RELATIONSHIP BETWEEN 100 M RACE TIMES AND START, STROKE, TURN, FINISH PHASES AT THE FREESTYLE JAPANESE SWIMMERS

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The purpose of this study was to examine the relationships between the race performance and elapsed time in each phase composing the race. The races of Japanese top 113 male and 117 female swimmers in the 100 m freestyle event were analysed. For analysis, races were divided into four phases: start, turn, finish, and first and second half of stroke phases. Statistically significant correlations between the total race time and the times of the four phases were obtained ($p<0.001$). From these simple linear regression analyses, new procedure predicting the total race time from the elapsed time of the four phases was re-established. In both male and female swimmers, the time of two stroke phases (male: $r=0.692$, $r=0.797$, female: $r=0.874$, $r=0.876$) and turn phase (male: $r=0.710$, female: $r=0.869$) were highly correlated with the total race time.

KEY WORDS: race analysis, swimming, male and female.

INTRODUCTION: In the literature, competitive swimming races have been divided into four phases: the start, turn, finish and stroke phases (Pai, et al., 1984). Several studies (Arellano, et al., 1994; Wakayoshi, et al., 1992) reported that there were significant correlations between the total race time and elapsed time of these four segmented phases. Therefore, it can be reasonably supposed that the time reduction of each phase would directly link to the improvement of total race time.
A series of studies by Nomura (1996a, 1996b and 1997) and the study of Ikuta (1998) have tried to develop a prediction procedure for the times of the four segmented phases from the total race time and examined the validity of the procedure in breaststroke, backstroke and butterfly events. From the data of Japanese top level swimmers, the authors made an attempt to estimate the time of these segmented phases from the total race time using simple linear regression equations. The equations had provided coaches and swimmers a clear target to improve their swimming time in those days. However, as the performance of swimming have been improved drastically in the last decade, it is necessary to renew the formula using the results from recent competition. Thus, the purpose of this study had two aims: 1) to re-examine the relationships between the times of the four phases and the total swimming time of the 100 m freestyle in recent, high level competition, and 2) to derive a new formula for estimating the elapsed time for each phase to achieve the target race time.

METHODS: The swimmer's displacement during 100 m freestyle swimming events at Japanese national swimming championships from 2012 to 2014, were videotaped using two digital camcorders located at 60 frames per second. The subjects were 230 top level competitive swimmers (113 male and 117 female). Time data were collected in all preliminary heats and two final (B-final and final) at 100 m freestyle swimming events.
The whole race of 100 m freestyle was divided into four phases by the reached position of the swimmer's head: start, turn, finish phase and stroke phase. The start phase is the period from the starting signal to the 15 m line. The stroke phase of first half (stroke-1) is the period from the end of the start phase to the 45 m line. The turn phase is the period from 5 m before the wall of the pool until 15 m after the wall of the pool. The stroke phase of second half (stroke-2) is the period from 65 m until the 95 m line. The finish phase is from the final 5 m to

finish (goal touch). Elapsed time of each phase was calculated from the frame rate (the resolution of the time resolution is 0.017 s). To detect each phase clearly from the swimmer's head position, markers were located at 5 m, 15 m, 25 m, 35 m and 45 m point of poolside. The total and 50 m lap times were obtained from the official record.
Descriptive statistics were conducted for all variables. Correlation coefficients and simple linear regression analysis were used to estimate the relationship between each phase and the total race time for males and females separately. The statistically significant level was set less than 0.05.

RESULTS and DISCUSSION:
Table 1 and 2 shows the average elapsed time of each phase, correlation coefficients to the total race time, the slopes of the linear regression lines and the intercepts of the simple linear regression lines of 100 m freestyle swimming. Figure 1 shows the relationships between the elapsed time of start, stroke-1, turn, stroke-2 and finish phases and the total race times. As shown in Tables and Figures, the elapsed time of each phase and the total race time were moderately or highly correlated ($p < 0.001$) for both male and female swimmers. For the male swimmers, the second stroke phase and the turn phase demonstrated high, significant correlation with the total race time. On the other hand, for female swimmers, the two stroke phases (first and second halves) and turn phase showed high, significant correlation with the total race time. Moreover, simple linear regression analysis of race time over each phase revealed that the values of slope of the stroke phases and turn phase were higher than that of other phases. The magnitude of the slope of simple linear regression line indicates the strength of the influence on swimming performance of each phase. Moreover, Ikuta et al., (2001) described that the start and turn phases are important in determining the race time for 100 m event. Thus, it is considered that swimming and turn techniques mainly influence the performance of the 100 m freestyle swimming.

Table 1

Average elapsed time of four segmented phases and variables of simple linear regression lines between the elapsed time of the four phases and total race time of 100 m freestyle (male).

	male (n=113) Race Time (s) = 50.80 ± 0.88				
	start	stroke1 (first half)	turn	stroke 2 (second half)	finish
average (sec)	5.91	15.58	10.02	16.68	2.60
S.D. (sec)	0.21	0.33	0.22	0.43	0.11
r Value	0.481	0.692	0.710	0.797	0.460
95% Confiden	0.326	0.582	0.605	0.718	0.301
slope	0.117	0.260	0.176	0.391	0.056
intersept (sec)	-0.056	2.376	1.090	-3.188	-0.223

Table 2

Average elapsed time of four segmented phases and variables of simple linear regression lines between the elapsed time of the four phases and total race time of 100 m freestyle (female).

	female(n=117) Race Time (s) = 57.24 ± 1.10				
	start	stroke1 (first half)	turn	stroke 2 (second half)	finish
average (sec)	6.89	17.44	11.39	18.60	2.92
S.D. (sec)	0.22	0.39	0.24	0.42	0.10
r Value	0.607	0.874	0.869	0.876	0.571
95% Confiden	0.478	0.823	0.816	0.826	0.434
slope	0.120	0.308	0.190	0.332	0.051
intersept (sec)	0.045	-0.175	0.517	-0.398	0.012

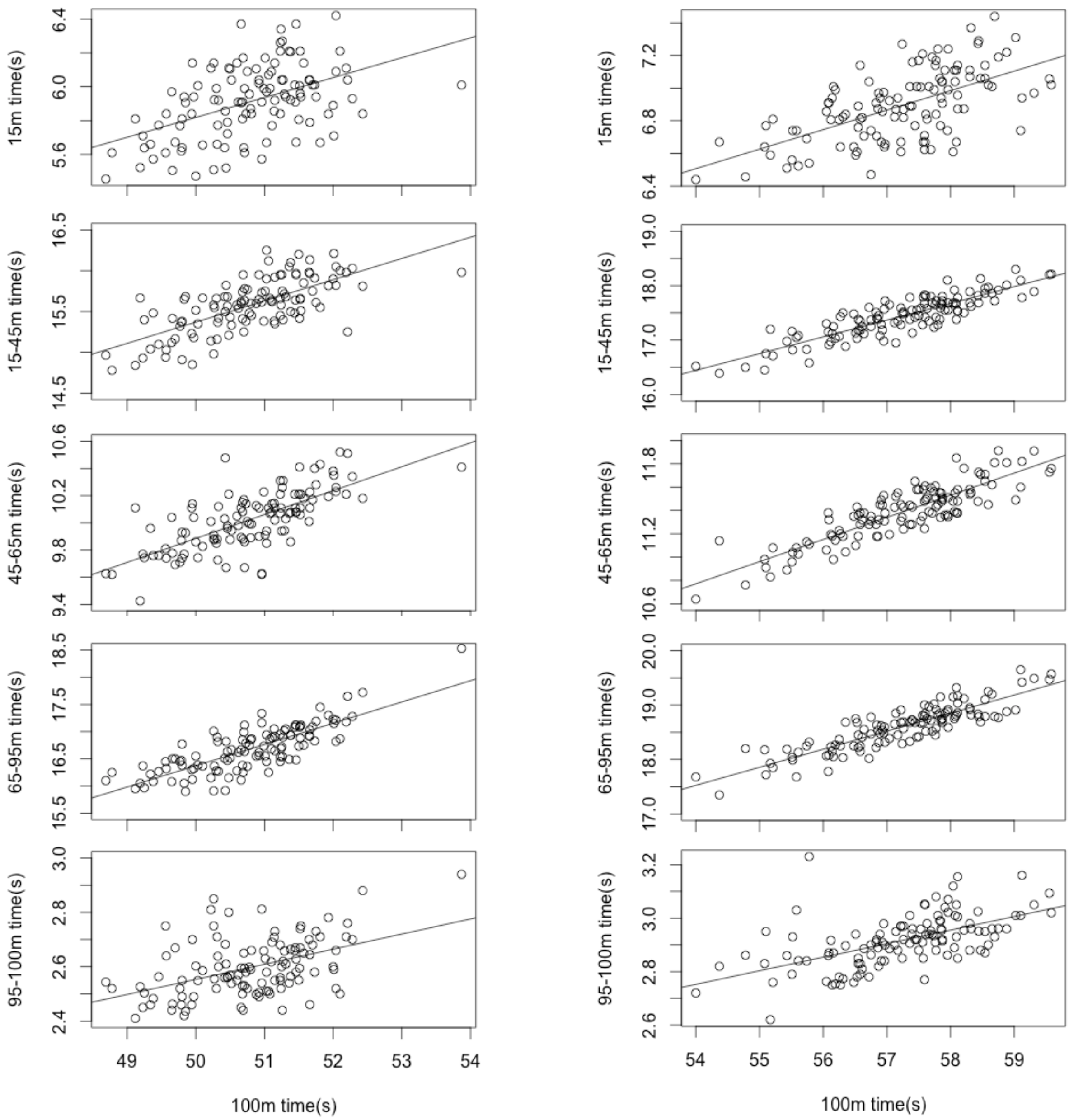

Figure 1: The relationships between of start, stroke (first half), turn, stroke (second half), finish phases and race time in 100 m freestyle (left: male, right: female).

In the present study, an attempt was made to establish formulas to estimate the target time of the four segmented phases from the total race time. For example, in the case of male swimmer whose race time is 49.00 s, the estimated target times of four phases are 5.68 s (start), 15.12 s (stroke-1), 9.71 s (turn), 15.97 s (stroke-2) and 2.52 s (finish), respectively. Likewise, in the case of female swimmer whose race time is 55.00 s, the estimated target times of four phases are 6.63 s (start), 16.75 s (stroke-1), 10.96 s (turn), 17.86 s (stroke-2) and 2.80 s (finish), respectively. These formulas allowed swimmers and coaches to set the target time of the four segmented phases to be attained through training program.
These formulas are also useful to illustrate the swimmer's pacing characteristics in the actual race. For example, the male winner (race time: 48.69 s) of the present study, although his start phase was shorter than the estimated time, the time of stroke-2 and finish phases were

longer than the estimated times. This result highlighted that there was potential room for improvement of the techniques in the stroke-2 and finish phases. Also, the female winner (race time: 54.00 s) exhibited a longer time in stroke 1 and 2 phases while the time of the start, turn and finish phases were shorter than the estimated times. It can be assumed that her swimming time to be potentially improved by shortening the time of these two stroke phases.

CONCLUSION: In this study, to analyse the performance in the competitive swimming event in detail, the 100m freestyle races were divided into four phases and the relationships between the race performance and elapsed time in each phase were examined using the results from Japanese national swimming championships. By the simple linear regression analysis new formulae were obtained for predicting elapsed times of four phases.
From the results, stroke phases and turn phase have a significant influence on swimming performance at 100 m freestyle in Japanese top level swimmers. In addition, the estimation formulae in this study would bring swimmers and coaches the criterion for evaluating race pace and swimming techniques in 100 m freestyle swimming event.

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