HOW TO DIVE-IN DURING SWIM START FROM THE BLOCK? – A KINEMATIC ANALYSIS

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SUMMARY
This conference contribution reports on the relationships between selected kinematic parameters on the dive-in behavior and the swim start performance (time to 7.5 m) in sixteen elite swimmers executing their preferred starting technique (grab start: N = 9, track start: N = 7) when starting from the block. The report introduces a new biomechanical evaluation model to assess body segment coordinates during the dive-in phase. So far, this period was not examined thoroughly due air particles swept along the body surface causing restrictions for visual inspection.

The main difference between both subgroups was found for the hip angle at water entry of the center of mass (CM) with track starters showing significantly more extended hips than grab starters. In both subgroups, for this measure and for the mean horizontal velocity of the CM during the dive-in phase highly significant correlations were found with the starting performance. In addition, only grab starters showed significant correlations between the starting performance and CM entry angle, the horizontal velocity during flight, and the maximum in the frontal area during dive-in. The lack in correlations in the track starter is thought be related to different execution modes when front- and rear-weighted track starts are performed.

INTRODUCTION
While the dive-in performance after swim start from the block is considered to be an essential prerequisite for swim start performance in general [1, 2], there are only few studies in the literature related to an examination of dive-in kinematic profiles in elite swimmers. This deficit might be due to apparent methodological problems involved when detecting body landmarks as air particles swept along the body surface distorting a clear vision. A new procedure was developed to identify body landmarks despite visual restrictions during the dive-in phase. Consecutively, a study was conducted to examine the kinematic dive-in pattern in elite swimmers.

METHODS
Sixteen male elite swimmers (weight: 84.0 ± 9.3 kg, height: 1.89 ± 0.05 m) participated in the study. Group mean performance for 100m-freestyle (s) was within 7% from the world record. Starting performance was studied in the course of a 50m speed test and measured by the time elapsed between the starting signal and the passage of the head at 7.5 m. Three video cameras (50 Hz) were used for data acquisition. While block performance and head passage at 7.5 m were analyzed by two above water cameras, an underwater video system was used to analyze the dive-in behavior. Since body landmarks are hard to be identified because of air particles carried along the body surface during dive-in, segment mid-lines were evaluated by a linear regression model using four representative midline points per segment for the calculations. For the trunk segment, a spline regression was used. Traditional body landmarks (segment end-points) were identified as intersections of two adjacent segment mid-lines (Fig. 1).

For the kinematic analysis of the dive-in behavior the following parameters were assessed: the rotational impulse about the transverse body axis (as computed by [3]) during the airborne phase, the mean horizontal velocity during dive-in (time between entry of finger-tips and the toes reaching its lowest point after complete entry of the body), CM entry angle (calculated for the last three frames before water contact), hip angle at CM entry, maximal frontal area covered by the highest and the lowest endpoints of the body segments during dive-in, and as a reference the horizontal velocity during the flight phase. The starting performance was examined by the time between the starting signal and the head passage at 7.5 m.

Figure 1: Dive-in phase after during swim start from the block: Segment mid-lines for shank and thigh are evaluated by a linear regression model with a four point estimate.

RESULTS AND DISCUSSION
The results of the kinematic analysis are listed in Tab. 1. Significant differences between both subgroups were only found for the hip angle at CM entry. For both subgroups, there were highly significant correlations between the starting performance and the mean horizontal velocity of the CM during entry (r = -0.81 for both grab starters and track starters) on one side and the hip angle at CM entry (r = 0.81 for grab starters and r = 0.82 for track starters) on the other. In addition, only grab starters showed significant correlations between the starting performance and CM entry angle (r = -0.73), the rotational impulse (r = -0.75) and the horizontal velocity during flight (r = -0.74). Taken together, these results indicate that dive-in behavior is very important factor for the starting performance. In fact, hip
angle at CM entry and the maximum in the frontal area during dive-in could explain 61 percent (corrected) of the variance in the starting performance for the grab starters \((R = 0.84)\) and 66 percent (corrected) for the track starters \((R = 0.88)\). For the grab starters, an additional variance of 16 percent variance could be explained by the mean horizontal velocity of the CM during entry. For the track starters, an additional variance of 20 percent variance could be explained by the horizontal velocity in the flight phase. All in all, these results provide evidence about the importance of a good dive-behavior for the starting performance. In addition, there are clear indications that good starters minimize their loss in horizontal velocity during dive-in by the use of a dolphin-kick.

**CONCLUSIONS**

For both subgroups, a dive-in behavior proved to be an important prerequisite for a fast starting performance. Most importantly, grab starters and track starters utilize a hyper-extended back at entry to prepare for a power dolphin kick at the end of the dive-in phase.

**REFERENCES**


**Table 1:** Starting performance from the block (StartPer) and kinematic parameters for the dive-in phase: rotational impuls (L), horizontal velocity during the flight phase (Vhor Flight), the mean horizontal velocity during dive-in (Vhor Entry), centre of mass entry angle (CM Angle), hip angle at CM entry (Hip Angle Entry), and the maximal frontal area of the body during dive-in (Area Entry).

<table>
<thead>
<tr>
<th>subgroup</th>
<th>Start Per (s)</th>
<th>L (Nms)</th>
<th>Vhor Flight (m/s)</th>
<th>Vhor Entry (m/s)</th>
<th>CM Angle (deg)</th>
<th>Hip Angle Entry (deg)</th>
<th>Area Entry (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>grab start</td>
<td>2.67 ± 0.11</td>
<td>32.8 ± 7.3</td>
<td>4.60 ± 0.18</td>
<td>3.67 ± 0.28</td>
<td>-32.1 ± 1.5</td>
<td>176.2 ± 7.1</td>
<td>0.85 ± 0.10</td>
</tr>
<tr>
<td>track start</td>
<td>2.65 ± 0.15</td>
<td>31.6 ± 4.7</td>
<td>4.59 ± 0.20</td>
<td>3.80 ± 0.13</td>
<td>-32.1 ± 2.3</td>
<td>183.9 ± 5.9</td>
<td>0.85 ± 0.14</td>
</tr>
</tbody>
</table>