

A KINETIC ANALYSIS AND RECOMMENDATIONS FOR ELITE SWIMMERS PERFORMING THE SPRINT START

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The object of this project was to identify on block characteristics of superior grab starts and identify if these also applied to the track start. Six elite swimmers were selected for the study. The characteristic most closely observed in excellent off block starting ability for the grab start was peak power normalised to body mass. Average power and maximum horizontal propulsive force normalised to body mass were closely linked as was work output, but not as highly as the previous parameters. Horizontal velocity off the block was not a good predictor of off block ability as the angle at which the swimmer left the block played an important role in the outcome. Time off the block and first movement time were poor indicators of starting ability. Similar characteristics, but with completely different force and power profiles, were evident for swimmers that utilised a track start.

KEY WORDS: swimming, competition, starts, Biomechanics, kinetic analysis, grab start

INTRODUCTION: It is generally undisputed that the start is of paramount performance in elite competitive sprinting. Trembly and Fielder (2001) in their chapter on Starts, Turns and Finishes in "The Swim Coaching Bible" indicated that the actions of the swimmer on the block were about "obtaining maximum explosive power". They reported that "the best starters are fast off the blocks; they get great distance through the air with a clean entry and strong kick".

There have been primarily two types of sprint starts used by elite swimmers in competition over the last 10 years. The two types are the grab and track start. Many investigations have been performed to examine which of the two types of start are superior. Some studies found the grab better, other studies found the track superior, while still other studies were not able to discriminate between the superiority of either. Vilas-Boas et al (2002) in studying the grab start with two versions of the track start found that despite finding differences between the three techniques, all three appeared to be equally valuable. Blanksby, Nicholson and Elliott (2002) in a study which examined the grab, track and track with handles start, identified little advantage to using any one of these starts over the others. Their intervention study however identified that the performance of all three starts was improved with a formal programme in which the start was routinely practiced. Issurin and Verbitsky (2002) examined start performances from analysis of finalists at the Sydney Olympic Games. They concluded that generally the track start resulted in faster times off the block and also to the 15m mark. Many other studies also revealed that the track start resulted in a shorter time off the blocks than the grab start. However this should not suggest that the track start was superior overall. The authors of this paper believe that time off the block is a poor indicator of starting ability and that a better measure is the average acceleration off the block. This is derived from a combination of off block horizontal velocity and the leave block time. A swimmer may be on the blocks longer, but if the velocity at which they leave the blocks is higher as a consequence, this may warrant the longer time spent on the block. All other aspects being equal, the faster the swimmer leaves the block in a horizontal direction the further they will travel before water entry. As average acceleration takes into account both horizontal velocity and time on the block it is a more encompassing measure than either of its components. But average acceleration does not fully quantify this aspect of the start, as the angle at which the swimmer leaves the block determines where the swimmer will enter the water. The overall start time to 15m includes an all important water phase of the start. The authors of this paper believe that the 15m time is more dependent on the water phase of the start, than the swimmer's actions on the block and in the air. Therefore the 15m time should not be considered as a criterion that determines which of the two on block start techniques is better. Strojnik (1998) reported very few differences on the block in the starts of the freestyle stroke as opposed to butterfly. This would tend to support the theory that the on block phase of the

start is essentially stroke independent. De La Fuente (2002) reported there was a lack of correlation between the force generated in a counter movement jump and the horizontal velocity able to be obtained off the block, for 60 varsity students specialising in swim coaching. This result would tend to indicate that as well as power, other factors including technique and coordination play an important role in obtaining a high velocity off the block and that the ability to produce a highly explosive lower limb muscular force is not the only ingredient in obtaining that high velocity.

It is believed by these authors that the critical aspects of an overall start include, in order of importance: water entry, underwater streamlining, underwater propulsion, breakout, and propulsion off the blocks. However, propulsion off the block is that initiating action upon which all other aspects are to some extent determined. The authors also believe that the grab and track start only determine the characteristics of the on block and airborne phases of the start. Once the swimmer contacts the water, the actions that are then performed are no longer grab or track start dependent. However, as the resulting parameters of the swimmer's motion on leaving the block will influence what happens after that event, there is a definite need to optimise the on block phase of the start. The aim of this study was therefore to investigate the on block characteristics of a sprint start, using the performances of elite swimmers whose abilities in the start phase of competition swimming were quite variable. The study aimed in particular to identify those beneficial aspects which were relevant for a grab start. It also aimed to investigate differences between characteristics that were optimal for a track start. The kinetic analysis investigated on block start characteristics of elite sprint swimmers including several FINA world record holders of sprint events.

METHOD: The start performance of six elite sprint swimmers was recorded. The swimmers were asked to perform their normal start as if in competition. Two of the swimmers who regularly use the two different starting techniques performed both the grab and track starts. Three performances of each technique were recorded to ensure that a typical start performance for each swimmer was investigated. Time elapsed from the gun to the swimmer reaching various distances in the start were timed using magnetic timing gates at 5m & 15m. A 900 by 600 mm Kistler force platform was mounted at an angle of 5 degrees downwards towards the pool on a metal frame bolted to the pool deck, to replicate a swimming starting block. A Rekketan rubberised cover was securely fastened onto the force platform's top. The 4 by Fz, 2 by Fy forces and starting signal were sampled at 500hz for the period 1 second before and 2 seconds after the gun. These measurements were digitally smoothed with a low pass cut off frequency of 10 Hz before being resolved into total vertical and total horizontal force profiles. The other parameters including the two components of velocity, power and work were derived from these computed parameters. Time on the block was identified as the time that elapsed between the starting signal and when the total vertical force fell to zero. Velocity off the block was the computed horizontal velocity at the instant the swimmer left the block. This was derived as the integral over time of the horizontal force expressed in body weight and multiplied by the gravitational constant. The vertical velocity was calculated in a similar fashion as horizontal velocity but gravity was also incorporated into the computation. The angle of the swimmer's CoG leaving the block was calculated from the horizontal and vertical velocities at the instant the swimmer left the block. The power profile was derived as the instantaneous product of resultant force by resultant velocity instant by instant. Work was derived as the integral of power over time. The investigation analysed the following characteristics: 1.First movement time (s), 2.Off block time (s), 3.Maximum horizontal propulsive force (N/kg of BM), 4.Projection angle of CoG leaving block (deg, -ve=down), 5.Horizontal velocity of CoG leaving block (m/s), 6.Average acceleration of CoG off the block (m/s/s), 7.Average Power developed on block (W/kg of BM), 8.Peak power developed on block (W/kg of BM), 9.Work done on block (J/kg BM), 10. & 11.Time to 5m & 15m (s).

RESULTS: Table 1. Order of starting ability Subj A (best), B, C, D, E, Subj F (worst)
Nat Ch – present National Champion, W Rec – Held World Record, WR=2&3–Held
Ranking of 2nd & 3rd in FINA World rankings, Nat Team – present Member of National Team

Swimmer	A	B	C	D1	D2	E1	E2	F
Level	Nat Ch	WR=2	W Rec	WR=3		Nat Team		W Rec
Gender	Male	Male	Female	Female		Female		Female
Stroke	Butterfly	Breast	Breast	Free	Free	Breast	Breast	Free
Swim Dist (m)	100	100	50/100	100/50		100		100
Type (Grab/Track)	Grab	Grab	Grab	Grab	Track	Grab	Track	Track
Preferred (Start used)	*	*	*	*		*		*
Comment (on ability)	Excellent	Great	Good	Fair		Fair		Poor
Body Mass (kg)	79.7	92.0	76.8	67.9		61.2		66.9
Movement time (s)	0.15	0.14	0.12	0.15	0.15	0.15	0.21	0.23
Leave block time (s)	0.80	0.85	0.83	0.87	0.82	0.89	0.77	0.89
Max Prop. Force (N/kgBM)	1.67	1.57	1.52	1.43	1.08	1.39	1.14	0.84
CoG Angle (Deg:-ve = down)	-1.5	-6.3	-5.7	-15.4	-19.7	-2.5	-2.8	-15.8
CoG Horz Velocity (m/s)	4.67	4.84	4.57	4.59	4.58	4.14	4.23	4.42
CoG Av. Accel. (m/s/s)	5.83	5.69	5.51	5.30	5.60	4.64	5.51	4.96
Average Power (W/kgBM)	20.51	20.13	19.17	17.13	17.56	16.35	18.57	16.09
Peak Power (W/kgBM)	89.74	83.78	76.79	67.88	52.04	67.72	54.87	43.74
Work Output (J/kgBM)	16.78	17.85	16.41	15.78	14.85	14.84	14.32	14.57
5m Start time (s)	1.50	1.56	1.60	1.79	1.76	1.96	1.83	1.76
15m Start time (s)	6.34	7.26	8.04	7.27	7.36	8.53	8.45	7.27

Comments:

Peak power was less for Track than Grab starts because of Track's bimodal power profile. Peak power in Grab start was found to most closely be linked to on block starting ability. First movement time and Off Block time were not good indicators of starting ability. Off Block time is less for Track starts compared to Grab starts.

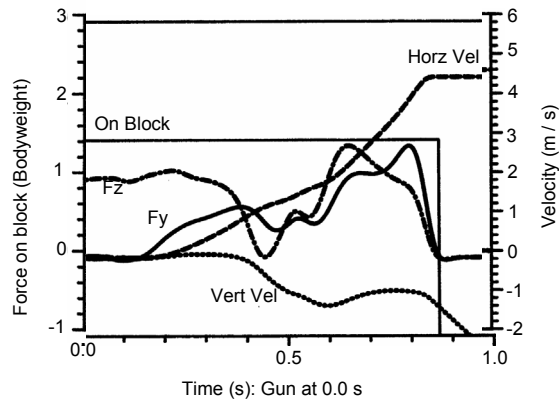


Figure 1. Force for Subject D Grab Start.

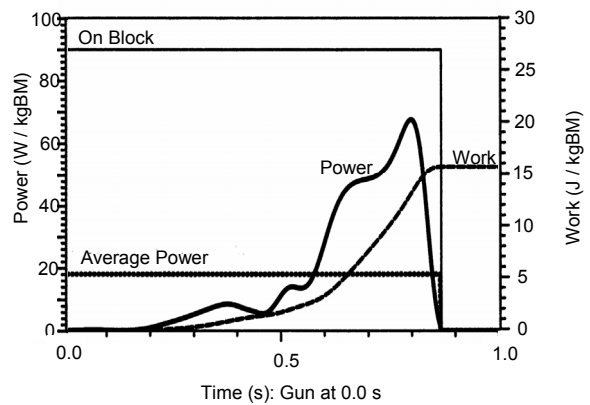


Figure 2. Power for Subject D Grab Start.

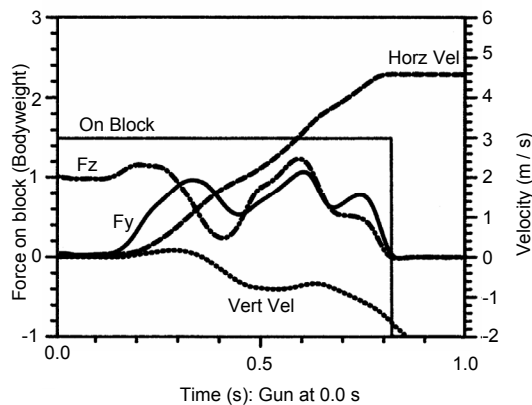


Figure 3. Force for Subject D Track Start.

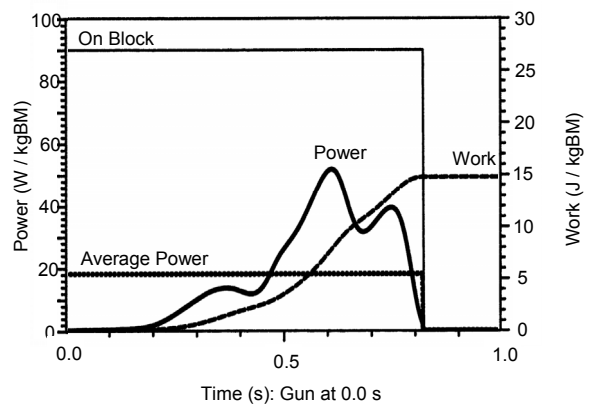


Figure 4. Power for Subject D Track Start.

Figures 1 and 2 are the force and power profiles for subject D performing a Grab start. Figures 3 and 4 are for the same subject performing a Track start. Note the bimodal curve shape, reduced peak power and reduced off block time in the track start.

DISCUSSION: Knowledge gained from this study could be used to advantage by coaches in a training environment if there is available to them biomechanical support and appropriate technological equipment to capture the parameters measured in this study. To compare two grab starts, peak power output would be the best indicator of superiority of the on block characteristics. To compare a single individual swimmer's performance, to identify if the grab or track start was preferable for that swimmer, this study would indicate that work output, average acceleration off the block and the angle the swimmer left the block were important ingredients and should all be considered. The on block phase of the start was independent of the event stroke, indicating that a swimmer could perform either the grab or track action on the block no matter whether the event was freestyle, butterfly, breaststroke or individual medley.

CONCLUSIONS: The characteristic most closely linked to off block starting ability for the grab start was identified to be peak power per kg of BM generated on the block. The power derived was produced by a combination of leg power and coordinated drive of the entire swimmer's body. Average power and maximum horizontal propulsive force generated per kg of BM were also associated with starting ability as was work output on the block per kg of BM, but not as highly as the previous parameters. Horizontal velocity off the block was not a good predictor of starting ability as the angle at which the swimmer left the block also played an important role in the outcome of the start. A projection angle of the swimmer's CoG at the instant of leaving the block of between +2 and -7 degrees was optimal (-ve = downward). Time off the block and first movement time were not linked with starting ability, provided they were not excessively long. Similar characteristics but with completely different force and power profiles were evident for swimmers that utilised a track start as opposed to a grab start. In the track start the power curve was bimodal, with the first peak, generated by the rear foot, being the greater of the two peaks. Both peaks in the track start were smaller in magnitude than the single peak obtained in the grab start power profile. The track start results, compared to the grab start for the swimmers who performed both starts, indicated that the off block time was shorter in duration for the track start by from 0.05 s to 0.15 s. This study indicated that in general terms neither the track nor grab start was superior overall in capability to the other, but that the preferred start should be the swimmer's choice based upon the quality of the swimmer's measured parameters indicated in this report.

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