KINETIC AND KINEMATIC ANALYSIS OF THE BACKSTROKE START

Suzanne Sinistaj, David Burkhardt, Sergio Carradori, William R. Taylor and Silvio Lorenzetti

Institute for Biomechanics, ETH Zurich, Switzerland

Race start technique in competitive swimming has developed considerably in recent years and is thought to be an important factor governing the outcome of a race. The purpose of this study was to measure the reliability of a new analysis system for swimming (PAS-S), as well as to analyse the backstroke start kinetics and kinematics and to compare the normal backstroke start with the backstroke start with a new start device. 16 high level competitive swimmers were examined in this study, which revealed that the measurements with the PAS-S are reliable. The analysis of the backstroke start showed the importance of a high preload force just before the start signal. Furthermore, if available, swimmers should use the new backstroke start device since the 15 m times were significantly faster even without considerable training with the new start device.

KEYWORDS: swimming start, backstroke start platform, kinetic analysis, kinematic analysis

INTRODUCTION: The start in competitive swimming has developed to become an important factor in the whole race outcome, with the start performance representing between 0.8% and 26.1% of the final race time (Mason & Cosser, 2001). Several changes in the rules and new starting blocks have led to changes in the starting technique, but studies that examine the backstroke start remain rare. Hohmann et al. (2008) searched for kinematic correlations between hands-off and feet-off, as well as between hands-off and hip entry. The authors were able to show that the 7.5m time is dependent on the maximal force on the wall plate directly before feet off. Furthermore, the data of Ngyuyen et al. (2014) demonstrated that the horizontal take off force had a high correlation with the starting time. For the ideal take off position, the hip position and a fast hip extension are important (Takeda et al., 2013). To our knowledge there are no studies measuring the forces on the grab bar.
Since 2014, a new backstroke start device can be used for the backstroke start. However, it remains unknown whether such a start device can provide an advantageous start time, and if so, by how much. Therefore the aims of this study were:

1. to test the new measurement system for its reliability.
2. to perform a kinetic and kinematic analysis of the backstroke start.
3. to compare the backstroke start with and without the start device.

METHODS: Fourteen male and two female 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. With the Performance Analysis System for Swimming (PAS-S), a system for detailed analysis of different starting techniques in swimming, about 30 kinetic and kinematic parameters were measured. The PAS-S was developed by Kistler Instrumente AG (Winterthur). The starting block consisted of an instrumented starting platform with two force platforms and instrumented starting grips as well as a mountable turning plate and a corresponding vision system with four cameras (three underwater, one above). The swimmers were measured three times at intervals of one week. Between the first and the second week, the whole PAS-S including the starting block and the wall plate was dismounted and remounted. Between weeks two and three, only the camera system was dismounted and reinstalled. In each session, all swimmers performed five track starts and five backstroke starts in a random order. In the third session, the swimmers additionally performed five backstroke starts using the new backstroke start device. The raw data of the PAS-S then was processed using MATLAB (MathWorks Inc.). The raw data was filtered (low pass Butterworth filter) and offset corrected. With this data kinetic parameters were calculated. The reliability of the system was calculated a) to compare of the standard deviations from session one, two and three of one kinetic parameter (horizontal maximal

grab force) and one kinematic parameter (15m time) and b) with the comparison of the means of the 15m times from sessions one, two and three. All statistical analyses were undertaken in IBM SPSS Statistics (v22) with ANOVA. For the kinetic and the kinematic analyses two force plots were created, one for the horizontal forces of the force platforms and one for the vertical forces of the force platforms. In addition, correlations between several parameters were calculated. For the comparison between the normal start and the start with the backstroke start device, t-tests were used in SPSS.

RESULTS: No differences were found in the 15m times for the start types (Table 1). Furthermore, no differences were found between the means of the 15 m performance in sessions one, two or three (Table 2). The same results were found in the comparison of the standard deviations of the 15m times (Table 3) and the maximal horizontal grab forces (Table 4).

Table 1

15m times: means and standard deviations from trackstart and backstroke start in sessions one, two and three.

Starttype	Session 1	Session 2	Session 3	Overall
Trackstart (Tn)	6.68 ± 0.40	6.87 ± 0.36	6.88 ± 0.41	6.81 ± 0.39
Backstroke Start (Bn)	8.04 ± 0.56	8.33 ± 0.55	8.37 ± 0.56	8.25 ± 0.57

Table 2

Comparison of the means of the 15m times between session one, two and three (start 1=trackstart, start 2=backstroke start).

ANOVA
Mean *time 15m*

start		df	F	Sig.
1	between groups	2	1.268	0.292
	in groups	42		
	sum total	44		
2	between groups	2	1.579	0.218
	in groups	42		
	sum total	44		

Table 3

a) Comparison of the standard deviation of the 15m times between sessions one, two and three.

ANOVA
Standard deviation *t 15m*

	df	F	Sig.
between groups	2	1.590	0.210
in groups	87		
sum total	89		

b) Comparison of the horizontal maximal grab force standard deviations between sessions one, two and three.

ANOVA
Standard deviation maximal vertical Grabforce *F*

	df	F	Sig.
between groups	2	0.478	0.622
in groupgs	87		
sum total	89		

Kinetic analysis of the grab forces showed the importance of a high preload force just before the start signal. Therefore it is important to ensure that after the start signal the horizontal grab force does not rise higher such that the swimmers can start faster (Figure 1). The same result was shown by the kinematic analysis, where a correlation was observed between the 15 m time and the time-on-block proportional to the time between the horizontal grab force maximum and the hands-off (Pearson = 0.645, p = 0.009). Furthermore correlations between the time-on-block to hands-off time and time-on-block to horizontal maximal grab force time were found.

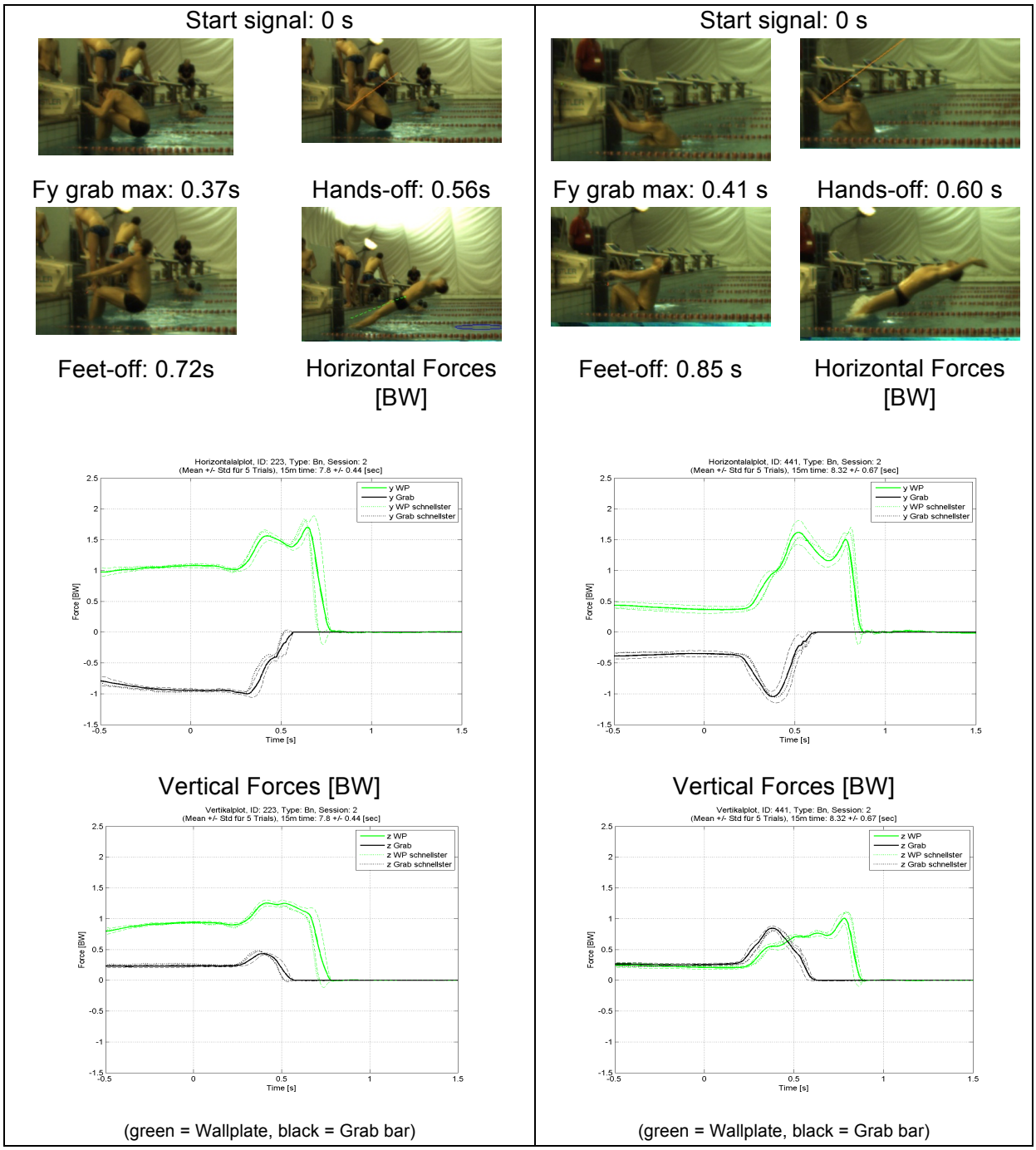

Figure 1: Comparison between a swimmer with a high preload (left) and one without (right).

The swimmers swam significantly faster, jumped further, entered the water in a better way (through a smaller hole) and dived deeper with the backstroke start device. There were no differences found in the time parameters hands-off and time-on-block between the start with the backstroke start device and the normal start in timing parameters (Table 5 and 6).

Table 5

15m times: means and standard deviations from backstroke start and backstroke start with start device.

Starttype	Time 15 m [s]
Normal Backstroke Start (Bn)	8.38 ± 0.58
Backstroke Start with Start Device (Ba)	8.31 ± 0.61

Table 6

P values of the comparison between Bn = Backstroke start normal and Ba = start with the backstroke start device. Significant values are highlighted.

Paar 1	Bn t 5m - Ba t 5m	0.002
Paar 2	Bn t 7.5m - Ba t 7.5m	0.001
Paar 3	Bn t 10m - Ba t 10m	0.003
Paar 4	Bn t 15m - Ba t 15m	0.011
Paar 5	Bn Time hands off - Ba Time hands off	0.654
Paar 6	Bn Time on block - Ba Time on block	0.590
Paar 7	Bn Entry metres - Ba Entry metres	0.000
Paar 8	Bn Entry Hole - Ba Entry Hole	0.012
Paar 9	Bn Max Depth - Ba Max Depth	0.001
Paar 10	Bn_Fz_grab_max - Ba_Fz_grab_max	0.000
Paar 11	Bn_Fz_grab_max_t - Ba_Fz_grab_max_t	0.081
Paar 12	Bn_Fy_graby_max - Ba_Fy_graby_max	0.041
Paar 13	Bn_Fy_graby_max_t - Ba_Fy_graby_max_t	0.907

DISCUSSION: For the first time, grab forces were measured separately in a backstroke start**.** The statistical calculations showed the reliability and resistance against mounting and dismounting of the PAS-S. This unique system has a huge potential for further scientific analysis of swimming starts and turns, as well as for the personal development of athletes.
The results of this study have demonstrated that the better entry through a smaller hole into the water; with the backstroke start device the swimmer could generate a higher speed off the wall. The results confirm the findings of Takeda et al. (2013), who showed that a small entry hole into the water is important for a good starting time. Importantly, the time to 15 m was faster when using the backstroke start device. These clear benefits were surprising since the swimmers could only train once with this starting aid before the testing sessions. It is entirely possible that with more practice the advantages of the start device could even be even higher. No differences were found between the normal start and the start with the device in terms of the kinematic parameters. The take-off timing seems to be the same as with the normal backstroke start.
Further research, most notably for the force developments and changes on the wall plate are necessary to understand the backstroke start and the backstroke start device better before conclusions and training advice can be provided to coaches and swimmers.

CONCLUSION: The PAS-S is a suitable instrument for analysis of starts and turns in swimming. Kinematic analysis of elite swimmers has revealed that an ideal starting position right before the starting signal seems important for a fast backstroke start. Furthermore, if available, the swimmers should use the new backstroke start device since the 15 m times were significantly faster even without considerable training beforehand.

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