A BIOMECHANICAL AND PHYSIOLOGICAL COMPARISON OF OLYMPIC FLATWATER CANOEING

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ABSTRACT

Simulation of sporting activities for the purpose of assessing physiological parameters and for conditioning athletes has been an important development within the sports world. The purpose of this study was to compare Olympic flatwater canoeing technique to that of an ergometer developed by Pyke et al. at Dalhousie University. The comparison, using three national team members, was both physiological and biomechanical in order to determine; 1) if accurate physiological measurements focusing on the upper body during racing conditions could be matched while using the laboratory ergometer; 2) if the ergometer movement patterns closely approximated the actual on-water racing stroke.

The results indicated that the techniques were similar physiologically and different biomechanically. VE and VO_2 max, for the 500 m. race and for a simulated 500 m. trial were close and consistent across all S's. Results for the 1000 m. were acceptable, but not as accurate as the 500 m. The use of the Pyke ergometer was judged on the whole to be a valid physiological testing procedure. The major difficulty with the ergometer was that it forced all S's to alter their racing strokes in order to successfully maintain movement of the mechanism. Changes in movement and velocity patterns of the trunk, arms and hands of all S's were considerable and led to the conclusion that this ergometer, in its original design, not be used as a training device.

INTRODUCTION

High performance athletes involved with Olympic flatwater canoeing in Canada are at a disadvantage in regard to technique training and conditioning during the 4-5 months when climatic conditions are not favorable for on-water training. In order to reduce this disadvantage, some sport scientists (Pendergast et al., 1979; Pyke et al., 1973; Klassen et al., 1970) have

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attempted to develop specific upper body simulator ergometers that measure and assist in conditioning the physiological components specific to the sport of canoeing.

The purpose of this study was to determine if the on-water performances of elite C1 paddlers would be closely matched by their performance on the Pyke simulator. This was accomplished by comparing selected biomechanical and physiological parameters.

DATA COLLECTION

Three C1 paddlers from the Canadian canoe team ranging in age from 15 to 23 years of age participated in the study.

The C1 canoeing ergometer studied consists of a modified Monark bicycle ergometer (Pyke et al., 1973). Every attempt was made to ensure that the paddler assumed the same anatomical position on the ergometer during the complete stroke cyle as would occur on the water. This was accomplished by having the athlete use his own kneeling pads and other paraphernalia. The paddle used by the subjects on the ergometer was modified, with only the handle and shaft portions of a regulation racing paddle being used.

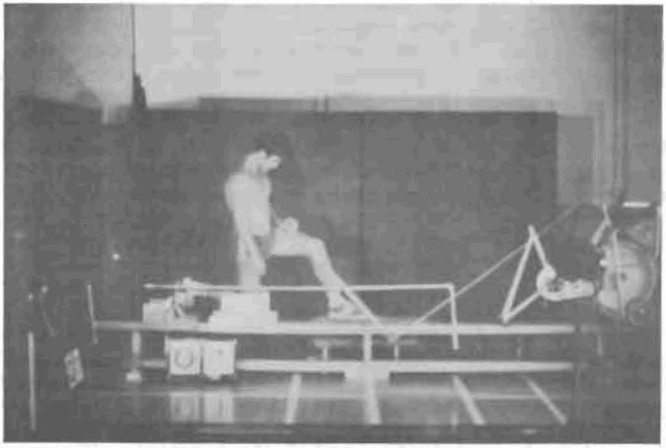

Figure 1.
Pyke Ergometer

The on-water competitive craft (Struer Co., Denmark) complied with all competitive specifications. The racing paddle used during the on-water testing was chosen by the subject.

Filming was conducted under two conditions. The subjects demonstrated on-water paddling technique at a stroke rate which was comparable to the mid-phase of a 1000 m race. A Locam 16 mm camera was fixed to a researcher by way of a body harness. The camera, battery drive and cameramen were positioned in a motorized boat moving at the same rate of speed as the subject in the canoe. Filming of the subjects was taken from the lateral perspective, at an exposure rate of 100 frames/sec. with a 75 mm zoom lens, under daylight conditions.

Filming of the canoe ergometer was performed in the laboratory, and was taken from the lateral perspective utilizing a 25 mm lens at an exposure rate of 100 frames/sec.

Under both test conditions several trials were filmed each containing numerous complete stroke cycles. Once proper rhythm and stroking smoothness were established, one complete stroke for each subject was selected randomly for comparison using the mid-portion of both the on-water and ergometer trials. This was done in order to eliminate any irregularities that might occur near the beginning and end of the trials.

The physiological evaluations for both on-water and simulator work sessions were conducted using the same equipment. With regard to on-water performance, physiological data were collected throughout the second portion of both a simulated 500 and 1000 m event. The subjects breathed through a two-way valve attached to a modified white-water helmet. The mouthpiece apparatus was connected to a three-way valve located at the rear of the helmet.

The expired air samples were collected in meterological ballons which were secured to the stern of the canoe. Sample of air (1 liter) was taken from the mixed expired air and analyzed for oxygen and carbon dioxide content with Beckman OM-1 and LB-2 analyzers respectively. The analyzers were calibrated with known gases. The total expired volume was determined by evacuating the ballons through a calibrated dry gas meter (Parkinson-Cowan, CD 4).

In the laboratory, all the phsyiological data were collected in the same manner as the on-water event with the exception that samples collected for each minute were progressive and continuous, with voluntary exhaustion used as the termination point.

ANALYSIS OF DATA

The paddling stroke was divided into three phases and four positions for analysis (Kearney et al., 1979; Plagenhoef, 1979). Phase 1: that portion of the stroke from initial water contact with the blade tip to the point where the paddle was 90° to the water surface (vertical). Phase 2: that portion of the stroke from the vertical position of the shaft to that position when the upper hand had minimal absolute horizontal displacement. Phase 3: that position of the stroke from the minimal movement of the upper hand forward to the position when the lower hand has initiated forward movement as it initiates the recovery of the blade from the water.

The movement patterns of both hands were measured by hand digitization, and included angle of travel from position one through four (Kearney et al., 1979); Plagenhoef, 1979). The displacement of the torso was measured by the angle of the torso at position one through four during the three phases of the stroke.

RESULTS

The absolute distances travelled by the upper and lower hands between the positions which delineate the three phases during both the on-water and ergometer are shown in Table 1. There were substantial intrasubject differences when comparing on-water and ergometer patterns.

TABLE I

Table 1: Comparison of Distance (Metres)* Travelled by Top and Bottom Hands, Between the Analysed Positions.

		Positions 1-2		2-3		3-4	
		top	bottom	top	bottom	top	bottom
Subject #1	on-water	.3048	.6858	.4420	.7772	.3048	.3048
	ergometer	.4938	.5029	.2896	.5334	.1829	.7286
Subject #2	on-water	.4145	.4877	.2316	.4755	.4511	.5730
	ergometer	.2012	.2560	.2012	.3901	.1280	.2438
Subject #3	on-water	.2682	.5364	.2682	.8047	.2926	.2073
	ergometer	.3048	.3780	.1463	.3170	.2073	.3048

* minus boat displacement

Table 2 indicates the direction of travel for the top and bottom hand during both the ergometer and on-water stroke which further substantiates the differences in movement pattern for each subject.

TABLE II

Table 2: Comparison of Direction of Travel of Top and Bottom Hand During On-Water and Dry Land Canoeing. (Degrees from horizontal)

		Positions 1-2		2-3		3-4	
		top	bottom	top	bottom	top	bottom
Subject #1	on-water	65	137	126	178	143	194
	ergometer	60	101	94	163	140	206
Subject #2	on-water	53	116	107	170	137	183
	ergometer	60	123	86	166	142	196
Subject #3	on-water	53	125	114	187	133	191
	ergometer	46	103	97	166	116	194

Trunk movement as measured by the changes in the trunk angle during the four stroke positions also shows differences among subjects (Table 3). The ergometer also produced changes in trunk movement which differ from on-water patterns.

TABLE III

Table 3: Comparison of Trunk Angle at 4 Positions During On-Water and Dry Land Canoeing

Subject		On-Water (L)°	Ergometer (L)°
Subject #1	Pos. 1	55	65
	Pos. 2	53	45
	Pos. 3	66	50
	Pos. 4	90	55
Subject #2	Pos. 1	55	57
	Pos. 2	55	50
	Pos. 3	74	50
	Pos. 4	85	60
Subject #3	Pos. 1	59	65
	Pos. 2	45	55
	Pos. 3	62	60
	Pos. 4	90	65

A comparison of the films of the ergometer and on-water stroke suggested that the same gross musculature was involved in spite of the fact that the movement patterns on the ergometer were shorter in duration and more acute in the direction of travel.

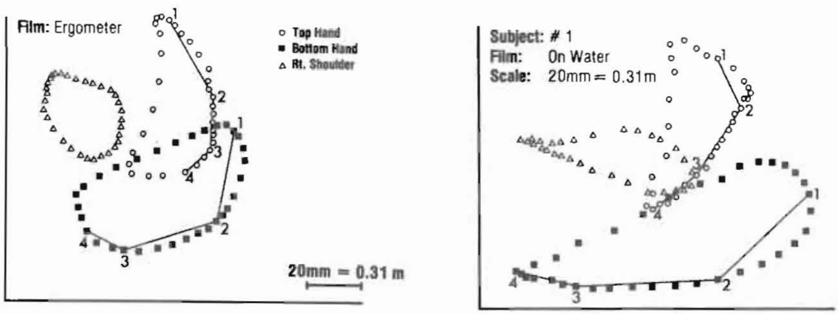

Figure 2.
Comparison of Movement Patterns
On-Water/Ergometer for Subject 1.

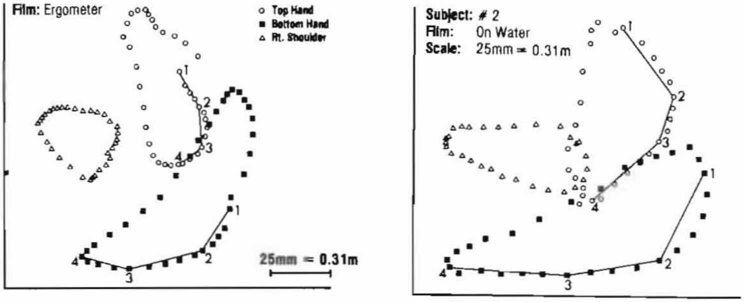

Figure 3.
Comparison of Movement Patterns
On-Water/Ergometer for Subject 2.

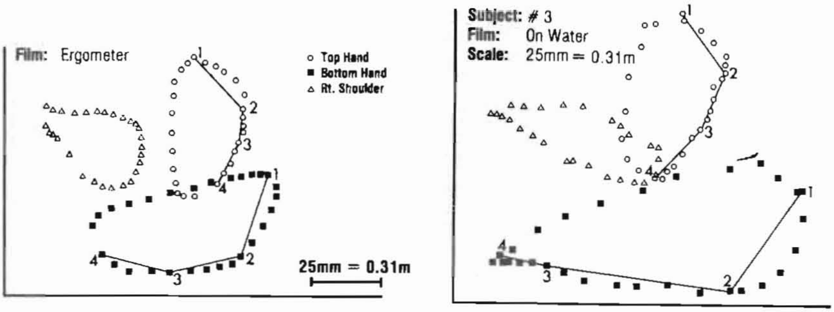

Figure 4.
Comparison of Movement Patterns
On-Water/Ergometer for Subject 3.

The physiological variables measured were similar for both the on-water and ergometer trails. The oxygen consumption values (l/min.) and respiratory quotient (R.Q.) were very similar between the ergometer and the 500 m event (Table 4). The mean ventilation volume was lower for the ergometer when compared to the 500 m event. The physiological data for the 1000 m event were not consistent with either the 500 m event or the ergometer (Table 4). The ventilation volumes were similar for the 500 and 1000 m events but were lower on the ergometer. The oxygen consumption data for the 1000 m events was considerably less than for the ergometer and 500 m event (Table 4).

TABLE IV

Table 4: Cardiorespiratory Data for Canoeing, From 500m, 1000m and Simulator Ergometer

Parameter	500m	1000m	Ergometer
Ventilation (VE) (L/min)	104.3	106.4	82.8
Oxygen Consumption (VO_2): (L/min)	3.40	2.58	3.40
(ml/kg/min)	48.56	36.85	48.55
Respiratory Quotient (R.Q.)	1.02	1.5	1.1

A major limitation of the ergometer is that the relationship between the body and position of paddle during the complete stroke cycle was reversed compared to on-water technique. With regards to the on-water stroke, the subject's body moves past the paddle whereas on the ergometer the paddle shaft moves past the athlete. Similarily, the ergometer appears to shorten and change the direction that both hands travel particularly in phase 3 of the stroke. In addition, the trunk movements associated with the ergometer technique are not comparable to the trunk extension movements observed for the on-water stroke.

The discrepancies noted for on-water and ergometer techniques appear to be related to the mechanical limitations imposed on the athlete by the ergometer. One limitation appears to be the length of rope used to connect the paddle with the resistance mechanism of the ergometer. This particular feature of the ergometer appears to account for the incomplete trunk extension and displacement of the paddle shaft past the athlete. In addition, another problem area associated with this model of canoe ergometer is its use of a resistance mechanism that requires a two-sided continuous cyclic action. This feature forces the athlete to adjust his recovery phase in an attempt to maintain the momentum of the resistance wheel. The athletes have to overcome the slack in the rope during this phase since this will negate any possible application of force to propel the resistance wheel. Finally, the resistance mechanism is not variable from one phase to the next and requires continuous force application to maintain movement. In the case of the canoeing ergometer, the continuous cyclic rotation of the drive wheel does not occur, since the force applied by the paddle motion only occurs on one side and must rotate the resistance wheel 180^0. If the force applied is not sufficient to rotate the resistance wheel completely the pedal mechanism slows down and will eventually stop on each stroke. This changes the stroke mechanics that must be used on the ergometer compared to the mechanics used on the water.

Physiologically, it appears that the ergometer does simulate the requirements of the cardiorespiratory system as determined by oxygen consumption (VO_2). The VO_2 for the 500 m event and ergometer were very similar indicating that the oxygen cost of both there exercises is consistent. This was not the case with the 1000 m event and probably reflects the slightly lower relative stress to which the body must accommodate during this longer duration race.

The ventilation volumes (VE) for the ergometer were lower than those observed for the two "race" conditions. The reasons for this difference are unclear but may be related to the fact that the ergometer requires more of a strength effort due to the resistance wheel, and thus the athlete performs a slight valsalva maneuver with each stroke. This "breath-holding" which accompanies force or power related activities may explain why the ventilation volumes are lower.

In summary, the central cardiorespiratory demands of the ergometer and on-water performances appear to be similar. However, due to the differences in stroke mechanics brought about by the resistance wheel, the way in which the body accommodates to the exercise may be quite different. Also, the local muscular contractions would have to be differenct considering that the stroke mechanics are definitely different. Of particular concern is the distinct difference seen in phase one where the on-water motion of the lower hand dictates a smooth, strong contraction of the shoulder extensors. However, the ergometer graphs indicate a very abrupt motion of the bottom hand indicating that the muscular contractions would more closely approximating an isometric effort in order to overcome the friction of the wheel. The use of this canoeing ergometer (resistance wheel type) dictates the style of paddling done by an athlete. This diversion from the normal on-water stroke technique tends to alter the biomechanical and to a lesser extent the physiological approach to the event and would seem to be an undesirable training device.

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