Original Article

Is the aerobic power a delimitating factor for performance on canoe slalom? An analysis of Olympic Slovak canoe slalom medalists and non-Olympics since Beijing 2008 to Rio 2016

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ABSTRACT

Information regarding the aerobic power on canoe slalom performance is scares. Moreover, the comparison of maximum oxygen uptake (VO_{2max}) via specific and non-specific ergometer for slalom kayakers may improve training prescription and controlling over Olympic cycles. Lastly, it is still unknown to what extent the VO_{2max} delimitate the high performance in this sport. To test this perspective, a highly qualified sample is desired. In overall statistics, Slovakian athletes gathered 14 Olympic medals over the last sixteen years. Therefore, the main aim of this study is to compare the aerobic power of Olympic medallists and Non-Olympic Slovakian kayakers via specific and non-specific evaluations from Beijing 2008 to Rio 2016 Summer Olympic Games. Forty-two male canoe slalom athletes from Slovak national team were evaluated between the years 2006 and 2016. Slovakian athletes were tested for specific (i.e. paddling ergometer) and non-specific (i.e. treadmill) incremental protocols for VO_{2max} determination. Over the last three Summer Olympic Games, the VO_{2max} of Slovakian Olympic medallists was consistently lower than most of the Slovakian team. Moreover, disregarding the medallist characteristic or the moment, Slovakian kayakers presented higher VO_{2max} on treadmill (57.7±6.8 $mL·kg^{-1}·min^{-1}$) when compared to paddle ergometer (46.9±6.5 $mL·kg^{-1}·min^{-1}$) (p=0.000;

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ES=1.6). Based on the collected data over the last ten years, we suggest that although aerobic power may play a relevant and indirect role on performance of slalom kayakers, does not delimitate the high performance in this sport. **Keywords:** Maximal oxygen consumption; Muscular power; Running speed; Paddler; Treadmill.

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INTRODUCTION

Over the last forty years, canoe slalom has been studied from several contexts, such as psychological (T. E. MacIntyre & Moran, 2007; T. MacIntyre, Moran, & Jennings, 2002), biomechanical (Hunter, Cochrane, & Sachlikidis, 2007, 2008; Leonardo Henrique Dalcheco Messias et al., 2018) race strategy and related aspects (Nibali, Hopkins, & Drinkwater, 2011; Sidney & Shephard, 1973). Concerning biochemistry and physiological analysis, recent investigations have discussed the role anaerobic metabolism on the canoe slalom athlete's performance (L H D Messias et al., 2015). Energy resynthesizes via anaerobic metabolism is indispensable during slalom trials, since athletes must perform high intensity efforts to overcome downstream/upstream gates and natural obstacles within less time (Leonardo Henrique Dalcheco Messias, dos Reis, Ferrari, & de Barros Manchado-Gobatto, 2014).

Despite the high intensity / low volume nature of canoe slalom competitions, Zamparo et al. (10) also demonstrated an important contribution of the aerobic metabolism during simulated races. In light of these data, subsequent studies proposed specific evaluations for aerobic evaluation of slalom kayakers (Manchado-Gobatto et al., 2014; Leonardo H D Messias, Ferrari, Reis, Scariot, & Manchado-Gobatto, 2015). Recently, it was showed the aerobic parameter from the critical power concept is inversely correlated with slalom kayaker's performance during simulated races (Ferrari et al., 2017). In this sense, the science beyond canoe slalom corroborates regarding the important role of aerobic metabolism for these athletes. However, two important points are still unexplored: a) studies have only provided information regarding the aerobic capacity of slalom kayakers. Information about aerobic power is scarce (Zamparo et al., 2006), which is an important parameter for prescription and controlling training load (Bassett & Howley, 2000; Bentley, Newell, & Bishop, 2007); b) it is still unknown to what extent the aerobic power delimitates the high-level performance in this sport.

Therefore, despite the advances on canoe slalom science, there is a lack of knowledge about the physiological characteristics on Olympic slalom kayaker's performance. Thus, a high-qualified sample is indispensable for properly investigate this perspective. To date, canoe slalom is the most successful Olympic sport in Slovakia. In overall statistics, Slovakian male and female athletes gathered 14 Olympic medals (i.e. 8 gold, 3 silver and 3 bronze) from Olympic Games in Sydney 2000 to Rio 2016. These outstanding results placed the Slovakian kayakers as references over the world, and from the scientific point of view, such athletes are a highly desired sample to be evaluated.

Despite a deep investigation on the above-mentioned issues will largely improve the knowledge on the Olympic canoe slalom athletes, it is also necessary to consider that athletes may have distinct Olympic cycles. Therefore, the comparison between specific or non-specific physical evaluations for aerobic power evaluation can improve training prescription and controlling during these periods. Moreover, if these perspectives were considered based on the comparison of Slovakian medallists with non-medallist over different Olympic events, then such data may strongly contribute for developing future canoe slalom champions; such investigation is unique and was never explored so far.

Therefore, the main aim of this study is to compare the aerobic power of Olympic medallist and Non-Olympic Slovakian kayakers via specific and non-specific evaluations from Beijing 2008 to Rio 2016 Summer Olympic Games.

MATERIAL AND METHODS

Participants

Forty two male canoe slalom athletes from Slovak national team were tested between the years 2006 and 2016. Seven of them took at least one medal (gold, silver or bronze) at summer Olympic Games (Sydney 2000, Athens 2004, Beijing 2008, London 2012 and Rio 2016). Informed consent was signed by all participants. The study was submitted to and approved by the ethics committee of Faculty of Physical Education and Sports of the Comenius University in Bratislava, Slovakia in accordance with ethical standards of the Helsinki Declaration.

Measures and Procedures

Olympic medallists were compared with the rest of national team. Only 1 boat per event from the same country was enabled at the last three Olympic Games. On the other hand, 3 boats per event were enabled at World and European Championship. For this reason the group of Slovak Olympic nominees comprised of athletes that had previously participated at world championships were compared between Beijing 2008, London 2012 and Rio 2016 Olympics. For instance, in individual category at world championship 2009, 2011 and 2017 two Slovak boats took podium in a same event.

Subjects were tested between the years 2006 and 2016 in the National Sport Center of Slovakia during general preparation period as a part of medical exam. Data were collected from the standard testing protocols used for canoe sports in National Sport Center since 2004 (Bielik et al., 2018). Testing sessions were performed under laboratory conditions (18-22 ºC, 45-55 % relative humidity). Slovakian athletes were tested for specific (i.e. paddling ergometer) and non-specific (i.e. treadmill) incremental protocols (Figure 1). Due to illness, injuries or even training periodization, different Slovakian athletes were evaluated over the three Summer Olympic Games. However, this factor did not impair on the main aim of this study, since athletes were not compared between Olympic Games, but yet the Olympic medallists and Non-Medallists during the same event. The training programs were annually designed and approved by the Slovak Canoe Association. As the athletes came from various clubs and/or training groups, the annual program and training structure differed to some extent due to distinct factors, such as seasonal, climatic and financial conditions. The training records included total training time distributed across particular types (strength, endurance, speed, coordination and flexibility), activity (Whitewater, flat water and pool paddling sessions, running, cross-country skiing, mountain biking, swimming etc.), and intensity zone, as well as specific comments regarding program details. We admit that not all of the athletes kept their training diary and therefore the generalization of the training structure would be confusing.

Athletes were recruited at the beginning of general preparatory period after a minimum of 2 - 3 weeks of regular training program to avoid or reduce the detraining effect after vacation. As previously reported, training cessation leads to large decreases in maximal strength and mean concentric velocity in the bench press especially in highly trained kayakers (Garcia-Pallares, Garcia-Fernandez, Sanchez-Medina, & Izquierdo, 2010). However, athletes usually do not experience total physical rest during vacation and prefer some other physical activities than canoeing. All the tests were carried out in the morning from 09:00 a.m. to 12:00 a.m. on separate days. Subjects were informed to avoid any vigorous exercise 48 h prior to the testing to minimize the influence of previous training or fatigue. The athletes were instructed to follow their usual diet and the exercise testing was carried out after an overnight fast and standardized breakfast prior to the examination.

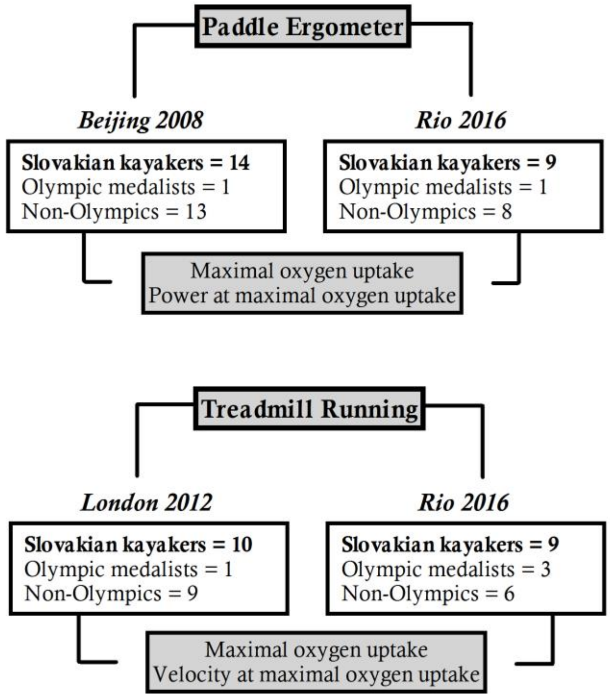

Figure 1. Experimental design of the aerobic power evaluation on specific (paddle ergometer) and non-specific (treadmill running) of Slovakian Olympic medallists and Non-Olympics over three Summer Olympic Games.

Incremental running protocol for maximal oxygen uptake and velocity at maximal oxygen uptake determination

Slovak kayakers were familiarized with running on motorized treadmill. Athletes completed a maximal incremental running test at 0 % slope on a treadmill (h/p/cosmos, Germany) starting at velocity 8 km·h^{-1} after a proper standardized warm up session. The velocity was increased by 1 km·h^{-1} every minute until volitional exhaustion. The last velocity increment was held for an entire minute. The test was terminated before voluntary exhaustion only if the oxygen uptake (VO2) values levelled off or decreased despite increasing workload and ventilation, and the respiratory exchange ratio (RER) was higher than 1.10. Verbal encouragement was provided mostly during the last minute of the test. Respiratory variables were continuously measured using breath-by-breath gas analyser system power Cube (Ganshorn, Germany). Systems were calibrated prior to each session. At least two exercise physiologists supervised the testing procedures during the entire period. VO2 data collected during the last 10 seconds of each workload were averaged.

Incremental paddling protocol for maximal oxygen uptake and power at maximal oxygen uptake determination

The incremental paddling protocol was conducted on an air-braked paddle ergometer (Dansprint, Denmark), starting at 60 W after a previous standardized warm up session. The power was set to increase by 20 W every 1.5 min until volitional exhaustion. Last power step was held for an entire minute. The ergometer was interfaced with a computer for the measurement of performance data. The rules for test termination and environmental conditions were similar to those for treadmill test and the same gas analyser system Power Cube (Ganshorn, Germany) was used.

Analysis

Data is presented as means and standard deviation (SD). Box and whisker plots were constructed based on the maximum, minimum and median values. Shapiro-Wilk test confirmed the normality of our data. The t-test for independent samples was conducted for comparison of VO_{2max} from paddle ergometer and treadmill; this analysis did not consider the Olympic medallist nature or the moment. Statistical significance was set at $p \leq 0.05$. Effect sizes (ES) Cohen (18), "The Earth Is Round (p < .05)." was also calculated and Cohen categories used to evaluate its magnitude were: small if $0 \leq |d| \leq 0.5$; medium if $0.5 \leq |d| \leq 0.8$; and large if $|d| \geq 0.8$. Analysis of variance between Olympic medallist and Non-Olympics and among the Summer Olympic Games was not performed for two major reasons: a) only one Slovakian Olympic medallist was evaluated on Beijing 2008; b) Since one boat per slalom discipline from the same country was enabled at the last two Summer Olympic Games, the variance is absent or based on only two (in the case of C2 discipline) or three (C2 plus K1 discipline) kayakers. Instead, comparison between the raw data of Slovakian Olympic medallists and Non-Olympics was expressed as percentage. Confidence intervals (CI) were calculated for standard deviation with $\alpha = 0.05$ ($\sigma/\sqrt{n}$) according to Hopkins (Hopkins, 2007).

RESULTS

Anthropometric results of Slovakian slalom kayakers throughout the last three Summer Olympic Games are shown on Table 1. Regarding the aerobic power evaluation on paddle ergometer, the Olympic medallist on Beijing presented similar VO_{2max} when compared to the mean (Figure 2a) or median (Figure 6a) of Slovakian athletes. On the other hand, the Olympic medallist present power at VO_{2max} higher than the mean (Figure 2b) and median (Figure 6b). When compared to the Slovakian athlete that presented the highest's results, the VO_{2max} and power at VO_{2max} from the Olympic medallist were 27.6 and 35.4 % lower, respectively. This scenario did not extend on Rio. The mean data of VO_{2max} and power at VO_{2max} from the two Olympic medallists were 9.2 and 19.1 % lower compared to the rest of the team (Figures 3a and 3b). Moreover, both Olympic medallists presented these results bellow the median (Figures 6c and 6d).

Table 1. Anthropometric results of the evaluated Slovakian slalom kayakers between Beijing 2008 and Rio 2016 besides medals won throughout the three Summer Olympics

Summer Olympic	Age (yrs)	Height (cm)	Weight (kg)	% fat	Medal	
					Gold	Silver
Beijing – Paddling (n=14)					1 (1)	-----
Mean	25	182.1	78.1	11.7		
SD	3	8.5	5.2	2.1		
Range	20 - 31	169 - 191	73.0 – 85.0	9.0 – 14.9		
CI (α=0.05)	2 - 5	6.1 – 13.6	3.7 – 8.3	1.5 – 3.3		
Rio – Paddling (n=8)					1	(1)
Mean	22	180.2	75.1	9.1		
SD	6	4.3	5.5	1.7		
Range	16 - 33	176 - 189	67.3 - 82.4	7.1 - 11.9		
CI (α=0.05)	4 - 12	2.8 – 8.7	3.6 – 11.1	1.1 – 3.4		
London – Running (n=10)					-----	-----
Mean	21	183.7	76.9	9.1		
SD	5	6.6	8.6	3.0		
Range	16 - 30	178 - 196	63.0 - 90.5	9.1 - 12.6		
CI (α=0.05)	3 – 9	4.5 – 12.0	5.9 – 15.7	2.1 – 5.4		

SD – standard deviation; the number between brackets on medals indicate that although the slalom kayakers have won the medal, they were not evaluated during the respective Summer Olympic.

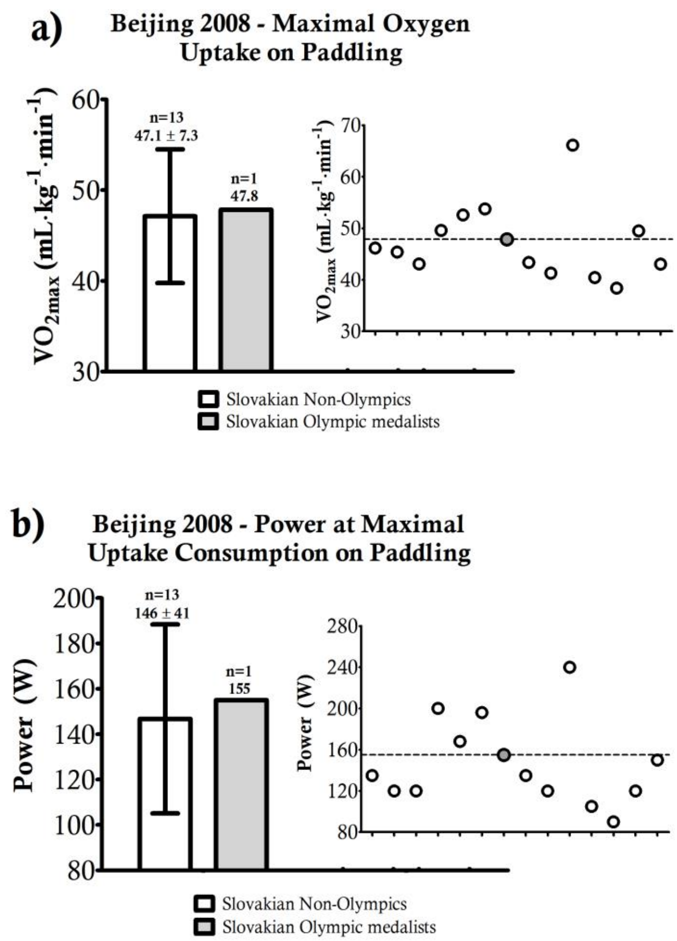

Figure 2. Results from Beijing 2008 on paddle ergometer. a) Left panel – mean and standard deviation regarding maximal oxygen uptake (VO_{2max}) of Slovakian Non-Olympics and Slovakian Olympic medallists. Right panel – individual values regarding maximal oxygen uptake (VO_{2max}) of Slovakian Non-Olympics and Slovakian Olympic medallists. b) Left panel – mean and standard deviation regarding power at maximal oxygen uptake of Slovakian Non-Olympics and Slovakian Olympic medallists. Right panel – individual values regarding power at maximal oxygen uptake of Slovakian Non-Olympics and Slovakian Olympic medallists. Note – dotted lines on right panels indicate the Slovakian Olympic medallist.

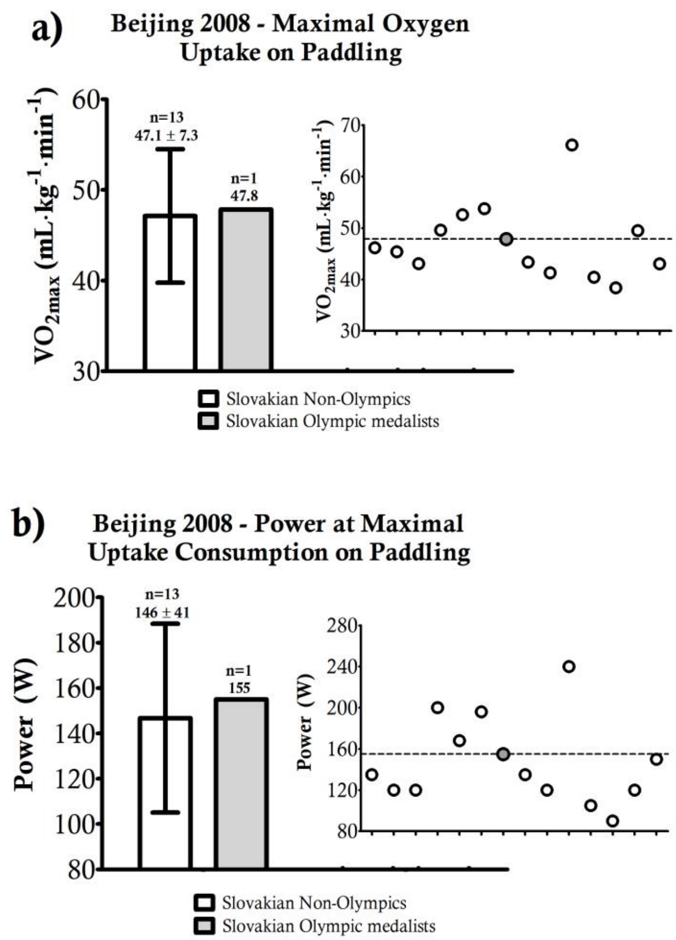

Figure 3. Results from Rio 2016 on paddle ergometer. a) Left panel – mean and standard deviation regarding maximal oxygen uptake (VO_{2max}) of Slovakian Non-Olympics and Slovakian Olympic medallists. Right panel – individual values regarding maximal oxygen uptake (VO_{2max}) of Slovakian Non-Olympics and Slovakian Olympic medallists. b) Left panel – mean and standard deviation regarding power at maximal oxygen uptake of Slovakian Non-Olympics and Slovakian Olympic medallists. Right panel – individual values regarding power at maximal oxygen uptake of Slovakian Non-Olympics and Slovakian Olympic medallists. Note – dotted lines on right panels indicate the Slovakian Olympic medallist.

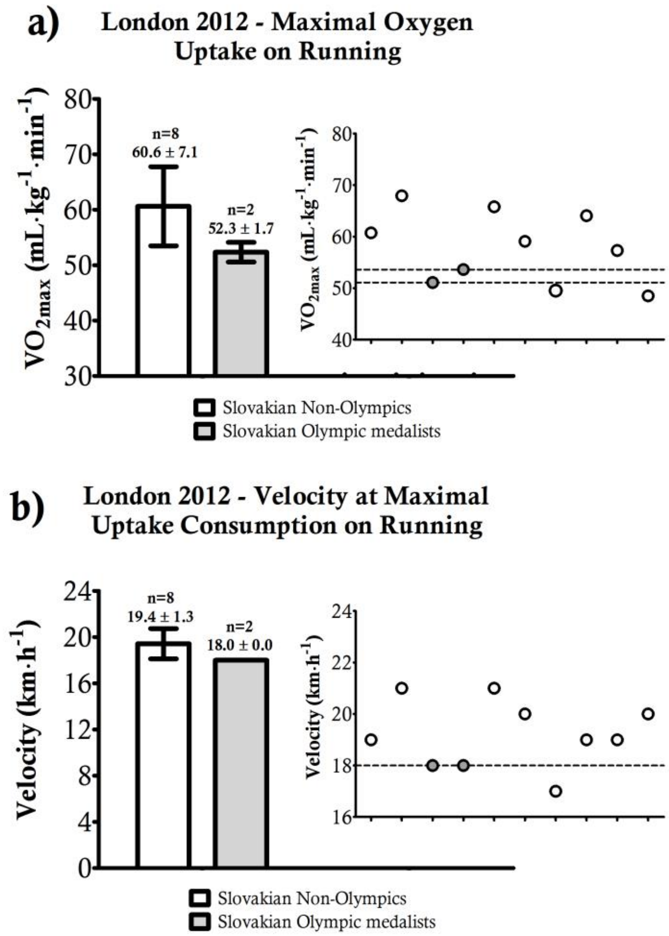

Figure 4. Results from London 2012 on treadmill. a) Left panel – mean and standard deviation regarding maximal oxygen uptake (VO_{2max}) of Slovakian Non-Olympics and Slovakian Olympic medallists. Right panel – individual values regarding maximal oxygen uptake (VO_{2max}) of Slovakian Non-Olympics and Slovakian Olympic medallists. b) Left panel – mean and standard deviation regarding velocity at maximal oxygen uptake of Slovakian Non-Olympics and Slovakian Olympic medallists. Right panel – individual values regarding velocity at maximal oxygen uptake of Slovakian Non-Olympics and Slovakian Olympic medallists. Note – dotted lines on right panels indicate the Slovakian Olympic medallist.

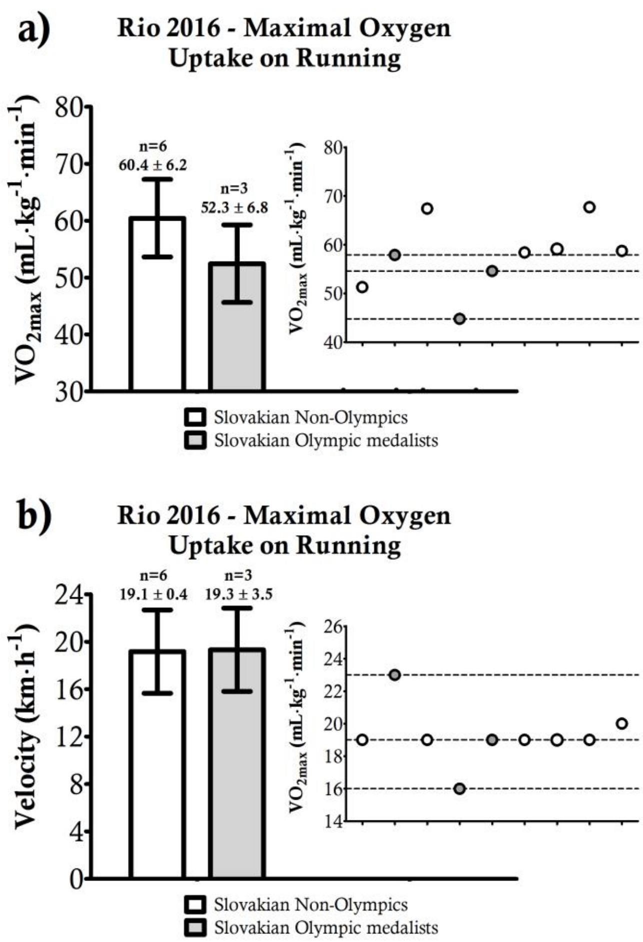

Figure 5. Results from Rio 2016 on treadmill. a) Left panel – mean and standard deviation regarding maximal oxygen uptake (VO_{2max}) of Slovakian Non-Olympics and Slovakian Olympic medallists. Right panel – individual values regarding maximal oxygen uptake (VO_{2max}) of Slovakian Non-Olympics and Slovakian Olympic medallists. b) Left panel – mean and standard deviation regarding velocity at maximal oxygen uptake of Slovakian Non-Olympics and Slovakian Olympic medallists. Right panel – individual values regarding velocity at maximal oxygen uptake of Slovakian Non-Olympics and Slovakian Olympic medallists. Note – dotted lines on right panels indicate the Slovakian Olympic medallist.

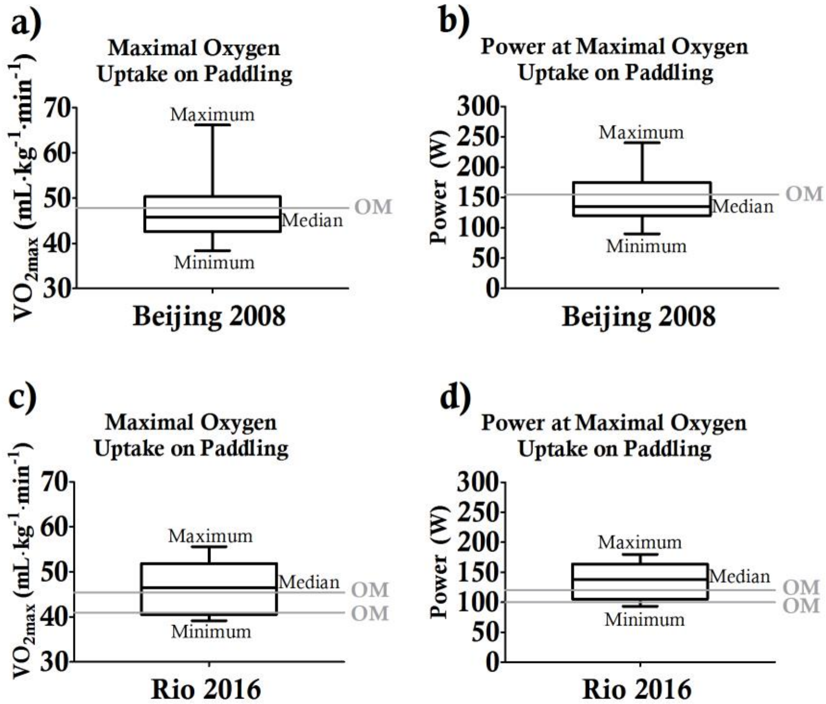

Figure 6. Box and whiskers of paddle ergometer evaluations from Slovakian kayakers on two Summer Olympic Games. a) Minimum, maximum and median values of maximal oxygen uptake on Beijing 2008; b) Minimum, maximum and median values of power at maximal oxygen uptake on Beijing 2008; c) Minimum, maximum and median values of maximal oxygen uptake on Rio 2016; d) Minimum, maximum and median values of power at maximal oxygen uptake on Rio 2016; OM – Olympic Medallist.

Olympic medallists also presented lower aerobic power on running when compared to the rest of team on the last two Summer Olympic Games (Figures 4, 5 and 7). On London, the VO_{2max} and velocity at VO_{2max} means from the two Olympic medallists were 13.6 and 7.2 % lower compared to the rest of the team (Figures 4a and 4b). Notwithstanding, Olympic medallists presented VO_{2max} and velocity at VO_{2max} close to the minimum values obtained from Slovakian team (Figures 7a and 7b). Similar scenario was visualized on Rio regarding VO_{2max} (Figures 5a and 7c). However, in terms of velocity at VO_{2max}, the mean data was similar between Olympic medallists the rest of the team (Figure 5b). Moreover, one Olympic medallist presented the highest velocity at VO_{2max} (Figure 7d). Disregarding the quality of kayakers and the moment, Slovakian kayakers presented higher VO_{2max} on treadmill when compared to paddle ergometer ($p=0.000$; $ES=1.6$) (Figure 8).

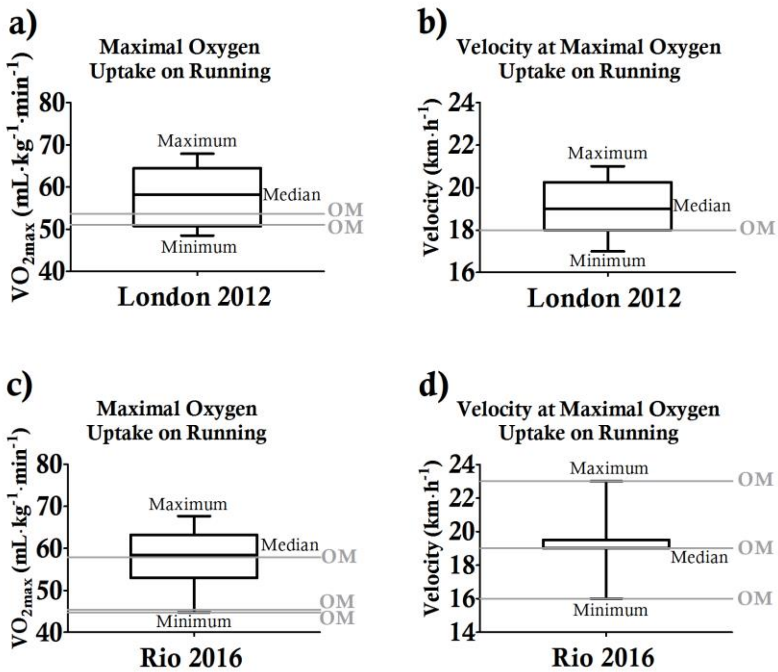

Figure 7. Box and whiskers of treadmill evaluations from Slovakian kayakers on two Summer Olympic Games. a) Minimum, maximum and median values of maximal oxygen uptake on London 2012; b) Minimum, maximum and median values of velocity at maximal oxygen uptake on London 2012; c) Minimum, maximum and median values of maximal oxygen uptake on London 2016; d) Minimum, maximum and median values of velocity at maximal oxygen uptake on London 2016. OM – Olympic Medallist.

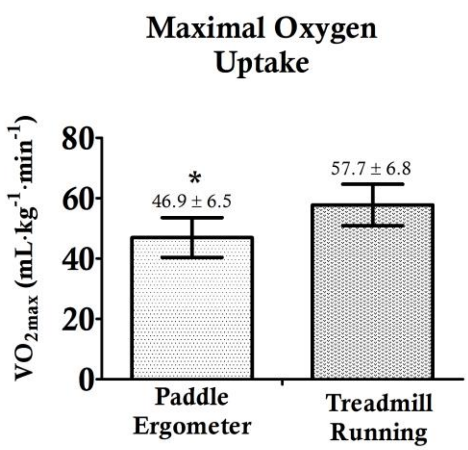

Figure 8. Comparison of maximal oxygen uptake from Slovakian kayakers determined on paddle ergometer and treadmill; *Indicate significant difference; p≤0.05.

DISCUSSION

The main finding of the present study was that aerobic power of Slovakian Olympic medallists was consistently lower when compared with most of Non-Olympic Slovakian athletes throughout the last three Summer Olympic Games. These results are unique and infer relevant perspectives: a) despite the oxidative system importance for prescription and controlling training load, aerobic power does not delimitate the high-level performance in this sport; b) the relevance of anaerobic metabolism, technical paddling and psychophysiological aspects may surpass the oxidative system during canoe slalom trials.

The aerobic metabolism analysis of slalom kayakers has been recently improved (Ferrari et al., 2017; Manchado-Gobatto et al., 2014; Leonardo H D Messias et al., 2015). Despite the significant relationship with the performance on simulated trials (Ferrari et al., 2017), oxidative system may play an indirect and important role for these athletes. This discussion must be aligned with evidences previously demonstrated regarding the substantial blood lactate production (8.29 ± 2.43 mM) after simulated races (L H D Messias et al., 2015). The lactate role has been extensively discussed over the years. Lactate shuttle theory (G A Brooks, 2002) described several important aspects of this anion, such its energy source capacity, autocrine-paracrine-endocrine effects and gluneogenic precursor (George A Brooks, 2018). Moreover, several tissues, especially those with oxidative properties, may act as lactate consumer (George A Brooks, 2018). Therefore, slalom kayakers may benefit from oxidative system during rest or intervals between trials, acting indirectly on performance.

Similar discussion was already conducted on previous investigations (Ferrari et al., 2017; Zamparo et al., 2006). However, literature is lacking regarding aerobic capacity indexes of slalom kayakers. This scarcity is even more pronounced in terms of aerobic power. Zamparo et al. (10) provided values in paddling ergometer (48.7±6.9 mL $kg^{-1} \cdot min^{-1}$) close to those reported here within the same exercise (Figure 8). Shephard (22) reported data of Dransart from 3 types of French championships; reported VO_{2max} in white water race and slalom course were 60 mL· $kg^{-1} \cdot min^{-1}$ and 55.6 mL· $kg^{-1} \cdot min^{-1}$, respectively. The Slovakian Olympic medallists on Beijing and Rio evaluated in this study presented aerobic power close to such values. As extensively discussed over the years, VO_{2max} can influenced by both central as peripheral factors (Bassett & Howley, 2000).

Indeed, the exercise that this parameter is being measured can also modify its relative results. Our data agree with this perspective. Although the paddle ergometer can be considered more specific for slalom kayakers than the treadmill, the VO_{2max} on paddling was significantly lower than in running. Despite sedentary individuals can get about 70 % of the leg value when using the arms (Bergh, Kanstrup, & Ekblom, 1976; Bobbert, 1960; Simmons & Shephard, 1971) the average for the canonists is much higher (90 %) (Vaccaro, Gray, Clarke, & Morris, 1984; Vrijens, Hoekstra, Bouckaert, & Van Uytvanck, 1975). This can be explained by different muscle engagement and physiological differences between upper and lower body. The same was previously reported in flat water canoeists, where the peak oxygen uptake recorded on the paddle ergometer was 77 - 89.1 % of the maximal oxygen uptake achieved on the leg or arm/leg ergometer (Bielik et al., 2018; Hahn, 1988; P. Tesch, Piehl, Wilson, & Karlsson, 1976). Presumably, running engages larger muscle mass than using arm ergometer even in elite canoeists. Running and cross-country skiing are common aerobic capacity training routine for Slovak paddlers at the general preparatory period. Otherwise, we accept that VO_{2max} determined on water could bring different outcomes, mainly because the paddlers do not include ergometer in training sessions. Furthermore, the ergometer system overcomes the same resistance (wind brake) in order to perform work, irrespective of body mass.

Recently we reported that silver medallists of Summer Olympic Games 2016 Rio (K4 discipline on flat water) have VO_{2max} on treadmill of 62.8 ± 4.4 mL·$kg^{-1} \cdot min^{-1}$ (Bielik et al., 2018). These findings are in agreement with the previously published results of elite Swedish kayak paddlers (P. A. Tesch, 1983; P. Tesch et al., 1976). As concluded by Michael et al. (31), elite flat water kayakers demonstrate superior aerobic and anaerobic parameters within maximal VO_{2max} about 58 mL·$kg^{-1} \cdot min^{-1}$. This is not far behind reported treadmill running values from junior (60 mL·$kg^{-1} \cdot min^{-1}$) or senior (55 mL·$kg^{-1} \cdot min^{-1}$) Whitewater contestants (Sidney &

Shephard, 1973), US Whitewater team (61 mL $kg^{-1}\cdot min^{-1}$) (Vaccaro et al., 1984) besides our results of the Slovak Olympic medallists. It is valid to state the influence of endurance and neuromuscular changes across periodized training cycle. A periodized strength and endurance program with special emphasis on prioritizing the sequential development of specific physical fitness components in each training phase seems to be effective for improving both cardiovascular and neuromuscular markers of highly trained top-level athletes (Garcia-Pallares et al., 2010; Garcia-Pallares, Sanchez-Medina, Carrasco, Diaz, & Izquierdo, 2009). To avoid the influence of different periodized training cycle, the athletes in our study were recruited in the same period.

Interestingly, regardless of the moment, we noticed lower speed on running at VO_{2max} for most of Slovakian Olympic medallists than the recently reported (21 $km.h^{-1}$) in flat water canoe medallists at summer Olympics 2016 (Bielik et al., 2018). Still different from flat water canoe sprint, in slalom and Whitewater contests, the value of physiological testing is somewhat limited, as performance is strongly influenced by experience and the ability to make precisely judged on paddling efforts under considerable emotional stress. Non-parametric items, such as skill, experience and resistance to stress, make a vital contribution. Moreover, a high level of concentration must be sustained throughout a race in order to maintain an optimal course, avoiding gates and/or rocks (Shephard, 1987).

We have recently showed that junior flat water international championship medallists reached higher total maximal oxygen uptake, speed at VO_{2max} test on treadmill and power at VO_{2max} test on paddling ergometer than the rest of the national team (Bielik et al., 2018). However, we do not report differences between Olympic medallist and the rest of the national team in present study of Whitewater paddlers. Messias et al. (9) speculate that the limited number of scientific studies focused on canoe slalom is also a reflection of the sport's characteristics, which hinders the application of scientific methods to evaluate physiological parameters. There is no consensus as to what one or two physiological factors determine success and performance in canoe slalom. We believe that complexity of canoe slalom makes it difficult to quantify the physiological demands of the sport. Besides that, canoe slalom qualification at the last two Olympic Games enabled maximum 1 boat per event from the same country. These rules out the other participants from Slovakia, even with a high level of physical fitness and performance, to take place at the event. High quality of potential Olympic nominees (rest of national team) is recognized by the past world championships, where paddlers have been alternating to take podium over the last 10 years both in single and double canoe events. Likewise, since 2009 to 2017 the Slovak paddlers won team event (C1) at every World Championship. In addition to that, two boats took podium in a same event at world championship in 2009, 2011 and 2017. We assume that beyond certain level the aerobic power is not the limiting factor of performance for canoe slalom.

It is valid to recognize that the present study did not provide variance analysis between Slovakian medallist and the rest of the team. However, this limitation is extended to future studies. Indeed, this analysis is hampered by the few samples of canoe slalom Olympic medallists (three or six depending on the discipline), which are highly qualified. Future studies may investigate whether the perspectives discussed in this investigation are also valid for junior athletes. Earlier detection of physiological parameters along with technical and psychophysiological can strongly contribute for developing future champions on canoe slalom.

CONCLUSION

This is the first study to provide information about the aerobic power of elite canoe slalom athletes over three Olympic Games. Moreover, the comparison between Olympic medallists and Non-Olympics was absent until now. Our results are unique and may significantly improve the science beyond this sport. We have demonstrated that aerobic power of these athletes is ergometer dependent. This information is strongly relevant for canoe slalom coaches properly evaluate the training efficiency over periods. Regarding the relevance of aerobic power on slalom kayaker's performance, based on the collected data over the last ten years, we suggest that although oxidative system may play a relevant and indirect role on performance, does not delimitate the high performance in this sport, since Slovakian Olympic medallist present lower VO_{2max} over the last three Summer Olympic Games. Factor such as technical paddling skill, experience, resistance to stress and improved anaerobic metabolism can surpass the oxidative system for maintain an optimal canoe slalom course.

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