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TESTS FOR PREDICTING ENDURANCE KAYAK PERFORMANCE

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ABSTRACT

Objectives: Previous studies investigating factors contributing to kayak performance have employed sophisticated physiological measures, and the use of specialised dynamometers, to simulate the kayak stroke. Such measures do not have general utility, and the aim of this study was to identify tests that could be performed in the field, in order to predict kayak performance. Methods: The following variables were measured on 23 competitive endurance kayakers, who provided written informed consent: Arm crank VO_2 peak; 1 minute dips; armspan; modified sit-and-reach; grip strength; body mass; height. These were selected on the basis of their being identified as possibly contributing to performance, and on their applicability in terms of on-site testing. The dependent variable for analysis was a 7 km race, performed one week after the field tests. Results: Using multiple regression forward stepwise selection, relative VO_2 peak (arm crank) was the only significant predictor ($p=0.006$, $r=–0.81$), with dips ($p=0.153$) and armspan ($p=0.133$) being next in terms of hierarchical contribution. For race performance and VO_2 peak, 65.8% of the variance in one measure was explained by the variance in the other. Utilising VO_2 peak, with race performance as the dependent variable, the following regression equation was generated: Time=46.315–0.22 (VO_2 Peak). Conclusion: Whilst several factors influence endurance kayak performance, in the context of novice talent identification it is concluded that a VO_2 peak test that is relatively sport specific (Arm Crank), has applicability and utility.

Keywords: Kayaking; Predicting performance.

INTRODUCTION

The overall aim of this study was to identify tests that can be performed outside the laboratory, in order to predict endurance flat-water kayak performance. As such, it takes into account the principles of talent detection and identification. *Detection* involves the unearthing of potential performers from the ranks of novices, whilst *Identification* refers to the process of recognising current participants who have the characteristics to become elite performers (Williams & Reilly, 2000). Put differently, talent identification is essentially the assessment of those attributes and capacities that underlie athletic success, and has elsewhere resulted in remarkable improvements in international athletic endeavour (Aitken & Jenkins, 1998).

Previous studies investigating factors contributing to kayak performance have employed sophisticated physiological parameters and laboratory-based equipment (Pelham & Holt, 1995; Aitken & Jenkins, 1998). Whilst clearly desirable from a reductionist and explanatory scientific perspective, such measures do not have general utility, in that the measures employed and equipment utilised (eg. sophisticated and expensive kayak ergometers) are limited to relatively few laboratories. Specifically, in the context of talent detection and identification, coaches and sports development officers need to use valid, reliable, and easy-to-administer tests that can be performed in the field.

Fry and Morton (1991) point out that training aimed at producing biological adaptations to improve performance, requires kinanthropometric, physiological, and psychological attributes. The relative contribution of these factors varies between sports, necessitating specificity of testing when attempting to identify potential. As Bunc and Heller (1994) note, evidence suggests that specific metabolic adaptation may only be verified using specific performance tests, based on the principle that adaptations are specific to the type of training used. This is supported by Van Someren *et al.* (2000) who stated that it is imperative that equipment used in simulating sport activities impose the same physiological demands as the sport itself. Relative to kayak ergometry there are some limitations to arm-crank testing. Nevertheless, arm-crank ergometry recognises specificity, and has the advantage of being more readily accessible than sophisticated kayak ergometer equipment.

In addition to the influence of skill, technique, and experience in kayaking, several physiological, mechanical, and anthropometric factors have been identified as being characteristic of better paddlers. Generally speaking, improved kayak performance has been associated with grip and muscle strength, lean body mass, arm span, standing and sitting height, anaerobic threshold, absolute aerobic power, predominance of slow-twitch fibres, and time to exhaustion (Tesch, *et al*., 1976; Shephard, 1987; Fry & Morton, 1991; Aitken & Jenkins, 1998).

In light of the above literature and an analysis of the musculature contributing to paddling technique (Hay & Reid, 1988), it was decided to employ the following standardised tests in accordance with the aforementioned paradigm of utility, applicability, validity, and reliability: Arm crank VO_2 peak; One-Minute Dips; Arm Span; Modified Sit-and-Reach; Grip Strength; Body Mass; Height. A further consideration in the selection of tests for multiple regression and prediction was of a statistical nature. Generally speaking, in seeking a good prediction equation, the independent variables should be highly related to the dependent variable but not each other.

METHODS

Participants

Twenty-three experienced male kayak paddlers from the Zululand Kayak Club in Richards Bay volunteered to participate in this research project, and all completed written, first-person informed consent forms. The characteristics of participants are presented in Table 1.

TABLE 1. **PARTICIPANT CHARACTERISTICS AND DESCRIPTIVE STATISTICS FOR VARIABLES MEASURED**

Variable	mean	s
race time (min and sec)	36.56	2.38
VO_2 Peak (arm) ml/kg/min	44.36	8.78
dips 1 min	14.39	9.44
armspan (cm)	182.30	6.36
sit reach (cm)	34.88	7.44
grip strength mean (kg)	52.62	6.18
mass (kg)	80.87	9.98
height (cm)	180.11	4.1
age (yrs)	35.74	10.53

Protocol

All testing took place in the field, on-site at the Zululand Kayak Club, Richards Bay, South Africa, and this was followed one week later by participants performing the normal weekly 7 km race at the club.

Arm crank VO_2 peak

An incremental test to maximum was performed on a Monark arm ergometer. Participants warmed up by cranking at 75 RPM, at a resistance of 30 watts for 3 minutes. Thereafter the resistance was increased by 15 watts every minute until exhaustion was reached. Increments of one minute duration at 15 watts were chosen to reduce the likelihood of local fatigue being the major determinant of cessation of exercise, rather than aerobic factors. A validated portable ergospirometry unit (Metamax, Cortex, Leipzig, Germany) (Coetsee, 1998/99; Van Someren *et al*., 2000) was used to measure and record all respiratory parameters from 2 minutes prior to the start of arm cranking until the participant stopped cranking through volitional exhaustion. Heart rate was measured throughout the test by means of a heart rate monitor (Polar Vantage, Polar Electro OY, Kempele, Finland) and transmitted to the Metamax. Data were recorded on the Metamax at 10 second intervals. For analysis, the mean of the last 30 seconds of each one minute workload increment was used.

The Monark arm ergometer was mounted on a specially designed platform with an attached seat. The axis of rotation for arm cranking was adjusted to shoulder height. Subjects performed a 5 minute, self-selected habituation session, 30 minutes before the test.

It could be argued that VO_2 peak is a sport specific training effect, rather than a predictor of performance. It is of course a training effect, but equally, it reflects the demands of the activity in question. So, for endurance kayaking, the measure has a logical link with performance prediction.

Armspan

Participants stood with the back against a tape measure fixed to a wall at shoulder height. Armspan was taken to be the distance between the second digit on the right and left hands, with the arms abducted to 90°.

Grip strength

Participants held a manual hand grip dynamometer next to the side, without touching the body. The most comfortable grip length for each participant was then set. The participant then attempted a maximal effort for ± 3 seconds with the dominant hand. They were then afforded the opportunity to request a resetting of grip length. After 3 minutes rest, the procedure was repeated, with the highest value accepted.

Modified sit-and-reach test.

Participants sat with their backs against a wall, with the legs and arms stretched out in front. The position of the fingertips was marked as zero. By leaning forward, the participant attempted to push the fingertips forward as far as possible over a ruler, holding that position for at least 2 seconds. The furthest distance reached in two trials was accepted.

Dips

On parallel bars set to shoulder width, each participant supported himself on the hands (with straight arms), without the feet touching the ground. The exercise was performed by bending the arms until the elbows reached an angle of 90 degrees. This was repeated as many times as possible in 1 minute.

Statistical Analysis

Descriptive statistics were produced, and Pearson Correlation Coefficients were used to examine the interrelationships between variables. The variables were entered into forward stepwise selection, with race time (RT) as the dependent variable. The data were tested for homoskelasticity, and the errors found to be normally distributed. There were no outliers (± 3 SD). Stepwise selection was used to find the most satisfactory solution to the prediction of RT, this solution being the one that produced the lowest standard error of the estimate. Put differently, the procedure enabled analysis of the individual and collective contributions to the prediction of RT. Finally, a prediction equation was developed.

RESULTS

The means and standard deviations for the variables are produced in Table 1. Subjects were older than cohorts in other studies: Tesch *et al.* (1976) = 25 yrs and Fry and Morton (1991) = 26.1 yrs. Height and body mass were similar to the Fry and Morton (1991) investigation (179.9 cm and 81.05 kg), as well as to several studies analysed by Shephard (1987). VO_2 peaks at 3.57 $l.min^{-1}$ and 44.36 $ml.kg^{-1}.min^{-1,}$ were less than Fry and Morton's (1991) corresponding values of 4.78 $l.min^{-1}$ and 59.22 $ml.kg^{-1}.min^{-1}$. However, the higher values were for Australian State selected paddlers, and the values for non-selected subjects were 3.78 $l.min^{-1}$ and 54.8 $ml.kg^{-1}.min^{-1}$. Tesch *et al.* (1976) reported a mean value of 4.61 $l.min^{-1}$ for elite Swedish paddlers, and this is consistent with data reported by Shephard (1987) for flatwater competitors in the French Championships (4.59 $l.min^{-1}$). Van Someren *et al.* (2000)

reported a peak value of 4.1 $l.min^{-1}$ for well-trained paddlers during a four minute maximal distance trial.

Table 2 presents the correlation coefficients for all the variables. Before proceeding to the discussion, it is worth noting that, rather surprisingly given the non-weight bearing nature of the activity, absolute VO_2 peak had a lower correlation with RT (-0.74) than did relative VO_2 peak (-0.81). This was one reason for excluding absolute VO_2 peak from the ensuing stepwise selection, the other being the undesirability from a statistical perspective of having closely related independent variables.

TABLE 2. **PEARSON CORRELATION COEFFICIENTS FOR THE VARIABLES MEASURED**

	VO2 Peak	**armspan**	**grip**	**sit reach**	**dips**	**time trial**	**mass**
VO2 Peak (arm)							
armspan	.09						
grip strength	.12	.08					
sit reach	.54**	-.01	-.24				
dips 1 min	.59**	-.43*	.27	.36			
race time	-.81**	-.14	-.22	-.44**	-.58**		
mass	-.26	.28	.19	.09	-.39	.09	
height	.30	.77*	.05	.23	-.16	-.21	.09

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

As can be seen in Table 2, the most significant Independent/Dependent variable relationship was between VO_2 peak ($ml.kg^{-1}.min^{-1)}$ and RT (-0.81). There were also significant relationships between RT and Dips (-0.58), and sit-and-reach (-0.44).

A forward stepwise multiple regression was carried out with RT as the response (dependent) variable, and a model incorporating VO_2 peak ($ml.kg^{-1}.min^{-1}$) explained 65.8% of the variance in RT, leaving 34.2% unexplained. The inclusion of the other variables improved the prediction of RT to 76%, leaving 24% of the variance unexplained. Figure 1 shows the relationship between RT and VO_2 peak.

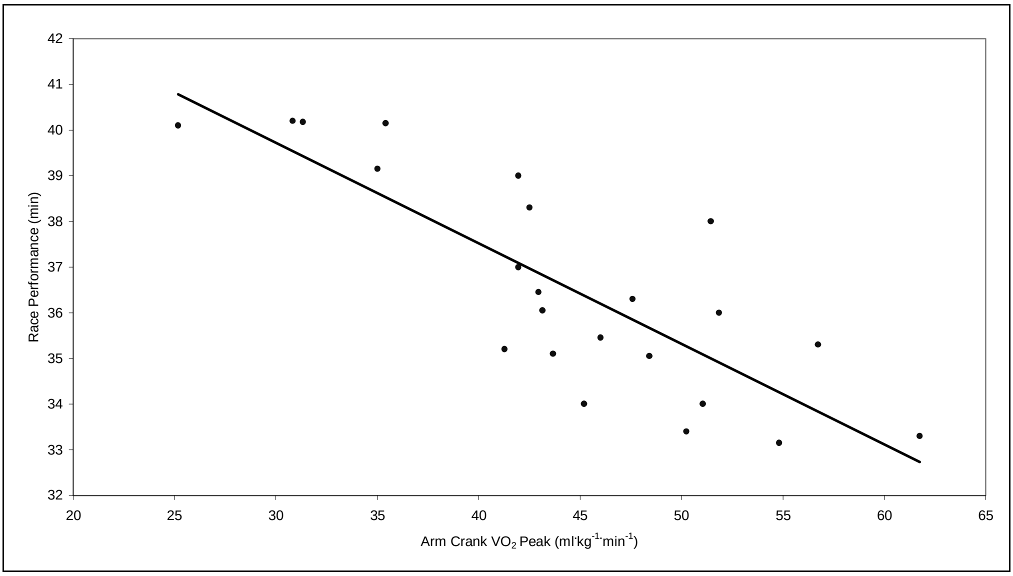

FIGURE 1. **RELATIONSHIP BETWEEN TIME-TRIAL PERFORMANCE AND VO_2PEAK**

DISCUSSION

Generally taking place under conditions of severe and prolonged exercise, kayak endurance racing is unique in its requirements on the upper body musculature. Further, the activities often take place in unfavourable environmental conditions. Specific training for participants probably results in greater muscle mass, more effective blood flow to the arms, and a relatively higher aerobic capacity to perform arm exercise in relation to leg exercise, compared to other athletes (Tesch *et al*., 1976).

What is even more unique is that while races of this nature can be considered aerobic events (for example the race in this study had a mean time of 36.56 mins), they have an important anaerobic component. Tactical considerations, including irregular surges or 'burns' require anaerobic energy sources. These are necessary from a psychological perspective *vis a vis* opponents, and perhaps more importantly, to either drop someone off your wake, or to utilise someone else's wake. Gray *et al.* (1995) found that wash-riding confers substantial metabolic savings, with VO_2 being 11% lower while wash-riding than when not.

The above suggests that both aerobic and anaerobic training are necessary for kayakers. Logically though, the parameters associated with aerobic metabolism are more important in the longer events than the shorter ones, and this lends support for VO_2 peak as a predictor variable for performance in this 7 km event.

Fry and Morton (1991) found that the expression of relative as opposed to absolute VO_2 max did not add power to its association with performance time. Intuitively, this makes sense, as the body mass is supported by the boat, and a large muscle mass may thus confer other advantages, such as strength. Similar findings have been reported for rowers, where, in a study investigating physiological predictors of 2000m rowing performance, there was a significant relationship ($r=0.848$, $p<0.001$) between VO_2 max and race performance (Cosgrove *et al*., 1999). The authors performed a stepwise multiple-regression, and found that VO_2 max was the single best predictor of race velocity, with a model incorporating VO_2 max explaining 72% of the variance in 2000m rowing performance. These results are of course similar to those obtained by the present study, although Cosgrove *et al. (*1999*)* utilised absolute VO_2 max as a predictor. So, logically and empirically, where body mass is supported (e.g. by the boat), performance should be better indicated by the absolute than the relative aerobic power. In this study, the correlation between RT and relative VO_2 peak was - 0.81, with the corresponding absolute value being a slightly lower (-0.74), both significant at $p<0.001$. This lack of congruence with theoretical expectations is perhaps explained by the fact that the kayaks used by participants are standard craft. So, all other things being equal, a heavy competitor will be lower in the water than a lighter one, resulting in increased surface drag (Cosgrove *et al*., 1999). This explanation agrees with Van Someren *et al. (*2000*)* who state that increased body mass in a kayaker will result in increased frictional drag, thereby increasing the resistance that must be overcome to propel the kayak. For this reason, and as a result of the statistical contribution outlined above, relative rather than absolute VO_2 peak was utilised.

Dips and RT were also significantly correlated (-0.58, $p=0.003$), indicating that the strength and endurance factors inherent in the exercise translate well to kayak performance. This could be attributed to the similar musculature employed by the two activities, *inter alia* Pectoralis minor and major, Triceps, Trapezius, and Deltoid (Hay & Reid, 1988).

Sit-and-reach also showed a significant relationship with RT (-0.44, $p=0.034$). This measure was not included in the battery as an explicit measure of general flexibility, as its limitations in that regard are well-known. It does however approximate the seated paddling position, and 'reaching' for the water may be an important mechanical advantage. One can of course over-reach, but generally speaking, it could be hypothesised that competitors with a reach advantage are able to displace water over a greater distance, conferring an advantage in velocity (assuming of course that stroke frequency is not negatively compromised). It was expected that this would be supported by a significant RT – armspan relationship, but this was not so. The explanation here clearly seems to be that armspan alone is not a significant enough predictor for performance in such a multi-faceted activity. Here it is worth noting that the prediction of future elite players from anthropometric measures may be problematic in younger age groups, primarily because growth, maturation, and differing rates of development can affect performance (Williams & Reilly, 2000). This is to say nothing of interests, motivation, psychological, and sociological factors, which all contribute to the complex construct that an ideal talent identification system demands.

With regard to contributions to predicting race performance, relative VO_2 peak obtained via arm ergometry was the only significant predictor ($p=0.006$). A model incorporating VO_2 peak explained 65.8% of the variance in 7 km paddling performance. Thus 66% of the variance in RT is explained by the variance in VO_2 peak, leaving 34% unexplained. Given the nature of the activity, the relative contribution of VO_2 is not surprising. One of the values of the findings of the present study is the specificity of the VO_2 peak test relative to the activity, enabling an accurate measurement of aerobic power contribution to performance. It is acknowledged that even though the test was performed in the field, it is a sophisticated measure. Nevertheless, with the increasing use of validated, portable ergorespirometry equipment, such testing will become more accessible in future.

Dips was the next closest predictor, but this was not significant ($p=0.153$). When all the variables were input, R Square was 76%, leaving 24% of the variance unexplained by the predictors. The fact that the other variables did not provide significant input indicates that the simpler field tests used are not suitable indicators for talent identification in this activity. This again emphasises the importance of specificity in testing. The following regression equation was developed: $T=46.345–0.22$ (VO_2 peak).

It is acknowledged that in the development of regression equations, the equation should ideally be tested on an equivalent sample. Cross validation could of course have been attempted by dividing the sample in half (reducing N). However, this would have reduced the ratio of subjects to independent variables, with low numbers predisposing towards spuriously high correlations. Furthermore, a small ratio limits generalisability.

CONCLUSION

Arm crank VO_2 peak was the strongest predictor of race performance over the distance covered in this research, but some doubt exists over whether relative or absolute measures would be best employed. In the context of talent identification, particularly given the skill and technical limitations of beginner kayakers, arm crank VO_2 peak (which is geared towards sport specificity) is a valid, reliable, preliminary indicator of potential. Using portable ergorespirometry equipment, the test can be administered in the field or in a laboratory. The other simple field tests employed in this study are unsuitable for talent identification or performance prediction in kayaking. It is worth noting that paddling is a multi-skilled activity, requiring aerobic power, anaerobic capacity, strength, endurance, balance, technical ability and a favourable morphology. As Shephard (1987) points out, it is still open to debate as to how much physiological testing can contribute to identifying talent, as skill, experience, and other factors make a vital contribution. Nevertheless, an arm crank VO_2 peak test may serve as a useful starting point.

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