The following article is a summary of doctoral research carried out investigating the physiological[(1)] factors associated with 200 m sprint kayak racing.

INTRODUCTION

Since 1994 the 200 m event has been included in the international and world championship sprint kayak racing programme. As a result, the shortest duration event has been reduced from approximately 1 min 40 sec for elite men's K1 500 m to less than 40 sec. There is plenty of anecdotal evidence and some scientific research (e.g. Tesch *et al.*, 1976; Fry and Morton, 1991) demonstrating that the differences in the physiological demands and requirements of the 1,000 m and 500 m events are fairly subtle. However, with this much shorter event it is expected that quite different demands will be imposed upon the paddler. The fact that very few data have been published regarding this event has prompted such research.

The aims of the current research were:

- to determine the physiological responses to 200 m kayak racing
- to identify the anthropometric[(2)] and physiological profile of 200 m kayakers of a range of abilities, and to determine the relationship of these with performance
- to question whether these findings could be used to prescribe an effective 200 m training programme

In addition, in order to determine the physiological characteristics of paddlers it was necessary to identify a suitable kayak ergometer.

1. THE PHYSIOLOGICAL RESPONSES TO 200 M KAYAKING

The only published information regarding the 200 m event is that of Byrnes and Kearney (1997). This showed that during a simulated 200 m trial (i.e. on an ergometer), 37% of the total energy expenditure was derived aerobically and 63% anaerobically. No data have been published concerning the physical demands of open water 200 m kayaking.

The current research measured the physiological responses of well-trained senior male paddlers performing a 200 m trial on the water.

The main results (reported as mean for all subjects) were:

- a peak rate of oxygen consumption ($\dot{V}O_2$) of 3.3 $L \cdot min^{-1}$
- a peak heart rate of 170 $beats \cdot min^{-1}$
- a peak post-exercise blood lactate concentration of 6.7 $mmol \cdot L^{-1}$

Although the peak $\dot{V}O_2$ (which reflects the aerobic energy yield) of 3.3 $L \cdot min^{-1}$ is lower than has been observed during the longer 500 m and 1,000 m distances, it corresponds to approximately 76% of the subjects' $\dot{V}O_{2peak}$ (3) during maximal kayak ergometry. Therefore, although Byrnes and Kearney (1997) have shown that only 37% of total energy for the 200 m is derived aerobically, paddlers must utilise quite a high aerobic capacity to achieve this. Similarly the heart rate (which reflects the work rate/metabolic demand of exercise) represented 87% of the paddlers' maximum heart rates achieved during maximal exercise on a paddling machine. These findings indicate that considerable demands are placed upon the ability of the kayaker to produce energy through aerobic means during this event.

The peak blood lactate concentrations following 200 m racing were 6.7 $mmol \cdot L^{-1}$, which again are lower than the concentrations that have been attained following the 500 m and 1,00 m events. Interestingly however, the fastest paddlers in the group exhibited far higher blood lactate concentrations (8.8 – 10.0 $mmol \cdot L^{-1}$), which are more comparable with those seen following 500 m and 1,000 m racing. This suggests that a well-developed glycolytic (anaerobic) capacity is important for successful 200 m racing. Due to the short duration of this event, it is likely that the 200 m requires a high rate of energy production from the anaerobic pathways, but is possibly too short in duration to maximally stress the capacity of these systems.

In summary, these findings illustrate that 200 m racing imposes high demands upon both the aerobic and anaerobic capabilities of the kayaker. This has implications for the prescription of appropriate training for this event.

2. A SUITABLE KAYAK ERGOMETER

Before the physical characteristics of 200 m kayakers and their relationship with performance could be identified, it was necessary to determine the suitability of an ergometer for the laboratory assessment of specific physiological factors. An ergometer must not only ‘feel’ similar to paddling but must also impose the same physiological demands as open water kayaking and be reliable (i.e. the results are reproducible).

The K1 ERGO (Australian Sports Commission) is an air braked kayak ergometer that may be interfaced with a personal computer for real time feedback and subsequent data analysis. Currently it is the most popular kayak ergometer in Australia and Great Britain.

In this study, paddlers performed 4 minute trials of both ergometry and water kayaking to compare the physiological responses. No differences were found in $\dot{V}O_2$ or $\dot{V}CO_2$ [4] (rate of carbon dioxide production), and only very small differences were found for ventilation rates and heart rate, showing that the ergometer imposed very similar demands to open water kayaking. In addition, it was found that ergometer performance could accurately predict the distance covered in a four minute open water kayaking trial with a standard error of 18 metres.

Repeated trials of high-intensity, short-duration exercise performed on the K1 ERGO indicated a high reproducibility for both the peak power achieved and the total work done (CV = 2.2% and 1.4% respectively[5]).

The K1 ERGO was found to be valid in terms of imposing the actual physiological demands of kayaking upon the athlete and of providing a reproducible method of physiological assessment. This means that we can be confident in the results gained from physiological tests carried out on the K1 ERGO ergometer.

3. ANTHROPOMETRIC AND PHYSIOLOGICAL CHARACTERISTICS OF 200 M KAYAKERS

A number of studies have been published describing the physical profiles of sprint paddlers (e.g. Tesch, 1983; Shephard, 1987; Fry and Morton, 1991; Misigoj-Durakovic and Heimer, 1992; Sklad *et al.*, 1994), though to date, no information is available on the characteristics of 200 m paddlers. In the present research, a battery of anthropometric and physiological tests was designed to determine the physical characteristics of 39 kayakers, and to establish their relationship with performance.

The 39 paddlers were categorised as 'elite', 'intermediate' and 'lower' according to 200 m race time. The elite paddlers (who had all represented Great Britain in international 200 m racing) were found to be characterised by the following (reported as mean ± S.D. for all elite subjects):

- a relatively high body mass (85 ± 5 kg)
- large upper body dimensions of chest circumference (106.9 ± 2.4 cm), tensed upper arm girth (36.9 ± 1.3 cm) and tensed forearm girth (31.3 ± 1.1 cm)
- a high degree of mesomorphy (i.e. a muscular build)
- a large lung capacity (forced vital capacity = 6.31 ± 0.67 L)
- the ability to achieve a high power output at their lactate threshold(6) (167 ± 19 Watts) and at their $\dot{V}O_{2peak}$ (251 ± 32 Watts), demonstrating high endurance capacities
- well developed rates and capacities for anaerobic exercise (i.e. power and speed endurance)
- high levels of upper body muscular strength

However the elite paddlers exhibited lower $\dot{V}O_{2peak}$ values relative to body mass, and a higher level of body fat than the intermediate and lower ability paddlers.

A number of anthropometric and physiological attributes were significantly related(7) to 200 m performance. The strongest of these relationships (in descending order) were as follows:

- total work done in 30 sec ergometer sprint test (i.e. anaerobic capacity / speed endurance/
- peak power in 30 sec ergometer sprint test (i.e. anaerobic power / speed)
- power output at the lactate threshold
- power output at $\dot{V}O_{2peak}$
- chest circumference

Further analysis of these findings indicated that 70% of the variance in 200 m performance between subjects was accounted for by the total work done in the 30 sec ergometry test and the power output at the lactate threshold. Together, these factors could predict performance with a standard error of 1.7 seconds.

Similar relationships with performance were also found in respect to the 500 m event. However, the present research and previous findings (Fry and Morton, 1991) indicate that $\dot{V}O_{2peak}$ and measures of endurance capacity are the attributes most highly related to 1,000 m and marathon racing performance

The present research not only highlights the physical characteristics of international 200 m paddlers but also reveal the relationship of specific anthropometric and physiological factors with performance. This supports the previous findings, demonstrating that 200 m racing requires considerable development of both aerobic and anaerobic energy systems. The relationships between physical characteristics and performance demonstrate the most important performance influencing factors for 200 m racing. This provides valuable guidelines for the prescription of physical training; specifically that the 200 m kayaker must develop superior levels of anaerobic power and capacity, whilst simultaneously establishing sound endurance capacities.

4. SPECIFIC TRAINING FOR 200 M SPRINT KAYAKING

The efficacy of these guidelines was investigated by exposing a group of paddlers to such a training programme for a 6 week period during the competitive season. This concentrated on the development of anaerobic power and capacity and sought to provide sufficient stimulus to maintain their aerobic conditioning.

The training programme consisted of:

- speed (1 x per week)
- lactate tolerance / anaerobic capacity (2 x per week)
- strength and power (2 x per week)
- transition / threshold training (2 x per week)
- base endurance (1 x per week)

A group of 8 junior national development squad paddlers followed this training programme for a period of 6 weeks immediately preceding the start of the competition period of the training year. Physiological parameters and performance of these paddlers and of a control group of 8 similar standard paddlers who continued their normal training, were measured before and after the programme.

Whilst the training group significantly improved their performance by 6.9%, the control group of paddlers also improved by 4.1%. Although this difference between the groups was not significant it did show that the training programme was more effective in improving performance. The training group also significantly increased their anaerobic power and capacity. Endurance capacity of the paddlers was assessed by the determination of power outputs corresponding to fixed blood lactate concentrations of 2 mmol·L^{-1} and 4 mmol·L^{-1} during an incremental ergometry test. Both the training and control groups exhibited very small increases in their endurance capacities.

This study showed that an accurate knowledge of the physiological demands and requirements of the 200 m event assists in the prescription of specific training for the 200 m event, resulting in significant increases in performance and measures of anaerobic power and capacity. Comparison with the control paddlers shows that although there was no significant difference, a margin of 1.3 seconds in favour of the training group, was achieved. The findings also suggest that only relatively low volumes of aerobic training are required to maintain aerobic conditioning for a 6 week period during the competitive season.

CONCLUSIONS

The conclusions of this research are as follows:

- The 200 m event requires a large contribution of both aerobic and anaerobic energy and therefore paddlers must address both of these in their training plan
- Elite 200 m paddlers are characterised by high levels of muscularity and muscle strength, very high levels of speed and speed endurance, and perhaps surprisingly, well developed capacities for endurance exercise
- These data can be used to prescribe specific 200 m training
- The K1 ERGO is a suitable ergometer for the physiological assessment of paddlers

GLOSSARY OF TERMS

(1) Physiological – relating to the function of the body's systems (e.g. cardiovascular, respiratory, metabolic and muscular).

(2) Anthropometric – relating to the measurements of body dimensions.

(3) $\dot{V}O_{2peak}$ – the peak rate of oxygen consumption. $\dot{V}O_{2max}$ is the traditional 'gold standard' measure of the maximal power of the cardiorespiratory system and is accepted to be a major determinant of high intensity endurance exercise. For upper body exercise the term $\dot{V}O_{2peak}$ is preferred.

(4) $\dot{V}CO_2$ – the rate of carbon dioxide production. This reflects the utilisation of energy substrates and the degree of anaerobic energy provision during exercise.

(5) Coefficient of Variation (CV) – a measure of the consistency of measures, i.e. how much measurements differ from one another.

(6) Lactate Threshold – the work rate beyond which a rapid increase in blood lactate is observed. This represents the highest exercise intensity that may be achieved without an accumulation of lactate and may therefore be maintained for prolonged periods.

(7) Significance – statistical significance refers to the confidence associated with a result. A result is significant if we are at least 95% confident that the result has not occurred by chance.

REFERENCES

Byrnes, W.C. and Kearney, J.T. (1997). Aerobic and anaerobic contributions during simulated canoe/kayak events. (Abstract). *Medicine and Science in Sports and Exercise,* 29, S220.

Fry, R.W. and Morton, A.R. (1991). Physiological and kinanthropometric attributes of elite flatwater kayakists. *Medicine and Science in Sports and Exercise,* 23, 1297-1301.

Misigoj-Durakovic, M. and Heimer, S. (1992). Characteristics of the morphological and functional status of kayakers and canoeists. *Journal of Sports Medicine and Physical Fitness,* 32, 45-50.

Shephard, R.J. (1987). Science and medicine of canoeing and kayaking. *Sports Medicine,* 4, 19-33.

Sklad, M., Krawczyk, B. and Majle, B. (1994). Body build profiles of male and female rowers and kayakers. *Biology of Sport,* 11, 249-256.

Tesch, P.A., Piehl, K., Wilson, G. and Karlsson, J. (1976). Physiological investigations of Swedish elite canoe competitors. *Medicine and Science in Sports and Exercise,* 8, 214-218.

Tesch, P.A. (1983). Physiological characteristics of elite kayak paddlers. *Canadian Journal of Applied Sport Sciences,* 8, 87-91.