A KINEMATIC STUDY OF BUTTERFLY TURN IN ELITE SWIMMERS

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The aims of this work were (i) to evaluate the different phases of the butterfly turn during a 200 m race (in long course), (ii) to determine if the wall contact times were related to swim velocity, (iii) to compare the turn variables of the European champion with the other swimmers studied. Two studies were carried out, the first one was to: (i) test 22 swimmers ranked in 3 groups according to their performance. The most significant results revealed that the third turn was performed quicker by G1 (the faster group) than by G3 (the slower group), both before ($p<0.01$) and after ($p<0.02$) the turn. The second study concerned objectives (ii) and (iii) by evaluating 15 swimmers based on a specific protocol. The main result found was that the longer the contact time on the feet on the wall, the higher the push-off speed.

KEY **WORDS:** swim turns, butterfly, kinematics, top level swimmers

INTRODUCTION: The reference studies concentrate either on the specific part of the turn timing during chronometrical performance in competition or on the analysis of the forces exerted on the wall during turns. However, no studies have reported the kinematic characteristics of the turn related to skill level. In addition, it has been suggested that contact times on the wall are more important in butterfly than in crawl. The constitutive phases of the butterfly turn permit an objective temporal identification.
If the ability to change direction quickly is essential in swimming events, it is therefore fundamental to acquire the highest possible push-off velocity. The kinetic and kinematic analysis of the turn during butterfly emphasized that high force peaks and low contact times can reduce the turn time (Lyttle & Mason, 1997).
The aims of this study were (i) to establish the different phases of the butterfly turn during a 200 m race, (ii) to determine if the contact time to the wall was related to swim velocity, (iii) to compare the turn variables of a European champion with the other swimmers.

METHODS: Population. The turn data of twenty-two finalist or semi finalist swimmers was obtained from technical analysis of the French National Championships of 1998 and 1999. The mean time for the 200 m butterfly event was 125.90 s (SD = 3.8). The 22 swimmers were ranked in three groups according to their performance level (in seconds): G1, n=7 (121.73; SD = 3.03); G2, n=7 (126.25; SD = 0.55); G3, n=8 (129.24; SD ≈ 2.3).
Fifteen swimmers participated in the specific protocol. These swimmers were all finalists (the 16 best times) at the French national championships in the 100 or 200 m butterfly event. The reference swimmer was the world vice champion (Perth, 1998), European Champion (Istanbul, 1999), Olympic finalist (Sydney, 2000), and current world record holder in short course (Antibes, 2001).
Procedures. During the French national championships, data were collected, then systematically analysed (Chollet et al., 1996). The turn time was calculated as the time taken between the passage of head 7.50 m from the wall and the first contact on the wall (approach time) plus the time between the first contact on the wall and the passing of the head 7.50 m afterwards (acceleration time or push-off) (Figure 1). During the 1998 and 1999 French National Championships, the total turn time as a percentage of the whole race was estimated at 22% for the 200 m butterfly and 14.9% for the 100 m event.
The procedure was video recorded with two specific cameras located from the side at 7.5 and 42.5 m from the start edge of the pool. The frame rate of the cameras was of 50 Hz. The two cameras were connected to an audiovisual mixer, a chronometer, a monitoring screen and a video recorder. The recording equipment was triggered by the official start signal allowed to official turn times.

During specific protocol testing, each swimmer swam 30 m butterfly (15 m before and 15 m after the wall). The procedure was video recorded with three cameras. Each subject was firstly coded and then each swimmer's trial was watched frame by frame with a frequency of 50 Hz. From the timer, temporal data was collected in the following manner. Firstly, seven location markers were identified to establish TO to T6 (Figure). Secondly, the four velocities were calculated starting

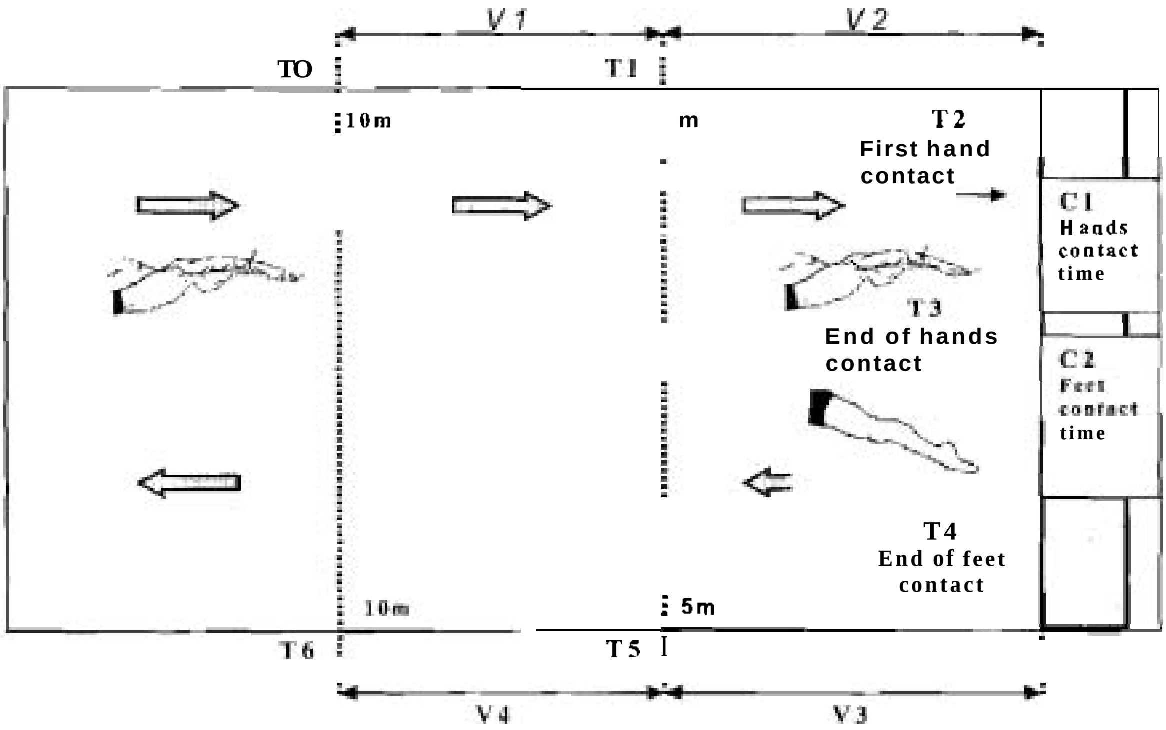

Figure **1.**

from the distance of 5 m before the turn (Vland V2) and after the wall (V3 and V4). The contact times were also measured based on differences between T2 and T3 corresponding to hands contact time (C1) and between T3 and T4 which were mainly representative of the feet contact time (C2).
In a second step, all velocities were calculated before the turn and after the wall, the contact times were also recorded.

RESULTS **AND** DISCUSSION: Butterfly Turn during Competition. Before the first turn, the results did not show a significant difference concerning the approach time. During this part of the race, slower swimmers tried to keep up with the race leader as long as possible. At this point, their was not much difference in distance between the swimmers, the three swim speeds corresponding to the different group were very close (G1 = 1.67, SD = 0.09 $m.s^{-1}$; G2 = 1.62, SD = 0.08 $m.s^{-1}$; G3 = 1.63, SD = 0.06 $m.s^{-1}$). However, at the first turn it was immediately evident that the faster group (G1) would be able to reach 7.50 m before the slower group (G3). This push-off time is the combined result of the push-off force on the wall and the ability to maintain a high velocity when pushing-off.
During the first turn, the technical characteristics of the turn highlighted because on the first 50 m. At the beginning of the event, muscular and cardio-vascular fatigue were not major factors as

only 50 m of the race at been completed. In the second turn, the approach to the wall was much faster for the expert group (G1). This could be explained by the significant difference in performance half way through the race between the fastest and the slowest group ($p < 0.02$). At the wall, after pushing-off, all groups succeed in boosting themselves, helped by the pressure on the wall at the beginning of a third 50 m. This was an expected part of the 200 m event strategy. During the third turn, significant differences were observed between the fastest and the slowest group (before turn 3 and after turn 3, $p<0.01$ and $p<0.02$). Although we did not conduct physiological tests, we assumed according to Costill et al. (1991) and Sharp et al. (1986) t at the difference between G1 and G3 could be logically explained by the physiological anaerobic capacities of the swimmers. By maintaining a maximum speed on 200 m butterfly, while tolerating a high lactate concentration, a high-level swimmer can achieve a maximal performance. These anaerobic adaptations related to training improve the buffer capacity of the muscle. For the same type of exercise, the lactate concentration rate was lower for the more highly trained swimmer.

The comparison between the time variables from the three turns, expressed as a percentage of total race time in the three groups studied (G1 = 21.94%; G2 = 22.11%; G3 = 21.98%), was not significant.

Kinematic Analysis **of** the Butterfly Turn. The longer the duration of the feet to wall contact time, the faster the push-off speed. In order to obtain an optimal push off speed a sufficient amount of contact is required. When the feet make contact with the wall and then vigorously push away, a stretch shorten cycle of the extensors that improves the mechanical output of the muscle group is achieved (Bosco et al., 1982).

This storage-restitution process involves an overproduction of energy that results in a force greater than the maximal isometric force. This process produces an increase speed to the end of push-off. The quantity of mechanical energy of elastic origin depends on the contact time of the feet on the wall, particularly when the leg extensor force is increased. Indeed, the tension-extension curve of the muscle indicates the value of optimal tension for the best restitution of force during extension (Cavagna et al., 1968). Our results agree with the findings of Lyttle et al. (1999) who suggested that a quick push-off time may not allow sufficient time to develop sufficient power, thus decreasing gravitational acceleration.

The study of Huellhorst et al. (1986), concerning the breaststroke turn showed that there was no effect of the push-off angle on the push-off velocity. This push-off force was thus converted in speed in the gliding phase, and could have a direct implication in the reduction of the time of the swim.

The detailed analysis of the European 200 m butterfly Champion showed a relationship between the feet contact time and push-off velocity which presents an original solution compared to the other swimmers' group. The feet contact time was significantly reduced from 0.56 s to 0.46 s; although the speed during the push-off remains high (3.33 $m.s^{-1}$ versus 3.18 $m.s^{-1}$ non significant for the other swimmers). This butterfly turn control revealed that the champion swimmer adopted a faster swimming speed when approaching the wall (1.89 $m.s^{-1}$ versus 1.81 $m.s^{-1}$) and the total contact time with the wall was reduced. The push-off phase was not different to that of the other swimmers.

The proportion of contact time with the wall compared to the total time of the turn was not significantly different from the other swimmers (19.07% versus 21.77%). The reduction of wall contact time versus increase speed at the end of the push-off, undoubtedly contributed to an improved performance for the champion swimmer.

Our results show higher velocity values after the push-off during butterfly, than those of push-off during the crawl tumble turn (Blanksby et al., 1996). The comparison of the crawl tumble turn with the crawl open-turn underlined values of contact time higher in the turn with touch of the hands and also speeds after the push-off which were higher than in the crawl tumble turn (Nicol and Kruger, 1979). However, they remain lower than the values recorded in our study (we must note that these two studies were carried out on a specific swimmer population age group). The velocity values found in our study during the turn in butterfly were also expectedly higher than in the study of the breaststroke done with elite swimmers (Huellhorst et al., 1986). The average times of wall contact (1.18 s) corresponded to the lowest time reported in literature. To our knowledge, the average speeds of wall push-off (3.18 $m.s^{-1}$) were among the fastest speeds ever found reported in previous series.

CONCLUSION: This study highlights the complexity of the butterfly turn. It involves a great number of variables that must be controlled in order to avoid the loss precious seconds. This study also showed that the 200 m butterfly European champion represented a reference for both the approach and push-off velocities, as well as wall contact times. Therefore, a fast and effective turn requires to adopt a speed of approach with pace of a race, to preserve this speed until the hands touched the wall, to have an optimal feet contact on the wall allowing a good elastic energy transfer combined with a strong push on the wall in order to obtain a high speed in the most possible hydrodynamic position.

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