ANALYSIS OF STROKE, COORDINATIVE AND TEMPORAL PARAMETERS IN TRANSITION FROM UNDERWATER TO SURFACE SWIMMING

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The objective of this study was to characterize the stroking, coordinative and temporal parameters of international swimmers during transition from underwater to surface swimming. 12 international junior swimmers were filmed on the four strokes and they were video analysed using DLT-2D algorithms to calculate the swimming velocity, stroking rate and stroking length at emersion as well as the index of coordination (IdC) and the % of each stroke phase duration on the complete cycle. The descriptive analysis of these data showed higher swimming velocity, stroking rate and IdC but shorter stroking length than previous studies characterizing free swimming. Also, the relative duration of the non-propulsive stroke phases was shorter when emerging from underwater. Therefore, the stroke, coordinative and temporal parameters should also be monitored during the transition phase of the swimming start and turns.

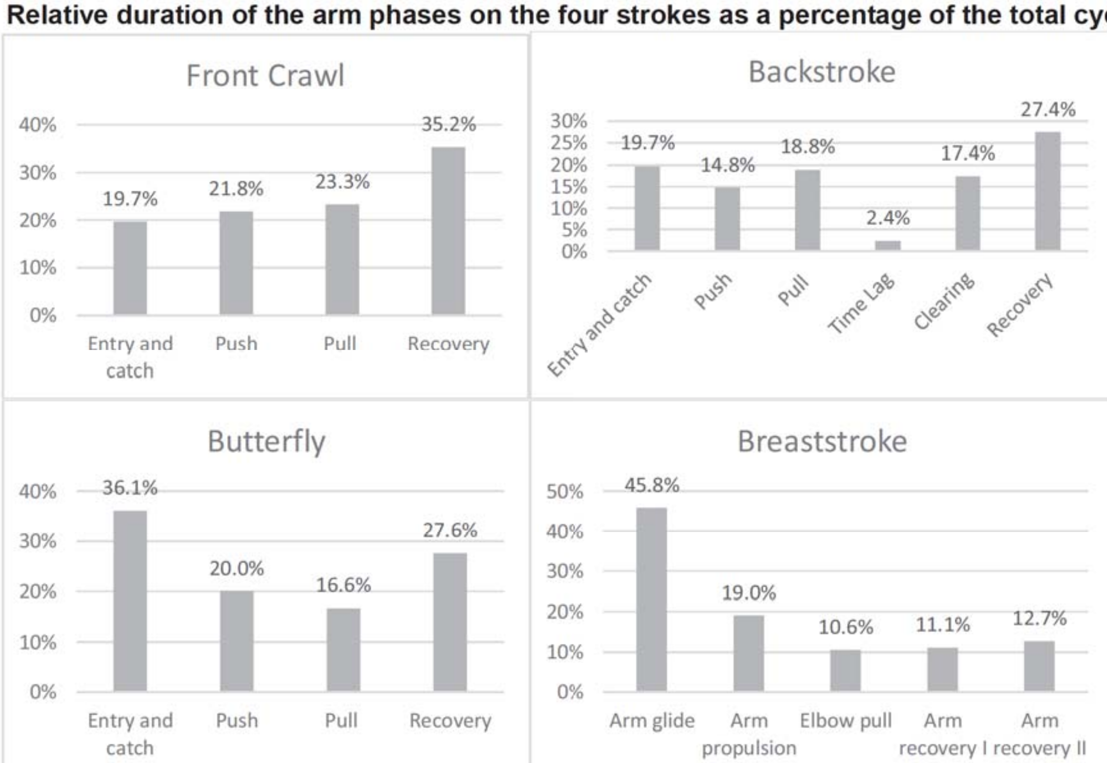
KEY WORDS: Biomechanics, motor control, performance.

Introduction: Different studies have reported that coordinative, temporal and stroke parameters in competitive swimming are conditioned by the performance level of the swimmers, gender and swimming speed (Seifert & Chollet, 2005). In the backstroke and freestyle strokes, the time gap between the propulsive phase of one arm and the other (IdC) was lower when swimming at a faster pace and its variation was correlated to an increased frequency and a reduced stroke length (Seifert, Chollet, & Bardy, 2004). In simultaneous strokes such as the butterfly and breaststroke, the time gap between the propulsive phases of arms and legs should ensure a propulsive continuity (Chollet, Seifert, Boulesteix, & Carter, 2006). As swimming speed or level of swimmers increases, the actions of the arms and legs show a greater "in-phase" coordination (Chollet, Carter, & Seifert, 2006), at the same time of increasing the stroking rate and decreasing the stroking length. For the temporal distribution of the stroke phases, an increase in the relative duration of the propulsive stroking phases (compared to the non-propulsive) was observed in different strokes when increasing swimming velocity. For example, in breaststroke, an increase of the propulsive time of the kick and stroke was associated with a decrease in the glide duration (Chollet, Seifert, Leblanc, Boulesteix, & Carter, 2004). However, these coordinative and temporal parameters have been characterized on the free swimming but not on the start and turn segments of a swimming race. Considering that 15m start and turn times include some swimming stroke cycles and that the starting and turning performances have a meaningful effect on the competitive swimming results (Veiga & Roig, 2016), we aimed to characterize the stroke, coordinative and temporal parameters of international swimmers during transition from underwater to surface swimming.

Methods: 12 youth swimmers (15.5±1.5 years of age) of the Spanish junior team participated in the study. Athletes were verbally indicated to perform a push start on each stroke at a 400m pace (V400) and they were laterally filmed during the transition phase from underwater to surface swimming. The transition phase was defined from the beginning to the end of the first arm stroke cycle after the push off the wall, except in breaststroke where the second arm stroke (after the pull out actions) was considered for analysis. A JVC GY-DV500E video camera at 50Hz was used to record the data and DLT-2D photogrammetry was used to determine the actual 2D coordinates of the swimmer's hip using the Photo23D software (Technical University of Madrid). As previously described (Chollet, Seifert & Carter, 2008), two different operators analyzed videos to identify key points of the arm phases. When the difference between operators did not exceed an error of 0.04 s, the mean of the two analyses was accepted to validate the key point of each phase. From the video footage, the following variables were calculated: average velocity (m/s), stroking rate /cycles/min) and stroking length (m/cycle), the backstroke and freestyle IdC, the arm-leg coordination in butterfly through the relative phases (RP), the propulsion index of the breaststroke (IFBP) as well as the relative duration (%) of each phase in relation to the entire cycle.

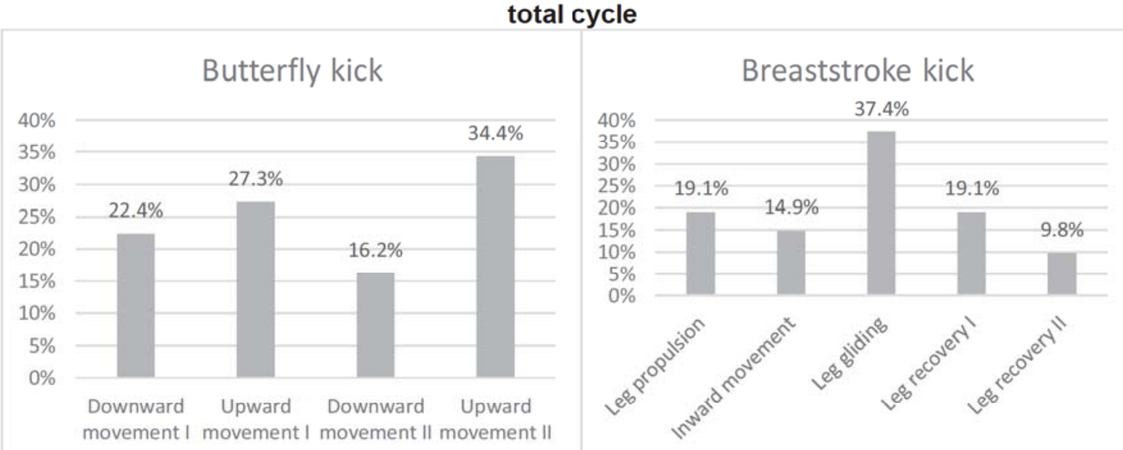
Results and Discussion: The IdC during transition was -7% in front crawl and -10.9% in backstroke, both in the "catch-up" mode and slightly higher than reported in literature (Chollet, Seifert, & Carter, 2008; Seifert, Chollet, & Bardy, 2004). These differences may be due to the push off from the wall which gives the swimmer a higher velocity compared to the surface swimming. In breaststroke, an IFBP (Seifert & Chollet, 2005) of 48.2% during transition was observed in the present research which is higher than previously reported during free swimming (41.1% males and 33.6% females at V200) (Seifert et al. (2004)), despite a slower velocity during breaststroke transition in our international youth swimmers. In the butterfly stroke, an "out of phase" coordination mode associated with an uncoordinated model of swimming for RP2 (232.4º) and RP3 (315.7º) phases were observed during transition. These values differ from the study of Seifert, Chollet, and Rouard (2007), where swimmers had a higher prevalence of the "in-phase" coordination mode, except for an "anti-phase" mode in RP2. Therefore, the conditions associated with the transition from underwater swimming to surface swimming may hinder the achievement of an in-phase coordination in the RP3 phase.

Figure 1
Relative duration of the arm phases on the four strokes as a percentage of the total cycle



For the distribution of the temporal stroke phases on the each stroke (Figure 1), the "entry and catch" phase of the front crawl in this study (19.6%) was substantially shorter than the 31.8% reported in the study of Seifert et al. (2004). This is in line with swimmers decreasing duration of entry and catch when swimming faster. However, our data also showed a longer recovery freestyle phase on transition (35.2%) compared to Seifert et al. (2004) (25.8%). This could be due to the recovery phase of transition being the first arm exit after the underwater swim. Therefore, swimmers could employ these phase to adjust stroking movements in relation to ascending body position. In breaststroke, the gliding phases were lower during transition (45.8% and 37.40% for the arms and legs gliding, respectively) with respect to surface swimming (Seifert & Chollet, 2005). This may be linked to a higher IFBP but it not resulted in a higher swimming velocity during transition in comparison to breaststroke free swimming. In butterfly, the relative phases of the kick cycle (Figure 2) showed that the downward motion in the first kick during transition was substantially longer (24.4%) than previously reported (between 15% and 18%) in the butterfly free swimming (Chollet, Carter, et al., 2006; Seifert, Chollet, et al., 2007). Swimmers probably execute a longer first kick to adjust timing with the beginning of the arms movement.

Figure 2
Relative duration of the butterfly and breaststroke kicking phases as a percentage of the total cycle



Many of the coordinative and temporal changes observed in our data compared with literature may be due to the increased stroking parameters of the transition cycle compared to surface swimming. In front crawl, backstroke and butterfly, the swimming speeds were higher than those reported in literature for V400 (Chollet, Carter, et al., 2006; Chollet et al., 2008; Seifert et al., 2004; Seifert, Delignieres, Boulesteix, & Chollet, 2007). These differences may be attributed to the fact that the swimmer precedes the transition by a push off the wall, which gives him a higher velocity than in surface swimming. This phenomenon was not observed in the breaststroke probably due to the greater drag forces acting on the swimmer on the second gliding position (Vilas-Boas et al., 2010) and the coordinative constraints of the underwater breaststroke pulling motions (Seifert, Delignieres, et al., 2007). As a consequence of the higher swimming velocity when emerging form underwater, the stroking rate values when beginning surface swimming in all four strokes showed higher values than previous studies during free swimming. Also, the stroking length values in all the four strokes at the transition phase were shorter than previously reported as the high swimming velocity probably prevented swimmers to perform a greater gliding (Chollet, Seifert, et al., 2006; Chollet, Seifert & Carter, 2008; Schnitzler, Seifert, Alberty, & Chollet, 2010).

Tabla 4. Stroking parameters of the four strokes on the transition phase from underwater to surface swimming.

	Average velocity (m/s)	Stroke rate (cyles/min)	Stroke lenght (m/cycle)
Front crawl	1.72	1.99	52.49
Backstroke	1.63	2.38	40.39
Butterfly	1.68	1.73	56.69
Breaststroke	1.16	1.91	37.3

Conclusions: Higher swimming velocities obtained by competitive swimmers when transiting from underwater to surface swimming seemed to modify the stroking, coordinative and temporal parameters in all four strokes. Therefore, these parameters should be monitored during the transition phase of the swimming start and turns in addition to free swimming.

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