Sport Sci Health (2018) 14:19–24
https://doi.org/10.1007/s11332-017-0395-0

ORIGINAL ARTICLE

Aerobic capacities, anaerobic power, and anthropometric characteristics of elite female canoe polo players based on playing position

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Received: 15 June 2017 / Accepted: 22 August 2017 / Published online: 1 September 2017

Abstract

Purpose To determine the aerobic capacities, anaerobic power, and anthropometric characteristics of elite female canoe polo players. A secondary purpose was to investigate positional differences between goalkeepers (GKs), flat 3 defenders (FDFs), and chase defenders (CHDFs).

Methods Twenty-one elite female canoe polo players (age 26.8 ± 2.1 years; height 166.9 ± 5.2 cm; body mass 61.4 ± 7.1 kg; and percent body fat 21.0 ± 3.8%) volunteered. Anthropometric variables, peak oxygen uptake ($\dot{V}O_{2peak}$), ventilatory threshold (VT), anaerobic peak power output (PPO), and mean power output (MPO) were determined.

Results $\dot{V}O_{2peak}$ was 40.88 ± 4.0 ml kg^{-1} min^{-1} or 2.50 ± 0.29 l min^{-1}, VT was 79.1 ± 8.6 $\%\dot{V}O_{2peak}$, PPO was 348.7 ± 32.1 W, 5.66 ± 0.64 W kg^{-1}, and MPO was 266.5 ± 29.4 W, 4.37 ± 0.56 W kg^{-1}. CHDFs and FDFs had significantly ($p < 0.05$) greater relative $\dot{V}O_{2peak}$ (19.5 and 15.0%, respectively) compared to GKs. GKs were significantly ($p < 0.05$) taller than CHDFs (6.3%) and FDFs (4.8%).

Conclusions Elite female canoe polo players have well-developed oxidative and non-oxidative energy systems, as well as low percent body fat. Positional differences demonstrated that CHDFs and FDFs had significantly higher aerobic power compared to GKs; however, GKs were significantly taller. These results may assist the coach or sport scientist to construct and implement tailored training programs and may be beneficial for talent identification.

Keywords Paddling · Female canoe polo · Oxygen consumption · Peak power · Ventilatory threshold

Abbreviations

$\dot{V}O_{2peak}$	Peak oxygen uptake
$v\dot{V}O_{2peak}$	Velocity at $\dot{V}O_{2peak}$
$\dot{V}O_2/HR$	Oxygen pulse (O_2 pulse)
HR@$\dot{V}O_{2peak}$	Heart rate at $\dot{V}O_{2peak}$
VT	Ventilatory threshold
PPO	Peak power output
MPO	Mean power output
BP	Bench press
PBP	Prone bench pull
BMI	Body mass index
RPI	Reciprocal ponderal index
GKs	Goal keepers
FDFs	Flat 3 defenders
CHDFs	Chase defenders
ANOVA	Analysis of variance
SD	Standard deviation

Introduction

Canoe polo is an emerging and growing sport in the world. Canoe polo is a dynamic ball sport contested on open water or in a swimming pool with two teams of five players and is played by both men and women. Players paddle polo

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kayaks, on a well-defined area (35 m in length by 25 m width), attempting to score into the opposing team's goal (measuring 1.0 by 1.5 m) which is placed 2 m above the water at each end of the pitch. A player acts as a goalie to defend the goal with their paddle. In addition, each team has up to three additional players who can substitute in at any time. The ball in canoe polo is the same that is used in water polo, and can be controlled by either hand or paddle. The game consists of two 10-min halves separated by a 3-min break [1, 2]. Canoe polo is a high-intensity intermittent sport, requiring periods of high effort followed by periods of lower intensity [2] and there are several physical components necessary to perform at a high level beyond the sport-specific skills (e.g., passing, rolling, and shooting) and tactical knowledge required.

Because the majority of the game is within low-to-moderate intensity, it is mainly covered by the aerobic energy system [1]. Furthermore, because the recovery between high-intensity efforts also is reliant on aerobic metabolism, the aerobic energy system is pointed out as main source in canoe polo [3]. On the other hand, anaerobic power has a significant role in many plays such as accelerations at commencement of competition to get possession of the ball, breakaway attempts during counterattacks, and individual play between athletes in different positions to displace each other and get dominance of the position. Previous researches in elite-level male canoe polo players demonstrate the importance of both oxidative and non-oxidative energy systems [1, 3, 4]. This means that measurements of maximal oxygen consumption, anaerobic power, and related physiological variables could be a criterion for detecting a successful player or team [4].

Presently, although several studies have investigated some physiological and anthropometric requirements of male canoe polo athletes [1, 3, 4], there is no scientific literature describing the physiological or anthropometric characteristics of female canoe polo players. Understanding the attributes associated with elite-level female canoe polo athletes can provide useful information to canoe polo coaches and scientists. Therefore, the primary aim of the present study was to identify and establish physiological attributes related to aerobic capacities and anaerobic power and anthropometric characteristics of elite female canoe polo players. A secondary purpose was to identify positional specific differences. Like other ball sports, canoe polo has specific positions including goalkeepers (GKs) and defenders. The most frequently defensive tactic is known as the flat 3. In this tactic, there is one player who is very agile and acts as a "chase" (known as the chase defender: CHDF). Three defenders form a line behind the chase (i.e., the flat 3 defenders: FDFs) (Fig. 1).

Previous researches in other similar team sports (e.g., water polo) have shown physiological and anthropometric differences based on specific positions [5]. Presently, no study has investigated positional differences among canoe polo players. We hypothesized that elite female canoe polo players would have well-developed aerobic and anaerobic energy systems, as well as a low percent body fat. Second, based on other team sports and expert knowledge of the game, we hypothesized that goal keepers would be taller and that chase defenders and flat 3 defenders would have a higher $\dot{V}O_{2peak}$.

Methods

Experimental protocol and procedures

Prior to testing, all participants attended a laboratory familiarization to become oriented with all procedures. Peak oxygen uptake ($\dot{V}O_{2peak}$), ventilatory threshold (VT), upper body anaerobic peak and mean power, maximum strength, sprinting time, and anthropometric characteristics were measured for all participants.

All testings were completed over four sessions during the specific preparation phase of yearly training period. Participants were instructed to arrive at the laboratory in a rested and well-hydrated state and to avoid strenuous exercise 48 h prior to testing sessions. The first session consisted of anthropometric, body composition, and sprinting time. The second session consisted of one repetition maximum (1RM) strength [bench press (BP) and prone bench pull (PBP) tests]. The third and fourth sessions consisted of a progressive incremental exercise test and upper body Wingate anaerobic test to determine aerobic capacities and anaerobic power, respectively.

Subjects

Twenty-one elite female canoe polo players (mean ± SD; age 26.8 ± 2.1 years; body mass 61.4 ± 7.1 kg; and

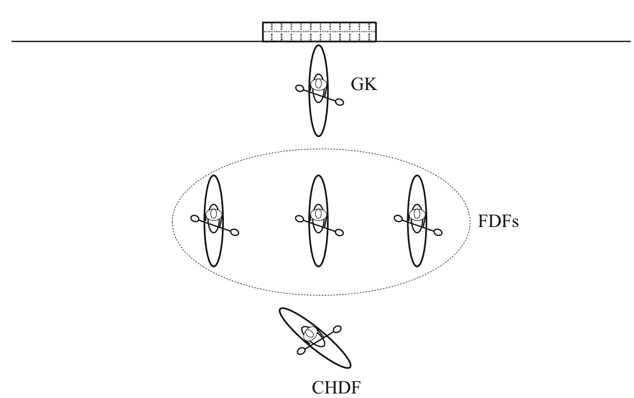

Fig. 1 Different positions of canoe polo players including goal keeper (GK), flat 3 defenders (FDFs), and chase defender (CHDF)

height 166.9 ± 5.2 cm) volunteered to participate in the present study. Among the participants, there were goalkeepers ($n = 5$), flat 3 defenders ($n = 9$), and chase defenders ($n = 7$). All participants were members of a national canoe polo team and 15 of whom were gold medalists in continental canoe polo championships. All subjects were informed as to the purpose of the study and known possible risks associated with the experiment, and all provided written informed consent. This study was approved by our University ethics committee, and testing was carried out according to the Declaration of Helsinki.

Procedures

Progressive exercise test

Participants completed a continuous incremental paddling test on a kayak ergometer (Dansprint, Hvidovre, Denmark) to determine $\dot{V}O_{2peak}$, VT, $\dot{V}O_2/HR$ (O_2 pulse; a surrogate of stroke volume), and velocity at $\dot{V}O_{2peak}$ ($v\dot{V}O_{2peak}$) using a metabolic measurement system (Cosmed K4B2, Rome, Italy). Before each test, the gas analyzer was calibrated according to the manufacturer's instructions. The incremental test commenced at an initial speed of 6 km h^{-1} and increased thereafter by 1 km h^{-1} every 1 min [2]. Participants completed as many stages as possible before they reached exhaustion or could no longer maintain the paddling speed on kayak ergometer. $\dot{V}O_{2peak}$ was defined by the following criteria: (a) the oxygen consumption ceased to increase linearly with an increase in workload and approached a plateau or dropped slightly, with the last two values within ±2 ml kg^{-1} min^{-1}; (b) ≥90% of age-predicted peak HR; and (c) a respiratory exchange ratio (RER) greater than 1.1 [6]. Ventilatory threshold (% $\dot{V}O_{2peak}$) was determined using the V-slope method [7] and $v\dot{V}O_{2peak}$ was defined as the lowest paddling velocity maintained for more than 1 min which elicited $\dot{V}O_{2peak}$ [4].

Wingate test

Participants performed a 10-s countdown phase, followed by a 30-s all-out effort on a mechanically braked arm ergometer (891E; Monark, Vansbro, Sweden) against a relative load factor of 0.050 kg per kg body mass (kg kg^{-1} BM) [8]. During the first 5 s of the countdown, the athletes began cranking at a comfortable cadence. Five seconds prior to the start of the test, the athletes began to crank at their maximum speed against the ergometer's inertial resistance. With less than 1 s left in the countdown, the appropriate load was manually applied. Subjects were verbally encouraged to continue cranking as fast as possible throughout the 30-s test. Peak power, mean power, and fatigue index were subsequently determined [2, 9].

Paddling sprint

Participants were tested for maximal sprinting velocity over a canoe polo playing area length using an electronic timing system. Namely, photocells were positioned to time the participants over a 35-m distance. After the warm-up, players completed three maximal paddle sprints with 4-min rest between attempts. The best of the three times was used for analysis with sprint times measured to the nearest 0.01 s.

Muscle strength

Maximal strength was determined by 1RM for BP and PBP. Testing protocols have been described previously [10, 11]. Participants began with a standardized warm-up involving 5 min of running at 8 km h^{-1} and eight repetitions at 50% of their estimated 1RM followed by another set of three repetitions at 70% of their estimated 1RM. Depending on the player's perception of difficulty of each lift, weight was added, and after a minimum of 5-min rest, a second repetition was attempted. The objective was to have most players reach their 1RM within 3–5 attempts. Strong verbal encouragement was provided during each attempt [3]. Both exercises were performed on the same Smith machine.

Anthropometric and body composition

Body mass (Wt) and stature (Ht) were measured to the nearest 0.1 kg and 0.1 cm, respectively, using a calibrated Seca Alpha (model 220; Seca, Birmingham, United Kingdom) scale and a Seca Alpha stadiometer. Body composition was analyzed using bioelectrical impedance analysis (Inbody 520, Korea). Height (m) and body mass (kg) were used to calculate their body mass index (BMI kg m^{-2}) and reciprocal ponderal index (RPI kg $m^{-0.333}$) [12].

Data analysis

Data are presented as mean ± SD values. The Shapiro–Wilk's test was used to check normality. Levene's test was used to determine variance differences between groups. A one-way analysis of variance (ANOVA) was conducted to analyze differences in dependent variables between different positions. A Tukey's post hoc test was used to determine, where the differences exist. Significance was set at $p \leq 0.05$ for all analyses. Statistical analyses were performed using the software program SPSS, version 21.0 (Statistical Package for Social Science, Chicago, IL, USA).

Results

Descriptive aerobic, anaerobic, sprint, and muscular strength variables are shown in Table 1. Anthropometric and body composition variables are shown in Table 2. $\dot{V}O_{2peak}$ was significantly ($p < 0.05$) greater in CHDFs and FDFs (42.63 ± 3.77 and 41.06 ± 3.81 ml kg^{-1} min^{-1}, respectively) compared to GKs (35.70 ± 1.31 ml kg^{-1} min^{-1}). GKs (174.4 ± 4.6 cm) were taller ($p = 0.02$) compared with the CHDFs and FDFs (164.1 ± 3.6 and 166.3 ± 4.6 cm, respectively). All other aerobic, anaerobic, sprint, muscular strength, anthropometric, and body compositions were similar between positions.

Table 1 Physiological characteristics of elite female canoe polo players

Variable	Mean ± SD	95% CI
$\dot{V}O_{2peak}$ (ml kg^{-1} min^{-1})	40.88 ± 4.0	39.08–42.86
$\dot{V}O_{2peak}$ (l min^{-1})	2.50 ± 0.29	2.38–2.64
$v\dot{V}O_{2peak}$ (km h^{-1})	11.77 ± 0.41	11.58–11.95
HR@$\dot{V}O_{2peak}$ (b min^{-1})	182.9 ± 8.8	179.0–186.7
O_2 pulse (ml b min^{-1})	14.1 ± 2.56	13.1–15.3
VT (%$\dot{V}O_{2peak}$)	79.1 ± 8.6	75.4–83.0
PPO (W)	348.7 ± 32.1	334.8–364.1
MPO (W)	266.5 ± 28.4	253.8–278.6
PPO (W kg^{-1})	5.66 ± 0.64	5.39–5.96
MPO (W kg^{-1})	4.37 ± 0.56	4.12–4.62
35 m sprinting (s)	12.1 ± .00	11.89–12.39
BP (kg)	58.8 ± 7.4	55.5–62.1
PBP (kg)	54.7 ± 6.4	51.7–57.2

HR heart rate, *VT* ventilator threshold, *PPO* peak power output, *MPO* mean power output, *BP* bench press, *PBP* prone bench pull

Table 2 Anthropometric characteristics of elite female canoe polo players

Variable	Mean ± SD	95% CI
Body weight (kg)	61.4 ± 7.1	58.1–64.7
Stature (cm)	166.9 ± 5.2	164.7–169.3
BMI (kg m^{-2})	22.1 ± 2.6	20.8–23.3
RPI (kg m$^{-0.333}$)	42.4 ± 1.8	41.5–43.2
Fat (%)	21.0 ± 3.8	19.2–22.7
Lean body mass (kg)	48.6 ± 3.8	46.9–50.4
Dry body mass (kg)	13.2 ± 1.0	12.7–13.7

BMI body mass index, *RPI* reciprocal ponderal index

Discussion

The aim of this study was to assess aerobic capacities, anaerobic power, and anthropometric characteristics of elite female canoe polo players. A secondary aim was to investigate positional differences. GKs had significant lower relative $\dot{V}O_{2peak}$, while height was greater compared to CHDFs and FDFs. This is the first study to provide aerobic capacities, anaerobic power, and anthropometric profiles of female canoe polo players. In addition, this is the first study to examine positional differences in canoe polo players.

Aerobic power plays an important role in canoe polo [1–3]. Forbes et al. [1] found that predominant movements of men's elite-level canoe polo were slow-to-moderate forward paddling (29%) and resting and gliding (27%) between bouts of high-intensity sprinting and contesting for position. As such, a well-developed cardiorespiratory system is essential to facilitate recovery (i.e., lactate clearance and phosphocreatine re-synthesis) following bouts of high-intensity work [13]. The results of the present investigation confirm that elite female canoe polo players have moderately high cardiorespiratory fitness (Table 1). $\dot{V}O_{2peak}$ can be classified as moderately high and slightly lower than values previously reported in the literature for high-performance female kayak paddlers (44.8 ± 6.02 ml kg^{-1} min^{-1} or 3 ± 0.30 l min^{-1}; determined using a kayak ergometer [14]) and middle-to-high class female kayakers (2.88 ± 0.84 l min^{-1}; obtained from the $\dot{V}O_2$ measured during the last minutes of the 1000- or 2000-m maximal paddling [15]). Furthermore, our participants showed higher absolute $\dot{V}O_{2peak}$ (Table 1) than do American female elite kayakers (2.05 ± 0.20 l min^{-1}; determined through laboratory kayaking [16]) and lower relative $\dot{V}O_{2peak}$ scores than do Italian female national kayakers (52.6 ± 4.3 ml kg^{-1} min^{-1}; determined during kayaking [17]).

Our study demonstrated that CHDFs and FDFs had 19.4 and 15.0% greater relative $\dot{V}O_{2peak}$ compared to the GKs. These results are in accordance with the demands of the games. On defense GKs position themselves under the net and use their paddles to block any shots, while the other players vigorously defend their position and net. Despite positional relative $\dot{V}O_{2peak}$ differences, there were no $v\dot{V}O_{2peak}$ or absolute $\dot{V}O_{2peak}$ differences.

The AT (% $\dot{V}O_{2peak}$) did not show any statistical significant differences between playing positions. In international men's canoe polo games, 69 (±20) % of the time was played at a heart rate (HR) intensity above the HR that corresponded to the VT that was determined during the an arm crank $\dot{V}O_{2peak}$ test [1]. The results of the present study found that VT (Table 1) was slightly lower than that of high-performance female sprint kayak paddlers (81.4 ± 5.1 %$\dot{V}O_{2peak}$ [14]) and elite female water polo players (83.0 ± 8.5 % $\dot{V}O_{2peak}$ [13]).

Canoe polo is an intermittent based sport which comprises of several high-intensity predominantly non-oxidative bouts including sprinting, turning, tackling, throwing, and pushing an opponent with the kayak to take position (i.e., contesting for position). Contesting for the position (frequency = ~31; duration = 5–10.8 s) is one of the predominant high-intensity movements of the game (28 ± 5%), while sprinting (frequency = ~12; duration 2.4–3.8 s) and turning (~35; duration 1.9–5.5 s) contributed to 2 ± 1 and 7 ± 1% of match time, respectively [1]. In elite male national players, each athlete performed ~10 high-intensity paddling sprints of ~5 s duration [3]. According to these findings, anaerobic metabolism would be an important characteristic of elite-level canoe polo. Our results revealed that anaerobic power for 21 professional female canoe polo players (Table 1) was lower than those of trained female athletes involved in a combination of sport-specific and strength-training programs with a focus on upper body anaerobic training (PPO = 476.0 ± 68.0 W; MPO = 281.0 ± 46.0 W [8]). These results are most likely due to the difference relative loading factor, 5 vs. 7.5% used during the upper body anaerobic power test [8]. Furthermore, our participants showed higher PPO and lower MPO than do U.S female slalom kayakers (PPO = 335 W, 5.4 W kg^{-1}; MPO = 308 W, 4.9 W kg^{-1} [18]).

Muscular strength is another important variable to predict paddling speed and as such is important for canoe polo players [3, 8]. Moreover, to get dominance of the position, canoe polo players frequently struggle to displace each other face to face in their defense and attack. It seems in such battles that the player with more dynamic strength may be successful in the engagement [4]. Dynamic muscular strength did not show any statistical significant differences between playing positions. The 1RM PBP values obtained in the present study (Table 1) was in accordance with values previously reported for elite female kayakers (54.0 ± 7.0 kg [19]). Furthermore, our participants showed lower 1RM BP values (Table 1) than do elite female kayakers (77.3 ± 10.0 kg [19]).

The relationship of anthropometric characteristics and technical ability of players have been established in different ball sports such as water polo [5, 20]. In canoe polo, similar to water polo, body size is important during the game by enabling the player to perform better in all positions and giving the advantage to tall players for reaching and controlling passes [4]. The results of this study support our hypothesis that GKs were on average taller than those in the other positions. During the game, GKs try to defend the goal placed 2 m above the water with their paddle. The available data indicate a similar trend in water polo players, with GKs being taller than players in the other positions [21].

Furthermore, regarding the anthropometric characteristics of these elite female players, the current players seem to be highly comparable to both elite female kayakers and rowers [19, 22] and elite female water polo players [23]. Although they have a slightly lower body mass (~3 kg) and height (~2 cm) than elite female kayakers (64.3 ± 8.5 kg and 169.5 ± 8.1 cm [19]) and elite female water polo players (65.9 ± 6.1 kg and 168.7 ± 7.0 cm [23]), the present players seem to be heavier (Table 2) than elite female light weight rowers (59.7 ± 1.7 kg and 168.8 ± 4.7 cm [22]).

Conclusions

This study provides aerobic capacities, anaerobic power, and anthropometric data for elite female canoe polo players. Our results suggest that elite-level female canoe polo players have moderately high cardiorespiratory systems, as well as well-developed anaerobic power. In addition, this study examined positional differences. Specifically, GKs were taller compared to CHDFs and FDFs, while CHDFs and FDFs had greater aerobic power. These results are important for coaches and sport scientist during talent identification and to construct and implement tailored training programs. Because the positional demands of the game are different, coaches should apply position-specific conditioning exercises and evaluate players accordingly, in order that players may receive appropriate training stimuli to match the physiological demands of their playing position. Moreover, coaches may use these tests to assist in profiling players and evaluating adaptations to training. Finally, by applying the results presented here, canoe polo coaches will be able to place their players in the most appropriate playing positions according to their physical capacities and anthropometric characteristics.

There are some limitations to this study that should be noted. First, we used a small sample size, which might influence differences if outliers were present. Normality was assessed for each of the outcomes, and it does not appear that the results of this investigation were affected by outliers. Second, as during the canoe polo game, upper body is predominantly involved, we decided to measure physiological variables through upper body tests.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All methods performed in the study were in accordance with ethical standards of the national research committee and with the 1964 Helsinki Declaration.

Informed consent Informed consent was obtained from all individual participants included in the study.

Funding No external financial support was received for this study.

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