KINETIC AND KINEMATIC ANALYSIS OF THE LEG POSITIONING IN THE FREESTYLE TRACK START IN SWIMMING

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In swimming competitions, the track start is an important part of the race. The aim of this study was to assess and compare the relative positioning of the dominant leg in the preferential freestyle track start. The data was collected using the (Kistler) Performance Analysis System for Swimming (PAS-S) that includes a force measurement and motion analysis system. The results taken from 15 high level competitive swimmers showed that 67.7 % of the subjects naturally position their dominant leg in front. Starting with the dominant leg in front (6.67±0.24) was significantly ($p < 0.001$) faster than in the rear position (7.25±0.23). However swimmers had faster starts when using their preferential track start. Detailed analysis of the swimming start and the footedness allows coaches and athletes to train the fastest starting technique.

KEYWORDS: swimming track start, start position, dominant leg, footedness.

INTRODUCTION: In swimming competitions the track start is an important part of the race (J. Cossor & B. R. Mason, 2001). Many scientific studies analyzing the swimming start have been performed in recent years, with investigators generally using either force platforms (Murrel D, 2012) or optical measurement systems (Nomura T, 2010; Takeda T, 2010) alone. Force platforms have also been utilized in the starting platform in combination with vision assessment systems (above and below the waterline) to analyze performance variables for starting performance (Honda KE, 2010; Takeda T, 2010; Vantorre J, 2010). In addition, Cossor JM (2010) used wireless accelerometers. In the study of Hardt, Benjanuvatra and Blanksby (2009) the relationship between lower limb asymmetry and stance preference in the swimming track start was explored. The majority of the participants produced better performances using the preferred track start stance, rather than the dominance of either limb in the forward or rear position. The conclusion was that further investigation is required to identify factors that predict the lateralized behavior of the track start.
The start position of the athletes is normally chosen based on the subjective feeling of the athletes. A detailed analysis of start performance based the athlete's footedness that includes force data for each foot, however, remains to be undertaken. Therefore, the aim of this study was to (1) identify the preferential positioning of the dominant leg in the freestyle track start, to (2) compare the preferred track start using the normal limb configuration (T_n) with the non-preferential track start opposite (T_o), and to (3) compare the track start with the dominant leg in the front position against the dominant leg in rear position. The results should enable athletes to improve their start performance and help coaches to identify the best start variant.

METHODS: 13 male and 2 female healthy, high-level swimmers (age: 20 ± 3 years, height: 1.85 ± 0.09 m, weight: 74 ± 11 kg, performance: 767 ± 88 FINA points) of the Swiss Swimming Training Base (SWTB) in Tenero participated in this study, which was approved by the local ethics committee. The study included a subjective component with 2 questionnaires, as well as 2 objective measurements using the new (Kistler) Performance Analysis System for Swimming (PAS-S) (Type 9691A) and the (Kistler) Quattro Jump (Type 9290AD).
The swimmers performed 10 track starts in a random order. Five track starts were performed with their preferential leg positioning T_n and 5 starts with the opposite variant T_o. Kinetic and kinematic data of the start and the first 15 meters were collected using PAS-S, a performance measurement system consisting of an instrumented starting platform with two force platforms and instrumented starting grips, as well as a corresponding vision system with four cameras (three underwater, one above). The measurement system had been

previously assessed for reproducibility after mounting and remounting (Sinistaj S. 2015).
The dominant leg was identified in each subject using single leg jump performance and a footedness questionnaire.
The time after 15 m (t 15m [s]), the time from the start signal until the leave of the block (Block time [s]), entry meters [m] and the peak power [W/kg]) were assessed using the PAS-S system. The horizontal/total momentum [Ns], the maximal horizontal force of the front plate and back plate [BW] and the maximal “negative” force of the grab bar [BW] were determined using MATLAB (Figure 1).

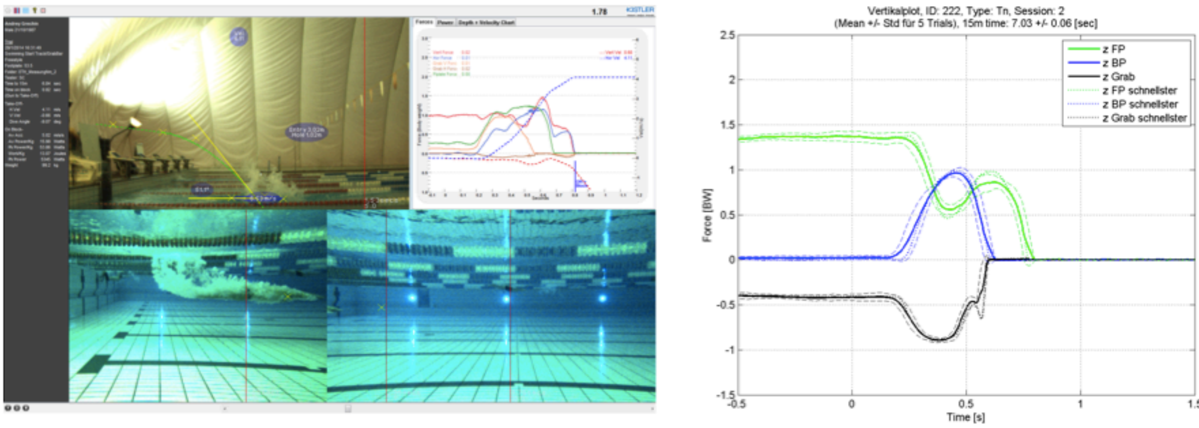

Figure 1: Video Sequence of the Analysis Software of PAS-S and horizontal force plots of MATLAB.

In order to objectively determine the footedness,the athletes performed single leg jumps on Quattro Jump and the maximal forces were measured. As predicting parameter of the leg dominance, the peak power has been determinate, like it is chosen at the Swiss Olympic medical centers, Tschopp M. (2003). Furthermore, the first questionnaire was the footedness questionnaire also used in the study of Hardt et al. (2009) to determinate the footedness of the athletes. The second questionnaire was a common questionnaire for further information of their swim capabilities.
To compare the two types of start, t-tests were performed. All the statistical analysis was performed in SPSS (version 22, SPSS Inc., Chicago). The t-test procedure was conducted with the chosen means of the parameters and corrected by the Bonferroni adjustment ($p<0.05$ or $p<0.00625$). Using descriptive statistics, the answers of the footedness questionnaire were compared with the maximum force of the jumps and the performance of their track start performance.

RESULTS: All 15 athletes completed the test protocol. In the preferential start T_n, 10 of the 15 subjects (66.7 %) positioned their dominant leg towards the front (Table 1). The comparison between the subjective answers of the footedness questionnaire and the objective measured parameters of the Quattro Jump showed that 7 of 15 (46.6 %) swimmers don’t recognized their peak power leg as take-off leg.

Table 1

Comparison of the subjective and objective variables to identify the dominant leg.

Swimmer	335	222	441	445	442	223	331	111	224	333	225	332	334	411	443
Footedness Questionnai	100% Right	100% Right	100% Right	100% Right	100% Right	71.4% Right	33.3% Right	100% Right	20% Right	45.4% Left	100% Right	100% Right	100% Right	85.7% Right	100% Right
4 Jump Peak Power	Right	Right	Right	Right	Right	Right	Right	Left	Left	Left	Left	Left	Left	Left	Left
Dominant leg position	Front	Front	Front	Front	Front	Front	Front	Front	Front	Front	Rear	Rear	Rear	Rear	Rear

By comparing T_n to T_o following results has been found. T_n showed a significantly better start performance compared to T_o in time to 15 m, block time, momentum and back plate maximum force. The peak power, the entry meters, front plate force and the grab bar values were similar.

Table 2
Comparison of track start normal (T_n) and track start opposite (T_o) parameters.

Dependent Paired Samples T-Test

		Preferential Track Start (T_n)			Opposite Track Start (T_o)			p-value
1	Time to 15m [s]	6.87	±	0.36	7.08	±	0.36	0.000 *
2	Block Time [s]	0.76	±	0.05	0.82	±	0.05	0.000 *
3	Entry Meters [m]	2.67	±	0.27	2.66	±	0.24	0.696
4	Peak Power [W/kg]	56	±	7	53	±	6	0.124
5	Momentum [Ns]	343	±	71	329	±	68	0.000 *
6	Front Plate max. [BW]	0.72	±	0.10	0.66	±	0.08	0.026
7	Back Plate max. [BW]	0.96	±	0.12	0.85	±	0.06	0.000 *
8	Grab Bar max. [BW]	-1	±	0.14	-0.92	±	0.18	0.020

*** significant after Bonferroni = p<0.00625**

For the self-chosen T_n, 10 swimmers placed their dominant leg in the front position while 5 swimmers preferred their dominant leg in the rear position (Table 3). Swimmers with the dominant leg in the front position were significantly faster to the 15 meter distance. However, all the other parameters regarding the forces, times and distance were similar between the leg positions.

Table 3
Comparison of swimming parameters Tn of the Dominant Front and Dominant Back parameters.

Independent Paired Samples T-Test

		Dominant Leg Front (n = 10)			Dominant Leg Rear (n = 5)			p-value
1	Time to 15m [s]	6.67	±	0.24	7.25	±	0.23	0.001*
2	Block time [s]	0.77	±	0.03	0.75	±	0.07	0.681
3	Entry Meters [m]	2.77	±	0.24	2.47	±	0.23	0.040
4	Peak Power [W/kg]	58	±	8	52	±	3	0.156
5	Momentum [Ns]	371	±	64	286	±	48	0.023
6	Front Plate max. [BW]	0.72	±	0.11	0.71	±	0.07	0.839
7	Back Plate max. [BW]	0.98	±	0.11	0.93	±	0.16	0.447
8	Grab Bar max. [BW]	-1.01	±	0.14	-0.97	±	0.14	0.614

***significant after Bonferroni = p<0.00625**

DISCUSSION: For the first time, a start block allowing the detection of the force for each foot during track start was used to compare the start performance dependent on the athlete's footedness. 2/3 of all swimmers placed their dominant leg in front for the start although nearly half of the athletes were unable to recognize their peak power leg.
Our results show that the preferential technique T_n is highly stabilized and reproducible by swimmers as it is always the faster variant, in agreement with earlier findings of Hardt and co-workers (2009). Prior research into swimming starts has shown that "what one does most, one does best" (Pearson et. al 1998). Starts in the non-preferred position T_o were slower in the block time and swim time but they also exerted less force on the back plate, and thus generated lower body momentum.
By comparing the dominant leg in front with the dominant leg in the rear position, it was possible to demonstrate all start parameters were similar. However, the athletes with the

dominant leg in rear position showed a greater time to 15m. This is probably caused by the longer propulsion time from the block with the stronger leg. Due to the fact that the number of subjects was low and not well distributed, further studies to confirm these findings are required.
Although it was reported by Hardt et al., 2009 that the front limb produces more force than the rear limb in the propulsive phase, our results indicate that the maximum force is larger for the rear foot. By analyzing the time after 15 m, not only the start performance on the block is important but the behavior in entering and gliding in the water are also considered. Here, the higher momentum is in line with a larger maximum force of the rear leg (rather than the front leg), shows the importance of a leg specific measurement of the force.

CONCLUSION: Performing track start in the preferential start position showed the best start performance. However, it also seems to be beneficial for the track start, that the dominant leg is in front. This might indicate that for novice swimmers, an objective footedness test might help the athlete and the coach to identify the best start position.

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