The Effect of Different Paddle Blade Types on Forward Stroke

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Abstract

The purpose of this study was to identify the effect of different paddle blade types during forward stroke. Eight male elite kayak athletes participated. The EMG data of biceps femoris and biceps rectus muscles and kinematic data of knee joints and trunk were collected and frequency of strokes and driving distance per a stroke were calculated. The frequency decreased with type 2 blades from 1.00±0.15 to 0.87±0.12 stroke/sec (p=.03). The driving distance per a stroke increased with type 2 blade (2.76±0.16 to 2.92±0.38 m, p=.02). There was no significant result in other variables. The results of this study can be utilized for proper paddle blade fittings that may improve one's overall rowing efficiency.

Keywords: *Kayak, Forward stroke, paddle blade, Knee flexion angle, trunk rotation*

1. Introduction

Kayaks were originally developed and used for hunting and transporting passengers. It has not been too long since kayaking was featured as competition sports. The first official kayaking competition was held in 1866, and kayaking was introduced as demonstration sports at the 1924 Olympic in Paris. It then became a part of the Olympic event at the 1936 Berlin Olympics [1].

Forward stroke during kayaking is the first paddling technique that athletes learn in order to move a boat forward [2]. By performing efficient forward stroke (maximizing propulsion force and minimizing drag force), athletes can improve race times. Optimized biomechanical performance that increases the propulsive impulse or decreases the drag impulse during a stroke cycle is essential skill that needs to be taught [3]. The aim of sprint kayak racing is to cross the finish line within the fastest possible time. To move a kayak forward the paddler must generate enough propulsive force to overcome the drag forces acting on the boat.

Design of the paddle blade tremendously affects the kayak racing which is competition for race times within a given distance [4]. While muscular strength and psychological factors are not easily modifiable during competitions, paddle blade types are modifiable to each individual and can affect forward stroke efficiency and outcome of the race.

Of all the factors that affect the posture of rowing, grip width is closely related to rowing performance even though proper width may vary between different body features [5]. If the effect of the grip width on rowing performance can be identified, athletes and coaches can use different grip width accordingly in different situations. The grip width is the fundamental technique that needs to be learnt first for amateurs as well as elite athletes to improve rowing performance. The reason that grip width is very important is because it is related to the injury rates as well. Most common injury for kayakers is sprain and is usually occur in shoulder joints or other upper extremities. It has been assumed that grip width is closely related to the upper extremity injuries since it changes the movement of upper extremity[6]. One could manipulate grip width to avoid overusing certain muscles and prevent injuries. For average kayakers, the posture that requires less loading on muscles are preferred than that of giving stress on the muscular structures but more prolusions force and speed.

To increase the rowing efficiency, one could change sitting posture in the cockpit. Ryue *et al.*, (2012) reported that changes in knee flexion angles change the stroke movement and lead to changes in overall rowing performance [7]. Interestingly, other studies have reported that foot position and grip width are associated with athletes' ranking in the Olympic games [8-10]. These results support the importance of biomechanical factors during kayaking.

However, no research has specifically investigated the influence of different blade types on forward stroke performance. The purpose of this study was to identify the effect of different paddle blade types during forward stroke. The results of this study may be utilized for proper paddle blade fittings that may improve one's overall rowing efficiency.

2. Method

2.1. Participants

Eight male elite kayak athletes participated. An elite athlete was defined as an athlete that was registered as a professional player in the canoe federation during the time of year this study was conducted. All the subjects had at least 4 years of experience in competitions. All prospective subjects were screened for current injury before testing and were excluded if they previously had surgical intervention that could affect rowing performance. All subjects maintained their normal muscular strength level since they participated this study within a month after their national competitions. Prior to participation, each subject was informed of the study's purpose. They read and signed a consent form prior to measurement.

Table 1. Subject Characteristic

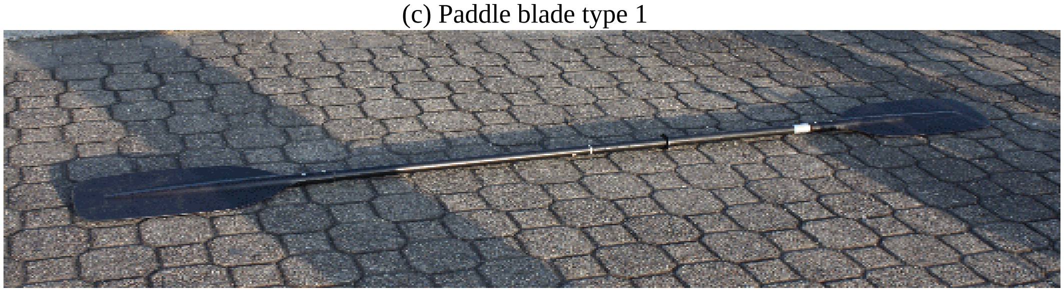
Subject (n=8)	Height (cm)	Body mass (kg)	Leg length (cm)	Arm length (cm)	Preferred Grip width (cm)
Mean	176.4	74.1	102.8	179.1	71.8
St.Dev.	6.6	7.1	6.4	6.8	6.2

2.2. Data Collection and Analysis

In this study, two different blade designs were tested. The type 1 design has one side of blade 90° rotated to the other. (Figure 1-(c)) The type 2 design has its two blades facing the same angle (Figure 1-(d)).


(a) Portable(inflatable) boat (b) Gyro sensor

(c) Paddle blade type 1



(d) Paddle blade type 2

Figure 1. The Equipments for Experiment

Subjects performed the forward stroke with the one type of blade first then they repeated with the other blade type. The order of paddle type was randomized. They were asked to use their normal grip style as usual. The subjects were encouraged to complete the task with as much work as possible. The distance that the boat traveled was 20 m. The EMG signal and kinematic data were collected once the boats passed 5 m. Subjects were allowed to take 5 min break between trials and were allowed to stretch and warm-up when they felt necessary. IMU sensors were attached on subjects' trunk, thighs, and legs. The range of motion (ROM) and angular velocities of knee joints and trunk were measured. The EMG electrodes were then placed on biceps femoris and rectus femoris bilaterally. In order for the electrodes to prevent from getting wet, they were wrapped around by vinyl wrap (Figure 2). IMU sensors were placed on the boat as well.

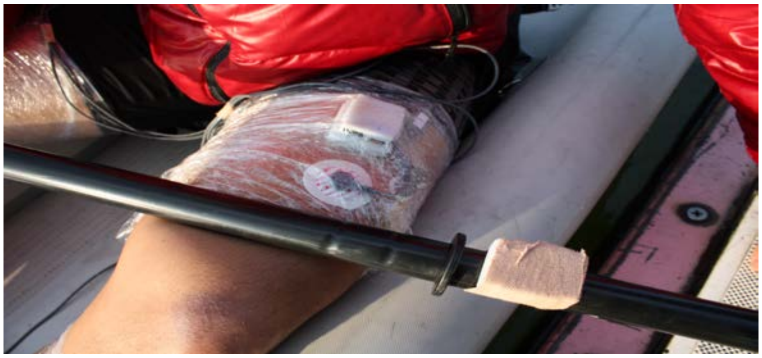


Figure 2. Attachment Placement of Gyro Sensor and Electrode

Video data were recorded in sagittal plane while subjects were performing the forward stroke. The data were calibrated using 2D DLT method and utilized to calculate forward stroke frequency per second and driving distance of the boat per a stroke.

EMG data were recorded at 1500 Hz. A bandpass filtere of 20~500 Hz was used. rectified RMS integrated EMG (mV*sec).

Frequency of strokes per second and driving distance during 1 stroke was observed to investigate kayaking performance. Bilateral knee joint flexion angles and angular velocities and longitudinal trunk rotation angles and velocities were analyzed to examine the biomechanical factors affected by the different blade types.

The analyzed period was during one left and right forward strokes started from the moment that the blade enters into the left side of water to the blade enters the same side again after one right stroke.

2.3. Statistical Analysis

Paired t test was performed using SPSS 20.0. The initial alpha level was set at $p<.05$.

3. Results

Means and standard deviation values are presented in tables and figures.

Table 2. Forward Stroke Performance by Stroke Frequency, Paddling Amplitude, Driving Distance

	Type 1	Type 2	P value
Stroke frequency[per/sec]	1.00 (0.15)	0.87* (0.12)	.03
Driving distance during 1stroke[m]	2.76 (0.35)	2.92* (0.38)	.02
Velocity of Boat[m/sec]	2.73 (0.16)	2.51 (0.16)	.12

Note. *significant difference between Type 1 and the Type 2, at $p<.05$, Standard deviation in parentheses.

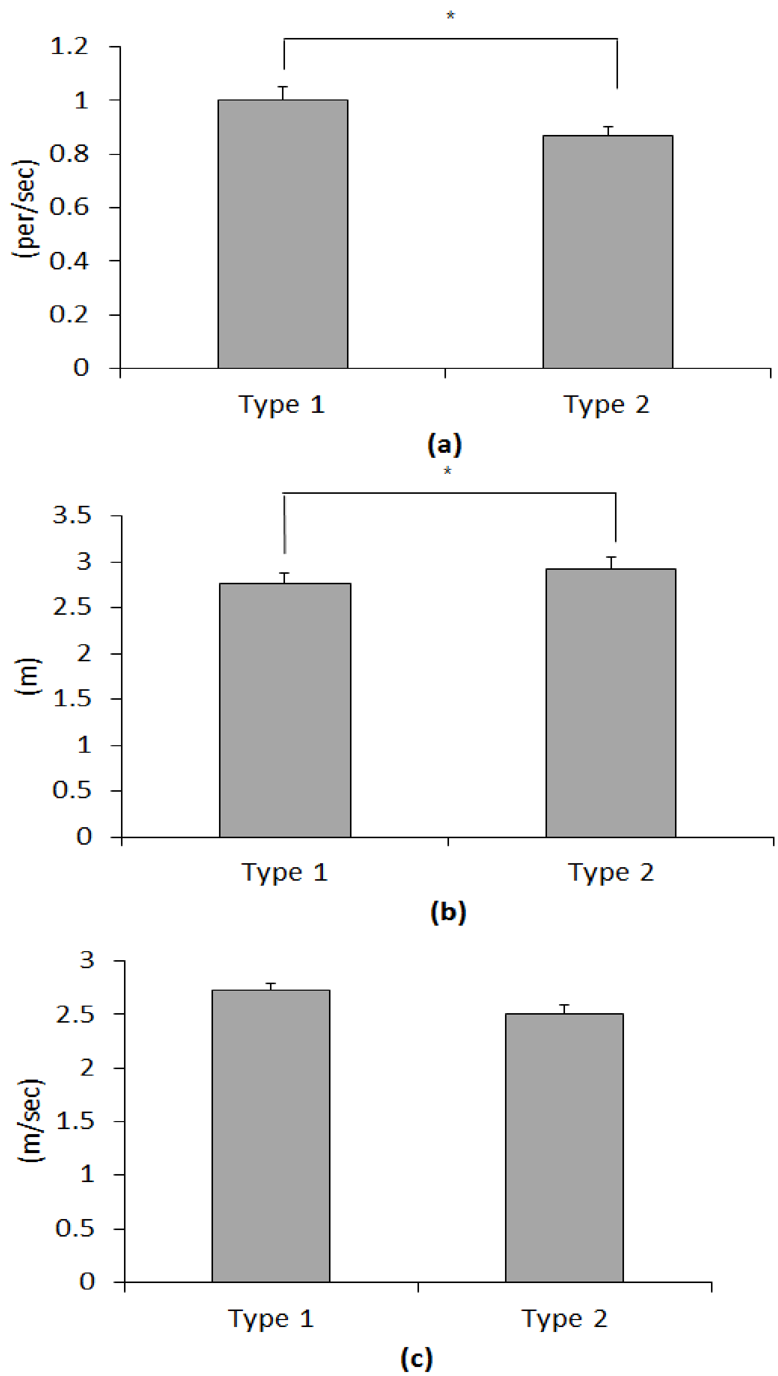


Figure 3. (a) Stroke Frequency. (b) Driving Distance during 1 Stroke. (c)Velocity of Kayak Boat Note. *significant difference at p<.05

Table 3. Joint Angle, RoM and Angular Velocity(mean±SD)

	Type 1	Type 2	P value
Joint Range of Motion [deg]			
Right Knee Joint angle	14.32±4.37	14.68±7.16	.832
Left Knee Joint angle	14.47±4.07	12.53±5.28	.350
Trunk Rotation angle	19.56±7.95	19.60±8.03	.912
Maximun Angular Velocity [deg/sec]			
Right Knee Joint velocity	107.73±39.79	120.21±39.73	.340
Left Knee Joint velocity	99.76±31.81	122.95±38.88	.163
Trunk Rotation velocity	114.51±40.23	122.02±33.64	.823

Table 4. Integrated EMG on Upper and Lower Extremity

unit[mV*sec]

	Type 1	Type 2	P value
Rt. Biceps Femoris	44.27 (22.22)	154.22 (21.39)	.44
Lt. Biceps Femoris	90.50 (44.72)	102.80 (98.41)	.82
Rt. Rectus Femoris	154.64 (66.49)	141.66 (98.31)	.65
Lt. Rectus Femoris	151.21 (74.73)	171.69 (100.22)	.63

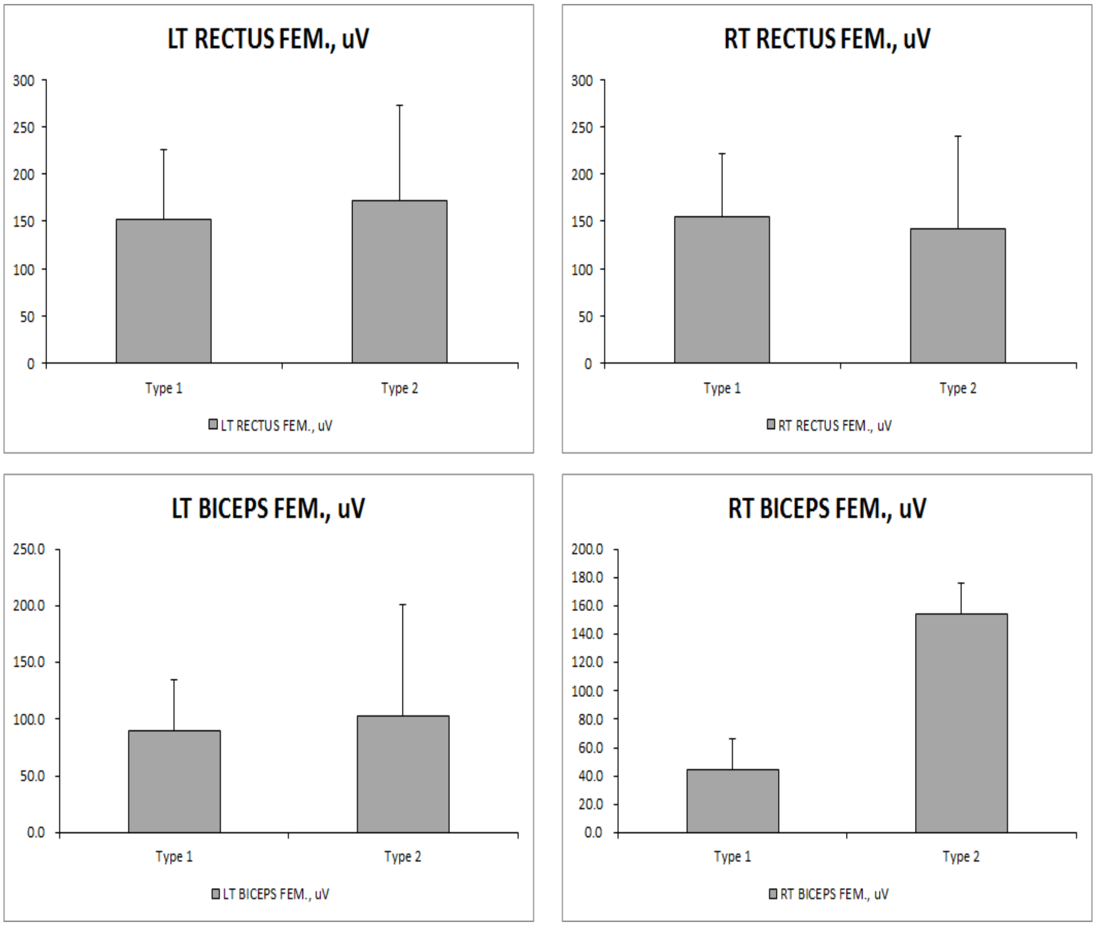


Figure 4. Integrated Electromyography of Thigh Muscles (Knee Joint Flexor/Extensor)

The frequency and driving distance per a stroke were significantly different between trials (Table 2). The frequency decreased with type 2 blades from 1.00±0.15 to 0.87±0.12 stroke/sec ($p=.03$). The driving distance per a stroke increased with type 2 blade (2.76±0.16 to 2.92±0.38 m, $p=.02$). There was no significant result in other variables.

4. Discussion

This study investigated the mechanism of the forward stoke pattern followed by the different paddle blade types. The dependent variables were the stroke frequency, driving distance with paired left and right strokes, speed of the boat, and knee joint and trunk ROM and angular velocity. Of the variables that represent kayaking performance, the stroke frequency and driving distance per a stroke were significantly different. The type 1 blade resulted in greater frequency and the type 2 blade resulted in greater distance per a stroke. With no significant difference in the speed of the boat, the type 1 blade led to greater frequency. Therefore, type 1 blade is thought to help better performance. The results indicate that type 1 blade led to greater number of strokes but was not efficient in terms of creating propulsion force. Ong *et al.*, (2006) reported that proper selection of a paddle blade is an essential step to efficiently propel a boat. Selecting a suitable paddle blade enables athletes to maintain maximum boat speed and stroke frequency [11]. A long paddle blade may create greater propulsion force, but it requires greater energy to recover for the next stroke because of the increased moment of inertia and weight. For this reason, the grip width that affects the inertial force plays vital role. Because the type 2 blade resulted in greater driving distance of the boat during one left and right stroke, the type 2 is considered as one that creates greater torque. According to Michael *et al.*, (2009), trunk moves left and right in order to provide later stability of a boat. A boat usually has not much of stability in lateral direction because of narrow width that is designed to reduce drag force. Any movement from trunk will aggravate the later movement of the boat and increase the drag. Therefore, it is needed to minimize unnecessary trunk movement to maximize speed of the boat [12].

The EMG data confirms the study by Ryue *et al.*, (2012). Their study states that support from the lower extremities are important during kayaking. In other words, a forward stroke delivers its resistant force against water toward an athlete's body, and then the resistance of the lower limb against the boat creates propulsion force [13].

Jackson(1995), Ong *et al.*, (2005, 2006), and Ackland & Lyttle(2006) investigated posture of strokes and size of boat. It was obvious that optimal body position and boat size for individuals should take into account different athletes' body features, height, and arms and legs length [14-15]. However, few studies have examined the relationship. Athletes are in situations that they have to go through equipment selecting process without information until they find optimal performance set-ups. However, some may choose one that gives them most comfort than greater performance [11]. This suggests that future studies are necessary to provide optimal and proper posture for athletes.

Michael *et al.*, (2009) defines a forward stroke in 4 phases (1. catch, 2. pull, 3. exit, 4. recovery). According to their study, paddling towards the front side of a boat initiates a stroke [3]. Trunk longitudinally turns towards the stroke and opposite lower limb pushes its foot support. The blade should be pulled and pushed straight back until it exits from water. At the same time, knee and hip joint should be extended in order to push back hips and rotate trunk. Trunk rotation consists of lumbar, shoulder, and pelvis rotations. During recovery, the trunk returns and starts rotating to the other side. The same movement left and right starts and ends the stroke. Michael *et al.*, (2009) also states that trunk rotation is essential factor during forward strokes. Because it enables athletes to use bigger muscles instead of limited linear shoulder movement in order to obtain propulsion. This movement may lead to physiologically more efficient energy consumption. As if Ackland *et al.*, (2003) reported, it seems that high level athletes utilize wider grip width and greater trunk rotation but reduce drag force by advanced stroke techniques [8]. Good performance in kayaking is determined by not only creating greater propulsion but also maintaining lateral stability to reduce drag [16].

5. Conclusion

In this study, the effect of different blade types on the forward stroke was investigated. This study can be utilized as guidance when athletes have to select blade types. Greater stroke frequency was observed with the type 1 blade and greater driving distance per stroke was observed with the type 2 blade. However, no significant differences were observed in knee joints and trunk rotation variables. These results indicate that types of blade influences the mechanism of forward stroke. Athletes should consider outcomes that different blade designs could provides and could select a proper blade for their purposes based on this study.

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