
Anthropometric and Physiological Predictors of Flat-water 1000 m Kayak Performance in Young Adolescents and the Effectiveness of a High Volume Training Camp

SCOTT C. FORBES†¹, DANIEL L. FULLER†², JOEL R. KRENTZ†², JONATHON P. LITTLE†², and PHILLIP D. CHILIBECK†²

¹Physical Education and Recreation, University of Alberta, Edmonton, AB, Canada; ²College of Kinesiology, University of Saskatchewan, Saskatoon, SK, Canada

†Denotes graduate student author, ‡denotes professional author

ABSTRACT

Int J Exerc Sci 2(2): 106-114, 2009. Our purpose was to determine the relationship of anthropometric and physiological variables with 1000m flat-water kayak (K_{1000}) performance. A secondary purpose was to determine the effectiveness of a high volume training camp. High performance young adolescent kayakers ($n=13$, 8 males, 5 females, 15 ± 1 yrs) participated in this study. Testing before and after the 3-4 week training camp included anthropometric measurements (height, sitting height, arm span, and body mass), strength (1-RM: bench press and bench pull), flexibility (sit and reach), and an incremental kayak ergometer test to determine peak oxygen uptake (VO_{2peak}) and anaerobic threshold, and an open water K_{1000} time trial. K_{1000} time was significantly correlated with height ($r=-0.81$; $p<0.01$), sitting height ($r=-0.85$; $p<0.01$), arm span ($r=-0.87$; $p<0.01$), bench press ($r=-0.92$; $p<0.01$), bench pull ($r=-0.85$; $p<0.01$), VO_{2peak} ($r=-0.87$; $p<0.01$) and anaerobic threshold ($r=-0.83$; $p<0.05$). Following the training camp there were no significant differences in body mass, strength, and VO_2 peak, however, anaerobic threshold (33.6 ± 6.2 to 42.3 ± 8.8 ml kg^{-1} min^{-1} , $p=0.001$) and K_{1000} (302 ± 44 to 289 ± 31 sec, $p=0.007$) significantly improved. The results of this study suggest that K_{1000} performance in young adolescent kayakers appears to require a high aerobic and strength contribution and that a high volume training camp is effective for improving anaerobic threshold and performance.

KEY WORDS: Exercise, athletic performance, anaerobic threshold, VO_2 peak

INTRODUCTION

Olympic kayak events are currently contested over the distances of 500 and 1000 m. In Canada, young adolescent paddlers (16 yrs and younger) only compete over the 1000 m distance at the national championships. At the National level, the individual event is completed in approximately 235 s and 260 s for

adolescent males and females, respectively. Optimal performance requires a complex blend of anthropometric, physiological, biomechanical and psychological factors (3). Determining the relationship between these attributes and performance may be valuable for designing training programs and for team selection (10).

The body of research relating physiological characteristics of elite paddlers to K_{1000} performance is relatively small. Fry and Morton (12) examined selected state team members ($n=7$, 26 ± 7 yrs) and non selected members ($n=31$, 25 ± 7 yrs) and found significant correlations between several anthropometric (sitting height, $r=-0.37$; body mass, $r=-0.37$; and sum of 8 skinfolds, $r=0.37$), strength ($30^\circ\cdot s^{-1}$, $r=-0.65$ and $r=-0.55$ for their right and left hand, respectively), and aerobic variables (absolute VO_{2max} , $r=-0.71$; relative VO_{2max} , $r=-0.64$) with 1000 m performance time. Tesch and colleagues (23) examined the physiological responses following 500, 1000, and 10,000 m races in four senior (25 yrs; range 22 to 28) and two junior (18 yrs) male Swedish team paddlers. The highest oxygen uptake was obtained after the 1000 m race, suggesting that performance requires a high aerobic contribution. Recently, Van Someren and Howatson (25) examined elite male kayakers ($n=18$, 25 ± 4 yrs) and found no significant correlations between any anthropometric variables and 1000 m performance. However, significant correlations were found between 1000 m performance and peak power ($r=-0.65$) and total work performed during a 30 s kayak ergometry test ($r=-0.74$) suggesting that 1000 m performance requires a high anaerobic contribution. To date, no studies have examined elite young adolescent paddlers. The primary purpose of this study was to determine which selected physiological and anthropometric parameters predict K_{1000} (1000 m kayak race) performance in young high performance adolescent paddlers.

Due to the relatively short racing season, paddlers in North America typically attend

a high volume training camp to increase performance for early season races. A secondary purpose was to examine the effects of a 3-4 week high volume spring training camp on selected physiological variables and performance. We hypothesized that K_{1000} performance would require a high aerobic and strength contribution, and a 3-4 week training camp would result in improvements in all the selected physiological variables and correspondingly performance time would decrease.

METHOD

Participants

Thirteen young high performance adolescent kayakers (8 males, 5 females, mean $\pm$ SD 15 ± 1 yrs) volunteered for the study. All were members of the local racing canoe club and competed at the National championship level. To qualify for the National championships, an athlete must finish top four in their respective provincial division. All subjects were required to fill out a Physical Activity Readiness Questionnaire, which screens for health problems that might present a risk with performance of physical activity (24). The University of Saskatchewan Biomedical Research Ethics Board for research in human subjects approved this study. Participants were informed of the risks and purposes of the study before they gave written assent with parental consent.

Experimental Design

All the participants were familiarized to the fitness testing equipment prior to the experiment. Each subject was given a battery of fitness tests in the laboratory before and after the 3-4 week training

camp, including anthropometric measurements of body mass, height, sitting height, and arm span; flexibility measurements of sit and reach, right and left leg and shoulder flexion; strength measurements of 1-RM bench-press and bench-pull assessments; and an incremental kayak ergometer test to determine $\text{VO}_{2\text{peak}}$ and anaerobic threshold (11). Approximately 3-5 days following laboratory testing subjects completed a K_{1000} time trial. All thirteen subjects completed the testing before the training camp and eight subjects (7 males, 1 female) returned for testing after the training camp, of which four completed a 3 week camp while the other four subjects completed a 4 week training camp.

Subjects were assessed at the end of their off-season. During this portion of the off-season subjects were engaged in resistance training (endurance weights, e.g. 8 exercises, 2 sets of 2 min on and 2 min recovery) 3 to 4 times per week for 60-90 minutes each session, running twice a week (~60 minutes per session), swimming twice a week (~60 minutes per session), and kayak ergometry 1 to 2 sessions per week (~60 minutes per session). During the spring training camp, subjects were engaged in 10-11 kayaking sessions per week with a duration of ~60 minutes per session, resistance training (maintenance weights, e.g. 3 sets of 12) twice a week, and running twice a week (60 minutes per session).

Anthropometrics

Body mass was assessed on a Toledo scale, which is accurate to the nearest 0.01 kg. Standing height and sitting height were measured to the nearest 0.1 cm with a wall-

mounted stadiometer. Each measurement was recorded three times and the two closest values were averaged to reduce testing error. All the measurements were done by a single technician to eliminate variability due to inter-rater reliability.

Flexibility

Prior to any flexibility test subjects were instructed to be adequately warm, which included light stretching. During the testing subjects were instructed to execute each movement in a slow and controlled manner. All measurements were recorded three times and the two closest values were averaged. The sit and reach, which simulates the seated position in a kayak, was used to determine hamstring, hip and lower back flexibility (2). Hip and shoulder flexion were assessed with the use of a goniometer.

Strength

Bench-pull and bench-press strengths were assessed using a one-repetition (1-RM) standard testing procedure as previously described (6). These two exercises were chosen due to the pushing and pulling motions during the kayak stroke. The bench-pull was conducted on a Hammer strength seated row machine. Subjects positioned the handles at shoulder height by adjusting the seat. Subjects were not allowed to lean backwards during the pulling phase (chest had to stay in contact with the padding). A complete repetition went from the straight-arm position, until the handles touched their chest, and then ended with the bar returning to the straight-arm position. For bench-press, subjects were positioned on the bench with both feet flat on the floor. Subjects were not allowed to lift their buttocks off the bench

Table 1. Correlation coefficients between 1000 m flat-water kayak (K_{1000}) performance time and laboratory test variables before and after the training camp.

Variable	Correlation with K_{1000} Time	
	Before (n=13)	After (n=8)
Anthropometric data		
Gender	0.83*	0.87*
Age (years)	-0.59*	-0.55*
Body Mass (kg)	-0.54	-0.36
Height (cm)	-0.81*	-0.74*
Sitting Height (cm)	-0.85*	-0.76*
Arm Span (cm)	-0.87*	-0.84*
Incremental test data		
Peak $\dot{V}O_2$ ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	-0.85*	-0.76*
Peak $\dot{V}O_2$ ($\text{l} \cdot \text{min}^{-1}$)	-0.87*	-0.90*
Anaerobic Threshold ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	-0.83*	-0.71*
Flexibility data		
Sit and Reach (cm)	0.04	-0.08
Left Leg Flexion (degrees)	0.52	0.34
Right Leg Flexion (degrees)	0.39	-0.20
Left Arm Flexion (degrees)	0.30	0.55
Right Arm Flexion (degrees)	0.17	0.24
Strength data		
Bench Press (kg)	-0.92*	-0.92*
Bench Pull (kg)	-0.85*	-0.85*
* $p < 0.05$		

or arch their backs during a lift. A complete repetition went from the top straight-arm position, down until the bar touched the chest, and then ended with the bar returning to the top straight-arm position. A warm-up for each exercise consisted of 10 repetitions using a weight determined by each subject to be comfortable. Weight was then progressively increased for each subsequent 1-RM attempt with a 2 min rest interval. The 1-RM was reached in four to six trials, including the warm-up set.

Incremental Test

An incremental protocol on a kayak ergometer was used to assess peak oxygen

uptake ($\dot{V}O_{2 \text{ peak}}$) and anaerobic threshold. The protocol has previously been described in detail (11). Briefly, the starting stroke rate was 70 strokes per minute and increased 10 strokes per minute every two minutes until volitional fatigue or stroke rate could not be maintained.

Expired Gas Measurements

During the incremental test on the kayak ergometer, expired gas samples were collected and continuously monitored for oxygen and carbon dioxide concentrations using a metabolic cart (Sensor Medics, Vmax Series 29, Anaheim, CA). Breath-by-breath values were averaged over 20 s intervals. Prior to testing, the flow volume

Table 2. Anthropometric, strength, and aerobic variables of 8 high performance young adolescent kayakers before and after a typical 3 to 4 week training camp.

Variables	Mean (SD)		% Change	p value
	Before	After		
Body Mass (kg)	69.7±12.1	70.0±12.0	0.5±2	0.542
Bench Press (kg)	77±16	75±14	-2±6	0.305
Bench Pull (kg)	121±22	123±22	2±8	0.537
Peak VO ₂ (ml kg ⁻¹ min ⁻¹)	44.9±9.8	48.9±11.9	11±10	0.023
Peak VO ₂ (l min ⁻¹)	2.99±0.72	3.37±0.94	11±11	0.16

sensor was calibrated with a 3 L syringe and the gas analyzers were calibrated with gas of known concentration, according to the manufacturer's instructions. The highest 20 second average achieved in the last minute of exercise was used as peak VO₂. The criterion for reaching peak VO₂ was a peak and/or plateau in VO₂ (<0.10 L min⁻¹) during exercise of increasing power output. Secondary criteria included a respiratory exchange ratio (VCO₂/ VO₂) greater than 1.1, reaching one's age predicted and/or known maximal heart rate, and the occurrence of volitional fatigue (9). A heart rate monitor (Polar S610i, Polar Electro Oy, Kempele, Finland) was used to monitor and store heart rate every 5 seconds. The anaerobic threshold was determined as the point at which CO₂ production and minute ventilation deviated from linearity as compared with the rate of rise in oxygen uptake as work rate was increased (27).

Statistical Analyses

Pearson's product moment correlation coefficients were determined between the independent variables (laboratory measures) and the dependent variable (K₁₀₀₀ time) before and after the training camp. Paired t-tests were used to test for differences between selected physiological parameters before and after the training

camp. An alpha level, corrected for the number of t-test (0.05/7) of 0.007 was considered significant for all comparisons. All values are expressed as mean ± SD.

RESULTS

The correlation coefficients between anthropometric, physiological, strength, and flexibility variables and kayak performance time are presented in table 1. From the anthropometric data, gender, age, height, sitting height, and arm span were all significantly (p<0.05) correlated to performance both before and after the training camp; however, body mass was not. Of the above variables, the highest correlation coefficient was arm span before the training camp and gender after the training camp. All the physiological and strength variables were significantly (p<0.05) correlated to performance before and after the training camp; however, measures of flexibility did not correlate with K₁₀₀₀ performance. The overall best predictor of performance was bench press 1-RM (r=-0.92).

The anthropometric, strength, and aerobic characteristics (mean ± SD) before and after the training camp are shown in Table 2. There was no significant difference in the subjects who completed a 3 week training

camp (n=4) and those who completed a 4 week training camp (n=4), therefore these groups were combined. Anaerobic threshold and performance significantly changed ($p<0.007$) as shown in figure 1 and 2. The time trials were both completed in calm wind conditions on the same course at the same time of day. There were no changes in any anthropometric, strength, peak VO_2 , or flexibility measures.

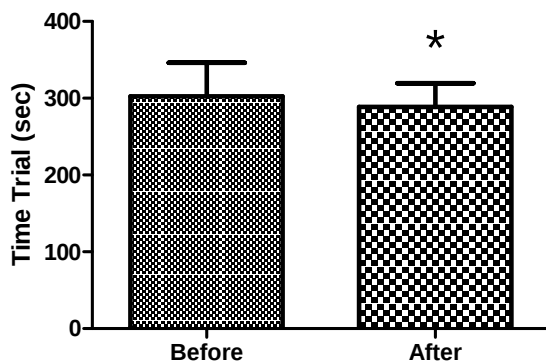


Figure 1: K_{1000} performance before and after the training camp (mean $\pm$ SD). *Significantly different from before the training camp ($p<0.007$)

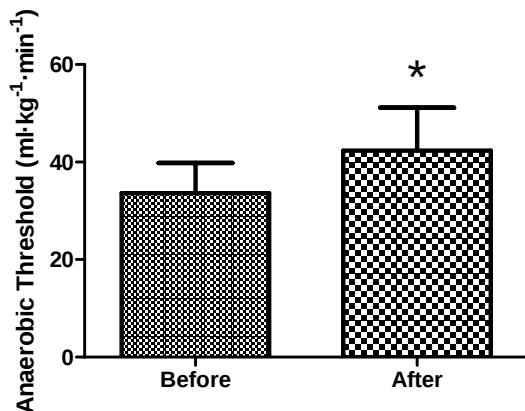


Figure 2: Anaerobic threshold before and after the training camp (mean $\pm$ SD). *Significantly different from before the training camp ($p<0.007$)

DISCUSSION

This is the first study to investigate the relationship between selected

anthropometric and physiological characteristics and performance in elite young adolescent paddlers. Results showed that K_{1000} performance was significantly correlated to several anthropometric, strength and aerobic variables. Furthermore, this is the first study to demonstrate that a high volume training camp was effective for increasing performance and anaerobic threshold.

Our results suggest that successful paddlers tend to be larger than average in standing height, which has been previously reported (3,12,16,20). The current study examined standing height, sitting height, and arm span, and found that arm span provided the highest correlation with performance, followed by sitting height, and then standing height. Fry and Morton (12) found that sitting height was significantly correlated to K_{1000} performance, while height was not. Previous research suggests that successful paddlers tend to be heavier (12,19); however, we found no significant correlation between body mass and performance. Bishop (3) supports our findings, as they found no significant correlation between body mass and K_{500} performance in female kayakers.

There were no significant correlations between any of the flexibility measures and K_{1000} time in the present study. No previous studies have attempted to correlate flexibility to performance in kayakers. Previous studies in other sports examining the effects of regular stretching on athletic performance have been equivocal. For example, Hunter and Marshall (13) found an increase in vertical jump performance; however, Nelson and colleagues (15) conducted a randomized

cross-over study and found no improvement in running economy after a chronic stretching program. Further research is needed to determine if an increase in flexibility affects paddling performance.

Of all the variables assessed, 1 RM bench press had the highest correlation with performance. Previous research has demonstrated that selected state team kayakers were significantly stronger ($p < 0.01$) than non-selected kayakers (12). However, we found a significant improvement in performance time after the training camp with no change in strength. This suggests that although strength is important other factors are necessary for successful performance.

The peak VO_2 values are very similar to values previously reported for high performance paddlers (3,5,11). One study showed an average relative peak VO_2 of $46.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ involving 15 trained kayakers (11), which was similar to the present study which showed an average peak VO_2 of $44.9 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ before the training camp and $48.9 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ after the training camp. However, these results are slightly lower compared to previous studies (4,21). The difference in the present study may be due to the maturation level of the subjects and because our subjects were assessed early in the training year, at a time when they would not be expected to record their highest peak VO_2 (3).

There was a significant correlation between K_{1000} time and both absolute and relative peak VO_2 . Previous research (3,14,18) suggests that although a larger individual may have a larger absolute peak VO_2 , their

kayak will sit deeper in the water, resulting in a greater wetted surface area and thus slowing the kayak. However, absolute peak VO_2 demonstrated a higher correlation coefficient than relative peak VO_2 , suggesting that absolute aerobic capacity may be more important than relative peak VO_2 .

Paddlers tend to have a high anaerobic threshold (8,22). We found a significant correlation between anaerobic threshold determined on an incremental test on a kayaker ergometer and performance. Unlike Bishop (3), we found that peak VO_2 provided a higher correlation compared to the anaerobic threshold. Bishop (3) estimated the anaerobic threshold by assessing the lactate threshold, while we estimated anaerobic threshold based on expired gases. Furthermore, Bishop (3) examined physiological attributes to predict k_{500} performance of females while we examined k_{1000} performance of males and females.

There have been very few studies examining the effects of training on physiological variables and paddling performance (1,7,17), and no studies have examined high performance adolescent paddlers. Ridge and colleagues (17) examined 10 moderately trained male kayakers and found significantly lower VO_2 and HR at submaximal workloads, as well as a significant increase in peak VO_2 and performance after 1 month of training. The current study found a significant increase in performance and anaerobic threshold, while no significant differences in peak VO_2 , strength, anthropometric, or flexibility were found following the 3-4 weeks of training.

This is the first study to suggest that K_{1000} performance in young adolescent kayakers appears to be associated with a high aerobic and strength contribution. The variables that correlated best with performance were peak VO_2 , bench press 1-RM, and arm span. This is important for coaches designing training programs and for team selection. Furthermore, our results suggest a high volume training camp in young adolescent kayakers is effective for improving anaerobic threshold and performance.

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