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The Relationship between Increasing Middle Range Length and Kayak Performance

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***Abstract*— Various biomechanical studies have been conducted to improve performance in canoe sprint kayaking. These studies showed that the middle, the phase in which the paddle generates the most propulsive force, and height of the stroke are important, but these indices have been analyzed in elite athletes, and whether they are beginner or intermediate athletes is unclear. In this study, we defined a new phase, the middle range, and proposed the stroke-middle ratio, which is calculated using the middle range, as a new index. To confirm the usefulness of this index, we measured 3D kayak paddling movements of beginner, intermediate, and advanced kayakers and calculated and compared their stroke rate and stroke-middle ratio. The results showed that there was a strong correlation (r=0.96) between kayaking performance and stroke-middle ratio, suggesting that the stroke-middle ratio and stroke rate can be used to evaluate performance in the field of instruction, including those in beginner and intermediate kayakers. The results suggest that the use of the stroke-middle ratio and stroke rate can be used to better evaluate performance in the field of instruction, including those in beginner and intermediate students.**

***Index Terms*— kayaking, Three-dimensional action analysis, Stroke, Evaluation index.**

I. Introduction

Since the Rio 2016 Paralympic Games, canoe sprint kayaking (Fig. 1) has been officially adopted as a sport, and canoeing has been attracting increasing attention. To achieve higher athletic performance, various scientific studies have been conducted, including physiological [1]-[3] and biomechanical studies [4]-[6]. Among them, kayak paddling, which is a propulsive motion, is considered a particularly important item for analysis [7]-[10]. Paddling has been studied mainly in terms of both form and stroke rate. In terms of form, catch, the moment when the tip of the paddle touches the surface of the water; finish, the moment when the paddle leaves the water, and middle, the moment when the paddle is perpendicular to the water surface in the sagittal plane, are used to classify the entire paddling. Of these, the middle phase is considered important because it is the moment when the most driving force is generated. However, since the middle phase is instantaneous, the method of analyzing it has not yet been established.

In addition, there was a strong negative correlation between the height of stroke and kayak speed in the paddling of elite

Fig.1 Canoe Sprint Kayaking

athletes [11]. For this reason, increasing stroke rate is currently the mainstream instructional strategy for improving kayak performance. However, no study showed whether this is also true for beginner and intermediate kayakers.

In this study, we first measured the paddling performance of beginner kayakers for 4 years, from 2017 to 2021, and investigated the improvement in performance and stroke rate. The results showed that the performance significantly improved, but the stroke rate did not change (Table 1). This suggests that the performance of beginner athletes can be improved without increasing the stroke rate. Based on these results, this study focused on the middle, which is considered an important phase, and defined the middle range, which is a wider range of the middle. This study aimed to clarify the influence of middle range on kayaking performance using data from beginner to advanced kayakers.

Table.1 Relationship between 200-m time and stroke ratio in beginner kayakers

	Subject	
	Beginner(2017)	Beginner(2021)
200m time	1'23"56	1'00"217
Stroke rate(stroke / min)	42.6	41.5

II. Subjects and Method

A. Subjects

The subjects consisted of five female kayakers, of whom one was an advanced kayaker, three were intermediate kayakers, and one was a beginner kayaker. The height and weight of the subjects were 160±5 cm and 53±5 kg, respectively.

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B. Middle range

Middle range was defined as the angle between the water surface and paddle seen from the sagittal plane. A paddle angle of 90° in Fig. 1 shows the general timing of the middle range. In this study, middle range was defined as an angle between 80° and 100° because it has a certain range of time and generates a large propulsive force.

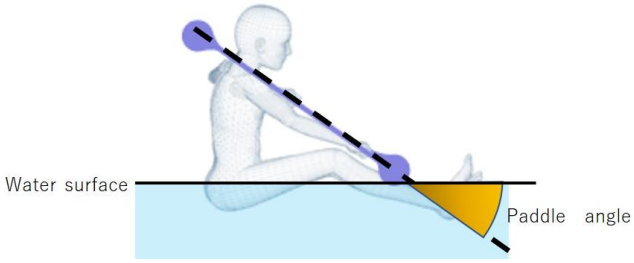

Fig. 2. Paddle angle

C. Stroke length and middle range length

In this study, stroke length is defined as the distance that the paddle tip travels between catch and finish. Middle range length is defined as the distance the paddle tip travels during the middle range.

D. Stroke-middle ratio

The greater the middle length, the greater the stroke length. Moreover, an increase in the stroke length causes a decrease in the stroke rate and performance (Gomes et al., 2020). Therefore, we believed it was important to increase the middle length and decrease the stroke length. We defined stroke-middle ratio (stroke length/middle length) as an evaluation index. The ideal value is as close to 1 as possible.

E. Measurement

Since kayaking is a water sport, it is ideal to perform measurements on the water, but some measurements are difficult to perform outdoors because they are affected by environmental factors such as wind and waves. Therefore, measurements using an ergometer are often performed indoors. In this study, indoor measurement using an ergometer was also conducted.

A three-dimensional motion analysis device, Vicon (Vicon Inc.), and an ergometer for kayaks, Kayak 02 (Start Line Inc.), were used as measurement devices. The measurement scene is shown in Fig. 3. A reflective marker was attached to the tip of the paddle, and the coordinates of the marker were measured at a sampling frequency of 100 Hz. The subjects were instructed to paddle as hard as they could for 10 s on the ergometer. Three trials were conducted, and a 5-min break was provided between each trial to confirm whether the experiment could be continued.

Since the load of the ergometer used in this study was larger than that of water, the results were smaller than the actual stroke rate.

F. Data analysis

The first three strokes of the data acquired in the measurement were deleted because they were not in a steady state. The numerical analysis software MATLAB (R2021a, MathWorks) was used to analyze the data. From the obtained coordinate data, the stroke rate and stroke-middle ratio were calculated.

II. Results

The results obtained are shown in Table 2. The 200-m time is the value actually measured on the water just before the measurement. Both the stroke rate and stroke-middle ratio were significantly different in intermediate and beginner subjects compared to advanced subjects.

A. Stroke rate

Comparing Intermediate 2 and Beginner (2017) kayakers, the stroke rate was larger in Beginner (2017) kayaker, but the 200-m time was faster in intermediate kayakers. However, the 200-m time of the intermediate student was faster than that of the beginner student (2017). In addition, when Intermediate 2 kayaker was compared with Beginner (2021) kayaker, there was no significant difference in stroke rate, but the 200-m time of Intermediate 2 kayaker was 5 s faster. The correlation coefficient between the 200-m time and stroke rate was r = -0.46, showing a rather strong correlation.

B. Stroke-middle ratio

The correlation coefficient between 200-m time and stroke-middle ratio was r = 0.96, indicating a strong correlation between 200-m time and stroke-middle ratio.

III. Discussion

From the results of stroke rate, it is clear that it is difficult to evaluate the performance of beginner and intermediate students only by stroke rate.

Regarding middle length, Beginner (2017) kayaker showed the largest value, but simultaneously, stroke length was also the largest, and 200-m time was the slowest among the subjects. This result is consistent with the findings of a previous study [11]. In addition, the stroke-middle ratio was also the largest, suggesting that this ratio defined in this study does not deviate from the results of previous studies.

However, among the three intermediates, Intermediate 3 kayaker showed the fastest 200-m time, despite having the lowest stroke rate and largest stroke-middle ratio. This may be due to the fact that mechanical factors, such as muscle strength, were not included in this study. To evaluate the performance in more detail, it is necessary to introduce kinematic factors.

Generally, it was suggested that the stroke-middle ratio is a useful index to evaluate the performance of beginner and intermediate athletes. When used together with the stroke-middle ratio, it can be expected to provide more effective instruction.

In the future, we will increase the number of advanced subjects and compare the stroke-middle ratio among advanced subjects to show that it is a useful index.

Table 2. Canoe sprint kayaking: 200-m time, stroke rate, and stroke-middle ratio in all subjects

	Subject					
	Advanced	Intermediate 1	Intermediate 2	intermediate 3	Beginner(2017)	Beginner(2021)
200m time	41"352	54"918	55"574	52"331	1'23"56	1'00"217
Stroke rate(stroke per min)	67.2	46.2*	41.4*	33.6*	42.6*	41.5*
Stroke length(mm)	387±76	349±93	417±57	417±77	880±62	465.3±42
Middle length(mm)	173±19	138±16	159±19	146±14	227±12	165.3±9.2
Stroke-Middle ratio	2.21	2.49*	2.61*	2.81*	3.87**	2.82*

*p<0.05, **p<0.01, compared with the Advance

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