Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 8), Art 225, pp. 2033 - 2039, August 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Monitoring performance in women's canoe polo athletes: An investigation using wearable technologies

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Published online: August 31, 2024
Accepted for publication : August 15, 2024
DOI:10.7752/jpes.2024.08225

Abstract:
Canoe polo is a rapidly growing and dynamic sport, yet its performance metrics remain underexplored. This pilot study aims to analyze the kinematic and physiological parameters of female canoe polo players during a simulated match using wearable technologies, specifically K-Sport GPS devices. Data were collected from 10 athletes on the Italian national team with K-AI Wearable Tech devices, which recorded key metrics including distance covered, speed, acceleration, and heart rate. The athletes covered an average distance of 545.1 m (± 60.80), with a peak speed averaging 3.03 m/s (± 0.26). Their maximum acceleration averaged 2.37 m/s2 (± 0.26), while maximum deceleration averaged −3.75 m/s2 (± 0.71). The average maximum heart rate was 168.6 bpm (± 11.38), and the average heart rate was 144.5 bpm (± 16.83), representing 75.2 % (± 8.57) of the theoretical maximum heart rate. These results suggest that canoe polo is a high-intensity, intermittent sport characterized by periods of moderate speeds (0 - 1 m/s) and bursts of activity at intermediate speeds (1 - 2 m/s). Brief, rapid accelerations and decelerations are essential for optimal performance in canoe polo, requiring well-developed anaerobic and aerobic energy systems. This study offers valuable insights for optimizing training programs and game strategies for female canoe polo players. It underscores the utility of wearable devices in monitoring and improving performance by providing objective and accurate data, enabling personalized training. Overall, the findings highlight the need for tailored training programs that enhance both anaerobic and aerobic capacities to enhance performance in this sport.
Keywords performance analysis, physiological monitoring, female athletes, K-Sport GPS, training optimization

Introduction

Canoe polo is a rapidly growing non-Olympic sport globally, thanks to its dynamic and engaging nature (Sheykhlouvand et al., 2016; Forbes, Kennedy, & Bell, 2013; Alves et al., 2012). Played both indoors and outdoors, canoe polo is a situational and competitive sport involving two teams of five players each, with three substitutes. Players use 3-meter-long and 65-centimeter-wide kayaks and double-bladed paddles to maneuver and accelerate the boat. Matches are held on a playing field measuring 35 meters in length and 25 meters in width. The objective is to score in the opponent's goal, positioned 2 meters above water level and measuring 1 meter by 1.5 meters, located at each end of the field (Federation International Canoe, 2019).

A canoe polo match is divided into two halves of 10 minutes each, with a 3-minute break between halves (Federation International Canoe, 2019). The match starts with a sprint from the center line of the field, during which both teams try to gain possession of the ball to initiate gameplay (Federation International Canoe, 2019). Each player has a maximum of 5 seconds to maintain possession of the ball (Forbes, Kennedy & Bell, 2013). A 60-second shot clock regulates ball possession time during the game. This clock resets in the event of a change of possession, a shot on goal that bounces off or hits a defender, and when a free throw or advantage is awarded following a foul. It does not reset in the case of a shot attempt that does not reach the goal or a temporary loss of ball control (Italian Canoe Kayak Federation, 2023; Forbes & Sheykhlouvand, 2016).

Canoe polo is a high-intensity intermittent sport (Sheykhlouvand et al., 2016; Forbes, Kennedy & Bell, 2013). Although most of the game is played at moderate intensity, fueled by the aerobic energy system (Sheykhlouvand et al., 2018; Sheykhlouvand et al., 2016; Forbes, Kennedy & Bell, 2013; Alves et al., 2012), anaerobic power plays a crucial role in specific actions such as initial accelerations to gain ball possession, counterattacks, and individual play (Sheykhlouvand & Forbes, 2018; Sheykhlouvand et al., 2018). Analyzing accelerations during matches could therefore be useful for developing more appropriate training regimes.

Existing scientific literature primarily focuses on the physiological and anthropometric requirements of male canoe polo athletes (Marques-Sule et al., 2022; Sheykhlouvand et al., 2015; Forbes, Kennedy & Bell,

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2013; Alves et al., 2012; Vastola et al., 2012), neglecting the physiological characteristics of female players (Sheykhlouvand, et al., 2018; Sheykhlouvand & Forbes, 2018).

Defining a performance model specific to female canoe polo players could prove extremely useful. Sports performance is a complex phenomenon determined by a multitude of interacting factors. To understand its dynamics, it is necessary to analyze these factors systematically and structurally. In this regard, the performance model represents a valuable tool for identifying the key elements that influence performance in a specific sport. Identifying these key factors helps develop targeted interventions to improve the specific skills and abilities required by the discipline (Vastola et al., 2012). However, few studies have delved into the performance model of canoe polo, making this area of research still underexplored.

The aim of this pilot study is to define the kinematic and physiological parameters characterizing the performance model of female canoe polo by analyzing a simulated match using K-AI Wearable Tech devices. These devices allow for the collection of detailed performance data from the athletes, including acceleration, speed, and distance parameters. Consequently, such devices could prove useful in investigating the characteristics that more precisely and accurately define the performance model of canoe polo. This study could contribute to expanding the existing literature on female canoe polo players and provide valuable insights for improving athletes' training and performance.

Material and methods

Participants

The sample for this study consists of 10 athletes from the Italian national women's canoe polo team. The average age, body weight, and height of the participants are 27.7 ± 6.9 years, 63.4 ± 6 kg, and 165.6 ± 5.2 cm, respectively.

Procedures and Measures

All athletes were informed of the potential risks, and the study was conducted in accordance with the Declaration of Helsinki. The study design was conceived and coordinated by Prof. Rodolfo Vastola, the head of the training and research center of the Italian Canoe Kayak Federation (FICK) and technical director of the national teams, along with the staff of the Laboratory for Innovative Teaching and Sports Performance Analysis at the University of Salerno (UNISA).

The assessments were carried out during a Senior Women's Training Camp at Lake Bacoli (NA). The study involved monitoring the athletes' performance using K-Sport sensors and measuring heart rate during a simulated match against the under-21 men's team. The women's team, consisting of ten athletes, was divided into two groups that alternated during the two halves of the game. Each group played 5 minutes in the first half and 5 minutes in the second half, for a total effective playing time of 10 minutes per athlete.

The type of GPS used in this study was K-AI Wearable Tech (KSport ® World Srl, Fano, Italy). Along with the device, a heart rate monitor (sampling frequency of 10Hz) provided by the same company was used.

The device (K-AI Wearable Tech) has a sampling frequency of 50 Hz for GNSS satellite tracking and integrates, through a revolutionary Sensor Fusion technology, with triaxial accelerometer, gyroscope, and magnetometer (sampling frequencies of 238 Hz). The K-AI was integrated into the K-Shirt, a vest specifically designed to house the device (Fig.1). The position was studied to make it as non-invasive as possible for the athlete. The shirt, made of highly technological Seamless fabric, ensures a perfect fit to the body, allowing for an accurate analysis of the athletes' technical skills and minimizing errors due to suboptimal device positioning.

Fig 1. K-AI Wearable Tech and K-Shirt (K-Sport-Universal Italia)

The data were collected by downloading all information from the devices using dedicated software (K-Fitness, K-Sport International, Italy). The information files, in ".cvs" format, were filtered and analyzed through the software and were directly stored on the online portal (K-Sport Online, K-Sport International, Italy). Through the portal, it was possible to download the Excel spreadsheet containing all the match data. In accordance with company guidelines, data on speeds, accelerations, and heart rate (HR) were recorded when the duration exceeded 0.40 seconds, while maximum peaks were recorded for durations over 0.10 seconds. The collected parameters are summarized in Table 1.

Table 1. Summary of parameters

Parameter	Description
D	The total distance traveled in meters during the match (m).
SMAX	The maximum speed reached during the match in meters per second (m/s).
AMAX	The maximum acceleration reached during the match in meters per second squared (m/s^2).
DMAX	The maximum deceleration reached during the match in meters per second squared (m/s^2).
HRMAX	The maximum heart rate reached during the match (bpm).
HRAVG	The average heart rate during the match (bpm).
%HRAVG	The percentage of the average heart rate relative to the theoretical maximum heart rate (%).
HRMAX	The predicted maximum heart rate for the athlete (bpm).

For each athlete, the distance covered (D) and the time spent (T) at certain speed thresholds (S) were also calculated, as shown in Table 2.

Table 2. Speed thresholds table

Measurement Interval	Speed Range (m/s)
S1 (D_S1 - T_S1)	0.0000 to 1.0000
S2 (D_S2 - T_S2)	1.0000 to 2.0000
S3 (D_S3 - T_S3)	2.0000 to 3.0000

Similarly, thresholds for accelerations and decelerations were defined, for which the distance covered (D) and the time spent (T) at each acceleration threshold (A) were also calculated, as shown in Table 3.

Table 3. Acceleration thresholds table

Measurement Interval	Acceleration Range (m/s^2)
A1 (D_A1 - T_A1)	-4.0000 to -3.0000
A2 (D_A2 - T_A2)	-3.0000 to -2.0000
A3 (D_A3 - T_A3)	-2.0000 to -1.0000
A4 (D_A4 - T_A4)	-1.0000 to 0.0000
A5 (D_A5 - T_A5)	0.0000 to 1.0000
A6 (D_A6 - T_A6)	1.0000 to 2.0000
A7 (D_A7 - T_A7)	2.0000 to 3.0000
A8 (D_A8 - T_A8)	3.0000 to 4.0000

Regarding heart rate, the maximum heart rate of all athletes was calculated using the Karvonen formula (Karvonen, Kentala & Mustala, 1957). Subsequently, the time spent (T) and the distance covered (D) at different percentages of heart rate relative to the maximum heart rate during the match were measured, using the following thresholds (Table 4).

Table 4. Heart rate thresholds table

Measurement Interval	Heart Rate Range (%)
HR1% (D_HR1 - T_HR1)	0 to 10
HR2% (D_HR2 - T_HR2)	10 to 20
HR3% (D_HR3 - T_HR3)	20 to 30
HR4% (D_HR4 - T_HR4)	30 to 40
HR5% (D_HR5 - T_HR5)	40 to 50
HR6% (D_HR6 - T_HR6)	50 to 60
HR7% (D_HR7 - T_HR7)	60 to 70
HR8% (D_HR8 - T_HR8)	70 to 80
HR9% (D_HR9 - T_HR9)	80 to 90
HR10% (D_HR10 - T_HR10)	90 to 100

Results

The data from the athletes regarding the monitored parameters are summarized in Table 5. The average distance covered by the athletes was 545.1 meters with a standard deviation of 60.80 meters. The average maximum speed reached was 3.03 m/s with a standard deviation of 0.26 m/s. The average maximum acceleration was 2.37 m/s^2 with a standard deviation of 0.26 m/s^2, while the average maximum deceleration was -3.75 m/s^2 with a standard deviation of 0.71 m/s^2.

The average maximum heart rate recorded was 168.6 bpm with a standard deviation of 11.38 bpm, while the average heart rate was 144.5 bpm with a standard deviation of 16.83 bpm. The percentage of average heart rate relative to the theoretical maximum heart rate was 75.2%, with a standard deviation of 8.57%. The average theoretical maximum heart rate was 192.3 bpm, with a standard deviation of 7.29 bpm.

Table 5. Performance parameters of the athletes during the simulated match

Athlete	D (m)	Smax (m/s)	Amax (m/s^2)	Dmax (m)	HRmax (bpm)	HrAvg (bpm)	%HRAvg (%)	Theoretical HR max (bpm)
Athlete 1	458	3.6	2.8	-4.4	152	124	65	191
Athlete 2	542	2.9	2.1	-4.2	153	112	60	187
Athlete 3	449	2.7	2.1	-2.9	181	165	84	196
Athlete 4	555	3.2	2.3	-4.5	172	142	71	201
Athlete 5	558	3.1	2.5	-3.8	161	136	70	194
Athlete 6	628	3.1	2.3	-3.2	183	162	82	197
Athlete 7	630	3.1	2.8	-4.9	167	146	79	185
Athlete 8	518	2.8	2.1	-3.3	168	148	74	201
Athlete 9	533	2.8	2.4	-2.9	183	159	82	193
Athlete 10	580	3	2.3	-3.4	166	151	85	178
Mean	545.1	3.03	2.37	-3.75	168.6	144.5	75.2	192.3
Std. Dev.	60.80	0.26	0.26	0.71	11.38	16.83	8.57	7.29

The results regarding the distribution of distances covered and time spent at different speed thresholds by the athletes during the simulated match are reported in Table 6. At speeds between 0 and 1 meter per second (D_S1), the athletes on average covered 208.90 meters, with a variation between individuals of about 25.25 meters. The average time spent in this speed range was 6 minutes and 27 seconds, with a standard deviation of 42 seconds. For speeds between 1 and 2 meters per second (D_S2), the athletes on average covered 253.70 meters, with a standard deviation of 49.05 meters. The average time spent in this speed range was 2 minutes and 57 seconds, with a standard deviation of 33 seconds. At speeds between 2 and 3 meters per second (D_S3), the athletes on average covered 81.90 meters, with a standard deviation of 46.51 meters. The average time spent in this speed range was 36 seconds, with a standard deviation of 20 seconds.

Table 6. Distribution of distances traveled and time spent at different speed thresholds

Athlete	D_S1 (m)	T_S1 (mm:ss)	D_S2 (m)	T_S2 (mm:ss)	D_S3 (m)	T_S3 (mm:ss)
Athlete 1	232	07:21	199	02:28	25	00:11
Athlete 2	228	06:35	249	02:57	65	00:28
Athlete 3	239	07:39	182	02:08	28	00:13
Athlete 4	207	06:07	295	03:30	52	00:23
Athlete 5	225	06:21	276	03:15	56	00:24
Athlete 6	172	05:33	281	03:13	174	01:14
Athlete 7	206	05:32	343	03:52	80	00:36
Athlete 8	208	06:57	203	02:15	107	00:48
Athlete 9	161	06:11	253	02:55	120	00:54
Athlete 10	211	06:18	256	02:52	112	00:50
Mean	208.90	06:27	253.70	02:57	81.90	00:36
Std. Dev.	25.25	00:42	49.05	00:33	46.51	00:20

The data presented in Table 7 show the distances covered and time spent at different acceleration thresholds for each athlete. The results indicate that at the acceleration threshold between -4.000 and -3.000 m/s² (D_A1 and T_A1), the distance and time spent are minimal for all athletes, averaging just 1 meter and a negligible amount of time. At the next acceleration threshold, between -3.000 and -2.000 m/s² (D_A2 and T_A2), the athletes spent an average of 2 seconds, covering an average distance of 3.30 meters. When considering the acceleration threshold between -2.000 and -1.000 m/s² (D_A3 and T_A3), the average distance covered by the athletes was 23.90 meters, with an average time of 24 seconds. The acceleration threshold between -1.000 and 1.000 m/s² (D_A4 and T_A4) proves to be the most significant. In this threshold, the athletes covered an average distance of 244.40 meters, spending an average time of 4 minutes and 39 seconds. At the acceleration threshold between 0.000 and 1.000 m/s² (D_A5 and T_A5), the athletes covered an average distance of 231.50 meters, spending an average time of 4 minutes and 20 seconds. Moving to the acceleration threshold between 1.000 and 2.000 m/s² (D_A6 and T_A6), the average distance covered was 34.90 meters, with an average time of 30 seconds. Finally, at the acceleration threshold between 2.000 and 3.000 m/s² (D_A7 and T_A7), the athletes covered an average distance of 5.20 meters, spending an average time of 3 seconds.

Table 7. Distance and time in different acceleration thresholds

Athlete	D_A1 (m)	T_A1 (mm:ss)	D_A2 (m)	T_A2 (mm:ss)	D_A3 (m)	T_A3 (mm:ss)	D_A4 (m)	T_A4 (mm:ss)	D_A5 (m)	T_A5 (mm:ss)	D_A6 (m)	T_A6 (mm:ss)	D_A7 (m)	T_A7 (mm:ss)
Athlete 1	1	00:00	3	00:03	17	00:23	212	04:51	191	04:14	26	00:25	5	00:04
Athlete 2	1	00:00	3	00:02	23	00:20	241	04:37	236	04:33	34	00:26	3	00:02
Athlete 3	1	00:01	4	00:04	21	00:27	188	04:21	200	04:32	30	00:32	4	00:03
Athlete 4	1	00:00	1	00:01	18	00:18	248	04:48	262	04:33	21	00:19	3	00:01
Athlete 5	1	00:00	2	00:01	23	00:23	259	04:54	238	04:14	29	00:25	5	00:03
Athlete 6	1	00:00	5	00:03	37	00:31	276	04:38	251	04:04	50	00:38	9	00:06
Athlete 7	2	00:01	5	00:04	30	00:32	279	04:36	249	03:54	53	00:47	10	00:06
Athlete 8	1	00:00	3	00:02	14	00:18	237	04:30	235	04:45	25	00:24	2	00:01
Athlete 9	0	00:00	2	00:01	22	00:20	254	04:49	217	04:20	33	00:27	5	00:03
Athlete 10	1	00:00	5	00:03	34	00:31	250	04:29	236	04:16	48	00:37	6	00:04
Mean	1.00	00:00	3.30	00:02	23.90	00:24	244.40	04:39	231.50	04:20	34.90	00:30	5.20	00:03
Std. Dev.	0.47	00:00	1.42	00:01	7.49	00:06	27.57	00:11	22.50	00:15	11.36	00:08	2.57	00:02

The percentages of heart rate achieved during the match relative to the maximum heart rate are divided into 10% intervals, from the HR1% range (0-10% of HR_max) up to the HR10% range (90-100% of HR_max), and are reported in Table 8. Very low heart rates (0-40% of HR_max) were not recorded, indicating that the intensity of the game was sufficiently high to keep all athletes consistently above 40% of HR_max for the entire duration of the match. Starting from levels of 40-50% of the maximum heart rate (D_HR5 and T_HR5), the athletes began to show some activity, with an average distance covered of 12.4 meters and an average time of 19 seconds. Between 50-60% (D_HR6 and T_HR6), 60-70% (D_HR7 and T_HR7), and 70-80% of the maximum heart rate (D_HR8 and T_HR8), the athletes showed progressively increased physical activity, with average distances covered of 47.6 meters, 78.1 meters, and 170.7 meters, respectively, accompanied by average times of 54 seconds, 1 minute and 42 seconds, and 3 minutes and 10 seconds. Between 80-90% of the maximum heart rate (D_HR9 and T_HR9) and 90-100% of the maximum heart rate (D_HR10 and T_HR10), the athletes reached average distances covered of 191.6 meters and 44.6 meters, with average times of 3 minutes and 3 seconds, and 52 seconds, respectively.

Table 8. Distance and time in different heart rate thresholds

Athlete	D_HR1 (m)	T_HR1 (mm:ss)	D_HR2 (m)	T_HR2 (mm:ss)	D_HR3 (m)	T_HR3 (mm:ss)	D_HR4 (m)	T_HR4 (mm:ss)	D_HR5 (m)	T_HR5 (mm:ss)	D_HR6 (m)	T_HR6 (mm:ss)	D_HR7 (m)	T_HR 7 (mm:ss)	D_HR8 (m)	T_HR8 (mm:ss)	D_HR9 (m)	T_HR9 (mm:ss)	D_HR10 (m)	T_HR10 (mm:ss)
Athlete 1	0	00:00	0	00:00	0	00:00	0	00:00	13	00:20	95	02:12	209	04:38	141	02:50	0	00:00	0	00:00
Athlete 2	0	00:00	0	00:00	0	00:00	0	00:00	82	01:57	187	02:30	180	03:50	60	01:04	33	00:39	0	00:00
Athlete 3	0	00:00	0	00:00	0	00:00	0	00:00	0	00:00	34	00:43	20	00:13	67	01:20	173	04:35	156	03:09
Athlete 4	0	00:00	0	00:00	0	00:00	0	00:00	10	00:21	66	01:07	132	02:30	243	04:41	104	01:21	0	00:00
Athlete 5	0	00:00	0	00:00	0	00:00	0	00:00	19	00:33	36	00:31	113	02:03	339	06:02	50	00:51	0	00:00
Athlete 6	0	00:00	0	00:00	0	00:00	0	00:00	0	00:00	0	00:01	32	01:02	126	01:42	448	06:26	21	00:49
Athlete 7	0	00:00	0	00:00	0	00:00	0	00:00	0	00:00	20	00:29	36	00:41	174	03:13	397	05:36	2	00:01
Athlete 8	0	00:00	0	00:00	0	00:00	0	00:00	0	00:00	17	00:43	37	00:49	409	07:24	55	01:04	0	00:00
Athlete 9	0	00:00	0	00:00	0	00:00	0	00:00	0	00:00	21	00:39	4	00:31	70	02:13	302	04:23	136	02:14
Athlete 10	0	00:00	0	00:00	0	00:00	0	00:00	0	00:00	0	00:00	18	00:39	78	01:14	354	05:37	131	02:30
Mean	0	0	0	0	0	0	0	0	12.4	00:19	47.6	00:54	78.1	01:42	170.7	03:10	191.6	03:03	44.6	00:52
Std. Dev.	0	0	0	0	0	0	0	0	25.42	00:36	57.03	00:50	74.31	01:31	122.46	02:11	168.35	02:29	67.120	01:15

Discussion

The aim of this study is to analyze the performance of senior athletes from the Italian national women's canoe polo team during a simulated match. Referring to Table 5, it is observed that the athletes covered an average distance of 545.1 meters, with a standard deviation of 60.80 meters. This suggests a certain uniformity in the distance covered by the athletes, with limited variations among them. The average maximum speed reached by the athletes was 3.03 m/s, with a standard deviation of 0.26 m/s. The minimal variation in maximum speeds indicates a relatively uniform level of performance among the athletes.

The average maximum acceleration was 2.37 m/s² (standard deviation: 0.26 m/s²), while the average maximum deceleration was -3.75 m/s² (standard deviation: 0.71 m/s²). The greater variation in deceleration compared to acceleration might suggest more pronounced individual differences in the ability to rapidly reduce speed. The average maximum heart rate was 168.6 bpm, with a standard deviation of 11.38 bpm, while the

average heart rate was 144.5 bpm ± 16.83 bpm. These values indicate significant variability in cardiovascular capacities among the athletes. Other studies have also found that the average heart rate of canoe polo athletes during a simulated match is around 146 ± 11 bpm (Alves, et al., 2012) and 159 bpm (Forbes, Kennedy, & Bell, 2013), although these reference samples were male. On average, the athletes work at 75.2% of their theoretical maximum heart rate, with a standard deviation of 8.57%, showing a moderate variation in the relative effort level among the athletes.

The analysis of the data suggests that canoe polo athletes show good consistency in performance in terms of speed and acceleration. However, there is greater variability in cardiovascular capacities, highlighted by the higher standard deviations for maximum and average heart rates. This may reflect individual differences in physical fitness and endurance capabilities. The averages of distances and times relative to speed thresholds reported in Table 6 indicate that the athletes spend most of their time at moderate speeds (0-1 m/s), with significant distance covered also in the intermediate speed range (1-2 m/s). The highest speed range (2-3 m/s) represents a smaller portion of the total time and distances covered, suggesting that higher speeds are used less frequently, likely for short sprints or to quickly react to game situations.

The relatively low standard deviations in the low-speed range (D_S1) indicate consistency in team performance, with all athletes following a similar movement pattern at moderate speeds. The higher standard deviations in the intermediate and high-speed ranges (D_S2 and D_S3) suggest greater variability in speed and sprinting abilities among the athletes, reflecting individual differences in terms of strength and power.

The averages of distances covered in different acceleration ranges (Table 7) provide valuable insights into the performance model characteristics of the team. The data indicate that most of the distance covered during the match occurred in the acceleration ranges between -1 and 1 m/s^2, suggesting that the athletes operate predominantly at moderate and constant speeds. This behavior is typical in high-intensity team sports, where brief accelerations and decelerations alternate with periods of movement at constant speed.

The average time spent in each acceleration range is equally informative. The analysis of the average time spent in each acceleration range (Table 7) reveals that the athletes spend most of their time in low and medium acceleration ranges (T_A4 and T_A5). This suggests that the team's performance model is characterized by a high frequency of movements at moderate speeds, with occasional rapid accelerations and decelerations. Such dynamics are consistent with the tactical demands of the game, where athletes need to maintain optimal positioning and quickly react to changing situations. On the other hand, the extreme acceleration thresholds (D_A1, T_A1, D_A7, T_A7) show very low values, indicating that these conditions occur rarely during the game. The standard deviation of times and distances covered in different acceleration ranges (Table 7) provides further insights into performance variability. The relatively low standard deviations in the low and medium acceleration ranges indicate consistency in team performance, with all athletes following a similar movement pattern. The higher standard deviations in the high acceleration ranges suggest that rapid acceleration capabilities vary more among the athletes, reflecting individual differences in terms of strength and power. These results show how the athletes managed different acceleration intensities during the simulated canoe polo match, highlighting varied and adaptable activity to the sport's dynamic demands.

Observing the results in Table 8, it emerges that most athletes spent a significant portion of time in the heart rate ranges of 40-70% of HR_max, with distances varying between 10 and 243 meters. This suggests that a considerable part of the game is played at moderate intensity, indicating that training should focus on improving aerobic endurance, allowing athletes to maintain high intensities for prolonged periods. The athletes also spent a substantial amount of time in the heart rate ranges of 70-100% of HR_max, covering significant distances. This underscores that canoe polo is a high-intensity sport, requiring athletes to sustain elevated heart rates throughout the match.

The relatively low standard deviations in the lower heart rate ranges (D_HR5 and D_HR6) indicate consistency in team performance, with all athletes following a similar movement pattern at moderate intensities. The higher standard deviations in the higher heart rate ranges (D_HR7, D_HR8, D_HR9, D_HR10) suggest greater variability in endurance and intensity capabilities among the athletes, reflecting individual differences in physical fitness and cardiovascular capacity.

Conclusions

The analysis of the data revealed that the performance model of the canoe polo team is characterized by movements predominantly at moderate speeds, interspersed with brief periods of rapid acceleration and deceleration. As also noted in the study by Forbes & Sheykhlouvand (2016), the predominant movements during a canoe polo match are performed at moderate intensities, consistent with the data from our study. Explosive actions performed at high speeds and over short distances, although occupying less time during the match, are decisive for performance and mainly involve non-oxidative pathways, highlighting the importance of anaerobic power for this sport (Forbes & Sheykhlouvand, 2016; Forbes, Kennedy & Bell, 2013).

These data confirm that canoe polo is an intermittent sport of moderate to high intensity, requiring adequate development of both anaerobic and aerobic energy systems, as stated in other studies (Sheykhlouvand et al., 2016; Sheykhlouvand et al., 2015; Forbes, Kennedy & Bell, 2013; Alves, et al., 2012; Vastola, et al.,

2012). This suggests that high-intensity interval training (HIIT) could be beneficial for improving performance in canoe polo, as it also seems to have a superior effect on cardiac and muscular function (Sheykhlouvand et al., 2016; Guiraud et al., 2013; Little et al., 2010). Furthermore, this study found that K-Sport GPS devices are useful for analyzing performance characteristics and could be employed for further studies on matches at national and international levels. Understanding these dynamics can provide valuable insights for optimizing training programs, helping to improve game strategies, and planning specific interventions for athletes based on their individual needs and positional characteristics on the field.

Disclosure statement No potential conflict of interest was reported by the authors.
Data availability statement Data available on request.
Acknowledgements The authors would like to thank Falcon Scientific Editing (https://falconediting.com) for proofreading the English language in this paper**.**

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