KINETIC COMPARISON OF THE SPRINT STARTS BETWEEN YOUTH AND SENIOR ELITE ATHLETES

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The purpose of this study was to identify differences in force, impulse and power characteristics in block starts and first two contacts between youth academy (n=20) and elite senior male sprinters (n=17). Senior sprinters were significantly faster out of the blocks with a horizontal velocity of 3.35 ±0.15 m/s compared to 3.14 ±0.16 m/s, leading to 10 m times of 1.64±0.045 s and 1.706±0.06 s respectively. Force application time of the arms, rear leg and front leg were significantly lower in the senior athletes (all p<0.0001). Relative peak vertical forces in arms, front and rear legs were all similar, but senior athletes generated greater peak horizontal force/BW (p<0.05) and power/BW from the rear leg (p<0.001). Understanding the function of the rear leg and implications on strength and technique will help to guide progression from youth to senior performance.

KEY WORDS: force, impulse, velocity, power

INTRODUCTION: The importance of the start in the 100m is evidenced by the fact that only 210ms separates the fastest Gold and the fastest Bronze medal winning performances in all the World Athletics Championships and Olympic Games finals from 2007 to 2016 (derived from our own 'What it takes to win' analysis of the mens' 100m). Given that the typical reaction time is 150ms (legal limit = 100ms) and block time is between 300-400ms, (Coh et al., 1998; Fortier et al., 2005), then strategies to improve starts could make the difference between winning a medal or not.

To this end, Graham-Smith et al. (2014) developed a unique force plate configuration and this has been utilised to examine the contribution of the arms and each leg to impulse generation and performance in the block start. The inclusion of arm forces and quantifying total system load has a significant effect on the quality of data, particularly around vertical velocity and projection angles. Within the context of applied support work the force plate configuration enables biomechanists to provide instantaneous feedback and was been adopted to profile force production characteristics of 19 senior male international sprinters (Graham-Smith et al., 2017). They observed that the arms contributed 13.9% and -2.9% to vertical and horizontal impulses, the rear leg 25.4% and 32.8% and the front leg 60.7% and 69.5% respectively. The rear leg produced the greatest horizontal force (919 ± 215N) while the front leg produced the greatest vertical force (1024 ± 156N). Within this group of senior athletes, the differentiator in performance was related more to the peak vertical and horizontal forces (relative to BW) generated from the front leg, which produced the strongest correlations with the time to 10m (r = -0.574, -0.591, both p<0.001). They concluded that the role of the rear leg appeared to be one which facilitates overcoming inertia, generating equal amounts of vertical and horizontal impulse, while the front leg generated 10% more vertical impulse than horizontal.

At Aspire Academy we work to develop the performance of youth athletes (under 18) and seek to ensure a successful transition into the National senior squad. In the absence of data collected on youth populations, as scientists we are often guilty of making incorrect assumptions that research conducted on senior athletes also applies directly to younger cohorts.

The aim of this study was therefore to compare force production characteristics of youth academy sprinters with those of senior international athletes to identify factors that will help guide their athletic development and transition to senior ranks.

METHODS: 17 senior male international sprinters (179.5 ± 7.3 cm, 75.8 ± 8.1 kg) and 20 youth Academy athletes (172.4 ± 6.7 cm, 61.6 ± 6.2 kg) took part in the study. Data collection was carried out as part of their training session with their coach present to guide the warm up. A

series of block starts and accelerations between 20m – 40m were then performed at maximal effort. Speed was recorded using a Laveg LDM 300C laser gun and split times over 10m intervals were recorded using a 5 point moving average.
An array of six Kistler force platforms (four 9287CA and two 9281E) was used to collect horizontal and vertical ground reactions forces through the four points of contact in the starts (feet and hands separately) and the first and second contact (see figure 1). All sprints were recorded in the sagittal view using a Casio Exilim ZR200 high speed video camera recording at 240 fps to ensure the entire foot was placed on the force platforms. This configuration enabled us to measure the entire system load in the set position and therefore quantify movement time, impulses and velocities at toe-off more accurately than systems that do not factor in arm forces (Graham-Smith et al, 2014). Force platforms were zeroed immediately before the athlete entered the blocks and were set to record at 1000 Hz for 5 seconds, with a 7 point moving average applied on acquisition. Body weight was measured for 10s prior to the first trial.

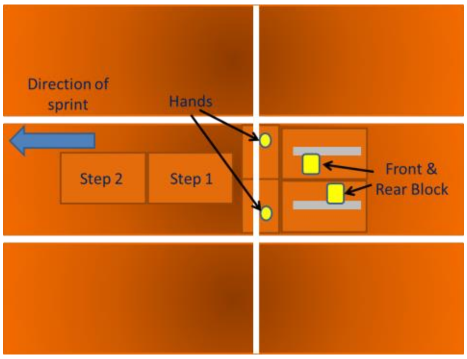

Figure 1: Experimental set up with the six force platform configuration

The total ground reaction forces (GRF) in the vertical and anterior-posterior directions were attained by summing forces from the six platforms. The onset of movement was taken from the instant the total vertical force increased above an arbitrary 40N threshold from the steady body weight force in the set position. The same threshold was used to identify flight and contact phases in the subsequent steps.
Impulses, accelerations, velocities and displacement characteristics of the centre of mass were derived from the total horizontal and vertical forces. The % contributions of front and rear legs and the arms to absolute horizontal and vertical impulses were also quantified. Differences in start characteristics between senior and youth athlete were determined using independent t-test with a significance level of $p<0.05$.

RESULTS & DISCUSSION: Not surprisingly the senior athletes were significantly faster than the youth athletes, demonstrating significantly lower 10 m and 20 m sprint times of 1.64 ±0.05 s and 2.77 ±0.07 s compared to 1.71 ±0.06 s and 2.92 ±0.12 s for the youth sprinters. Senior athletes had greater horizontal velocities at toe-off from the blocks and first and second contacts (all $p<0.01$). Youth athletes similar vertical velocity at toe-off from the blocks, but greater vertical velocities at toe-off in the first and second steps (both $p<0.01$). Consequently, projection angles at toe-off were similar for the start, at around 10 degrees, but youth athletes had significantly greater projections in the first and second contacts of 7.7 and 7.1 degrees compared to 5.9 and 5.1 degrees for the seniors (see Table 1).
With respect to the temporal aspects of the start, the senior athletes spent significantly less time in the blocks, 0.362 ±0.029 s compared to 0.402 ±0.041 s by the youth athletes ($p<0.01$). So, despite the senior athletes being taller and heavier, and having to displace their centre of mass further they still spent less time in the blocks and generated greater horizontal velocity at toe-off. Whilst this is interesting and may help to create normative data to guide progression, we could just assume that senior athletes are simply stronger and more powerful. The ability to quantify the loading characteristics of the arms and the front and rear legs has highlighted

subtle differences in sprint start kinetics. Table 2 reveals that senior athletes utilise their arms less to the contribution of vertical and horizontal impulse than the youth athletes, (12.5% to 15.9% vertical, p=0.047, and -1/8% and -2.5% horizontal, p=0.035). This implies that they are able to offset any loss of balance through their block positions, lower extremity strength and confidence in their ability to make successful first and second foot contacts without falling over. Senior athletes generated significantly greater relative horizontal force from the rear block compared to youth athletes, (1.24 BW vs 1.03 BW respectively, p=0.02), and greater peak horizontal power (relative to BW). Horizontal power shows a characteristic double peak and is derived from the combined forces. The first peak is predominantly due to the rear leg whilst the second peak is entirely due to the front leg. Senior athletes demonstrated greater horizontal power in the first (1.93 and 1.42 W/BW, p=0.000) and second pushes (3.36 and 3.06 W/BW, p=0.017). No significant differences were observed for the relative vertical forces generated from the rear and front blocks.

Graham-Smith et al. (2017) observed that within their sample of senior athletes the differentiating factor between horizontal velocity out of the blocks and time over 10m was the relative horizontal and vertical forces generated by the front leg. This study has highlighted the importance of the rear leg as a differentiator between youth and senior athletes. In this regard, it appears that the progression of sprint start competency and performance is initially focussed around the ability of athletes to generate sufficient horizontal force through the rear foot, so as not to over rotate and lose balance, which provides a faster transition onto the front leg. As they become more competent then greater emphasis appears to be placed more on front leg force production and being able to keep the angle of trajectory lower in the first two steps.

Table 1: Comparison of time, velocity and projection angles in the start and first two contacts

	Senior		Youth		t	p
	Mean	SD	Mean	SD		
Time to 10m (s)	1.640	0.045	1.706	0.063	-3.71	0.000
Time to 20m (s)	2.768	0.066	2.922	0.117	-4.88	0.000
Horizontal Velocity Toe-off Blocks (m/s)	3.35	0.15	3.14	0.16	4.11	0.000
Horizontal Velocity Toe-off 1st Contact (m/s)	4.59	0.22	4.40	0.20	2.76	0.004
Horizontal Velocity Toe-off 2nd Contact (m/s)	5.52	0.25	5.29	0.25	2.75	0.005
Vertical Velocity Toe-off Blocks (m/s)	0.58	0.11	0.59	0.12	-0.29	0.387
Vertical Velocity Toe-off 1st Contact (m/s)	0.48	0.09	0.59	0.12	-3.45	0.001
Vertical Velocity Toe-off 2nd Contact (m/s)	0.50	0.15	0.67	0.12	-3.77	0.000
Projection Angle Toe-off Blocks (deg)	9.8	1.9	10.6	2.1	-1.24	0.114
Projection Angle Toe-off 1st Contact (m/s)	5.9	1.2	7.7	1.5	-4.04	0.000
Projection Angle Toe-off 2nd Contact (m/s)	5.1	1.5	7.2	1.4	-4.47	0.000
Movement Time (s) Blocks	0.362	0.029	0.402	0.041	-3.35	0.001
Flight time Block to 1st Contact (s)	0.070	0.019	0.076	0.018	-0.94	0.177
Contact time (1st step) (s)	0.189	0.022	0.195	0.022	-0.76	0.226
Flight time 1st to 2nd Contact (s)	0.052	0.014	0.064	0.021	-2.11	0.024
Contact time (2nd step) (s)	0.168	0.017	0.170	0.018	-0.44	0.332

Table 2: Comparison of limb contributions and power in the block start

	Senior		Youth		t	p
	Mean	SD	Mean	SD		
Front Leg						
Contact time (s)	0.362	0.029	0.402	0.041	-3.41	0.001
Peak Vertical Force /BW	1.39	0.15	1.43	0.11	-0.99	0.158
Peak Horizontal Force /BW	1.14	0.13	1.11	0.12	-0.73	0.234
Vertical Impulse (BW.s)	0.259	0.027	0.275	0.035	-1.62	0.061
Horizontal Impulse (BW.s)	0.236	0.026	0.229	0.026	-0.77	0.223
contribution to total Vertical Impulse (%)	61.4	6.0	59.6	6.0	0.94	0.177
contribution to total Horizontal Impulse (%)	69.2	7.3	71.8	8.1	-1.04	0.155
ratio Vertical to Horizontal %	0.89	0.10	0.84	0.08	1.86	0.033
Rear Leg						
Contact time (s)	0.202	0.058	0.281	0.105	-2.89	0.004
Peak Vertical Force /BW	1.10	0.18	1.01	0.24	1.26	0.114
Peak Horizontal Force /BW	1.24	0.23	1.03	0.35	-2.20	0.020
Vertical Impulse (BW.s)	0.110	0.020	0.113	0.027	-0.40	0.349
Horizontal Impulse (BW.s)	0.111	0.025	0.098	0.027	-1.51	0.070
contribution to total Vertical Impulse (%)	26.0	4.7	24.5	6.3	0.82	0.215
contribution to total Horizontal Impulse (%)	32.6	7.3	30.7	7.8	0.77	0.223
ratio Vertical to Horizontal %	0.81	0.10	0.81	0.15	-0.13	0.452
Arms (combined)						
Contact time (s)	0.112	0.030	0.146	0.030	-3.42	0.001
Peak Vertical Force /BW	0.81	0.17	0.83	0.20	-0.36	0.361
Peak Horizontal Force /BW	-0.13	0.05	-0.13	0.03	0.22	0.411
Vertical Impulse (BW.s)	0.054	0.026	0.075	0.030	-2.24	0.017
Horizontal Impulse (BW.s)	-0.006	0.004	-0.008	0.003	-1.52	0.067
contribution to total Vertical Impulse (%)	12.5	5.7	15.9	6.0	-1.73	0.047
contribution to total Horizontal Impulse (%)	-1.8	1.1	-2.5	1.1	1.86	0.035
ratio Vertical to Horizontal %	-8.44	4.10	-7.12	2.72	-1.13	0.126
Power						
Peak Vertical Power 1 / BW	0.81	0.17	0.90	0.23	-1.37	0.096
Peak Vertical Power 2 / BW	1.03	0.19	1.03	0.19	0.01	0.496
Peak Horizontal Power 1 / BW	1.93	0.41	1.42	0.39	3.84	0.000
Peak Horizontal Power 2 / BW	3.36	0.41	3.06	0.40	2.19	0.017

CONCLUSION: The study has revealed some interesting findings that may help to focus specific attention around the importance of force application through the rear block when working with youth sprinters. This is likely to require a combination of technical input and conditioning to ensure the athlete does not lose balance and is able to continue accelerating at a lower projection angle in the first two contacts. All athletes in this study were competent sprinters and were well drilled in setting up their preferred block positions, i.e. block separation distances and inclination angles. Further research will continue to explore differences between senior and youth athletes with respect to block positioning and joint kinematics, as well as profiling strength and power development characteristics to guide progression.

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