CHARACTERISTICS OF TURN PERFORMANCE IN ELITE BREASTSTROKE SWIMMERS

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The purpose of this study was to investigate relationships between the breaststroke turn phase time and movement during the turn phase in male competitive swimmers. The participants were six male breaststroke swimmers. All subjects performed three 100 m breaststroke trials with a push start, and the trial with the shortest time was selected for analysis. The swimmers were filmed using four cameras, and kinematic variables during the turn phase were calculated using two-dimensional analysis. The total turn time was 8.96 ± 0.20 s, and the 5 m RTT was 5.60 ± 0.13 s. Significant negative correlations were found between total turn time and distance at the point of first kick (4.99 ± 0.88 m) (r = -0.818, p = 0.047). All variables demonstrating significant correlations with distance at the point of first kick were associated with the pullout phase, except for push-off horizontal velocity. This suggests that both the push-off horizontal velocity and the pullout phase following the open turn play crucial roles in the turn performance of elite swimmers.

KEYWORDS: Elite swimmer, breaststroke, pullout phase

INTRODUCTION: Most international swimming competitions are held in long-course pools (50 m). However, the number of international competitions using short-course pools (25 m) has recently increased, partly in association with the establishment of the International Swimming League (ISL) in 2019. Short-course competitions require more turns than long-course competitions. Given that the proportion of the turn phase is larger in relation to the total race, improving turn technique is crucial for enhancing performance.

Studies examining the breaststroke turn phase have reported that shortening the pivot time—that is, the turn movement time—shortens the turn phase time. Moreover, the peak velocity after the turn movement, starting position of one stroke and one kick, and time and distance at point of surfacing affect performance (Blanksby, Simpson, Elliott, & McElroy, 1998). In 2006, the rules were revised to allow one dolphin kick during pull-outs at the start and turn. Therefore, the importance of the underwater phase after kicking the wall was acknowledged but has not since been investigated further.

The purpose of the present study was to clarify the characteristics of elite male breaststroke swimmers' turn phase by examining the relationship between turn performance and movements during the turn phase in the 100 m maximum-effort swim in breaststroke.

METHODS: The participants were six male elite breaststroke swimmers (height: 177.8 ± 7.4 cm, weight: 72.1 ± 9.0 kg, age: 22.1 ± 2.8 years, swimming points: 865.1 ± 79.1 points). The institutional ethics committee of XX University approved the study (approval number 22-11), and all participants provided written informed consent prior to the study's commencement.

The experimental trials were conducted in a short-course swimming pool. After 50 minutes of designated warm-up, the participants wore racing swimsuits, and LED markers (Kirameki; Nobby Tech, Tokyo, Japan) were placed on the surfaces of their bodies in the following locations: the ulna at the wrist, the greater trochanter, and the lateral malleolus.

Two high-speed video cameras (FDR-AX700; Sony, Tokyo, Japan) synchronized using LEDs were used to capture the turn phase from the participants' side (capture rate: 100 Hz, exposure time: 1/1,000 s). Additionally, a digital video camera (HDR-PJ630V; Sony) in a housing case (SPK-HCE; Sony) was used to capture the turn motion (capture rate: 60 Hz, exposure time: 1/1,000 s). The Sony digital video camera was also used to capture the starting and finishing phases (shooting speed: 60 fps, exposure time: 1/1,000 s) to measure swimming time. From the captured images, manual and automatic digitizing were performed using a two-dimensional motion analysis system (Frame-DIAS V; Q'sfix, Tokyo, Japan). The coordinates of the markers attached to the swimmer were calculated using the fractional linear transformation method. For the purpose of the study, the total turn time was defined as the time from 5 m before to 10 m after the turn (Nicol, Ball & Tor, 2021). Table 1 presents the calculated kinematic variables. Descriptive data are expressed as means and standard deviations. The Shapiro-Wilks test was used to assess the normality of the distribution of each parameter. Pearson's product–moment correlation coefficients (*r*) were calculated to clarify the relationship between turn performance (total turn time and 5 m round-trip time [5 m RTT]) and kinematic variables. Additional statistical analyses were conducted using SPSS Statistics (version 29.0; IBM Corp., Armonk, NY, USA), with significance set at $p < 0.05$.

Table 1: Definitions of kinematic variables in the turn phase.

PARAMETER	DESCRIPTION
Total turn time (s)	Time from 5m before the turn to 10 m after the turn.
5 m RTT (s)	Time from 5 m before the turn to 5 m after the turn.
-5 m, 5 m and 10 m split times (s)	The time for the greater trochanter to pass the specified distance point before and after making contact with the wall.
Time on wall (s)	The time between hand contact and foot departure from the wall.
Hand contact duration (s)	The time between hand contact and hand departure from the wall.
Pivot time (s)	The time between hand departure and foot contact with the wall.
Foot contact duration (s)	The time between foot contact and foot departure from the wall.
Push-off horizontal velocity (m/s)	Average horizontal velocity of the greater trochanter up to 0.5 s after the foot leaves the wall.
Distance at point of first dolphin kick (m)	The distance from the wall at which the first dolphin kick is made following push-off to the greater trochanter.
Distance at point of first stroke (m)	The distance from the wall at which the first stroke is made following push-off to the greater trochanter.
Distance at point of first kick (m)	The distance from the wall at which the first kick is made following push-off to the greater trochanter.
Distance at point of surfacing (m)	The distance from the wall at which the head first breaks the water surface following push-off to the greater trochanter.
Time at point of surfacing (s)	The time point after wall contact when the head breaks the water surface for the first time following push-off.
Average horizontal velocity to the point of surfacing (m/s)	Average horizontal velocity from the wall at which the head first breaks the water surface following push-off to the greater trochanter.

RESULTS: Table 2 presents the kinematic variables of elite breaststroke swimmers. The average trial time was 63.00 ± 1.03 s, and the first 50 m lap time was 30.24 ± 0.47 s. The average swimming velocity, calculated by subtracting the turn time from the first 50 m lap time, was 1.65 ± 0.03 m/s.
We found a significant negative correlation between total turn time and distance at the point of the first kick (Figure 1). Significant correlations were observed with the distance at the point of the first kick for several variables: push-off horizontal velocity (r = .846, p = 0.034), distance at the first dolphin kick (r = 0.963, p = 0.002), distance at the point of the first stroke (r = 0.974, p = 0.001), distance at the point of surfacing (r = -0.975, p = 0.001), and time at the point of surfacing (r = 0.946, p = 0.004). All significantly correlated variables were related to the pullout

phase, with the exception of push-off horizontal velocity. Consequently, we decided to investigate further the relationship between push-off horizontal velocity and swimming performance. However, we found no significant correlation between the average trial time (r = 0.133, p = 0.802) and the average swimming velocity (r = -0.651, p = 0.161) for push-off horizontal velocity.
No significant correlation was observed between the 5 m RTT and any of the variables studied.

Table 2: Mean value of each kinematic variable during the turn phase.

PARAMETER	Mean ± SD (n = 6)
Total turn time (s)	8.96 ± 0.18
5 m RTT (s)	5.60 ± 0.18
-5 m to wall time (s)	2.54 ± 0.07
Wall to 5 m time (s)	3.03 ± 0.13
5 m to 10 m time (s)	3.36 ± 0.08
Time on wall (s)	1.10 ± 0.08
Hand contact duration (s)	0.45 ± 0.05
Pivot time (s)	0.37 ± 0.07
Foot contact duration (s)	0.28 ± 0.04
Push-off horizontal velocity (m/s)	2.58 ± 0.16
Distance at point of first dolphin kick (m)	4.80 ± 0.92
Distance at point of first stroke (m)	5.21 ± 0.87
Distance at point of first kick (m)	8.23 ± 1.18
Distance at point of surfacing (m)	9.21 ± 1.40
Time at point of surfacing (s)	4.77 ± 0.38
Average horizontal velocity to the point of surfacing (m/s)	1.79 ± 0.06

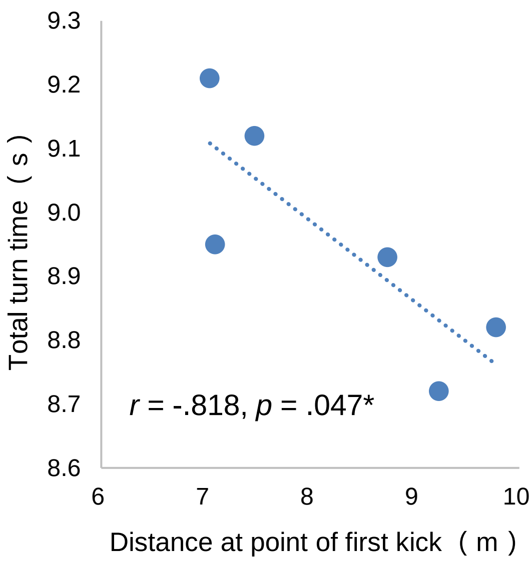

Figure 1: Relationships between turn performance and kinematic variables.

DISCUSSION: The purpose of the present study was to investigate the relationship between turn performance and movement during the turn phase of the breaststroke 100 m maximum-effort swim in elite male competitive swimmers. The variable that showed a significant relationship with total turn time was distance at the point of first kick. Significant correlations were also found between distance at the point of first kick and the push-off horizontal velocity and pullout phase variables. These results suggest that increased push-off horizontal velocity is key to improved turn phase performance and may influence subsequent increases in distance at point of first kick.

Our study confirmed the importance of the push-off horizontal velocity after the start of the turn and the pullout phase. In open turns during breaststroke, after kicking the wall and before proceeding to the stroke phase, swimmers perform stroke and kick movements in the following sequence: dolphin kick; one stroke; one kick. This sequence of actions is called the pullout phase. The swimmers' performance will improve if they can perform one stroke and one kick at a higher speed and longer distance than their swimming speed after kicking the wall. The average swimming speed for the first 50 m of the first half of the 100 m in the trials in this study was 1.65 m/s. Meanwhile, the average velocity at which the swimmers kicked out from the wall was 2.58 m/s, and their average velocity during movement in the water was 1.79 m/s, which was higher than the average swimming velocity. Considering the above, it was predicted that the subjects would maintain a glide posture after kicking out from the wall and would perform subsequent movements according to their own swimming velocity. Therefore, a higher push-off horizontal velocity will likely help increase the subsequent glide distance and time in the water. The technique used in the pullout phase is also likely to be important, but this is difficult to quantify given that it is a complex movement performed three-dimensionally in the water. In a study of pullout phases in international competitions (McCabe, Mosscrop, Hodierne, & Tor, 2022), the authors reported that although pullout phases may be classified into three types of techniques, the techniques employed by individual swimmers varied.

A previous study (Blanksby et al., 1998) reported that a shorter pivot time leads to a shorter 5 m RTT, but the present study did not yield similar findings. The aforementioned study (Blanksby et al., 1998) focused on junior athletes, and one factor contributing to the difference in findings may be that the present study's participants were more proficient in turning movements. Among our participants, no significant correlation was observed between turn performance and open turn movement time, such as time on wall and hand–ground contact time. The present study's findings indicate that pivot time, the importance of which has been acknowledged in coaching and other settings, does not significantly affect turn performance at a certain level.

Our results indicate that the pullout phase after the rotational movement of the turn should be emphasized during training to improve performance during the turn phase. In particular, it is important for swimmers to kick the wall strongly after the turn, to obtain a high velocity, and to create a glide posture with a small deceleration. Based on previous studies, it is necessary to increase the proficiency of the open turn movement itself during childhood (Blanksby et al., 1998). Later, as the athlete's performance improves, attention should be paid to the push-off motion after the turn and the timing of one stroke and one kick during the glide phase.

This study had some limitations: the participants were all elite male athletes, and only the 100-m test was used; as such, the findings may not be applicable to female athletes or the 200-m event. Future studies should elucidate the optimal wall kicking motion after the turn and investigate methods of evaluating the technique used during the pullout phase.

CONCLUSION: This study examined relationships between turn performance and the kinematic variables during the turn phase in elite breaststroke swimmers. The results indicate that distance at the point of the first kick after the turn significantly influences turn phase time. It was concluded that push-off horizontal velocity following the turn is the most critical factor influencing these variables.

REFERENCES

Blanksby, B. A., Simpson, J. R., Elliott, B. C. & McElroy, K. (1998). Biomechanical Factors Influencing Breaststroke Turns by Age-Group Swimmers. Journal of Applied Biomechanics, 14, 180-189. doi:10.1123/jab.14.2.180

McCabe, C., Mosscrop, E., Hodierne, R. & Tor, E. (2022). The characteristics of the breaststroke pullout in elite swimming. *Frontiers in Sports and Active Living*, *4*. doi:10.3389/fspor.2022.963578

Nicol, E., Ball, K. & Tor, E. (2021). The biomechanics of freestyle and butterfly turn technique in elite swimmers. Sports Biomechanics, 20, 444-457. doi:10.1080/14763141.2018.1561930