THE CHARACTERISTICS OF AN ELITE SWIMMING TURN

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Swimming turn performance significantly contributes to overall swimming performance. Consequently, the characteristics that determine superior performance of the turn are of interest for performance improvement. The present study aimed to characterise the biomechanical properties of the swimming turn amongst an elite level population and identify any characteristic differences between genders and turn type. To achieve this aim retrospective data collected from the Wetplate Analysis System was analysed. Data provided from this system reported 26 parameters related to swimming turn performance. Analysis identified significant differences between the characteristics of the freestyle and butterfly turn, and between the turns of male and female athletes. Results from the present study are of interest for the development of turn-specific training interventions.

KEYWORDS: biomechanics, freestyle, butterfly

INTRODUCTION: The swimming turn is a skill performed during all long course events greater than 50 m in competitive swimming. The turn is typically defined as the time period from which an athlete's head passes the 5 m mark on approach to the wall and returns to the 10 m mark on the proceeding lap (Slawson, Conway, Justham, Le Sage, & West, 2010). The importance of the turn is marked by its contribution to total race performance. Over a 200 m event, the turn contributes 21% to total race performance and progressively more as race distance increases (Slawson et al., 2010). Consequently, understanding of the characteristics that contribute to optimal turn technique is required in order to improve overall race performance.

Whilst established as an important factor of race performance, the characteristics that define turn technique amongst an elite population remain unclear. The turn is described in two types, the tumble turn and the open turn. The tumble turn is utilised during freestyle and backstroke events, and is characterised by a foot contact period made following a forward somersault on approach to the wall (Slawson et al., 2010). Analysis of the tumble turn has identified turn start distance (Blanksby, Gathercole, & Marshall, 1996; Puel et al., 2012), peak force (Araujo et al., 2010; Blanksby et al., 1996), impulse (Araujo et al., 2010), horizontal speed at force peak (Puel et al., 2012) and breakout distance (Blanksby et al., 1996) to be of greatest importance to tumble turn performance. The second type of turn, the open turn, is utilised during breaststroke and butterfly events. This turn is characterised by two wall-contact periods, the first a simultaneous hand touch and the second a foot contact period (Slawson et al., 2010). Analysis of the open turn has identified pivot time, push-off velocity, breakout distance and speed at stroke resumption have been found to be most important to turn performance (Blanksby, Simpson, Elliott, & McElroy, 1998).

Although previous research has contributed to the understanding of turn mechanics, the majority of research has been conducted with age-group or 'experienced' samples. Due to technique differences between these populations and that of an elite population (Lyttle, Blanksby, Elliott, & Lloyd, 1999; Puel et al., 2012), results of previous research have limited applicability. The large number of parameters previously identified to be of most importance to turn performance suggests that the turn is better investigated as a whole skill rather than as a combination of its contributing parts or parameters.

Existing knowledge of the turn has also failed to identify how the characteristics of the turn differ between genders. Previous literature has reported gender differences in the speed at which tumble turn segments are performed, the relative importance of stature to tumble turn performance (Arellano, Brown, Cappaert, & Nelson, 1994) and the relative importance of underwater velocity to open turn performance (Mason & Cossor, 2001). Research is yet to directly compare the biomechanical characteristics of the turn between male and female swimmers.

Similarly, research is yet to directly investigate the biomechanical differences between tumble and open turns. In a series of studies conducted with age-group athletes, Blanksby et al. (1996/1998) investigated the biomechanical parameters important to freestyle and breaststroke turn performance. Although characteristic differences were described between turn types, the use of different parameters for the investigation of breaststroke and freestyle turns prevented the direct comparison of turn characteristics.

The present study was the first to directly investigate the characteristic differences between tumble and open turn performances through the analysis of butterfly and freestyle turns. Comparison between these turns may subsequently be linked to the comparison of breaststroke and backstroke turns due to the similarity in rotation. The aims of this study were to characterise the swimming turn within an elite population, and to identify the differences between turn type and gender during turn performance.

METHODS: Retrospective data collected from the Wetplate Analysis System was used to characterise the turn performances of elite swimmers. This system was a proprietary system developed by the Australian Institute of Sport (AIS) for the biomechanical analysis of starts, turns and relay changeovers (Mason, Mackintosh, & Pease, 2012). Each trial completed using this system reported a total of 26 parameters related to turn performance. Ethical approval for the use of collected data was obtained from the AIS Ethics Committee (Project number 2017060). The 4260 trials contained in the Wetplate Analysis System database were initially filtered to only include those completed by elite athletes. Athletes were defined as elite if they had represented Australia at a minimum of one international level competition eg. Olympics or World Championships. The fastest turn trial of each athlete was subsequently selected for analysis to prevent power biases. Once filtered, a total of 39 trials for male freestyle (81.76 ± 7.55 kg, 21 ± 3 years), 41 trials for female freestyle (66.00 ± 6.27 kg, 20 ± 4 years), 12 trials for male backstroke (80.53 ± 8.58 kg, 20 ± 2 years), 15 trials for female backstroke (64.25 ± 6.06 kg, 19 ± 3 years), 9 trials for male breaststroke (83.72 ± 8.24 kg, 20 ± 3 years), 14 trials for female breaststroke (65.75 ± 6.42 kg, 20 ± 4 years), 21 trials for male butterfly (81.48 ± 7.28 kg, 22 ± 4 years) and 23 trials for female butterfly (64.63 ± 6.50 kg, 19 ± 4 years) were available for analysis. Backstroke and breaststroke subsets were excluded from analysis due to the small amount of available data. The use of butterfly and freestyle turn data allowed the comparison of open and tumble turns.

Statistical analysis followed similar protocols utilised by Tor, Pease, and Ball (2014). Descriptive statistics were calculated for each parameter. The Kolmogorov-Smirnov test confirmed that all parameters were evenly distributed ($p > 0.05$). A series of independent t-tests were subsequently used to compare each parameter between strokes and between genders. Effect sizes were calculated using Cohen's (d) to determine the strength of the difference between groups (Cohen, 1988). Scores of 0.2 were classified as small, 0.5 as medium and 0.8 as large. All statistics were calculated using SPSS Statistics Software (Version 22 for Mac).

RESULTS: Comparison of butterfly and freestyle turns revealed a significant difference in total turn time. Butterfly turns were characterised by a deeper depth at maximum force (-.10 m, $p < 0.01$*) reduced departure angle (-1.87 degrees, $p = 0.01$*), reduced take off vertical velocity (-.13 ms^{-2}, $p < 0.01$*) and lower average acceleration (10.14 ms^{-2}, $p < 0.01$*). The underwater trajectory of the butterfly and freestyle turn also differed. Butterfly swimmers reached their maximum depth at a later time (-1.41 s, $p < 0.01$*), were longer underwater (2.20 s, $p < 0.01$*) and surfaced at a greater distance from the wall (2.35 m, $p < 0.01$*). All temporal parameters significantly differed between turn types with the exception of average velocity from 5 m to 7.5 m**.**

Comparison of butterfly turns between male and female swimmers found a significant difference in total turn time. Average acceleration (.74 ms^{-2}, $p < 0.01$*), average power per kg (9.22 W, $p < 0.01$*), peak power per kg (22.32 W, $p < 0.01$*) and work per kg (2.68 J,

$p < 0.01$*) differed between male and female swimmers. Male swimmers were also longer underwater (.81 s, $p = 0.01$*) and surfaced at a greater distance from the wall (2.70 m, $p < 0.01$*). All temporal parameters were significantly different between male and female swimmers during the butterfly turn.
Analysis of the freestyle turn revealed a significant difference in total turn time between male and female swimmers. Male swimmers had a greater impulse during wall contact (0.32 ms^{-2}, $p < 0.01$*), average acceleration (1.83 ms^{-2}, $p < 0.01$*), average power per kg (5.65 W, $p < 0.01$*), peak power per kg (9.40 W, $p < 0.01$*) and work per kg (1.22 J, $p < 0.01$*). Males also has a greater horizontal head distance from the wall at the time of maximal depth (0.49 m, $p = 0.03$*). All temporal parameters were significantly different between male and female swimmers during the freestyle turn.

DISCUSSION: The present study sought to characterise and compare the swimming turns of elite swimmers. This study was the first of its kind to directly compare turn characteristics between butterfly and freestyle turns and between male and female swimmers.
Biomechanical characteristics differed between butterfly and freestyle turns. Butterfly turns were characterised by a maximal force that was deeper on the wall. This resulted in swimmers reducing the angle of departure in order to reach a similar depth to freestyle swimmers during the underwater phase. Butterfly turns were also characterised by a longer underwater phase and a greater distance at the point of surfacing. It is expected that freestyle swimmers surfaced earlier due to the higher surface speed of freestyle swimming when compared to butterfly swimming (Kennedy, Brown, Chengalur, & Nelson, 1990). Conversely, butterfly swimmers may prolong the underwater phase when compared to freestyle swimmers due to a greater proficiency of the underwater kicking motion. As the kick characteristics of the underwater phase mirror those of butterfly free swimming, it may be expected that butterfly swimmers are more proficient at this movement. This is supported by temporal analysis which found average velocity from 5 m to 7.5 m to be the only temporal parameter that did not differ between turn types. This phase is associated with the underwater kicking phase of the turn and would explain findings that butterfly swimmers spent longer in the underwater phase.
Gender comparison revealed a difference in total turn time between male and female swimmers during the butterfly turn. This was due to the greater peak and average power produced by males, which resulted in male swimmers leaving the wall at a greater velocity. The faster turn time of male swimmers may also be attributed to the longer time spent in the underwater phase, the greater distance at the point of surfacing and the higher velocities reached during the underwater phase. The benefit of prolonging the underwater phase was a consequence of the reduced forces acting upon the swimmer during this phase when compared to surface swimming (Lyttle et al., 1999). The age of swimmers in the present study may have also contributed to observed results. Male athletes were older than female athletes and consequently may have been more experienced. As swimmer history was not available from retrospective data, this claim cannot be substantiated. Future studies may choose to compare the turn performances of elite athletes of a similar age and swimming experience in order to substantiate this hypothesis.
Comparison of the freestyle turn between male and female swimmers found a significant difference in total turn time. Similar to gender differences of the butterfly turn, the difference was a result of the increased peak and average power produced by male swimmers. The resultant increase in departure velocity was advantageous to swimmers by enabling swimmers to glide for a longer period before reaching the optimal speed to initiate underwater kicking (Lyttle & Blanksby, 2000). During this glide phase, the swimmer was able to minimise drag forces and consequently maintain speed longer, benefitting turn performance. In contrast to analysis of the butterfly turn, no significant differences were reported during the underwater phase. This observation may be explained by the reduced time spent in the underwater phase during the freestyle turn. Reduction of this phase is a result of the increased surface speed of the stroke when compared to butterfly swimming.

CONCLUSION: This study was the first to directly compare the biomechanical characteristics of the butterfly and freestyle turn between strokes and between genders. Analysis revealed differences in the depth at maximal force, vertical take-off velocity, departure angle, average acceleration and underwater phase of the turn between butterfly and freestyle turns. Difference in total turn time between male and female swimmers during the butterfly turn was attributed to differences in peak power, average power and the characteristics of the underwater phase. Males produced greater force outputs off the wall and spent longer in the underwater phase, resulting in faster turn performance. Males were also significantly faster than females during the freestyle turn. This was a result of an increased peak power and average power produced by male swimmers, resulting in a higher push-off velocity. Results indicated that there were variances in turn characteristics between butterfly and freestyle turns and between male and female swimmers. Such differences should be considered during the development of training interventions aimed at improving turn performance.

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