ± 344	0.45 (-0.10 to 1.00)	0.09 (-0.48 to 0.66)	0.50 (-0.07 to 1.06)
Sprint Distance (m)	Defender	94 ± 58	97 ± 60	110 ± 74	-0.05 (-0.62 to 0.52)	0.23 (-0.32 to 0.78)	0.18 (-0.42 to 0.78)
	Midfielder	167 ± 54	162 ± 55	206 ± 84	0.09 (-0.49 to 0.66)	0.55 (-0.03 to 1.13)	0.62 (0.04 to 1.19)
	Forward	131 ± 45	132 ± 52	158 ± 65	-0.03 (-0.58 to 0.51)	0.48 (-0.10 to 1.05)	0.43 (-0.14 to 0.99)
Max Velocity (kph)	Defender	26.8 ± 1.6	27.3 ± 2.0	27.0 ± 1.7	-0.31 (-0.88 to 0.27)	0.15 (-0.40 to 0.70)	-0.16 (-0.76 to 0.44)
	Midfielder	27.9 ± 1.4	28.2 ± 1.5	28.6 ± 1.3	-0.16 (-0.73 to 0.41)	0.47 (-0.11 to 1.04)	0.29 (-0.28 to 0.85)
	Forward	27.1 ± 1.3	27.7 ± 1.4	28.5 ± 2.4	-0.42 (-0.97 to 0.13)	0.70 (0.12 to 1.28)	0.40 (-0.17 to 0.96)

Data are mean ± S.D. *denotes a significant difference (p <.05)

Table 2: Pooled tournament physical demands by position

	Defender mean ± SD	Forward mean ± SD	Midfielders mean ± SD	Defenders *vs* Midfielders ES (95% CI)	Defenders *vs* Forwards ES (95% CI)	Midfielders *vs* Forwards ES (95% CI)
Total Distance (m)	6153 ± 990	5451 ± 793	5783 ± 810	0.41* (0.08 to 0.74)	0.79* (0.45 to 1.12)	0.41* (0.09 to 0.74)
Match Duration (mins)	57.1 ± 10.8	44.5 ± 7.9	47.3 ± 10.4	0.93* (0.59 to 1.28)	1.35* (0.99 to 1.70)	0.31 (-0.02 to 0.63)
High Speed Distance (m)	1123 ± 373	1359 ± 296	1446 ± 264	-1.00* (-1.35 to -0.65)	-0.70* (-1.03 to -0.37)	0.31 (-0.02 to 0.64)
Sprint Distance (m)	100 ± 64	140 ± 55	179 ± 68	-1.20*(-1.55 to -0.84)	-0.67* (-1.00 to -0.34)	0.64* (0.30 to 0.97)
Max Velocity (kph)	27.0 ± 1.7	27.7 ± 1.8	28.2 ± 1.4	-0.79* (-1.13 to -0.45)	-0.42* (-0.75 to -0.09)	0.31 (-0.02 to 0.63)

Data are mean ± S.D. *denotes a significant difference (p <.05)

should also be noted that 5 out of the 6 teams in WL3 were in the world rankings range 1-15, demonstrating that all 3 tournaments were very balanced in terms of opposition quality. In addition, the 6N tournament was played approximately 6 weeks prior to the beginning of the Olympic Games and all six teams involved in the 6N competed in the Rio 2016 Olympic Games. These further contextual factors add weight to the assertion that opponent quality was well standardised and the possibility that there may be something more intrinsically demanding about an Olympic event.

An important factor to consider is the number of players available in each of the tournaments and how it may account for some of the observed differences. In the 6N and WL3, there are 16 available outfield players, whereas in the OG there are only 15 due to rule differences. This has the implication that the total playing time available (60mins match time) and the activity of 10 outfield players at any one time (i.e. 60 x 10 = 600 available match time minutes) can potentially be divided by only 15 players in an OG, compared to 16 players in the other two tournaments. Could this artefact in player number therefore automatically increase player activity level profiles between OG and 6N/ WL3? The one less player available in an OG may only come from one position on the field. Within this particular team, the players available during the 6N and WL3 were 6, 5 and 5 in terms of defenders, midfielders and forwards respectively versus 5, 5 and 5 in the OG respectively. It is interesting to note that the one less defender in the OG was also accompanied by a main effect of position, where defenders covered significantly less total distance in 6N compared to OG. However, they also covered significantly less total distance than WL3, which therefore demonstrates it is not clear that one less player in an OG necessarily automatically inflates the need for increased running demands and explains the positional differences between tournaments. In support of this is also the fact that the OG resulted in significantly greater high intensity distance compared to WL3 in forwards when there were 5 forwards available in each tournament, and also that there were differences in running demands between WL3 and 6N when player numbers were identical. Although defenders had significantly less total distance in 6N versus WL3/OG in addition to significantly less match duration, the authors feel that this again does not account for the differences in total distance. Significant differences were also noted in midfielders and forwards between 6N and WL3 despite no running interactions in these positions. As mentioned above, there are only 600 match time minutes available for players to accrue activity in any one game. Match

duration was measured in real-time on the GPS software, whereas in the actual game itself, a timing clock is stopped and started during Penalty Corners (PC), video referrals, injuries, goal celebrations etc [3]. Therefore, it is more likely that this time difference could also be attributed to increased stoppages during the games accruing more 'real-time' as, for example, video referrals were only available during WL3 and OG and not 6N. However, these outside variables such as PC number, goals etc were not quantified in each tournament currently. Additionally, how much game-time a player accumulates is also completely at the coaching staff's discretion, so the observations of the current study may not be generalizable to all other teams depending on the tactical decisions made by coaching staff.

Our results demonstrated that there were differences between OG and WL3/6N in all running variables, however this did not lead to significant positional x competition interactions across the majority of the variables. The OG tends to have higher values than in each running variable across each position in the majority of cases. As there were few position x competition interactions, this suggest that the significantly increased activity demands between tournaments (Figures 1 & 2) are spread over the positions and amongst the team rather than one specific position. Although the differences between tournaments had significant yet small effect sizes, this does not mean that they are practically not important. Five OG games were played in a 7 day period, and with even small increases in physical demand in elite athletes, this may have major implications on recovery between games and subsequent performances as the tournament progresses. For example, Lythe & Kilding [22], demonstrated that during competitive match play in hockey, physical output can be maintained even when players are likely to be more fatigued due to fewer substitutions, however technical performance may suffer as a result. This therefore implies the possibility that even though there may not be statistical differences or large effect sizes between running variables in the various tournaments in our study, that performance can still suffer through technical reduction, due to accumulating fatigue as the tournament progresses. We have previously demonstrated in women's international hockey that within an international tournament (WL3) large decrements in running performance can occur from the start to finish [23]. Even though this wasn't an aim within the current study to quantify this relationship, it still raises the possibility that even small increases in output over time may exacerbate performance decrements within an OG scenario compared to other tournaments. However further research is needed to confirm these conjectures.

The current study can be used by coaches as a framework for analysing differences in tournament scenarios over the course of competitive seasons and to highlight potential differences that may exist. The authors are cautious not to suggest that the positional data per se can be used indefinitely to develop specific preparation guidelines between tournaments as such data sets can be altered by other contextual factors e.g. coaches may employ different tactics or make more/less substitutions that have the potential to affect physical outputs. The study does highlight that it would be potentially erroneous of coaches & physiologists/ scientists to assume similar physical demands across all international tournament scenarios and provides some sort of indication of physical demands at an Olympic Games. Furthermore, the current data does not outline the nature of the additional physical activity between tournaments. It is important to contextualise physical activity data in order to effectively understand and alter performance. Further research is needed to also develop the other contextual factors surrounding why there are differences in physical activity profiles between tournaments in hockey, and what form do they take e.g. technical, tactical, situational factors, and how they affect performance outcomes (e.g. circle penetrations, shots on goal, attacking 25s etc.).

The current study demonstrates that competition level even within the same playing level, can alter running demands in international hockey, despite similar levels of opposition ranking. The current data suggests that preparation for an Olympic Games, and also possibly an Olympic Games qualifying event, warrant additional physical preparation compared to regular in-season competitions.

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