ANALYSIS OF THE STARTING PHASE IN COMPETITIVE SWIMMING

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INTRODUCTION:

Tab. 1: Example of the start phase in the 1996 Olympic Games

Name / country	event	15 m-time s	final time	rank
Pankratov / RUS	100 m S / M	5.73	52.27	1.
Miller / AUS	100 m S / M	6.13	52.53	2.
Kulikov / RUS	100 m S / M	6.00	53.13	3.
Rouse / USA	100 m R / M	6.43	54.10	1.
Falcon / CUB	100 m R / M	6.73	54.98	2.
Bent / CUB	100 m R / M	7.38	55.02	3.

From Table 1 we learn that the 100 m dolphin Olympic champion for men, Pankratov, gained an advantage of 0.40 sec during the initial 15 meters compared with the silver medallist Miller (AUS). Comparing the final race times there is a difference of only 0.28 sec. In male backstroke swimming the Cuban Brent reaches the highest swimming velocity in the cyclic movement, but he loses too much time during the start phase and the turns. Consequently he finishes "only" third behind the other Cuban, Falcon, and behind the Olympic champion, Rouse (USA), who performs extraordinarily well in the start phase.
For the qualitative and quantitative analysis of biomechanical parameters of dive start execution in competitive swimming, the Leipzig Institute for Applied Training Science has developed a measuring station which is applied for complex performance diagnostics of the national team members of the German Swimming Association, as well as for training. This station consists of a video system, a starting block with a dynamometric platform, a computer with specific hardware and specific electronic equipment. A minor solution can also be applied without the specific starting block. With the help of the measuring station several split times and velocities can be monitored, the trajectory of the center of gravity and derived values can be calculated. Additionally, the forces applied by the athlete on the starting block can be measured.

METHODS AND PROCEDURES:

Theoretical approach

In contrast to other authors investigating into the influence of several parameters on start phase performance using statistical procedures (for example GUIMARES and HAY 1985, YOSHIDA and SAITO 1981), we only use a simple mechanical

model to derive an analytical function for 7.5 and 15 m split start times (KÜCHLER, 1994).
The 15 m start time is the sum of blocktime t_B, flight time t_F, underwater time t_W and transition time $t_Ü$:

$$t_{15m} = t_B + t_F + t_W + t_Ü$$

Based on a simple mechanical model approach (point mass, ballistic throw, water resistance) you get the 15 m start time as an analytical function depending on only a few parameters (KÜCHLER 1994, 1997):

$$t_{15m} = F\,(t_B, X_O, Y_O, V_{XO}, V_{YO}, C_{eff}, m, l, V_{7.5\text{-}15m})$$

The parameters are:

t_B	block time
X_O, Y_O	horizontal re.. vertical coordinate of center of gravity at the take-off of the feet
V_{XO}, V_{YO}	horizontal re. vertical component of the center of gravity velocity at the take off of the feet
C_{eff}	water resistance value
m	swimmer's body mass
l	swimmer's body height
$V_{7.5\text{-}15m}$	mean velocity between 7.5m and 15m

Using this function start time can be simulated and the influence of different parameters on start time can be determined on a qualitative level. Simulation calculations showed that 15 m start time is essentially determined by the horizontal component of the center of gravity velocity V_{XO}, by the water resistance value C_{eff} and the velocity $V_{7.5\text{-}15m}$.

Construction of measuring station: The movement execution during the start phase is monitored with a maximum of five synchronized video cameras. The video frames of individual cameras are mixed and described using a timer information and a time code (VITC signal). Timer/timecode-generator and measuring data monitoring are started with an electrical impulse parallel to the acoustic starting signal.
The starting block has a dynamometric platform monitoring the three force components. The forces on the platform are measured with the help of strain gauges as electrical voltage signals. The electrical voltage values are monitored by the computer using an AD-card.
We use an IBM compatible computer with an additional AD-converter and a Screen Machine card for the presentation and manipulation of video frames. The strength signals are digitized with the AD-converter, the timecode is monitored via a motion link and a serial interface.

Software

Protocol control and evaluation is implemented with a program which was developed using the developmental system DELPHI by Borland International. It is composed of the following elements: measuring station configuration, event and athlete management, input dialogue (consisting of the components calibration, dynamometrics, split time analysis and trajectory analysis), as well as a simple presentation of results. A connected database makes detailed data processing possible.

Test protocol

Before starting the test protocol a calibration for the video picture is done by recording certain calibration bodies in certain places. Video recordings and data monitoring are initiated a few seconds before the starting signal - with the first call for the start. The monitoring of the strength data can be terminated when the swimmers have left the starting block. Video recordings are terminated when the swimmers have passed the 15 m line. Then either a new trial can be started or the monitored data can be immediately analyzed.

From the strength data the input program calculates the block time and the reaction time. The other quantitative findings result from video analyses or from a combination of both procedures. Initially a split time analysis is performed. This forms the basis for the calculation of time differences of interest, as well as deduced velocity values.

Then the trajectory is analyzed using certain body postures. Here we use a body model (with reference to SAZIORSKI, ARUIN & SELUJANOW 1984) and a procedure to rectify pictures by HILDEBRAND 1997. To do this the flight parabola of the center of gravity is calculated as a basis for the determination of other values such as flight time, take-off angle and flight distance.

RESULTS AND DISCUSSION: Based on the findings concerning performance during the starting phase we can make the following statements:

The main reason for only a medium start time *(* $t_{7.5m}$,, t_{15m} *)*.is a too low horizontal component of take-off velocity.

The reasons are:

- insufficient jumping "strength" as a consequence of deficient muscular performance capacity for the extension in the knee joint, ankle and hip joint,
- ineffective use of existing strength potentials caused by errors in the coordinated strength application in the individual joints during take-off.

A second main reason is a loss of velocity during the entry phase when ineffective movements develop excessive braking forces.

The braking is caused by:

- hands gripping too far (long local distance between the entry point of the hand and the center of gravity),
- an abrupt change of the downward movement by arm/hand and trunk movements during entry,
- incorrect body posture during entry (the legs hit the water because of deficient hip extension, head is too low).

Finally, we found a too-low propulsion efficiency of the propulsive impulse during the transition phase.

This is caused by:

- insufficient strength potential of the trunk muscles,
- limited ankle flexibility (freestyle, backstroke, dolphin),

- disadvantageous body posture during gliding phases (affecting flow) and during the underwater breaststroke re. too long gliding phase in breast stroke swimming.

CONCLUSIONS: Swimmers can only achieve top performances during the start phase if they are able to perform the following three components on the same, high level:

- an optimal take-off performance (increase of horizontal component of take-off velocity),
- a decrease of drag forces during entry,
- an increase of propulsive efficiency during the transition phase (dolphin movement, underwater breaststroke).

Results of video analyses during international swimming events (World Cup, European Championships) confirm our findings.

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