IMPROVEMENT OF THE TRAINING PADDLE FOR A SWIMMER WITH UNILATERAL TRANSRADIAL DEFICIENCY

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Devices for swimmers with arm amputation/deficiency have not been sufficiently developed and therefore many improvements can be realized. A prosthesis for training of a swimmer with transradial deficiency was developed, although the paddle itself was not designed since a commercial paddle was connected to the socket [1]. Two type of paddle for a swimmer with transradial amputation/deficiency have been designed and commercially sold, although any discussion about their design is not available [2]. In another previous study, a paddle for training of a swimmer with transradial amputation/deficiency was designed based on the results of numerical simulation, and an actual prototype was developed [3]. However, since that paddle was designed based on the simulation with standard swimming motion, the paddle was found to be too large for an actual swimmer. Therefore, in another previous study, the swimming motion of a swimmer with unilateral transradial deficiency was analyzed by simulation in detail [4]. Based on the findings obtained in those previous studies, an improved paddle was newly developed in this study. The improved paddle is shown in Fig. 1(a). It consists of the so-called paddle part which has a hinge at the top, the rubber tube to prevent the paddle rotating excessively, the forearm part made of a duralumin pipe, and the curved plate to attach to the upper arm. To determine the dimensions of the paddle, a parameter study was conducted using the simulation model shown in Fig. 1(b). The results of parameter study are shown in Fig. 1(c) and (d). In the parameter study, an index R_T, which is defined by

$$R_T = r_D / r_I \tag{1}$$

was evaluated . The ratios r_D and r_I represent how much the averaged joint torque at the shoulder during underwater stroke with the paddle becomes larger than that without the paddle for the deficient and intact limbs, respectively. In this study, it was assumed that the value of R_T closer to 1 was better. From the parameter study, the bending angle at the elbow and the forearm length were determined as 30 degrees and 130 mm, respectively, as a compromise between the crawl stroke and backstroke. Performance comparison by simulation among four conditions are presented in Table 1. It was found that R_T of the newly developed paddle was successfully closest to 1 among the four conditions, while the other performance

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indices, such as the swimming speed and propulsive efficiency, were comparable to the other conditions. A test swimming in a pool was performed by a female swimmer with unilateral transradial deficiency (1.56 m height, 21 years old). The ethics approval by Tokyo Institute of Technology was obtained before the test (No. 2019026). A positive impression that the developed paddle was much better to swim than a commercial one could be obtained. More quantitative further evaluation will be the next step.

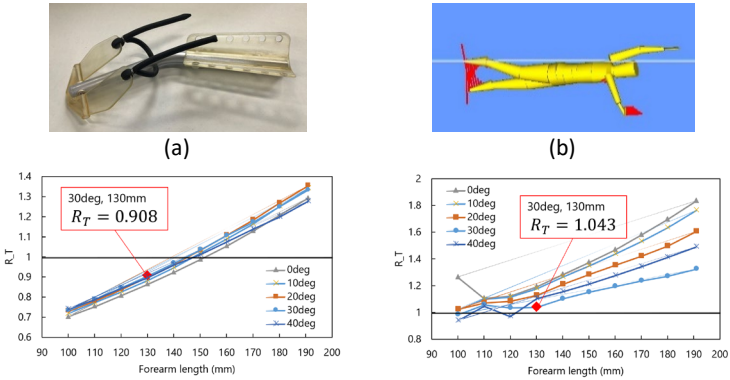

Fig. 1: Developed paddle and simulation results, (a) developed paddle (for the right arm), (b) simulation model, (c) dependency of R_T (ordinate) on forearm length (abscissa) and angle (legends) for crawl stroke, (d) dependency for backstroke.

Table 1: Performance comparison among new, previous, commercial, and no paddles.

	 New Paddle	 Previous Paddle	 Commercial Paddle	 No Paddle
Swimming Speed [m/s]	**1.38**	**1.53**	**1.39**	**1.25**
Propulsive efficiency	**0.188**	**0.222**	**0.205**	**0.173**
Paddle weight [g]	**147**	**135**	**72**	—
R_T	**0.91**	**1.49**	**1.26**	**0.39**

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