EVOLUTION OF THE BUTTERFLY COORDINATION IN RELATION TO VELOCITY AND SKILL LEVEL OF SWIMMERS

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The purpose of this study was to identify stroke phases and arm and leg coordination during butterfly swimming as a function of swim velocity and performance level. Twenty four swimmers constituted two groups based on performance level. All swam at three different velocities, corresponding to the appropriate paces for respectively the 400 m, 100 m and 50 m. The different stroke phases and the arm and leg coordination were identified by video analysis. The coordination was studied by the temporal gap analysis separating the changes of arm and leg movements. The most important results showed that expert swimmers are characterised by their capacity to control and adapt their coordination with an increase in velocity, contrary to non expert characterised by lag times into movement of arms to place their legs actions.

KEY **WORDS:** swimming, butterfly, arms and legs, coordination

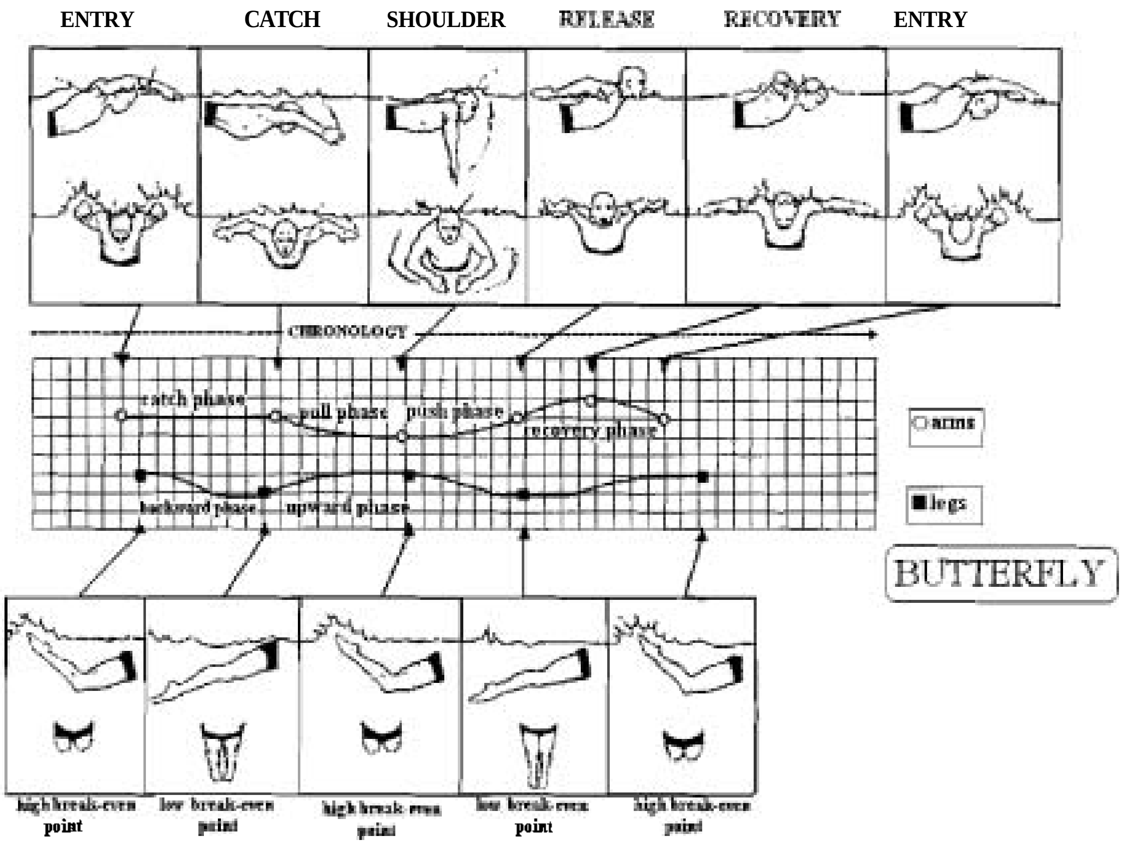
INTRODUCTION: In butterfly swimming, motor continuity depends on the coordination of the arm and leg movements. In this stroke, good coordination is associated with two undulations, each composed of an upward phase and a backward phase for each complete arm cycle. Costill et al (1992), Cousilman and Counsilman (1994), and Maglischo (1993), define precisely the synchronization between the arms and the legs: the downbeat of the first kick should be made during the entry and outsweep of the arms, and the downbeat of the second kick should coincide with the upsweep of the underwater armstroke. It appears that the relationships between the arm and leg movements and, between the right arm and the left arm evolve according to velocity. For example, Chollet et al (2000) showed in crawl, that the index of coordination, used to measure precisely the lag time between the end of propulsion of one arm and the start of propulsion of the other, increased significantly with velocity and with performance level. No previous study has been interested in the expert's arm-leg coordination in butterfly with regard to velocity. Nor has any previous work compared the coordination of non-expert to expert butterfly swimmers.
The aim of this study was (1) to determine how the arm-leg coordination evolves in butterfly among experts swimmers at different velocities, and (2) to compare the coordination of expert swimmers with that of non expert swimmers at specific paces.

METHODS:
Subjects

Group	Percentage to 100m butterfly world record	Level	Male	Female	Total
Experts (G1)	90.62%	International	6	3	9
Non experts (G2)	67.46%	regional	9	6	15

Video Analysis. The stroke phases and modes of arm and leg coordination were recorded with two underwater front and profile cameras (S.VHS Panasonic) set at rapid shutter speed (50 Hz). They were connected to a double entry visual mixer (Panasonic WJ-AVE5), a video-timer (FOR-A) and a video recorder. A third independent camera filmed all trials in profile from above the water to quantify the swim velocity.
Experimental Protocol. The protocol used was the one described by Chollet et al. (1998). Each swimmer swam 12.5 m at three different swim velocities – 400 m (V400), 100 m (V100) and 50 m (V50). The time and the stroke rates achieved were controlled.

Analysis of Arm and Leg Coordination. The coordination data collected on strip video time-code was analysed field by field with every phase of movement of the arms and legs having a starting point and a finishing point. These events of interest were noted for the arms - entry of the hands in the water, beginning of the hand's backwards movement, hand's arrival in the vertical plane to the shoulders and the exit of the hands from the water. For the legs, the events of interest were - the high and low break-even point of the first and the second undulation These data were collected for three complete arm cycles using a specific computer program. To indicate the timing and coordination the results were represented as shown in Figure 1.



Fiaure **1 -** Svnchronisation structure of arm and lea for **butterflv** swimmina.

The temporal appearance of the coordination was studied with the temporal gap analysis (T) separating the change of phase of the arm and leg movements. For example, T1 corresponds to the temporal gap between the entry of the hands in the water and the high break-even point of the first undulation. These spatio-temporal relations were expressed relative to a complete arm cycle (figure 2).

Statistical Analysis. The comparisons of means of the phases and gaps were undertaken with a two-way ANOVA (velocity and performance level), including each respectively three levels of velocity (400, 100 and 50m) and two levels (expert or non expert swimmer), completed by the PLSD test of Fisher. All analyses were done using STATVIEW, and significance was fixed at 0.05 level of confidence.

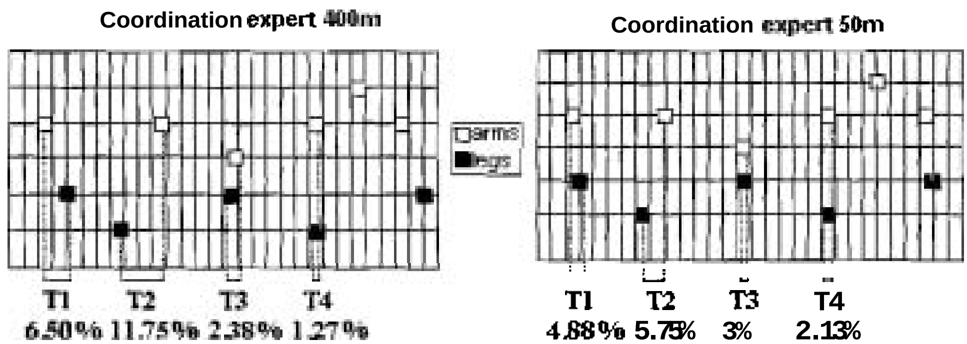
RESULTS:

Spatio-Temporal Parameters. The swim velocity was significantly ($p < 0.05$) increased ($1.49 \pm 0.11\ m.s^{-1}$: V400 to $1.70 \pm 0.12\ m.s^{-1}$: V50 for the group G1 : experts, and $1.24 \pm 0.09\ m.s^{-1}$: V400 to $1.46 \pm 0.09 m.s^{-1}$: V50 for the non expert group : G2). The stroke rate also increases with velocity, passing for G1 from 42.7k3.06 cycles.min^{-1} (V400) to 53.91.3.47 cycles.min^{-1} (V50) and 38.25±5.52 cycles.min^{-1} to 50.081.5.00 cycles.min^{-1} for G2. The distance per stroke decreases with the increase in velocity for both groups, by 0.07±0.03m.cycle^{-1} by and 0.07±0.005 m.cycle^{-1} respectively.

Arm Phase. For the expert group (G1), the increase of velocity results in a reduction of the catch phase of 2.3±1.3% ($p < 0.05$), a stability of the pull and push phases with mean values of 23.2±0.9% and 22.73±0.5% respectively, and a non significant tendency of the recovery phase to increase with velocity, passing from 24.1±3.42% (V400) to 31.3±4.59% (V50).

Leg Phase. The results of the phases of undulation for the expert group (G1),from the upbeat of the first kick to the upbeat significant change with the increase of velocity. The downbeat of the first kick increases with velocity, passing from 15.7±1.06% (V400) to 19.4±1.47% (V50).

Coordination of Arm and Leg Movements as a Function of Swim Velocity. The analysis of the structure of arm and leg coordination for the expert group (G1) shows the steady spatio-temporal relations between arm and leg movements for T1, T3 and T4. The mean values are 5.07±0.94%, 2.88±0.29% and 1.80±0.41% respectively. On the contrary, the spatio-temporal relation for T2 evolves with the elevation of the pace, passing from 11.75±3.96% (V400) to 5.75±3.27% (V50) (Figure 2)



SV	Level	T1	T2	T3	T4	Moyenne
(V400)	G1	6.50 ± 2.40	11.75 ± 3.96	2.38 ± 1.87	1.27 ± 1.30	5.47i4.12
(V50)	G1	4.88 ± 4.43	5.75 ± 3.27*	3.00 ± 2.92	2.13 ± 2.32	3.94i1.44

Abbreviations : G1 : experts group swimmers; SV : imposed swim velocitv ; *: significant difference (p<0.05) with'the 400m velocity.

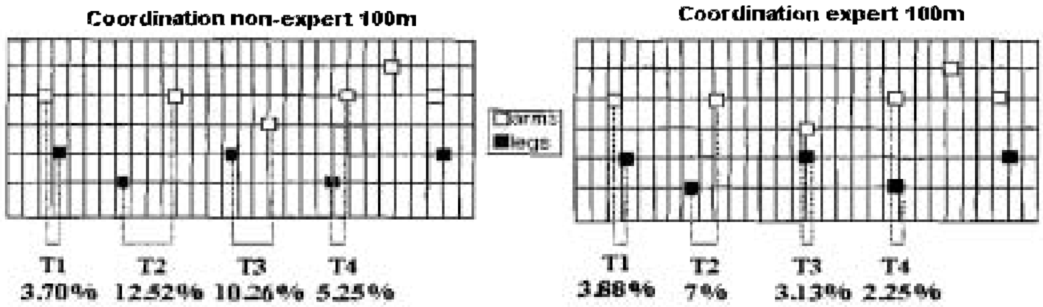
T1: entry of the hands in the water / high break-even point of the 1st undulation
T2: beginning of the hands backwards movement / low break-even point of the 1st undulation
T3: hands arrival in the vertical plane to the shoulders / high break-even point of the 2nd undulation
T4: hands release from the water / low break-even point of the 2nd undulation

Figure **2 -** Representation of the arm and leg coordination in butterfly at different swim velocities for the expert group.

Coordination of Arm and Leg Movements as a Function of Level. The comparison between experts and non experts at V100 shows significant differences ($p < 0.05$) for the spatio-temporal relations T2, T3 and T4. These values for G1 are 7±3.32%, 3.13±2.42% and 2.25±1.39% respectively. For G2, they are significantly superior with 12.52±4.55% (T2), 10.26±3.75% (T3) and 5.25±3.66% (T4) (Figure 3).

DISCUSSION: The spatio-temporal parameter analysis shows that in butterfly the elevation of the swimming velocity is accompanied by an increase in stroke rate and a decrease in stroke length. These observations are in agreement with those made for crawl by Keskinen and Komi

(1993) and for butterfly by Chollet et al (1996). As the velocity increases, the drag also increases (Kolmogorov & Duplisheva, 1992). The increase in velocity results in an increase of the backward phase of the first undulation, which can be explained by the fact that this propulsive phase of the legs intervenes during a non propulsive phase of the arms (the catch phase). The arm and leg coordination of the expert swimmer varies vary little with velocity.
The constancy of the temporal gaps of T1, T3 and T4 as well as the regular evolution of T2



SV	Level	T1	T2	T3	T4	Moyenne
(V100)	G1	3.88 ± 2.32	7.00 ± 3.32	3.13 ± 2.42	2.25 ± 1.39	4.07 ± 1.79
	G2	3.70 ± 2.29	12.52 ± 4.55*	10.26 ± 3.75*	5.25 ± 3.66*	7.73 ± 3.75*

Figure **3 -** Representation of the arm and leg coordination in butterfly for expert and non expert swimmer at **100m** pace.

demonstrates that the expert swimmer has a capacity to control his coordination, varying a phase only to adapt to an increase in the velocity. The comparison of coordinations between the expert and non expert group for the 100m butterfly demonstrates the difference between the two levels of performance. The significant increase of the temporal gaps of T2, T3 and T4 demonstrates that unlike the expert, the non expert has requirement to increase certain lag time of the movements of arms to place his legs actions. The study of coordination modification, so much for the evolution of the velocity that of the level of practice, provides an indication of the technical skill of the swimmer.

REFERENCES:

Chollet D., Chalies S., & Chatard J.C., (2000). A new index of coordination for the crawl : description and usefulness. International Journal of Sports Medicine, **21,** 54-59.

Chollet D., Pelayo P., Tourny C. & Sidney M. (1996). Comparative analysis of 100m and 200m events in the four strokes in top level swimmers. Journal of Human Movement Studies, **31,** 25-37.

Chollet, D., Tourny-Chollet, C., & Gleizes, F. (1998). Evolution of co-ordination in flat breaststroke in relation to velocity. Biomechanics and Medicine in Swimming *VIII.* Jyvaskyla, Finalnd: University of Jyväskylä.

Costill D.L., Maglischo E.W., & Richardson A.B. (1992). Swimming. Oxford : Blackwell Scientific Publications.

Counsilman, J.E. & Counsilman, B.E. (1994). The new science of swimming. Englewood Cliffs: Prentice Hall.

Keskinen K.L., & Komi P.V. (1993). Stroking characteristics of front crawl swimming during exercise. Journal Applied Biomechanics. **9,** 219-226.

Kolmogorov S.V., & Duplisheva A. (1992). Active drag, useful mechanical power output and hydrodynamic force coefficient in different swimming strokes at maximal velocity. Journal of Biomechanics, 25, 311-318.

Maglischo, E.W. (1993). Swimming even faster. Mountain View: Mayfield Publishing.