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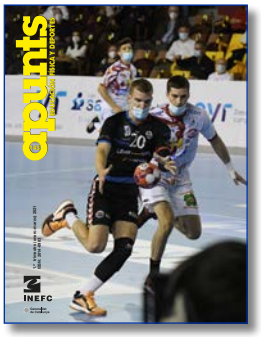

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International Competition Kinematic Demands in Men's Field Hockey

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Handball Spain: Ademar León and Liberbank Sinfín play the first match with masks during a Sacyr Asobal league game in October 2020, to comply with the regional regulations of COVID-19. J.Casares/(EPA) EFE/ lafototeca.com

Abstract

The objective of this research was to describe kinematic characteristics during international men's field hockey matches. Sixteen players (age: 25.12 ± 3.66 years; height: 177.12 ± 4.96 cm; weight: 72.45 ± 5.01 kg; caps: 79.12 ±78.96) belonging to the Spanish national team were monitored by means of Global Positioning Systems (GPS) and accelerometry in the course of five matches in the 2017 European Championships. The analyses were performed by game quarter (Q1, Q2, Q3 and Q4), positions (defenders, midfielders and forwards) and minutes played (per match). The data analysed included distances, accelerations and decelerations in different ranges of intensity. Defenders presented less high-intensity kinematic activity (speeds, number of sprints, metres/min) as opposed to midfielders and forwards. The by-quarter analysis showed that Q1 featured the highest kinematic activity for all positions. With regard to minutes played, the cluster analysis placed the players in three groups (<37, 37-48 and >48 minutes). The players who played <37 minutes travelled the largest amount of metres sprinting (>21 kph) and m/min as compared to other groups, whereas those who played between 37-48 minutes travelled the greatest distance at high-intensity (>16 kph) and performed the greatest number of sprints. The study results show that the physical demands on elite field hockey players depend on their position on the field and playing time, with greater activity in Q1 and with less relative high-intensity kinematic activity in players who play most minutes during the match.

Keywords: GPS, hockey, team sports, movement analysis, competition analysis.

Introduction

Field hockey is a team support involving 11 players per side, usually classified in four positions: goalkeeper, defenders, midfielders and forwards. Games involve alternating periods of different intensities, high speeds and high neuromuscular demand (the main ones being sprints, changes of direction, accelerations/decelerations) and lower-intensity periods (walking, trotting) (Jennings et al., 2012). Therefore, players are required to have certain conditional capacities, besides high technical and tactical skill (Jennings et al., 2012; Lythe & Kilding, 2011; Spencer et al., 2004).

In recent years, the sport has undergone major changes both in its rules and in the evolution of equipment which have had an enormous influence on the way the actual game is played (White & MacFarlane, 2015). One of the most important modifications was in total playing time and its new distribution, which as of the 2014-2015 season changed from two 35-minute halves to four 15-minute quarters (International Hockey Federation, FIH; 2014).

The use of global positioning systems (GPS) and accelerometry during training and competition is now very common in many sports, and more specifically in field hockey it has increased in recent years (Cummins et al., 2013; Vescovi & Frayne, 2015; White & MacFarlane, 2015). Since the use of such devices is permitted during official FIH matches, rapid progress is being made in knowledge of the sport (Aughey, 2011; Polglaze et al., 2017) which is key to ascertaining its kinematic demands in competition and in making progress in adapting training to the demands of competition, even rendering it possible to analyse and manage training load in real time in competition (Gabbet, 2010; Ishan et al., 2017; Polglaze, et al., 2017; White & MacFarlane, 2015).

The use of technology in field hockey for monitoring purposes has commonly focused on recording and analysing variables pertaining to movement: total distance, mean and maximum speed and movements in the different speed ranges (Lythe & Kilding, 2011; Polglaze et al., 2017). Nevertheless and as noted above, accelerations, decelerations and changes of direction occur frequently and contribute substantially to players' energy and more particularly neuromuscular demands, whereby it is important that they be taken into account as well (Spencer et al., 2004).

Previous studies have shown that in the course of a competitive match players can perform more than 900 acceleration and deceleration actions (Morencos et al., 2018). Average total distance travelled in international men's hockey matches is lower in comparison with football or Australian rules football (5,824-10,160 m, 9,000-12,000 m, 11,880-12,310 m, respectively), although the relative intensity is higher (131m·min-1, 111m·min-1, 109m·min-1, respectively) (Polglaze et al., 2017; Taylor et al., 2107). These differences may be ascribed to factors such as unlimited substitutions, which can be made without interrupting play, as well as to a greater proportion of available reserve players ($n=6$) for active players ($n=10$) meaning that the demands of competition can be spread out over more players.

Previous research into changes in the rules had already stressed the description of the kinematic demands in this sport. For example, Polglaze et al. (2017) presented position-specific data with the old rules of the game: forwards travelled an average of 5,409 ± 689 m in the 41:57 ± 5:23 minutes that they played. Defenders travelled an average of 6,257 ± 909 m in the 52:04 ± 7:12 minutes that they played, and finally midfielders travelled an average of 6,292 ± 855.5 m in the 46:11 ± 5:51 minutes that they played. However, in Jenninngset et al. (2010) this relationship between distance travelled and intensity according to position on the field changes: forwards travelled an average of 9,819 ± 720 m with 2,189 ± 456 m at high intensity (>15 kph). Midfielders travelled an average of 10,160 ± 215 m, with 2,554 ± 134 m at high intensity, and finally, defenders travelled an average of 9,453 ± 579 m with 1,734 ± 177 m at high intensity. In this case, the midfielders covered the greatest total distance and at high intensity.

The studies conducted following the new playing time distribution show that in the international game, forwards cover the greatest distance at high intensity (3,090 ± 565 m) compared to midfielders (2,680 ± 360 m) and defenders (2,257 ± 498 m). As for total distance travelled, once again forwards cover the greatest distance followed by midfielders and defenders, respectively (Ihsan et al., 2018). According to Lombard et al. (2017), forwards travelled an average of 5,159 ± 1,194 m, of which 29.7% was at high intensity (14.1 – 19 kph). Defenders travelled an average of 6,220 ± 1,797 m, with 17.9% at high intensity, and midfielders travelled 6,256 ± 1,859 m, 25.6% at high intensity. In their analysis, the relationship between distance travelled and playing time was 178.3 ± 22.3 m and 29.2 ± 8.6 minutes of play for forwards, 134.4 ± 16.6 m and 47.3 ± 14 minutes of play for defenders and 160.0 ± 5.6 m and 39.6 ± 12.6 minutes of play for midfielders. In terms of metres per minute, forwards travelled 178.3 ± 22.3 m, defenders 134.4 ± 16.6 m and midfielders 160.6 ± 15.6 m. In this case, total distance and playing time diminish with the new playing time distribution, although mean intensity and the percentage of distance travelled at high intensity increase.

Few studies have been conducted with the new times format, which is why it is important to continue to provide information about kinematic demands in competition in this sport since the demands of competition need to be

understood thoroughly in order to prepare players better during training.

Therefore, the objective of this study was to analyse and describe international competition kinematic demands in men's field hockey (Spanish national men's team) with particular emphasis on positions, match quarters and minutes played in competition.

Methodology

Participants

Sixteen field players (age: 25.12 ± 3.66; height: 177.12 ± 4.96 cm; weight: 72.45 ± 5.01 kg; caps: 79.12 ± 78.96) of the Spanish men's field hockey team participated in the study (Table 1). This study was approved by the Scientific Research Ethics Committee (CREC) of the Consejo Catalán del Deporte of the Government of Catalonia under number 18/CEICGC/2017. For data collection purposes the participants were informed directly and agreed to participate voluntarily by signing the informed consent form.

Procedure

The players were monitored in the course of five matches of the 2017 European Championships held in the Netherlands ($n = 78$ cases). The goalkeepers were excluded from the study due to the number of devices available. Three matches corresponded to the group phase and two matches to the play-offs for the 5th to 8th places. For the by-position analysis, the players were grouped into defenders ($n = 6$, 28 cases; there were two matches in which one player did not play any minutes for tactical reasons), midfielders ($n = 5$, 25 cases) and forwards ($n = 5$, 25 cases).

The total match time (60 minutes) and the time of each of the 15-minute match quarters (Q1, Q2, Q3 and Q4) were used for the analysis. The activity of the players on the field (actual playing time) was analysed, excluding the breaks between quarters or when the players were on the substitutes' bench, either for technical reasons or temporary yellow cards. The matches were played with break periods of 36-48 hours between each match.

Monitoring was performed by means of GPS devices (Wimu® model v1.6, RealTrack Systems, Almería, Spain) which operate with a sampling frequency of 10 Hz. This device complies with the IMS standard as provided for in the FIFA quality programme for electronic performance and tracking systems (EPTS). According to Macfarlane et al., (2016), 10 Hz devices appear to be more valid than 1 Hz and 5 Hz devices. The rate of satellites connected to each unit was maintained between three and 11 throughout the Championship. Moreover, among other features each unit has an accelerometer and gyroscope of 100 Hz. The unit was fitted to a harness designed specifically for this purpose and the device was placed between the shoulder blades. All of the players occupied the same position in the five matches and used the same GPS unit in order to minimise inter-device variability (Jennings et al, 2010). With regard to intra-device precision, Wimu® has a proven precision of between 0.69% and 6.05%, a test-retest reliability of 1.47 and an inter-unit precision of 0.25 (Bastida et al., 2018). However, and related to the foregoing, a greater number

Table 1
Characteristics of the study participants.

	$n = 6$	$t = 5$	$t = 5$	$t = 6$
	Defenders	Midfielders	Forwards	Totals
	mean SD	mean SD	mean SD	mean SD
Weight (kg)	73.48 ± 5.75	71.38 ± 2.86	72.3 ± 6.45	72.45 ± 5.01
Height (cm)	179 ± 4.04	172 ± 2.91	180 ± 3.87	177.12 ± 4.96
Age (years)	24 ± 3.4	27.4 ± 3.97	24.2 ± 3.27	25.12 ± 3.66
Caps (number)	70.66 ± 96.01	106.8 ± 83.64	61.6 ± 58.45	79.12 ± 78.96

of errors has been reported as movement speed increases (Linke et al., 2018).

Subsequently, the data from each GPS were downloaded using the SPro® software (v 1.0.0 Compilation 933, Real-Track Systems, Almería, Spain). Once the data had been filtered through the software they were input into a personalised spreadsheet (Microsoft® Excel® for Mac, v 14.7.1).

The variables recorded for subsequent analysis (Table 4) were: minutes played (min; MP), total distance (m; TD), peak speed (km·h^{-1}), distance travelled at high-intensity (DHI: >16 km·h^{-1}), distance travelled at high intensity per minute (DHI/min), total distance per minute (m/min total), distance per minute played (m/min played), number of sprints (>21.0 km·h-1 for more than 1 second), number of sprints per minute (sprints/min), and number of accelerations (Acc) and decelerations (Dec) analysed in 3 intensity categories: low (Z1: 1-2.5 m·s^{-2}), moderate (Z2: 2.5-4 m·s^{-2}) and high (Z3: >4 m·s^{-2}). All the variables except peak speed were expressed in absolute terms and according to minutes of play (MP; m·min-1 or n·min-1). The "work:rest (W:R)" ratio was established, dividing the distance travelled >6 km·h^{-1} / distance <6 km·h^{-1} to establish work density.

Data analysis

A dataset analysis was performed and the data were presented as means and standard deviations (±SD) with a 95% confidence interval (CI) and effect size (ES). A two-way ANOVA was used to ascertain differences by positions and by quarters (positions x quarters). A cluster analysis was performed to establish groups according to the minutes played variable, with three groups established according to: <37 min, 37-48 min and >48 min (Table 2). The thresholds for the ES were <0.2; 0.2–0.6 (trivial), 0.6–1.2 (small), 1.2–2.0 (moderate), 2.0–4.0 (large) and 2.0–4.0 (very large) (Hopkins, 2002). All the statistical analyses were performed using the SPSS 18.0 statistics package for iOS and the level of significance accepted was $p<0.05$.

Results

The analysis showed that total distance was 5.18% greater for midfielders versus defenders and 5.12% with regard to forwards (ES: 0.29). Defenders presented less high-intensity kinematic activity (speeds, number of sprints, metres/min) as opposed to midfielders and forwards. With regard to distance at high speed (>16 km·h^{-1}), forwards covered most metres (1,066.89 ± 250.56), 22.77% more than defenders and 0.6% more than midfielders (ES: 0.13) (Table 3). Sprint distance (>21.0 km·h^{-1}) was also greater for forwards and midfielders than for defenders (+49.41%; ES: 0.06 and +1.41%, respectively), with defenders presenting fewer demands in terms of total amount and in terms of total number of minutes played (figures 1C and 1D). The W:R ratio was greater for forwards than for defenders in Q3 and Q4 (Figure 1E). The acceleration and deceleration variables pertaining to time played (minutes) in Z1 were around 23% greater for those who played less than 37 minutes versus those who played more than 48 minutes (Table 3). This tendency towards a greater effort related to minutes played was repeated in each of the three acceleration and deceleration areas established.

In the by-quarter analysis, there was greater kinematic activity in Q1 for all positions. Only the acceleration variables in Z1 and Z2 and decelerations in Z1 fell in Q4 versus

Table 2
Amount of players per playing time and position cluster.

	Match 1			Match 2			Match 3			Match 4			Match 5		
	0-37min	>37 <48	>48	0-37min	>37 <48	>48	0-37min	>37 <48	>48	0-37min	>37 <48	>48	0-37min	>37 <48	>48
FOR	3	2	0	4	1	0	3	2	0	3	2	0	4	1	0
MID	2	3	0	2	2	1	2	2	1	2	3	0	2	3	0
DEF	2	1	3	2	1	3	3	1	2	1	1	3	2	0	3
TOTAL	7	6	3	8	4	4	8	5	3	6	6	3	8	4	3

DEF=defenders; MID=midfielders; FOR=forwards

Table 3
Comparison of kinematic variables according to minutes played.

	MP	N				ES		95% CI	
	0-37min	38	80.25	±	14.20			75.59	84.92
m/min (total)	>37 <48	27	97.51	±	8.56	*1.41		94.12	100.90
	>48	13	100.48	±	8.14	*1.55	.35	95.56	105.41
	0-37min		8.33	±	3.67			7.12	9.54
Distance sprinted/min	>37 <48		8.11	±	2.81		.06	7.00	9.22
	>48		4.33	±	2.20	*1.18#1.43		3.00	5.67
	0-37min		210.39	±	36.01			198.55	222.22
m/min (played)	>37 <48		168.57	±	18.06	*1.4		161.42	175.71
	>48		135.52	±	15.28	*2.32#1.91		126.29	144.76
	0-37min		30.72	±	9.77			27.51	33.93
DHI/min	>37 <48		25.26	±	6.97	*.62		22.50	28.02
	>48		15.62	±	6.75	*1.65#1.39		11.55	19.70
	0-37min		875.05	±	296.20			777.69	972.41
DHI	>37 <48		1076.84	±	263.20	*.71		972.72	1180.96
	>48		834.56	±	323.01	#.85	.13	639.37	1029.76
	0-37min		5890.96	±	1035.71			5550.53	6231.40
Total Distance	>37 <48		7170.19	±	573.23	*1.46		6943.43	7396.95
			7334.85	±	578.54	*1.53	.29	6985.24	7684.46
	0-37min		17.61	±	4.14			16.24	18.97
Acc/min Z1	>37 <48		15.58	±	2.05	*.6		.40	14.77
	>48		13.56	±	1.23	*1.1	1.10	.34	12.82
	0-37min		3.37	±	.89			3.08	3.66
Acc/min Z2	>37 <48		2.97	±	.45		.53	2.79	3.15
	>48		2.69	±	.46	*.84	.62	2.42	2.97
	0-37min		.70	±	.28			.60	.79
Acc/min Z3	>37 <48		.69	±	.17		.64	.62	.75
	>48		.53	±	.18		.65//.92	.43	.64
	0-37min		15.59	±	4.12			14.24	16.94
Dec/min Z1	>37 <48		14.13	±	1.69		.44	13.46	14.80
	>48		12.07	±	1.40	*.96	1.28	11.23	12.92
	0-37min		2.82	±	.76			2.57	3.07
Dec/min Z2	>37 <48		2.32	±	.41	*.78		2.16	2.48
	>48		2.22	±	.24	*.92	.33	2.08	2.37
	0-37min		.82	±	.28			.73	.91
Dec/min Z3	>37 <48		.74	±	.24		.30	.64	.84
			.65	±	.16		.66//.41	.56	.75
	0-37min		1.37	±	.41			1.23	1.50
W:R	>37 <48		1.66	±	.28	*.8		1.55	1.78
	>48		1.21	±	.22	#1.71	.43	1.07	1.34
	0-37min		502.53	±	133.64			458.60	546.45
Acc Z1	>37 <48		664.22	±	69.53	*1.45		636.72	691.73
			738.31	±	82.66	*1.91	1.00	688.36	788.26
	0-37min		96.63	±	28.63			87.22	106.04
Acc Z2	>37 <48		126.22	±	15.70	*1.22		120.01	132.43
			146.23	±	25.86	*1.77	1.03	130.60	161.86

Table 3 *(Continuation)*
Comparison of kinematic variables according to minutes played.

	MP	N				ES		95% CI	
	0-37min		20.37	±	9.28			17.32	23.42
Acc Z3	>37 <48		29.44	±	6.76	*1.1		26.77	32.12
			28.54	±	8.14	*0.9	.12	23.62	33.46
	0-37min		447.55	±	139.44			401.72	493.38
Dec Z1	>37 <48		603.41	±	59.38	*1.37		579.92	626.90
	>48		657.00	±	87.67	*1.63	.70	604.02	709.98
	0-37min		80.63	±	22.33			73.29	87.97
Dec Z2	>37 <48		99.56	±	16.84	*.93		92.90	106.22
	>48		120.46	±	11.88	*1.96#1.35		113.28	127.64
	0-37min		23.79	±	9.86			20.55	27.03
Dec Z3	>37 <48		31.67	±	9.72	*.09		27.82	35.51
	>48		35.23	±	8.88	*.11	.37	29.86	40.60
	0-37min		238.32	±	112.99			201.18	275.46
Distance sprinted	>37 <48		341.59	±	106.46	*.93		299.48	383.71
	>48		233.06	±	108.17	#1.01	.04	167.70	298.43
	0-37min		20.89	±	8.51			18.10	23.69
No. sprints	>37 <48		27.37	±	7.36	*.8		24.46	30.28
			18.54	±	8.68	#1.13	.27	13.30	23.78

* Significant differences with 0-37; # Significant differences with >37<48. Acc: accelerations; Dec: decelerations, MP: minutes played; ES: effect size for significant and non-significant values; CI: confidence intervals; W:R: work:rest ratio; DHI: distance at high intensity

Q1 for midfielders and defenders (figures 2A to 2F). The W:R ratio diminished in Q4 versus Q1 for defenders and midfielders (Figure 1E).

Finally, a cluster analysis grouping the players according to MP was performed. Three clusters were obtained: 1) from 0 to 37 minutes, 2) between 37 and 48 minutes, and 3) more than 48 minutes. The players belonging to group 1 (0-37 min.) presented greater values for total relative distance (m/min), distance at high intensity and distance sprinted in comparison with groups 2 (37 to 48 minutes) and 3 (more than 48 minutes): 19.8±5.8% greater than group 2 (37-48 minutes) and 35.5±6.9% more than group 3 (more than 48 minutes). Accelerations and decelerations per minute in Z1 and Z2 were greater for group 1. The W:R ratio was greater for group 2 compared to group 1 (Table 4).

Discussion

The main objective of this study was to analyse and describe international competition kinematic demands in men's field hockey with particular emphasis on positions, match quarters and minutes played in competition. The main findings were: a) there are differences between positions for virtually all of the variables analysed; b) defenders present the greatest reduction in the W:R ratio in the course of the quarters; c) the variable that remains most stable over the game quarters in all positions is distance at high intensity per minute; d) defenders present the greatest reduction in kinematic activity in all the variables compared to defenders and forwards; e) the players who play fewest minutes cover the greatest relative distance with regard to minutes of play, presenting greater intensity; f) Q1 presented the greatest kinematic activity in all the study variables, except in DHI/min, and g) forwards travelled the greatest number of metres at high intensity and made the greatest number of sprints.

Although any comparison with other published studies may be complicated (because different movement analysis techniques were used as well as different GPS devices, a different categorisation of intensity ranges for the speed, acceleration, etc. variables), some of the values found in this paper are higher in some of the aspects studied. For example, and according to previous studies, international hockey players change speed 512 times per match (Buglione et al., 2013), which is equivalent to once every 6.8 seconds of playing time. In this study, the hockey players changed speed more than 1,500 times in the course of a match, either positively or negatively, which is equivalent to a total of 25 times per minute, which constitutes practically 300%

Table 4
Comparison of the kinematic variables with regard to time, match quarters and positions.

		C1	ES	C2	ES	C3	ES	C4	ES
	Position								
m/min (played)	Defenders	175.22 ± 61.36		160.51 ± 35.66		154.71 ± 40.47		156.75 ± 42.53	
	Midfielders	207.65 ± 46.34	.60	189.45 ± 46.53	*.7	191.44 ± 50.70	*.8	184.06 ± 46.35	.61
	Forwards	212.05 ± 37.98	*.7 .10	196.45 ± 37.99	*.97 .16	194.74 ± 32.66	*1.1 .07	192.16 ± 45.58	*.8 .17
DHI/min	Defenders	21.78 ± 17.31		21.93 ± 10.25		18.81 ± 9.78		18.85 ± 10.21	
	Midfielders	27.64 ± 15.92	.35	29.01 ± 9.48	*.7	28.22 ± 9.60	*.97	27.85 ± 7.94	*.97
	Forwards	30.66 ± 20.24	.5//.1	31.03 ± 10.07	*.9 .20	31.54 ± 11.02	*1.22 .32	32.00 ± 12.94	*1.13 .38
Distance sprinted/ min	Defenders	5.92 ± 5.36		5.88 ± 3.99		4.10 ± 3.22		5.05 ± 3.54	
	Midfielders	9.63 ± 4.06	*.77	8.79 ± 4.95	.65	6.91 ± 4.74	.70	8.41 ± 4.67	*.82
	Forwards	10.01 ± 5.34	*.76 .08	9.20 ± 4.68	*.76 .08	9.20 ± 5.09	*1.21 .46	9.41 ± 6.03	*.9 .18
No. sprints/ min	Defenders	0.53 ± .46		0.45 ± .29		0.42 ± .39		.41 ± .31	
	Midfielders	0.76 ± .37	.55	0.72 ± .27	*.9	0.61 ± .31	.53	.66 ± .29	*.83
	Forwards	0.95 ± .47	*.9 .50	0.82 ± .43	*1.02 .09	0.78 ± .45	*.86 .44	.72 ± .33	*.97 .20
W:R	Defenders	1.46 ± .54		1.25 ± 39		1.19 ± .45		1.11 ± .40	
	Midfielders	1.75 ± .50	.55	1.40 ± 34	a .40	1.56 ± .45	*.8	1.33 ± .29	.65
	Forwards	1.79 ± .59	.6//.07	1.44 ± .49	.04//.09	1.72 ± .65	*.9 .30	1.43 ± .46	*.77 .26
Acc/min Z1	Defenders	17.94 ± 7.08		16.13 ± 4.24		14.64 ± 5.02		15.31 ± 5.37	
	Midfielders	17.27 ± 2.25	.12	14.99 ± 3.04	.30	14.88 ± 3.29	a .05	14.35 ± 3.74	.20
	Forwards	19.84 ± 4.19	.32//.76	16.80 ± 4.29	.16//.5	17.97 ± 4.69	*.7#.8	15.65 ± 4.53	.07//.31
Acc/min Z2	Defenders	3.28 ± 1.28		3.08 ± .88		2.98 ± 1.18		2.94 ± 1.27	
	Midfielders	3.54 ± .85	.24	2.94 ± 1.00	.15	2.93 ± .92	.04	2.75 ± .84	.17
	Forwards	3.68 ± .81	.37//.17	3.34 ± .98	.3///.4	3.27 ± .95	.27//.36	2.82 ± .90	.11//.08
Acc/min Z3	Defenders	.60 ± .37		0.74 ± .38		.61 ± .35		.52 ± .24	
	Midfielders	.68 ± .33	.22	0.64 ± .29	.30	.49 ± .21	.41	.49 ± .22	.13
	Forwards	.83 ± .34	.64//.44	0.84 ± .45	.24//.53	.81 ± .32	#1.18 .60	.78 ± .31	*.9#1.08
Dec/min Z1	Defenders	16.36 ± 6.70		14.23 ± 3.83		13.14 ± 4.52		13.32 ± 5.15	
	Midfielders	16.06 ± 2.15	.06	13.00 ± 3.00	a .35	13.25 ± 2.60	a .03	12.20 ± 2.39	.27
	Forwards	17.72 ± 3.72	.25//.55	15.36 ± 3.37	.31//.74	16.16 ± 5.02	*.63#.72	13.98 ± 3.71	.14//.57
Dec/min Z2	Defenders	2.83 ± 1.07		2.52 ± .81		2.47 ± 1.02		2.25 ± .80	
	Midfielders	2.82 ± .63	.01	2.57 ± .90	.05	2.62 ± .85	.16	2.48 ± .78	.30
		2.81 ± .66	.02//.01	2.39 ± .72	.17//.22	2.70 ± .93	.23//.09	2.22 ± .81	.06//.35
Des/min Z3	Defenders	.83 ± .38		.80 ± .29		.64 ± .35		0.70 ± .38	
	Midfielders	.86 ± .49	.07	.66 ± .36	.43	.62 ± .23	.06	0.71 ± .50	.02
	Forwards	.91 ± .39	.2//.11	.80 ± .43	//.35	.82 ± .39	.5//.6	0.82 ± .38	.31//.24

a indicates significant difference with quarter 1. b indicates significant difference with quarter 2. c indicates significant difference with quarter 3; *indicates significant difference with defenders. # indicates significant difference with midfielders (in the same quarter).

more in terms of total accelerations and therefore virtually multiplies accelerations per minute threefold. Besides the possible differences due to the different tools used, match format (4 quarters vs. 2 halves) or player level could explain these differences.

Regarding differences between positions, it should be mentioned that the kinematic demands presented by defenders are lower than those of midfielders and forwards, which concurs with previous work conducted according to the new time distribution (Ishan et al., 2018), and as can be seen in Table 4, in many cases these differences are significant. DHI and sprint would also seem to be influenced by the player's position. Thus, in this research defenders present significantly lower data than midfielders and forwards while

Table 5
Total average 5 matches by positions.

	n=28		*n*=25		*n*=25	
	Defenders		Midfielders		Forwards	
	mean	SD	mean	SD	mean	SD
min played	42.86	13.09	37.28	9.76	33.40	5.77 *
m/total min	88.45	19.35	92.56	10.38	87.92	12.40
m/min played	160.99	40.17	193.15	41.03	198.85	26.07 *
DHI/min	20.19	9.42	28.18	6.96	31.31	9.74 *
Distance sprinted/min	5.25	4.11	8.43	4.65	9.45	5.23 *#
Number of sprints/min	.45	.36	.68	.31	.82	.42 *
Peak speed	25.48	2.81	26.85	1.24	27.46	1.68 *
W:R	1.24	.33	1.51	.33	1.60	.39 *
Acc/min Z1	15.81	4.55	15.37	2.15	17.57	2.90
Acc/min Z2	3.04	.99	3.04	.56	3.28	0.58
Acc/min Z3	.62	.27	.58	.18	.81	.20 *#
Dec/min Z1	14.11	4.38	13.63	1.65	15.81	2.90
Dec/min Z2	2.49	.77	2.62	.59	2.53	.57
Dec/min Z3	.74	.26	.71	.23	.84	.26

* Significant differences with defenders # Significant differences with midfielders

forwards present the highest values in these variables, which concurs with previous studies (Lythe et al., 2011; Jennings et al., 2012; Polglaze et al., 2017; Ishan et al., 2018).

Another factor to be taken into account in game intensity is time played, as has been observed in previous studies (Vescovi & Fraine, 2015). Defenders played the greatest number of minutes (42.86 ± 13.09 min.), whereas midfielders (37.28 ± 9.76 min.) and forwards (33.40 ± 5.77 min.) spent less time on the field. Therefore, there would appear to be a dependent relationship between time played and intensity of actions, since the players who played more minutes had lower values per minute played.

With regard to the comparison between the different match quarters, it should be emphasised that while most of the variables tended towards a reduction, this was not always the case. More specifically, DHI/min for forwards increased with the quarters. However, the number of sprints per minute tended to diminish in all positions. Of the variables studied, 54.5% improved in Q4 versus Q3, whereas the rest (45.5%) worsened. The highest values were always obtained in Q1 and/or in Q2 (Table 4 and figures 1A to 1E and 2A to 2F)

As for minutes played according to the cluster analysis, significant differences were observed in m/min played, DHI/min, distance sprinted and Acc/min Z1, with players who played fewer minutes (0-37 min) presenting greater intensity. By contrast, total distance was greater in players who played more minutes, which may be due to the time/intensity ratio: the longer the playing time the lower the intensity of actions, although the longer the playing time the greater the total amount.

While the movements were measured by the usual methods established for the evaluation of physical demands in hockey (and other team sports), their efficacy as indicators of work and intensity for intermittent activity, which involve frequent changes of speed, is questionable (Polglaze et al., 2017). Real work estimates should include acceleration, which directly and substantially contributes to energy cost. Therefore, in assuming that locomotion occurs at a constant speed, the energy cost of this type of intermittent activity is probably underestimated (Osgnach et al., 2010).

Despite the controversy surrounding the relationship between success in sports and high intensity, teams with a better ranking appear to need to travel less distance at high intensity than poorer-placed teams (Jennings et al., 2012). Nevertheless, a number of studies have demonstrated the importance of high-intensity actions (high-intensity running, sprints) in the final outcome in different team sports. This may be due to players' qualitative level, the team's degree of tactical synchronisations and the match situation on the scoreboard or the time of the season among other factors.

In this respect, the frequency and distribution of accelerations and decelerations appeared to yield a better representation of the internal load of a match or training drill,

since in energy terms they are the most solicited actions in team sports (Ingebrigtsen et al., 2015), whereas measurements based on movement (external load) would appear to underestimate the real cost of intermittent sports such as hockey (Polglaze et al., 2017). Therefore, in order to estimate the load involved in a given drill as precisely as possible, emphasis should be placed on the amount of accelerations and decelerations and on their distribution and accumulation over time as well as their magnitude.

Some of the main limitations of this paper pertain to the number of matches studied and the absence of internal load and technical-tactical information. Knowing the impact of the activity performed by the players on their body would help to calculate cardiovascular efficiency indexes and also make it possible to study its evolution in the course of the match and draw comparisons between positions. Moreover, information could be obtained about the number of occasions in which each player participates on the field as well as the duration of each participation and between participations, also providing more detailed information about the density of efforts made in international men's hockey

Conclusions and practical applications

Knowing the kinematic demands on players during competition is the starting point for designing training drills, managing workloads or monitoring the process of transitioning injured players back into competition. Having competition-specific data will facilitate, for example, the design of conditional priority and low-specificity drills that reproduce the demands of competition in training. Moreover, and with respect to technical-tactical priority drills, the analysis of training kinematic demands and their comparison to competition may help to modify the conditions of these drills in order to adapt them to the conditional reality of competition. In addition, the differences between positions originated by technical and tactical roles and minutes played may help to guide and determine workload size, particularly on after-match days. Distinguishing what and how much to do depending on what has already been done could constitute a personalised recovery strategy depending on the workload accumulated in the match.

Due to the evolution of high-intensity actions in the course of the match quarters in competition, making changes more frequently and having a pre-set rotation that guarantees player recovery may be a strategy to follow in order to ensure that all of them can keep up the same pace of play during a match or a tournament. Having a greater number of forwards in the match squad so that they can be used during the competition, in the knowledge that this position involves the greatest number of high-intensity actions, could be another useful strategy for maintaining or improving their high level of effort.

In conclusion, the results of this study show that the kinematic demands on elite hockey players depend on their position on the field, with greater activity in the first quarter, and with less kinematic activity in players who play most minutes during the match.

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