Analysis and influence of the underwater phase of breaststroke on short-course 50 and 100m performance

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ABSTRACT

The aim was to analyse the influence of the breaststroke underwater phase on 50 and 100m performance. A total of 108 performances in 50m (61 males and 47 females), and 126 performances in 100m (71 males and 55 females) were recorded during the 2019 Short-course National Spanish Championship. The underwater swimming time, distance and velocity were analyzed after the start and turns. Pearson correlation coefficients (r) and regression analysis were applied to compute the relation between the variables. The relative contribution (%) to final time and the differences between events and gender were studied through independent samples t test ($p < 0.05$). High correlations were obtained for both events and genders between start time and final time ($r = 0.76$-0.91). The emersion velocity was higher in 50m than in 100m ($p < 0.001$; $d > 1.0$) and in males (50m: 2.18 ± 0.10m·s^{-1}; 100m: 1.87 ± 0.08m·s^{-1}) than in females (50m: 1.92 ± 0.09m·s^{-1}: 100m: 1.71 ± 0.08m·s^{-1}). Performance in both events was influenced significantly by turn velocity ($r \geq -0.85$), and combined with the start, contributed to around 55% of the final time. Coaches should optimize the underwater phases of start and turns on breaststroke performance in short-course.

Keywords: Race analysis; Tactical and Strategy; Sport Performance; Swimming.

INTRODUCTION

A key aspect behind the growing performance achievements in swimming involves the measurement and evaluation of quantifiable data to provide feedback to coaches and swimmers (Arellano et al., 2018; Mooney et al., 2016). In this regard, the scientific community have shown considerable interest in the swimming events under the Olympic regulations, where the swimming races take part in a distance of 50m (denoted as long-course) (Arellano et al., 1994; Marinho et al., 2020; Morais et al., 2019; Nowacka & Słomiński, 2018; Veiga et al., 2013; Veiga & Roig, 2017). However, some sprint modalities such as 50m breaststroke are not included in the Olympic program (www.fina.org), while the events conducted in a 25m swimming-pool (denoted as short-course), may require different performance strategies due to a higher number of turns (Arellano et al., 2018). Therefore, several questions arise as to how the specific breaststroke underwater phases performed after the start and turns can influence performance at different short-course race distances.

The role played by the start and turn phases has been of great interest of sport analysts since these are crucial factors in final performance in short events (Arellano et al., 2018; Morais et al., 2019; Olstad et al., 2020; Veiga & Roig, 2017). The underwater phase has been reported as the most important component of the total start phase, explaining 95% of the starting time ($r = 0.97$) (Guimaraes & Hay, 1985; Vantorre et al., 2014). Some authors have related the underwater velocity in 100m breaststroke with the 15m start time ($r = -0.73$) (Mason & Cossor, 2001); the time to 15m with final time ($r = 0.97$) (Olstad et al., 2020); and the requirements of strength ($r = -0.74$) and power ($r = -0.66$) to impact the start time (Cuenca-Fernández et al., 2015; West et al., 2011). Hence, a good kinematical organization together with a great muscle function seems important for both the block and the underwater phases (Cuenca-Fernández et al., 2019; Fischer & Kibele, 2016; Seifert et al., 2007).

Regarding the open turn used in breaststroke, this is understood to be slower than the flip turn used in freestyle and backstroke (Lyttle & Mason, 1997; Tourny-Chollet et al., 2002); and its influence to final performance has been reported to range between 19-20% in long-course (Morais et al., 2019). Moreover, in this stroke swimmers show the shortest underwater breakout distances (Marinho et al., 2011; Veiga & Roig, 2017; Vilas-Boas et al., 2010). Specifically, some studies have reported that apart from minimizing gliding and the wall contact time, the push-off intensity and a quick pull-out are the key determinants that should be considered by the swimmers to enhance this action (Lyttle & Mason, 1997; Tourny-Chollet et al., 2002). One study conducted in long-course reported that the fastest swimmers were not the fastest turners (Mason & Cossor, 2001). However, if the combination of start and turns explain almost one-third of the total race time in 100m breaststroke long-course (~31%) (Morais et al., 2019), then a good performance of these actions could be even more relevant in short-course.

It is important to note that contrary to the 15m-leg-undulations-limit established for the underwater subsections of the three other strokes (Mason & Cossor, 2001), the constraints in breaststroke are: i) to glide with only one dolphin kick in streamline position; ii) to perform the first pull-out phase with the upper limbs only, and iii) to break-out of the surface with the head before the hands turn inward at the widest part of the stroke that initiates the swimming” (Leblanc et al., 2007; Maglischo, 2003; Seifert et al., 2007). Thus, the underwater distance that a breaststroke swimmer can reach after the start and turns, is only limited to the realization of the movements' aforementioned, but there is no mark limit that swimmers must adapt to (FINA rules SW 7.4). Therefore, optimizing the timing of these underwater subsections appears to be critical to obtain the maximum velocity (Naemi et al., 2010; Veiga et al., 2014).

Numerous recommendations have emerged in this regard. For instance, given that one of the primary goals is minimizing drag, for the same range of speeds the first glide position performed with the arms at the front must be emphasized in relation to the second position performed with the arms along the trunk (Marinho et al., 2011; Vilas-Boas et al., 2010), and this action should be performed in at least 0.6m depth in which wave drag is negligible (Lyttle et al., 1998; Naemi et al., 2010). On the other hand, although it has been suggested that extending the first gliding more than 6m could produce a significant loss of velocity due to the drag acting on the body (Houel et al., 2013), this is highly dependent on the individual's body shape, posture, alignment and size (Naemi et al., 2010). Therefore, the gliding phase should be kept as long as its velocity is higher than the velocity of swimming (Marinho et al., 2011; Veiga et al., 2013; Vilas-Boas et al., 2010).

In addition, it has been suggested that an early placement of the dolphin kick could produce greater mechanical power, maintaining more easily the underwater body acceleration (Gavilán et al., 2006). This strategy has shown shorter time to 15m in female breaststrokers (McCabe et al., 2012). A higher body stability (e.g. through a higher gliding velocity) would guarantee starting the downward movement of the dolphin kick when the lower limbs are still raised (Psycharakis & Sanders, 2010), and this would be beneficial to increase the extension and thrust of this action (Cohen et al., 2012; Shimojo et al., 2019). In any case, other factors such as the ankle flexibility (Arellano et al., 2002) or the ability to transfer the strength to the water during the simultaneous arm pull-out (Cuenca-Fernández et al., 2020; Ruiz-Navarro et al., 2020; Sadowski et al., 2020), could also counteract or favour the influence of these subcomponents to the start and turn time.

Thus, considering that improvements on the acyclic phases of a swimming race can have a significant effect on the final race time (Morais et al., 2019), the identification of the variables with the higher influence in final performance could be especially relevant for optimizing performance in short-course events, given that a large amount of teams perform swimming training and participate in events in this venue throughout the season. For that reason, the aim of the current study was to assess the influence of the breaststroke underwater swimming phases on 50 and 100m short-course. Our hypothesis was that, the swimmers who reach greater underwater velocity after start and turns would be the ones to obtain a shorter final time.

METHODS

Participants

The 50 and 100m breaststroke data was obtained at the 2019 Short-Course National Championship held in Gijón (Spain). A previous study revealed the importance of evaluating athletes in a competition situation given that performance is considerably better than usually reported while testing (Veiga et al., 2013). In 50m breaststroke, 108 performances were analyzed (61 males [age 23.29 ± 5.10] and 47 females [age: 20.61 ± 4.71]), while in 100m, 126 performances were analyzed (71 males [age: 21.74 ± 3.93] and 55 females [age: 19.58 ± 4.67]). Mean performances of the males corresponded to 86.85% and 87.50% in the 50 and 100m breaststroke short-course world records, while mean performances of the females corresponded to 86.54% and 86.97%, respectively. All procedures were in accordance to the Helsinki Declaration regarding Human research. The University committee approved the study with the reference number 852.

Performance variables

The variables analyzed are detailed in table 1.

(Please insert Table 1 near here)

Data collection

An indirect photogrammetric methodology was carried out through video-analysis of the swimmers performance, given that this is a major tool for coaches and researchers, and a common strategy used to obtain quantitative and qualitative data during competitions (O’Donoghue, 2006; Smith et al., 2002). Two video cameras (Sony 4K, 1080p 50 Hz) were placed at the top of the swimming-pool stands and the two images were connected and overlapped by a video switcher (ATEM Mini, Blackmagic Design Pty Ltd., Perth, Australia). One of the cameras made it possible to record the start flashing light that served as reference to synchronize our recordings with the official stopwatch. The swimmer’s data was obtained after detailed observations through in-house customized software for performance analysis (Kinovea, v. 0.8.15, France). The pool was divided in 8 lanes by floating buoys that alternated in colour every 5m. Thus, the calculation of the distances was possible after the calibration of our in-house software based on the pool’s marks (Figure 1). The Intra-Class Correlation Coefficient (ICC) was used to verify the agreement between evaluators (n = 2). This ranged between 0.98 and 0.99, showing high agreement.

Statistical Analysis

The normality distribution and homocedasticity of the data were assessed and verified through the Kolmogorov-Smirnov and Levene tests, respectively. The Saphiro-Wilk test was chosen to test the normality of the 50m-female data ($n < 50$). The mean and standard deviation (SD) were calculated for all the selected variables of 50 and 100m events. Pearson product-moment correlation coefficients (r) between all variables and Final time were obtained and simple linear regression analyses were applied to evaluate the potential associations between T15, Race_ET, Race_ED, Race_VE, Race_TT and Race_TV with Final time. Additionally, these variables were clustered by gender (males and females) and result (finalists and non finalists), and the differences were studied using the independent samples *t* test.

The partial contribution (%) of the temporal variables related to the underwater phases, were obtained to evaluate their relative influence on final performance. The differences between events and gender were computed using the independent samples *t* test, while Cohen's d was computed to assess the standard effect size between 50 and 100m Breaststroke, and interpreted as: (i) small/trivial if $d \leq 0.2$; (ii) moderate if $0.2 \geq d \leq 0.8$ and; (iii) large if $d \geq 0.8$ (Cohen, 1988). All statistical procedures were performed using SPSS (version 24.0; Chicago, IL), with a level of significance set to $p < 0.05$.

RESULTS

The correlations between the age of the participants and Final time were weak in 50m and moderate in 100m (Table 2). Final time was strongly correlated with T15 ($r = 0.76 – 0.91$) and V15 ($r = -0.77 – -0.91$) in both events and genders. The regression analysis showed that T15 explained Final time by 83% and 68% in 50m, and by 62% and 59% in 100m, for males and females, respectively. The T15 was lower in 50m than in 100m ($p < 0.001$), in males than in females, and in finalists compared to non-finalists ($p < 0.001$). The partial contribution of T15 to Final time revealed higher relative influence in 50m (~22-23%) compared to 100m (~10%) (Table 4). The relative duration of the underwater phase regarding the start represented 72.50% and 65.05% for males and females in 50m, and 79.16% and 68.11% in 100m, respectively.

(Please insert Table 2 near here)

(Please insert Table 3 near here)

(Please insert Table 4 near here)

No correlations were obtained between the variables of emersion time with Final time, and no differences were obtained between finalists and non-finalists, although males achieved less time in the 50m ($p = 0.034$) (Figure 2). The distance and velocity of emersion obtained weak negative correlations with Final time in 100m and moderate in 50m, both after the start (ED1 and VE1) and turns (ED2, ED3 and ED4; VE2, VE3 and VE4) (Table 2). These relations became stronger when gathering the mean outcomes for the entire race (i.e. Race_ED and Race_VE) (Figures 2 & 3). Higher emersion distances were reached in 100m after the start and first turn. However, males obtained lower values of velocity compared to 50m and the values of females were similar between 50 and 100m after the turn (Table 3). The total emersion time had a similar influence on Final time for both genders and events (~34-30%) (Table 4).

(Please insert Figure 2 near here)

(Please insert Figure 3 near here)

The turn time and velocity obtained strong correlations with Final time in both genders and events (Table 2). In 100m, the second and third turn (r = -0.86 – -0.94) obtained higher correlations than the first (r = -0.70 – -0.86). The turn velocity (Race_TV) was more related with Final time in 50 and 100m breaststroke than Race_TT, explaining 89-94% of the variance of this action (r > -0.94). The only turn performed in 50m was similar in time to the first turn performed in 100m (Table 3), although males performed the turn in less time and at a higher velocity ($p < 0.001$), especially in 50m ($p < 0.001$). The relative influence of turn time to Final time was lower in 50m (~32-33%) for males and females, compared to 100m (~45%) (Table 4).

DISCUSSION

The main purpose of this study was to analyse the influence of the breaststroke underwater phases in 50m and 100m short-course. It was hypothesized that the swimmers who reached a greater underwater velocity after start and turns would be the ones to achieve the greatest final performance in a 25m pool. Our results showed that the emersion time was not able to predict final performance, while achieving a high emersion distance was only relevant for males in 50m. However, a high velocity during the emersion and a short time at 15m was associated with a shorter Final time in both events and genders and, as with the turns, these skills were also considered essential in swimmer’s performance in 100m breaststroke.

As for age and Final time, a moderate relationship was found in males (r = -0.53) and females (r = -0.57) in 100m. Thus, either the biological growth or the professional experience seems relevant to achieve a good result in a 100m breaststroke performance. The quality of the technical-tactical practices could have a high influence on final performance regardless of the age (Nowacka & Słomiński, 2018). Moreover, the level of expertise and cognitive development are key factors of high sports performance that increase after years of practice (Guimarães et al., 2019). Some authors reported that swimmers participating in short events are usually older than the rest of the disciplines (Arellano et al., 1994; Nowacka & Słomiński, 2018). However, the results reported in those studies may not be comparable since they were obtained in long-course with Olympic participants. In this study, the age effect between events was trivial (d = 0.2 – 0.3), although there was a trend towards a higher age for males in 50m (Table 3). Thus, this relation is yet to be confirmed.

Start phase and Final time

A low T15 and high V15 were strongly related with lower Final time in both genders and events, which suggests that faster swimmers have better start skills. Our associations in males 100m (r = ~ 0.78) were lower than the ones obtained by Olstad et al. (2020), (r = 0.97), although the higher number of participants in our study possibly accounted for this. The start values were better in 50m, and in males compared to females (Figures 2 & 3). At this stage of the race, fatigue cannot be responsible for the differences between events. Therefore, 100m swimmers may improve their start performance by adopting a similar strategy as their 50m counterparts (Morais et al., 2019). Regarding the gender differences, these were similar to those obtained elsewhere (Mason & Cossor, 2001; Veiga & Roig, 2017). The men were able to utilize the underwater phase of the start better than the women. Thus, the requirements of this phase seem to play in favour of the higher levels of maximal and explosive strength of males in comparison to females (Marinho et al., 2011; Nowacka & Słomiński, 2018; West et al., 2011).

The start time depends on multiple subcomponents from the block phase and underwater phase (Fischer & Kibele, 2016; Vantorre et al., 2014). However, the time of emersion did not seem to be relevant to final performance, even though the relative duration of this phase over start time (~68-79%) was higher than the 49.6% reported by Seifert et al. (2007) in national swimmers and the 60% reported by Mason and Cossor (2001) in Olympic Swimmers. This lack of correlation could be explained because the emersion time may depend on the swimmer’s choice, which means that some may end it earlier and others later for the same purpose of maintaining a high velocity. Some studies have reported that the starting performance in 100m events are characterized by an underwater profile, which is based on an increase of the underwater distance/time to save energy for the subsequent swimming phase (Marinho et al., 2020; Veiga et al., 2014). In the present study, the emersion time and distance achieved in 100m was higher than in 50m. However, only the emersion distance was relevant for success in 50m males (r = -0.64)

An increase of the emersion distance would reduce the clean swimming phase. Some literature has reported that the best swimmers achieve longer time and distances in the underwater phases compared to non-experts (Mason & Cossor, 2001; Vantorre et al., 2014; Veiga et al., 2016). In this study, only the 50m male finalists obtained higher distances than non-finalists (Figure 2). As the velocity achieved during the emersion (2.64-2.31 $m \cdot s^{-1}$) was superior than the velocity achieved at 15m during the clean swimming phase (50m ~2.31-1.96 $m \cdot s^{-1}$), then an extension of this phase could be beneficial to Final time as long as this velocity is maintained (Veiga et al., 2014). However, the distances of emersion in 100m (13.37 – 12.20m) were higher than in 50m (12.50 – 11.48m), and lower emersion velocities were obtained in 100m (Table 2). In addition, the females travelled at least 1m more in 100m with similar velocities than in 50m, but they did not obtain any improvement in performance. Thus, it seems unlikely that greater distances and higher velocities can be achieved at the same time. Possibly, the pacing strategy chosen by the swimmers differed between events, prompting swimmers to adopt a more aggressive strategy in 50m to end the underwater phase before experiencing a loss of speed. This should be confirmed in future studies.

Achieving a good performance in 15m contributed to attain a shorter Final time. Nevertheless, this variable may also include some swimming strokes into the start segment (Veiga et al., 2013). The estimation of race segments with fixed distances is widely accepted (i.e. using 15m mark to define the start phase) given that it allows for an easy comparison between swimmers (Thompson et al., 2004). However, this does not accurately represent the swimmer’s actual speed during the underwater phase. For instance, short-fixed distances after start and turns (e.g., 5m) could mistakenly show higher velocities for taller swimmers than shorter swimmers, since they would reach these marks before without necessarily being the fastest. For that reason, this study included both the values relative to the emersion of each swimmer (VE1), and the values relative to a fixed distance such as V15. Specifically, the VE1 in 100m (2.51 – 2.30 $m \cdot s^{-1}$) was above the ~2.3 – 2.0 $m \cdot s^{-1}$ reported previously (Marinho et al., 2020; Olstad et al., 2020; Veiga et al., 2013), but similar to ~ 2.48 – 2.13 $m \cdot s^{-1}$ reported by Morais et al. (2019). Regarding the V15 (2.23 – 1.92 $m \cdot s^{-1}$), the values were within the range of ~2.28 – 1.92 $m \cdot s^{-1}$ reported in other studies (Marinho et al., 2020; Morais et al., 2019; Veiga et al., 2014), and superior than the 2.02 $m \cdot s^{-1}$ reported by Olstad et al. (2020). Therefore, regardless of the differences provided by the participants' level, these variables seem not to be affected by long or short-course.

The relative influence of the start phase to 50m Final time was considerable (~22-23%), although lower than the ~26% reported in 50m freestyle by Arellano et al. (2018). To author's knowledge, there not exist any peer-reviewed records of the contribution of this phase to Final time in 50m breaststroke short-course. With regard to 100m, the partial contribution of the start phase (~10%) was in agreement with the ~11% reported by Morais et al. (2019) and Olstad et al. (2020) in long and short-course. As the analysis of the underwater subcomponents was not conducted separately, it is not entirely clear which one affected start performance the most. In any case, the best performance would be achieved when the net resultant of these phases results in the highest velocity, regardless of the gliding time or the distance extension strategy (Veiga et al., 2013). The low correlations between ET1 and Final time ($r = -0.26 – -0.27$), were similar to those obtained by Veiga et al. (2016) in long-course ($r = -0.17 – -0.27$) and seems to corroborate that swimmers maximize the start distances only when a net gain of average velocity is probable (Morais et al., 2019; Veiga et al., 2014). Therefore, achieving a high velocity during the emersion should be the primary goal to improve the start phase.

Turn phase and Final time

In a study conducted by Mason and Cossor (2001), a non-significant relationship between the pre-turn swim velocity and the turn velocity was noted, suggesting that swim stroke and pre-turning performances are not related. Therefore, although some authors have observed turn performance as the distance of 5m after the wall (Blanksby et al., 1998); others in the distance of 10m after the wall (Arellano et al., 2018; Mooney et al., 2016; Veiga et al., 2013); and others in the distance of 15m after the wall (Marinho et al., 2020; McCabe et al., 2012; Morais et al., 2019), all the studies agree in including the 5m to approach the wall in turn performance. Actually, the real start and turn distances of competitive swimmers are shorter than previously considered with the 15m mark and therefore, average velocities are also different (Veiga et al., 2014; Veiga et al., 2013). For those reasons, the 5m-in and the 10m after the wall were used in this study as the distances fixed for turn performance.

The variables of turn with fixed distances (TT1 & TV1) achieved higher correlations with Final performance than the variables of emersion (ET2, ED2 and VE2). These variables could be more representative in the turn than in the start, since the distance and velocity reached after turns are lower than after the start (Table 2). Actually, we did not obtain strong correlations between emersion distance after turns and total time at both events, only in 50m males (r = -0.64). This was expected, a swimmer cannot obtain the same velocity pushing from the wall than the one achieved during the take-off. Furthermore, the inertia of the water entrained with the body when approaching the wall is a negative factor in the subsequent push from the wall (Naemi et al., 2010). Hence, a greater individualization of the emersion distance after turns as well as good physical skills seems important to improve the final performance (Nowacka & Słomiński, 2018; Veiga et al., 2013; West et al., 2011).

The values of distance (ED2) and time of emersion (ET2) after the first turn were lower in 50m than in 100m; however males seemed to breakout faster in 50m (Table 3). The time (~5.2 – 5.5s) and distance covered (~8.2 – 9.4m) were similar to the values obtained by Marinho et al. (2020) in international swimmers in 100m long-course (Time: ~5.5s; Distance: ~8-10m) and to the ones obtained by Olstad et al. (2020) in trained swimmers in 100m short-course (Time: 5.73s; Distance: 9.43m). So, there were no differences prompted by neither the short-course nor the participants' level in these components. It is worth noting that a deterioration of the values of emersion was appreciated in the last turn, but not the values of turn velocity (Table 2). It is possible that the first strokes after the breakout phase aid swimmers to recover from the velocity drop experienced during the emersion. In any case, although the emersion time of the last turn was similar to the others, that was not the case for the distance and velocity (Table 2). So it seems that fatigue affected the push-off and pull-out effectiveness (Figueiredo et al., 2011; Olstad et al., 2020).

The partial contribution of turn time ranged between ~32-33% to Final time in 50m, and around ~45% in 100m breaststroke (Table 3). Our results in 100m were similar to the 44.30% obtained by Olstad et al. (2020) in short-course, and superior than the ~19 – 20% obtained in long-course by Morais et al. (2019) and the 18.26% by Blanksby et al. (1998), although the latter only included the 5m-in and the 5m out. Therefore, although we did not find any other records of the turn influence in short-course, it is obvious that the turn time is expected to have a higher influence in a short race with a higher number of turns. For example, our values in 100m in short-course were close to the ones obtained by Thayer and Hay (1984) in 200 yards breaststroke (~39%), possibly due to the relative increase in Final time and the same number of turns performed in both events. This also happened in the relative influence of the emersion time in 50 and 100m breaststroke obtained in this study, as it was similar for both events (~30-34%).

With this, turn skills performed at a higher speed are essential to enhance Final time (Figures 2 & 3). In 100m, it seems that the second and third turns, were more relevant to attain a lower Final time. Hence, our data pointed out similarly what was noted by Arellano et al. (1994) about the last turn in 200m events in long-course. Nonetheless, not only is turn velocity a fundamental skill at both events and genders upon Final time, the swimming strategy adjustment according to swimmers' individual and biological characteristics (including cyclic variables such as stroke-rate or stroke-length) prior the turning wall might gather a greater momentum at push-off as well as underwater gliding velocity to break the water surface farther and, hence, save energy for the final sprint (Marinho et al., 2020; Veiga et al., 2014). Therefore, a successful strategy would consist in applying a greater acceleration at 5m-in (Morais et al., 2019; Veiga & Roig, 2017).

Combination of start and turn phases

Although achieving a high emersion distance was important for both genders and events (i.e., Race_ED), the emersion velocity during the start and turns (i.e., Race_VE) was more relevant to achieve a good performance, explaining the 62% and 41% of the Final time in 50m ($r \geq -0.64$), the 51% and 46% in 100m ($r \geq -0.68$), and with clear differences between finalists and non finalists in both events (Figures 2 & 3). In general, it seems that achieving large emersion distances, was more effective for males and more determinant in 50m. However, the majority of the individual correlations were higher after the turns than after the start (i.e., ED2 – ED4), so it seems that it is more meritorious to achieve large distance after a turn than after the start. The emersion time after the start and turns (Race_ET) did not predict final performance. This was shorter after the start than after the turn, possibly because the underwater velocities were higher after the start. For that reason, the relative influence of the emersion was higher after the turn than after the start (Table 4), because the time accounted was higher, although the distance and velocities achieved were lower.

The partial contribution of start and turns ranged between ~55% of the Final time in both events and genders. The higher number of turns in 100m explained why the variables Race_TT and Race_TV were the ones with the highest relation to Final time (Figures 2 & 3). The contribution of start and turns reported by Arellano et al. (2018) in 50m freestyle contributed about 45% of the final time, while Morais et al. (2019) reported ~31% in 100m breaststroke of the final race time, although this difference was explained by the pool length. Thus, it seems that the amount of training time spent in starts and turns is of extreme importance in breaststroke short-course, given that the partial contribution of these phases is considerably high in these two events. In this regard, obtaining large percentages in any of these swimming components could also be an indicator of deficiencies in performance on that component (i.e. less velocity, more time consuming).

CONCLUSION

The analysis of breaststroke underwater phases was explained in 50m and 100m events in short-course. The relevance of our study is that the start and turn phases have a significant influence in final breaststroke performance. Therefore, swimming training programmes should be adapted by performance analysts and strength and conditioning coaches to optimize performance of this skill during practice. In addition, coaches are encouraged to test different underwater strategies in order to find the most suitable approach for each swimmer.

DISCLOSURE STATEMENT

The authors have no conflicts of interest to report.

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Table 1. The variables analyzed at 50m and 100m breaststroke short-course.

Variable	Description
T15	Time to 15m: From when the swimmer leaves the block to when the swimmer's head crosses 15m (s).
V15	Velocity to 15m: Obtained by dividing the distance of 15m by the time to cover it ($m \cdot s^{-1}$).
ET1 - ET4	Emersion time either after the start (ET1), or after turns (ET2, ET3 and ET4). From the last contact with the wall or block until the head breaks through the water surface (s).
ED1 - ED4	Emersion distance reached either after the start (ED1), or after turns (ED2, ED3 and ED4). From the last contact with the wall or block until the head breaks through the water surface (m).
VE1 - VE4	Velocity of emersion either after the start (VE1) or after turns (VE2, VE3 and VE4) ($m \cdot s^{-1}$).
TT1 - TT3	Turn time including the distance of 5m of approaching into the wall, until the swimmer's head reaches 10m after wall (s).
TV1 - TV3	Turn velocity obtained from the distance established for turn (5 + 10m) divided by the time elapsed during such action ($m \cdot s^{-1}$).
CST	Clean swimming time extracting E1- E4 and the the 5m prior wall touch.
Race_ET	Race Emersion Time: The average of ET1 to ET4 (s).
Race_ED	Race Emersion Distance: The average of ED1 to ED4 (m).
Race_VE	Race Velocity during the Emersion: The average of VE1 to VE4 ($m \cdot s^{-1}$).
Race_TT	Race Turn Time: The average of TT1 to TT3 (s).
Race_TV	Race Turn Velocity: The average of TV1 to TV3 ($m \cdot s^{-1}$).

Table 2. Mean ± Standard deviation (SD) and Pearson's correlation coefficients (r) of the variables collected in 50 and 100m breaststroke (* $p < 0.05$; ** $p < 0.01$).

Variables	**Male 50m**		**Female 50m**		**Male 100m**		**Female 100m**	
	Mean ± SD	**r**	**Mean ± SD**	**r**	**Mean ± SD**	**r**	**Mean ± SD**	**r**
Final Time	29.07 ± 0.97		33.01 ± 1.15		63.55 ± 2.07		71.70 ± 2.66	
Age	23.29 ± 5.10	.-284*	20.61 ± 4.74	.-468**	21.74 ± 3.93	.-531**	19.58 ± 4.67	.-578**
T15	6.51 ± 0.39	.915**	7.64 ± 0.28	.826**	6.72 ± 0.37	.788**	7.81 ± 0.36	.769**
V15	2.31 ± 0.14	-.915**	1.96 ± 0.07	-.822**	2.23 ± 0.12	-.789**	1.92 ± 0.09	-.772**
ET1	4.72 ± 5.25	-.117	4.97 ± 0.55	-.006	5.32 ± 0.48	.062	5.30 ± 0.64	.038
ET2	5.25 ± 0.39	-.212	5.35 ± 0.52	-.179	5.59 ± 0.53	-.172	5.49 ± 0.52	-.155
ET3					5.58 ± 0.50	-.154	5.52 ± 0.68	-.135
ET4					5.59 ± 0.66	-.012	5.34 ± 0.47	.012
ED1	12.50 ± 0.92	-.649**	11.48 ± 1.03	-.329*	13.37 ± 1.28	-.269*	12.20 ± 1.20	-.278*
ED2	9.02 ± 0.79	-.644**	8.20 ± 0.94	-.445**	9.40 ± 0.83	-.505**	8.46 ± 0.84	-.424**
ED3					9.41 ± 0.91	-.536**	8.57 ± 1.23	-.314*
ED4					8.90 ± 0.91	-.389**	7.85 ± 0.79	-.467**
VE1	2.64 ± 0.15	-.643**	2.31 ± 0.15	-.441**	2.51 ± 0.21	-.355**	2.30 ± 0.12	-.572**
VE2	1.71 ± 0.10	-.671**	1.53 ± 0.08	-.615**	1.68 ± 0.08	-.556**	1.54 ± 0.08	-.484**
VE3					1.68 ± 0.09	-.707**	1.55 ± 0.15	-.296*
VE4					1.60 ± 0.11	-.566**	1.46 ± 0.09	-.779**
TT1	9.67 ± 0.34	.928**	10.79 ± 0.45	.804**	9.77 ± 0.35	.811**	11.10 ± 0.43	.706**
TT2					9.54 ± 0.42	.907**	10.76 ± 0.46	.914**
TT3					9.72 ± 0.39	.860**	10.99 ± 0.53	.931**
TV1	1.69 ± 0.06	-.972**	1.50 ± 0.05	-.947**	1.49 ± 0.05	-.899**	1.33 ± 0.04	-.851**
TV2					1.52 ± 0.05	-.938**	1.35 ± 0.05	-.947**
TV3					1.50 ± 0.06	-.923**	1.33 ± 0.05	-.927**
CST	23.07 ± 0.76	.960**	26.21 ± 0.97	.944**	38.12 ± 1.18	.842**	50.57 ± 1.98	.973**
Race_ET	4.99 ± 0.30	-.204	5.16 ± 0.44	-.110	5.52 ± 0.41	-.089	5.42 ± 0.45	-.078
Race_ED	10.76 ± 0.79	-.703**	9.84 ± 0.83	-.457**	10.27 ± 0.80	-.505**	9.27 ± 0.86	-.418**
Race_VE	2.18 ± 0.10	-.790**	1.92 ± 0.09	-.642**	1.87 ± 0.08	-.718**	1.71 ± 0.08	-.689**
Race_TT					9.68 ± 0.36	.933**	10.95 ± 0.44	.922**
Race_TV					1.51 ± 0.05	-.967**	1.34 ± 0.05	-.967**

Table 3. P-values and Effect sizes comparing 50 and 100m performances.

	Males		Females	
	P-value	**Effect size**	**P-value**	**Effect size**
Age	0.051	0.34	0.269	0.22
Final time	0.000	> 1.0	0.000	> 1.0
T15	0.000	0.55	0.012	0.52
V15	0.002	0.61	0.012	0.49
ET1	0.000	> 1.0	0.004	0.58
ET2	0.000	0.72	0.184	0.26
ED1	0.000	0.77	0.002	0.64
ED2	0.010	0.46	0.135	0.29
VE1	0.000	0.70	0.541	0.07
VE2	0.033	0.33	0.484	0.25
TT1	0.096	0.29	0.001	0.70
TV1	0.000	> 1.0	0.000	> 1.0
CST	0.000	> 1.0	0.000	> 1.0
Race_ET	0.000	> 1.0	0.005	0.58
Race_ED	0.001	0.61	0.001	0.67
Race_VE	0.000	> 1.0	0.000	> 1.0
Race_TT	0.696	0.05	0.086	0.33
Race_TV	0.000	> 1.0	0.000	> 1.0

Table 4. Mean ± standard deviation and Effect size of the partial contribution (%) obtained for males and females by the Time to 15m, Emersion time and Turn time to Final time in 50 and 100m Breaststroke.

		Partial contribution (%) to 50m				**Partial contribution (%) to 100m**				**Effect size 50 vs 100m**	
		Male	**~**	**Female**	**P-value**	**Male**	**~**	**Female**	**P-value**	**Males**	**Females**
Time to 15m		22.40 ± 0.73%		23.17 ± 0.50%	0.001	10.58 ± 0.38%		10.90 ± 0.33%	0.001	> 1.0	> 1.0
Emersion Time	**Total**	34.39 ± 2.63%		31.34 ± 3.00%	0.001	34.82 ± 2.95%		30.30 ± 2.90%	0.001	0.153	0.353
	ET1	16.28 ± 1.37%		15.07 ± 1.75%	0.001	8.39 ± 0.79%		7.42 ± 0.92%	0.001	> 1.0	> 1.0
	ET2	18.10 ± 1.63%		16.26 ± 1.80%	0.001	8.81 ± 0.93%		7.68 ± 0.83%	0.001	> 1.0	> 1.0
	ET3					8.80 ± 0.89%		7.72 ± 1.05%	0.001	> 1.0	> 1.0
	ET4					8.81 ± 1.08%		7.46 ± 0.73%	0.001	> 1.0	> 1.0
Turn Time	**Total**	33.26 ± 0.44%		32.70 ± 0.87%	0.001	45.69 ± 0.63%		45.83 ± 0.73%	0.238	> 1.0	> 1.0
	TT1					15.38 ± 0.33%		15.49 ± 0.47%	0.232	> 1.0	> 1.0
	TT2					15.01 ± 0.30%		15.01 ± 0.26%	0.998	> 1.0	> 1.0
	TT3					15.30 ± 0.32%		15.33 ± 0.30%	0.648	> 1.0	> 1.0

Figure 1. An example of the video recordings used for the analysis.

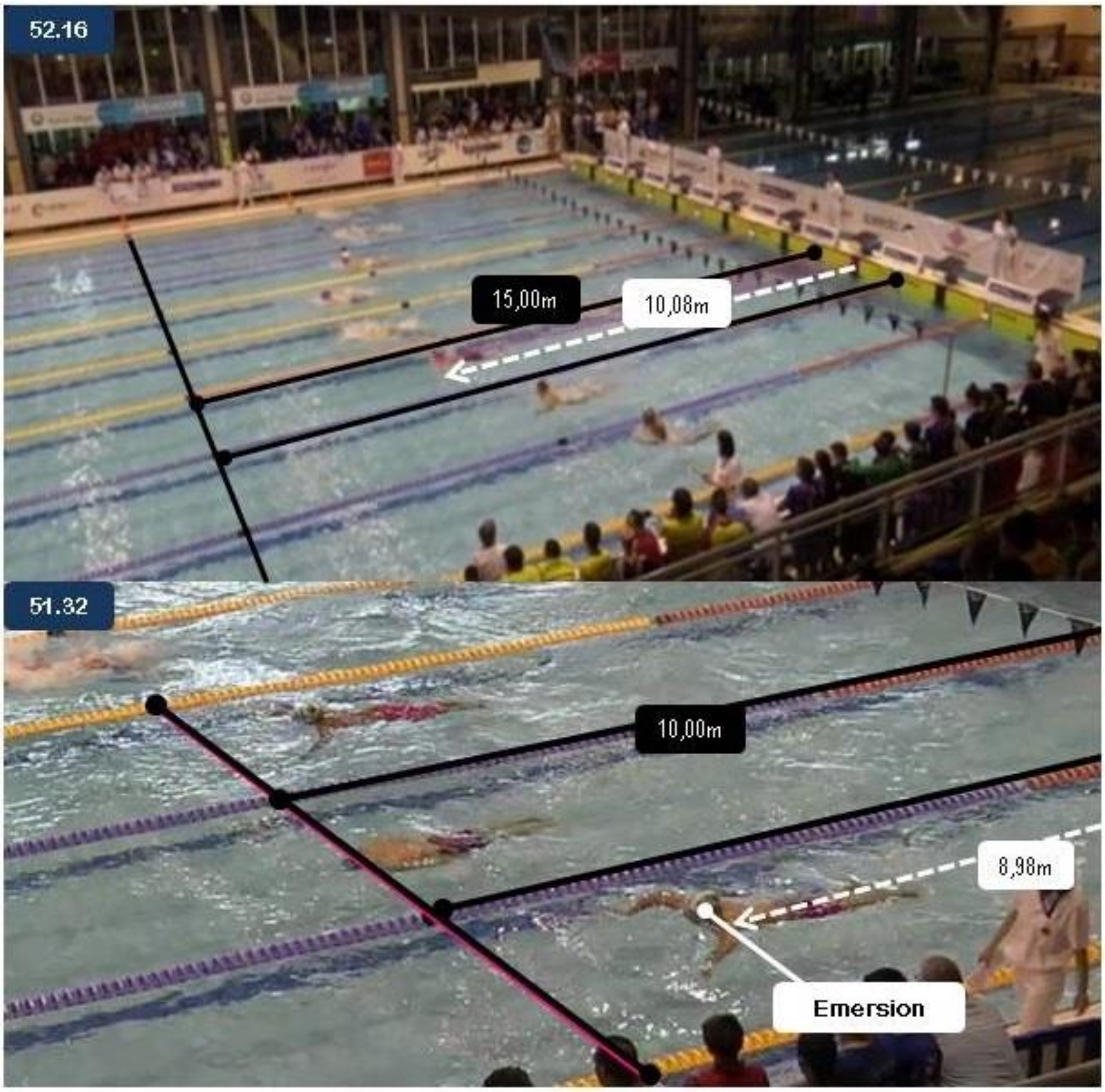

Figure 2. Linear regressions between Final time and underwater variables in 50m Breaststroke. Data clustered by gender (Males and females [§ = p < 0.05]) and result (Finalists and non-finalists [* = p < 0.05]).

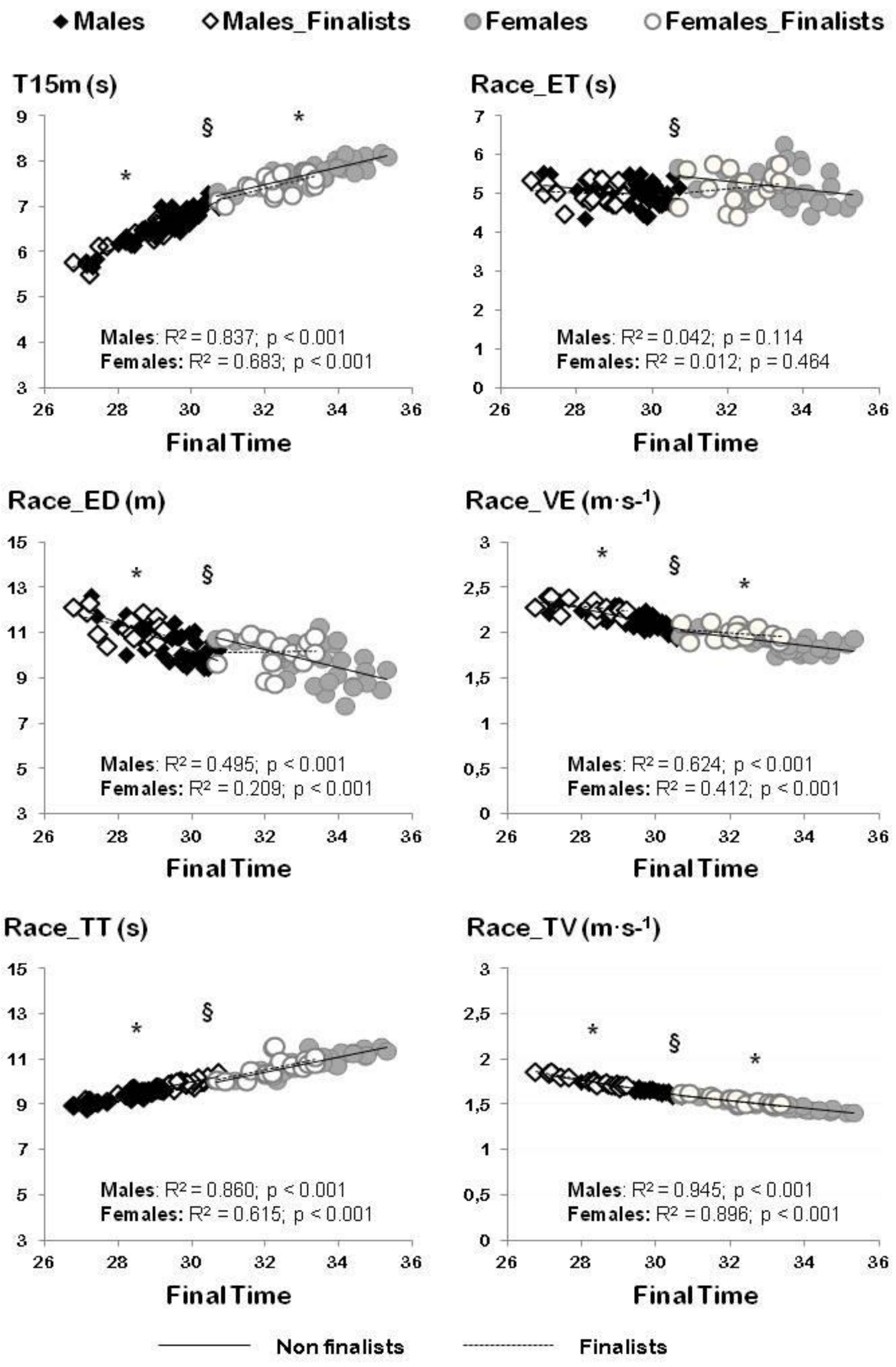

Figure 3. Linear regressions between Final time and underwater variables in 100m Breaststroke. Data clustered by gender (Males and females [§ = p < 0.05]) and result (Finalists and non-finalists [* = p < 0.05]).