SOME QUALITATIVE COMPARISONS OF BENT AND STRAIGHT CANOE PADDLING TECHNIQUES

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The bent paddle has become popular, not only among racers, but also among touring and recreational paddlers. The makers claim that the bent paddle keeps its pushing surface at a 90° angle to the water during the most powerful part of the stroke for a longer period of time than the straight paddle, thus maximizing horizontal propulsive forces.

The paucity of literature on the bent paddle suggested that a pilot study was needed. It was the purpose of the present study to compare bent and straight paddles, while being used in the bow of the canoe, at both slow (touring) and fast (racing) paces.

REVIEW OF LITERATURE

A review of the literature included materials presented in the scientific literature as well as material written for the practitioner (e.g., the performer or the coach/teacher).

Broer and Zernicke (1979:389-390) reviewed the leverage mechanics of the canoe and paddle. The canoe is a first class lever, with its fulcrum located at its center of gravity. When a force is applied, the canoe rotates around its center of gravity to accommodate the applied force plus any weight it may be carrying. The paddle is also a lever, in fact a combination of first and third class levers. The paddle acts as a first class lever when the bottom hand acts as the fulcrum for forces produced by the upper hand, and acts as a third class lever when the upper hand acts as the fulcrum for forces produced by the lower hand. A longer force arm and the potential for greater force can be achieved by placing the lower hand as far down the paddle as is comfortable.

The paddle should be placed in the water as far forward as possible, to keep the blade almost perpendicular to the water surface for the force producing phase. However, if the reach is too far forward, the paddle will enter the water at an angle, and some of its force will be directed downward, tending to lift the canoe. The flat surface of the blade should face the direction of movement through the water in order to maximize the force on the water. Failure to keep the blade close to perpendicular at the beginning of the stroke results in an amount of force being lost in a downward direction, while continuing the stroke too long brings the paddle to an angle in which a great deal of force is lost in an upward direction (Broer and Zernicke, 1979:392; Luttgens and Wells, 1982:498-500).

Mason (1980:10) estimated that in eight hours of paddling, about 14,400 strokes are used, and felt that choosing the correct paddle is very important. He favoured a short paddle with a narrow blade. The narrow blade means less resistance is met as it passes through the water, thus causing a less fatiguing stroke. The shorter paddle causes it to be used mainly as a first class lever because the lower hand remains stationary, while the upper hand drives straight forward.

The Canadian Canoe Instructors Handbook (1976) suggested that a 'trade-off' exists between broad and narrow blades. A large blade, though capable of producing more force, requires more energy to do so, while a narrow blade, though requiring less energy, is capable only of producing less force. Riviere (1969) preferred a wide-bladed paddle mostly because it can be used in a greater variety of situations. He also preferred a long one, equal to his height, because it allows "for more leverage" (i.e., a longer force arm) and permits the paddler to apply force farther out from the canoe for ease of maneuvering.

The paddle stroke involves a gliding and a propelling phase. Too long a glide phase leads to a drop in the canoe's speed and a high energy output to reaccelerate. The paddler has to develop a kinesthetic feeling for his movements, balancing the two phases to keep the canoe moving smoothly (Canadian Canoe Instructors Manual, 1976). Importantly involved, of course, are factors concerned with one vs. two man paddling and whether the paddler is located in the bow or the stern.

The most revolutionary development in the area of paddles (and the subject of this study) has been the bent canoe paddle. Hiddle (1978) claimed that the advantage of the bent paddle was that it enabled the paddler to use "more of one's body" in a stroke, and not just the arms and shoulders. In addition, at the end of the stroke when the paddler is at his strongest, the blade of a bent paddle is kept closer to a 90° angle to the surface of the water than a straight paddle (Fig. 1). Mason (1980) made similar claims for the bent paddle, citing that, in the critical area of a stroke when a paddler is at his strongest, more force than normal can be applied to propel the canoe forward, and less force is directed to pulling the canoe down into the water.

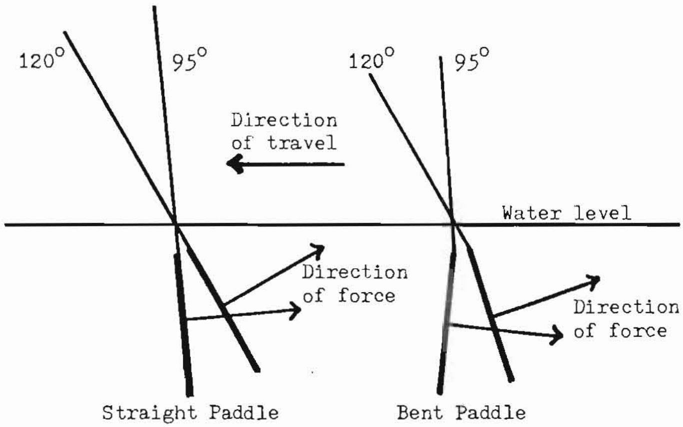

Figure 1. Angles of Blades through 'Critical' Area

Nolan and Bates (1982:50-57) set out to investigate the claims for the bent paddle with a scientific study involving five marathon canoe racers. Marathon style racing requires a canoe that is fashioned similar to the North American Indian canoe, a craft that is considerably different from those used in international style racing. The purpose of their study "was to evaluate and compare the effectiveness of the conventional straight canoe paddle and the 15^{o} angled paddle." Their results indicated significantly greater canoe velocity when employing the angled paddle. The angled paddle produced a more acute angle upon paddle entry to the water, and less rearward movement in the water during the period of maximum canoe acceleration. They concluded that significant benefits could be gained by using angled paddles during marathon canoe racing, and might even be of benefit for other canoeing or kayaking performances.

Many other studies have been concerned with paddling or rowing and include: anatomical ones concerned with basic muscular action (Scott, 1963; Broer and Zernicke, 1979); studies involving film analysis of Olympic style flatwater kayakers and canoeists (Mann and Kearney, 1980; Plagenhoef, 1979); a study of energy costs in rowing (Asumi, et al, 1978); and studies which take advantage of advanced telemetric devices to gain knowledge about force-time curves and boat acceleration (Ishiko, 1970:249-252; Schneider, et al., 1978:115-119).

PROCEDURE

A 29 year old male, with extensive canoeing experience, was selected to perform strokes in the bow of the canoe, while one high speed camera recorded his performances. He was instructed to paddle on the left side of the canoe at what he considered to be a slow, or touring pace, and then at a fast, or racing pace, using a straight and then a bent paddle. Both touring and racing paces were selected based on the implications of the Nolan and Bates study (1982:50-57). The subject was given a period of time to warm up and to become familiar with the canoe (which was a 14 foot, fiberglass recreational model), the filming environment (which was an Olympic-sized indoor swimming pool), and the two paddles (which were his own). The blades of the two paddles were the same size but the shafts were different, the straight one being 1.8 m long while the bent one was 1.4 m. The blade of the bent paddle was set at a 10^{o} angle to the shaft, while that of the straight paddle was in line with the shaft. A second person, using a straight paddle in the stern of the canoe, was instructed to paddle at the pace set by the bow and to maintain a straight course.

A 16 mm LOCAM camera was set to transport film at 90 frames per second, with a 1/270th second shutter speed. A rotating drum, which recorded real time, was set in the visual field of the camera; also, timing lights which operated independent of the camera were set at a frequency of 10 Hz. The visual field of the camera was about six metres wide, which was more than adequate to complete a paddling stroke for each variable. The subject's joints were marked at the wrists, elbows and left shoulder to facilitate film analysis.

Film analysis was done using a Recordak P40 in which the 16 mm film was magnified approximately 40 times. Tracings were made approximately every 1/10th of a second, of the performer, canoe and paddle, for each of the four paddling conditions. From these tracings, segment lines were evolved so that the following angles could be measured: the angle between the trunk and the horizontal, measured from the ventral surface of the trunk; the angles between the trunk and the left and right upper arms, i.e., shoulder joints, measured from the dorsal surfaces of the upper arms to the trunk line; and the angles between the upper arms and forearms, i.e., elbow joints, measured from the ventral surfaces of each segment.

The angles of blades in the water were of interest so tracings were made of the part of the paddle which was visible, namely, the shafts of the paddles. In the case of the straight paddle, a projection of the blade into the water was assumed to be an extension of the shaft, and could be measured as the angle the shaft made with the horizontal (Fig. 2). To account for the 10° angle of the bent paddle, tracings were made of the shaft and when measured, 10° was subtracted from each value.

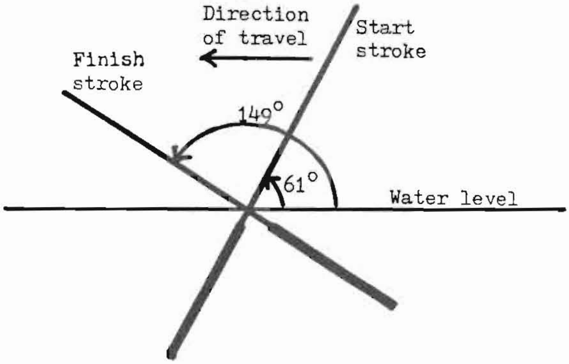

Figure 2. Method of Measuring Angle of Inclination of Blade

Internal timing lights and the rotating drum both confirmed that the camera transported the film at 90 frames per second, and this figure was used in all calculations.

RESULTS AND DISCUSSION

The following table summarizes the data obtained for each of the four paddling conditions.

TABLE 1
STROKE TIMES

	Straight Slow	"Bent" Slow	Straight Fast	"Bent" Fast
Total time for stroke (sec)	1.76	1.58	1.18	0.90
Potential propulsion phase (sec)	0.96	0.80	0.67	0.53
Number of strokes per min	33.98	37.78	50.51	66.67
Propulsion phase/min (sec)	32.82	30.23	34.19	35.53

The total time for each stroke was calculated as the time from blade entry until the next blade entry into the water. As can be seen from Table 1, the time taken to complete a stroke with the bent paddle, at both fast and slow speeds, was less than that of the straight paddle (0.90 and 1.58 compared with 1.18 and 1.76 seconds, respectively). The potential propulsion phase was defined for each stroke as the time between entry of the blade tip into, and exit from the water. As can be seen in the table, the potential propulsion phase, per stroke, for the straight paddle was greater than that for the bent paddle.

However, because of the bent paddle's shorter stroke time, more strokes were taken with it per minute (67 and 38 vs 51 and 34). As a result, in any one minute, paddling at a fast pace, 35.53 seconds were spent with the bent paddle in the water (i.e., in a potential propulsion phase of the stroke) while only 34.19 seconds were spent in the water with the straight paddle.

Interestingly, this relationship did not materialize for the slow, touring pace. At a slow speed, the bent paddle was in the water for only 30.23 seconds of every minute, whereas the straight paddle was in a potential propulsion phase for 32.82 seconds. It would be interesting to see if such a pattern existed with several athletes, and over several trials.

The data for this section suggest that the bent paddle has the potential to produce more forward propulsion over time than the straight paddle. In addition, more of this propulsion may be produced while the paddler is at the strongest part of his stroke. However, force-time curves vary from person to person (Ishiko, 1971; Schneider, et al., 1978); the advantages of the bent paddle (if there are any) may not be utilized equally by all persons.

In the critical area of the stroke, defined by most as the area covered by the paddle when it is between 95° and 120° to the horizontal, the bent paddle's blade directs more force in a horizontal direction than does that of the straight paddle (Fig. 1). It follows that the angle which the bent paddle leaves the water is always steeper than that of the straight paddle (Fig. 3). For the present study, the bent paddle's blade left the water at angles of 134° and 142°, for the fast and slow speeds. The significance of the steeper angle means the blade encounters less water resistance and slips out of the water easily, and at an earlier point in the stroke. The straight paddle emerged from the water later in the stroke when horizontal forces were diminishing and vertical forces were increasing; angles of 149° and 152° were recorded. The bent paddle also feathers to the side of the canoe more readily, reducing wind resistance.

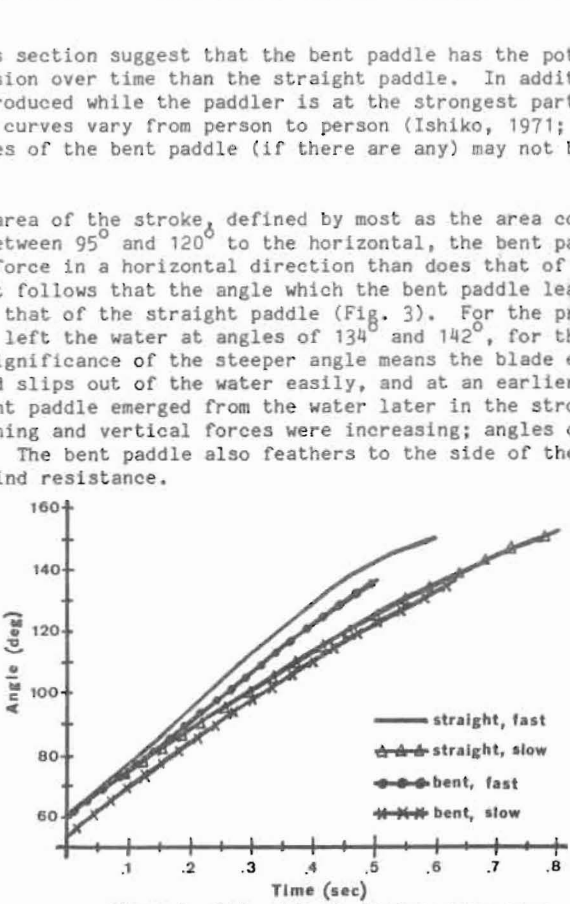

Figure 3. Angle of Paddle Blade to Water Level

On entry, the blade of the bent paddle may be more horizontal than the straight paddle and therefore in a position to direct forces downward; for the present study, only the bent paddle at the slow speed entered the water at a shallow angle of 54° while the other entries were calculated at 61°. Naturally, in response to the shallow entry, the reaction force on the canoe lifts the bow which also changes the surface area of the canoe which is presented to the water (i.e., more broad area). This aspect is, of course, seen as a disadvantage; it would be helpful to determine if the other advantages of the bent paddle outweigh this disadvantage which occurs during the early phase of the stroke.

Tracings made of the trunk showed that the trunk moved through a greater range of motion using the bent paddle (Fig. 4). It would appear that use of trunk muscles was more pronounced when paddling with the bent paddle than with the straight paddle. Considering that trunk muscles are generally stronger than upper arm and shoulder girdle muscles, the bent paddle stroke has the potential for applying more force and with less fatiguing results.

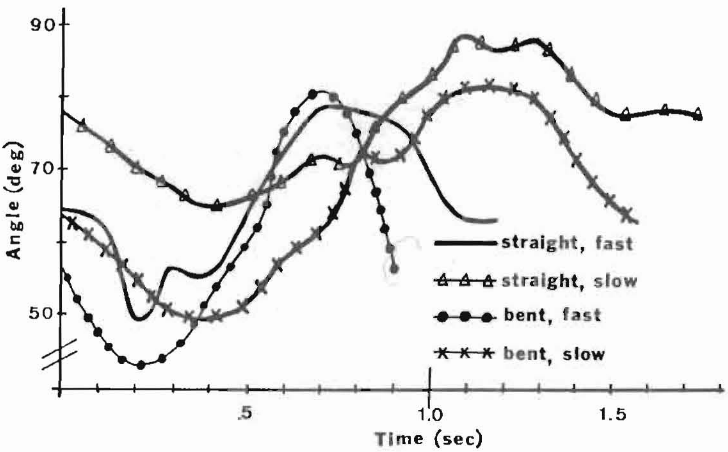

Figure 4. Angle of Inclination of Trunk for Each Variable

Also, in combination with the action of the upper extremities, which add additional degrees of freedom, the range of motion of the trunk provides a greater range through which the paddle can move. It has already been shown that the bent paddle moved through the water in a shorter amount of time than the straight paddle, at both speeds. If the bent paddle blade covered more distance in a shorter amount of time, it obviously moved more quickly. As well, using the work equation as the product of force and distance, the bent paddle had the potential for doing more work.

In a future study, it would be valuable if the displacement attributed to the paddle blade could be quantified. If the canoe remained stationary, it might be possible to extract such a figure; however, if the canoe is moving forward, the tendency is for the paddle's blade to remain fixed (in space) while the canoe and paddler lever themselves past the blade. Of course, the blade did not remain fixed and there were even instances within the stroke when the blade travelled forward as it was carried along by the canoe and paddler.

It can be inferred from the forward movement of the paddler's trunk and limbs, while using both the bent and straight paddles, that his center of gravity moved forward also. The action-reaction forces involved in this movement tend to decelerate the canoe (Mann, et al., 1980). A future quantitative analysis should study the detrimental effect of this on the canoe's motion.

In the absence of any electromyographic recordings, it was almost impossible to determine extent of upper extremity contribution to the strokes. For example, it was not possible to know whether a joint moved actively as a result of muscular forces acting on it directly, or passively as the result of an action elsewhere. It would appear that shoulder joint actions were similar for all strokes, except that the slow strokes were spread over time. There was usually a greater angle between upper arms and forearms when using the bent paddle, but this was partly a function of the shorter paddle. Overall, these results suggested that the arm muscles must do more work when using a straight paddle to achieve a similar force output to what would be produced using a bent paddle.

The lever actions of the paddles, though difficult to define, appeared similar for all strokes. Most literature treats the stroke as if the paddle is being used as a first or third class lever. Only Broer and Zernicke (1979) and Mann and Kearney (1980) acknowledged that a combination of these two levers is operational in which the upper hand pushes while the lower hand pulls the paddle around a pivotal point. In the present study, consistent with Mann and Kearney's findings, the bent paddle, which was also the shorter paddle, seemed to have its pivotal point move up its shaft as the stroke progressed, while the straight paddle's pivotal point seemed to shift down the paddle's shaft. Only if force outputs for each arm can be determined can one indicate the advantages of each system.

CONCLUSIONS

From the data generated in this study, there is the slighest suggestion that the bent paddle may be more advantageous to use in fast, race-paced canoeing. No such conclusion was warranted for slow, leisure-paced paddling. If used at all, it would appear that the bent paddle is more practical to use in the bow of the canoe because the bow stroke does not usually have to involve elements of steering. The "J" stroke, or other steering maneuvers which must be employed in the stern would not accommodate well to the configuration of the bent paddle. A possible combination for touring and/or racing could be a person in the bow using the bent paddle and one in the stern with a regular straight paddle.

Future studies should involve more subjects with more trials. Attempts should be made to quantify forces generated by the paddle, contributions of the paddle in the stern, and kinematics of the canoe itself. Electromyographic recordings of selected upper extremity and trunk musculature coupled with electrogoniometric recordings or cinematographic records of upper extremity movement would provide information concerning efficiency and fatigue elements.

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