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START BLOCK KINETICS: WHAT THE BEST DO DIFFERENT THAN THE REST

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The purpose of this study was to analyze the push – off forces of male and female sprinters from a wide range of performance levels, including the currently two fastest sprinters in the world. A force start block was used to measure the forces applied to the front and rear blocks. In total, 430 full effort starts of over 99 subjects were analyzed. World – class athletes did not leave the blocks with a higher center of mass velocity, but with a shorter block time. They were able to produce higher maximum forces and rates of force development. Maximum forces were more balanced between the front and rear leg. These results further highlight the importance of high force capacities for a successful sprint start. The more evenly distributed maximum forces of the front and rear leg of world – class athletes might be a technical feature that could help lower level athletes to improve their performance. Training success should be monitored using force measurements in the blocks.

KEY WORDS: Push of forces, 100 m race, elite level.

INTRODUCTION: In short sprint running events, starting performance has a critical impact on the final result of the race. A successful start is characterised by a high horizontal velocity of the sprinter's center of mass (CoM) at the instant of block clearance. Further, this velocity should be reached in the shortest possible time. Therefore, short reaction times and short push - off times are mandatory for good starting performances.
Several studies investigated sprint starts from athletes of different levels of performance. (Fortier et al., 2005, Slawinski et al., 2010, Aerenhouts et al., 2011) Several differences between athletes of different performance levels could be identified, even though results were not always consistent between different studies. This could be explained by the fact that the performance differences as well as the absolute levels of performance were different between studies. Further, there is no study that has described the starting performance of the very best athletes in the world, which leaves a gap of information with respect to the absolute top level of performance.
Since acceleration equals force divided by the mass of an athlete, information on push – off forces is important for the understanding of performance differences in the sprint start. Consequently, Bezodis et al. (2010) identified the normalized average horizontal external power as the potentially best measure of sprint start quality, which can be easily calculated from the forces applied to the blocks and anthropometric information.
Therefore, the purpose of this study was to investigate the push – off force characteristics from a wide range of male and female athletes including the currently two fastest male sprinters in the world. It was hypothesized that faster athletes would clear the blocks with a higher CoM velocity with shorter push – off times than lower level athletes due to their superior explosive force capacities.

METHODS: For the purpose of this study, a custom – made starting block was developed by the technical staff of the German Sport University. The starting block consisted of a very stiff, steel center rail and different block base units for the front and rear foot, respectively. Different base units were used for each block inclination angle, which were screwed to the center rail in order to provide a highly stiff system for force measurements. Small custom made force platforms, comprising four Kistler piezo type 3D force transducers each, were mounted on top of the block bases for force measurements. Signals were amplified (8 channel amplifier, Kistler Instrumente AG, Winterthur, Switzerland), AD converted and stored on a Notebook by

means of custom – made Labview software. The whole system was portable and was used to collect data at different locations (see figure 1).
Force signals were filtered using a recursive 4th order digital Butterworth filter (100 Hz cut – off frequency). The following parameters were extracted for analysis: Reaction time (T_{react}), block time (T_{block}, time from first reaction to block clearance), center of mass velocity at block clearance (V_{CoM}, determined by integration of horizontal force curves), normalized average horizontal block power (NAHBP, see Bezodis et al. (2010) for calculation; instead of leg length, total body height was chosen for normalization since leg length was not available for all subjects), maximum forces and rates of force development (RFDs) of the resultant force for the front and rear leg ($F_{maxfront}$, $F_{maxrear}$ and $RFD_{maxfront}$, $RFD_{maxrear}$, respectively).

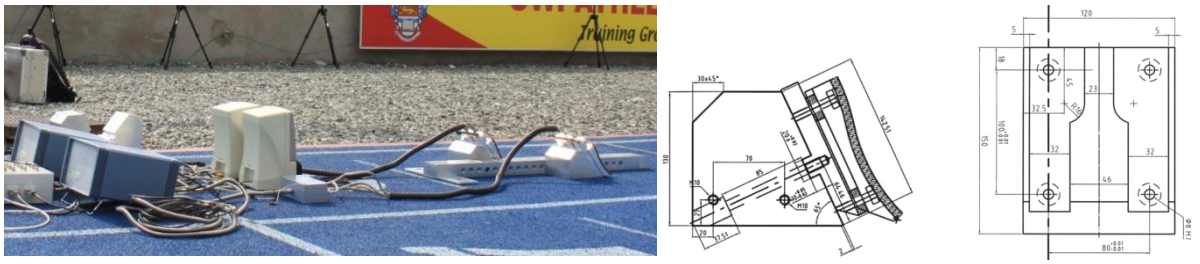

Figure 5: Experimental setup of the study and schematic drawing of the force detection unit.

In total, start performances of 99 male and female athletes were investigated. Subjects were mainly recruited from different German track and field clubs. Performance levels of these athletes varied from regional level to top German level including the complete female German national sprint team and one of the top 3 German 200 m sprinters of all time. Since these athletes do not represent the actual top performance level in the world, further athletes from the Racers Track and Field Club were analyzed at their home track in Kingston, Jamaica. This training group incorporated the London 2012 Olympic champion and silver medal winner in the men's 100 m race. Subjects were divided into five groups based on their 100 m personal record (PR 100 m) (see table 1 for subject details). Each subject contributed 3 to 5 starts to the dataset. Mean values for each subject were determined.
To determine the relationship between 100 m race and starting performance, Pearson's product moment correlations between PR 100 m and performance variables were calculated. Further, a one factor ANOVA was used to determine if results differed between groups. If a group effect was detected by the ANOVA, post – hoc tests (Bonferroni correction) were applied to identify detailed differences between groups. The level of significance was set to 0.05.

RESULTS: Contrary to our expectations, top level athletes did not leave the blocks with a higher horizontal CoM velocity. No significant differences between groups and no significant correlation between PR 100 m and CoM velocity could be obtained. Nonetheless a strong correlation between PR 100 m and push off time could be observed (r = 0.71), indicating that top level sprinters leave the blocks earlier than lower levels sprinters (see table 1). Significant differences and correlations (r = -0.32 to -0.51) were found for maximum forces and RFDs for both legs (table 1 and figure 2). The ratio between $F_{maxfront}$ and $F_{maxrear}$ was more balanced in the male world – class group compared to the fast and slow men groups (1.02 to 1.19 and 1.20, respectively). NAHBP was increased for the male world – class group and a significant correlation between PR 100 m and NAHBP could be observed (r = -0.40) (see table 1 and figure 2). No significant differences could be found between male and female sprinters of comparable levels of performance (Men slow vs. Women fast). Still, on average, the female groups had lower values in all force parameters and longer block times compared to the male groups.

Table 2
Start performance parameters and subject details

		Men worldclass		Men fast		Men slow		Women fast		Women slow	
Age (years)***	mean	23.45	c	20.40	a	18.60	ad	23.70	ce	18.22	ad
	std	2.73		3.77		2.50		4.64		2.59	
Height (cm)***	mean	182.36	de	181.27	de	180.60	de	171.30	abc	172.65	abc
	std	6.77		5.40		8.40		6.11		4.96	
Weight (kg)***	mean	80.05	bde	73.22	ade	72.00	de	60.77	abc	62.83	abc
	std	6.94		7.26		8.60		4.54		6.49	
PR 100m (s)***	mean	10.06	bcde	11.08	ace	11.69	abe	11.37	ae	12.48	abcd
	std	0.28		0.21		0.14		0.22		0.48	
T_{react} (s)	mean	0.16		0.18		0.19		0.20		0.21	
	std	0.09		0.04		0.04		0.02		0.04	
T_{block} (s)***	mean	0.34	bcde	0.39	ae	0.40	a	0.39	ae	0.43	abd
	std	0.02		0.03		0.02		0.03		0.03	
V_{CoM} (m/s)	mean	3.54		3.77		3.86		3.74		3.51	
	std	0.55		0.45		0.43		0.65		0.51	
NAHBP**	mean	1.05	e	0.98	e	0.96		0.97		0.74	abd
	std	0.30		0.23		0.21		0.30		0.24	
$F_{maxfront}$ (N/kg)*	mean	16.27		16.14	e	16.42		15.82		14.46	b
	std	2.64		1.45		1.68		3.26		2.68	
$F_{maxrear}$ (N/kg)***	mean	15.98	de	13.59	e	13.66		11.36	ae	10.86	abd
	std	2.57		2.37		3.09		2.93		2.90	
$RFD_{maxfront}$ (N/kg/s)***	mean	237.37	bcde	137.48	a	122.64	a	132.21	a	109.38	a
	std	75.31		47.72		41.73		41.29		45.61	
$RFD_{maxrear}$ (N/kg/s)***	mean	335.27	de	247.33		230.51		204.30	a	182.91	a
	std	95.21		86.28		112.61		82.06		97.89	

*,**,***: significant group effect of ANOVA ($p<0.05$,$p<0.01$,$p<0.001$, respectively)
a,b,c,d,e: significant difference ($p<0.05$) to Men World Class Group, Men fast, Men slow, Women fast and Women slow Group, respectively

DISCUSSION: The purpose of the present study was to analyze a complete dataset of push – off forces from the starting blocks from male and female athletes of a wide range of performance levels. It could be shown that world – class sprinters use their potentially superior explosive force capacities in a way that they do not maximise CoM acceleration in the blocks, but rather try to minimize block time. Further, they seem to use both of their legs more equally for force production. They are capable of producing the same force impulse in a shorter period of time and therefore show greater NAHBP values than lower level sprinters. The differences between male and female sprinters can be explained by the lower force producing capacities of the female sprinters, even though the fast female group did not show significant differences to the slow male group, indicating a similar level of force capacities or a more efficient starting technique of the female sprinters. The main limitation of the study is that hand forces could not be determined. Since the measurement system needed to be portable in the present study it was not possible to collect ground reaction forces from the hands. Still, hands leave the ground immediately after the initiation of the push off and provide only minor forces in the vertical direction.

CONCLUSION: It could be shown that world – class athletes produce higher forces at higher RFDs to produce a short block time during the sprint start. This further emphasizes the role of a high level of maximum / explosive force in the training of the sprint start. A focus should be further put upon an equally hard push off from the front and the rear leg. In order to control the technical and conditional training progress, force measurements in the starting blocks could be used as a feedback system.

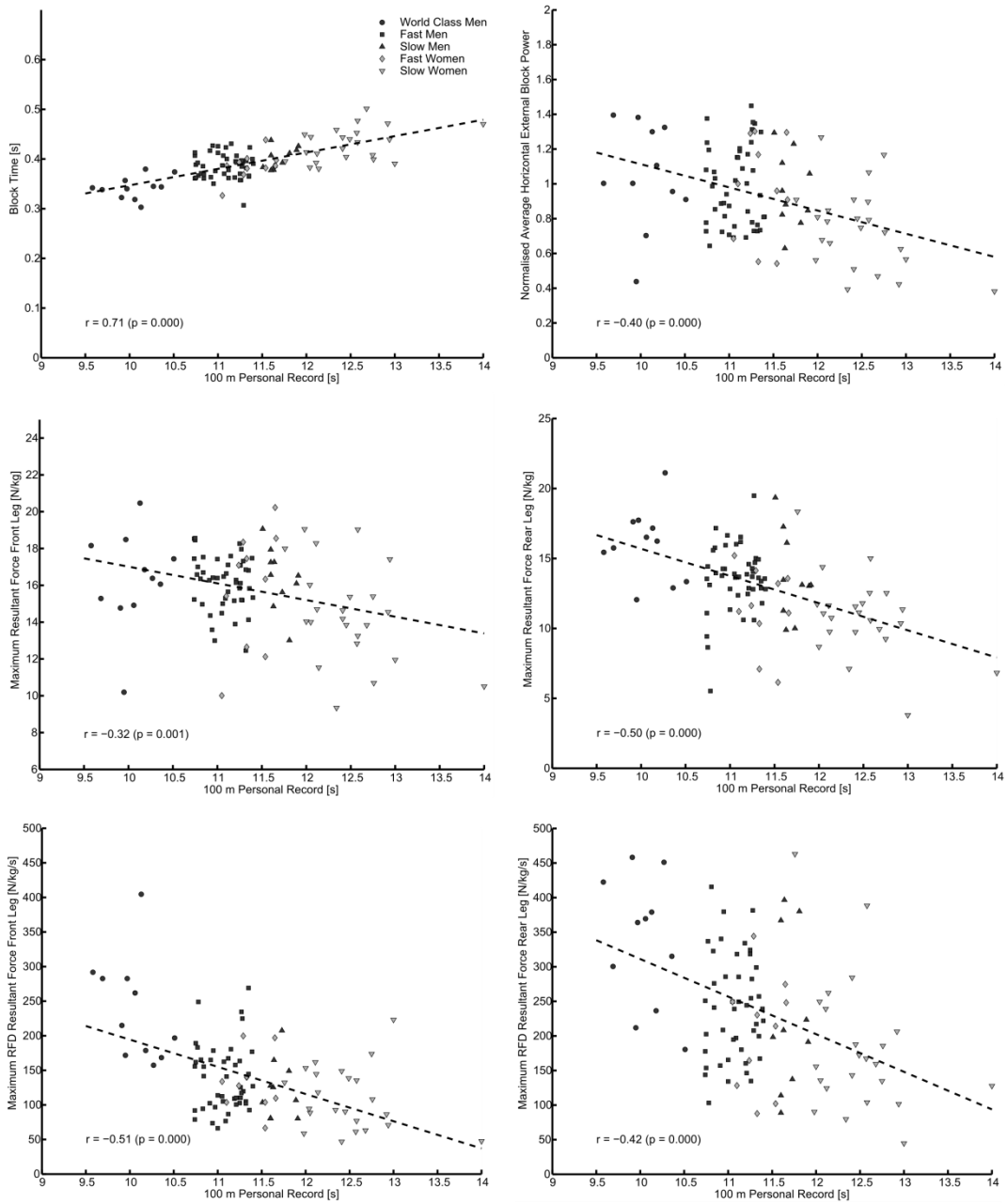

Figure 2: Pearson's product moment correlations between PR 100 m and selected parameters.

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