A COMPARISON OF TRUNK AND SHANK ANGLES BETWEEN ELITE AND SUB-ELITE SPRINTERS DURING SPRINT ACCELERATION

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Acceleration is a movement that requires skilful positioning of the body to apply force in the desired direction. The sagittal plane orientation of the trunk and shank are features that coaches use to visually assess sprint acceleration technique. This study examined differences in trunk and shank angles between elite and sub-elite sprinters during early acceleration using inertial sensors. Elite sprinters exhibited more vertical trunk positions throughout all four steps compared to sub-elite with moderate to very large differences at discrete events (d = 0.79 - 2.16). Shank angles were more vertical at touchdown in sub-elite compared to elite sprinters (d = -0.70 - -0.39), but similar at toe-off. These results suggest that less horizontal trunk lean during acceleration is a feature of higher level sprinters, coaches should be conscious of this when giving technical feedback.

KEYWORDS: acceleration, coaching, sprint start, sprinting, track and field

INTRODUCTION: The early acceleration phase of sprinting is recognised as a specific skill and is characterised by step-to-step changes in kinematics (Nagahara, Matsubayashi, Matsuo & Zushi, 2014; von Lieres und Wilkau, Irwin, Bezodis, Simpson & Bezodis, 2018). Higher levels of acceleration performance have been associated with a more horizontally orientated ground reaction force (Morin, Eduoard & Samozino, 2011). Body orientations which allow for effective horizontal force production are therefore needed and coaches have indicated that posture, although poorly defined, is an important aspect in sprint coaching (Jones, Bezodis & Thompson, 2009). A more forward lean has been associated with greater propulsive forces during accelerated running (Kugler & Janshen, 2010), however, some sprint coaches have indicated that too much forward lean of the trunk may be detrimental and could compromise extension during stance (McMillan S., personal communication, 21 Jan 2020). Furthermore, parallel trunk and stance shank segments at touchdown have been identified by coaches as a desirable body orientation for effective acceleration (von Lieres und Wilkau et al., 2018). There is a dearth of evidence to support, or refute, these common coaching concepts, particularly in high level sprinters. This study therefore aimed to compare trunk and shank orientation between elite and sub-elite sprinters during early acceleration and assess whether parallel trunk and shank segments occurred at touchdown.

METHODS: Eleven competitive sprinters participated in the study and were classified as elite or sub-elite based on a personal best (PB) 100 m time of less than 10.2 s or 11.2 s for males and females respectively. The elite group consisted of four male (PB 10.03 ± 0.13 s) and one female (PB 11.04 s) sprinters and the sub-elite group consisted of three male (10.56 ± 0.08 s) and three female (11.91 ± 0.29 s) sprinters. On an outdoor track, following the sprinters' accustomed warm up, each sprinter completed three maximum effort sprint starts from blocks, of which the best trial (defined as fastest 30 m time) was included in the analysis. Data was recorded using tri-axial inertial measurement units (IMUs) (Myomotion, Noraxon, USA) sampling at 200 Hz and a synchronised sagittal plane high speed video camera (100 Hz). Sensors were fixed to the medial surface of each shank and the posterior surface of the trunk at the T1 level. Calibration was performed in an upright standing posture that established a 0° segment angle. Sagittal plane deviation from this position was defined such that forward lean of the trunk or shank is represented by a positive value where a larger value indicates a more horizontal orientation. Video and IMU data were acquired using myoResearch 3.12 software (Noraxon, USA). Instances of touchdown and toe-off were identified from the video and each step normalised to 101 data points, where 0% was block exit and 100%, 200%, 300% and 400% the corresponding toe-off at the end of step 1, 2, 3 and 4 respectively (Step 1 and 3 as one leg, step 2 and 4 the alternate). One sprinter in the elite group did not record trunk data and was excluded from trunk analysis. Group means and standard deviations (SD) for trunk and shank angles were calculated and presented as time-series. The difference in orientation angle between the trunk and stance-limb shank at touchdown was calculated for each sprinter (TS_{diff}) and expressed as group means and SD, with a positive value indicating that the trunk was more upright than the shank. Between-group differences at touchdown and toe-off were assessed using Cohen's d effect sizes. The magnitude of the effect sizes was described using the following thresholds: 0-0.2 is trivial, 0.2-0.6 is small, 0.6-1.2 is moderate, 1.2-2.0 is large, and >2.0 is very large (Hopkins, Marshall, Batterham, & Hanin, 2009).

RESULTS: Across all four steps, there were trivial to small differences between elite and sub-elite shank angles at toe-off (ES -0.11 – 0.29), while there were small to moderate differences in shank angle at touchdown (ES -0.70 – -0.39) (Table 1). There were moderate to very large differences between the groups for trunk angle at touchdown (ES 1.08 – 2.16) and moderate to large differences at toe off (ES 0.79 – 1.43), with the elite group exhibiting a more upright trunk throughout. Trunk and shank angles at touchdown typically became more vertical over the four steps, with similar changes in each group (Figure 1, Table 1).
The TS_{diff} was not found to be close to zero at any step in either group; there was therefore no clear evidence of the trunk and stance limb shank segments being parallel at touchdown in either group (Table 1). At touchdown the trunk segment was consistently more upright than the shank and the difference between shank and trunk was more pronounced in sub-elite sprinters. Time-series of mean trunk and shank angles are presented in Figure 1 – note each athletes' touchdown occurred at a different percentage time and thus the angle of the mean profile at touchdown in figure 1 does not necessarily match the mean of each athletes' touchdown angle reported in table 1.

Table 1: Trunk and shank angles (°) and difference between segments (TS_{diff}) for the elite (E) and sub-elite (SE) groups at touchdown and toe-off events. Mean ± SD and Cohen's d effect size

		Step 1		Step 2		Step 3		Step 4	
		TD	**TO**	**TD**	**TO**	**TD**	**TO**	**TD**	**TO**
Trunk	E	56.2±2.4	49.6±6.6	50.9±3.8	42.5±7.3	45.9±9.2	41.3±12.3	41.8±3.0	33.4±10.3
	SE	67.3±12.5	58.3±13.0	60.9±11.4	55.8±11.0	59.3±8.6	51.8±9.9	54.7±7.2	49.2±11.5
	d	1.16	0.79	1.08	1.36	1.51	0.97	2.16	1.43
Shank	E	41.2±5.9	51.2±4.6	29.8±3.7	49.6±2.9	23.1±5.4	48.1±3.4	17.3±4.0	46.7±2.7
	SE	38.4±6.0	51.1±5.8	27.1±8.7	50.1±2.2	18.7±9.0	47.7±5.0	13.9±5.4	47.4±2.5
	d	-0.46	-0.01	-0.39	0.20	-0.58	-0.11	-0.70	0.29
TS_{diff}	E	14.6±5.4		21.6±4.1		22.8±11.2		24.0±4.2	
	SE	28.9±14.6		33.8±15.9		40.6±12.1		40.8±9.9	
	d	1.19		0.95		1.50		2.04	

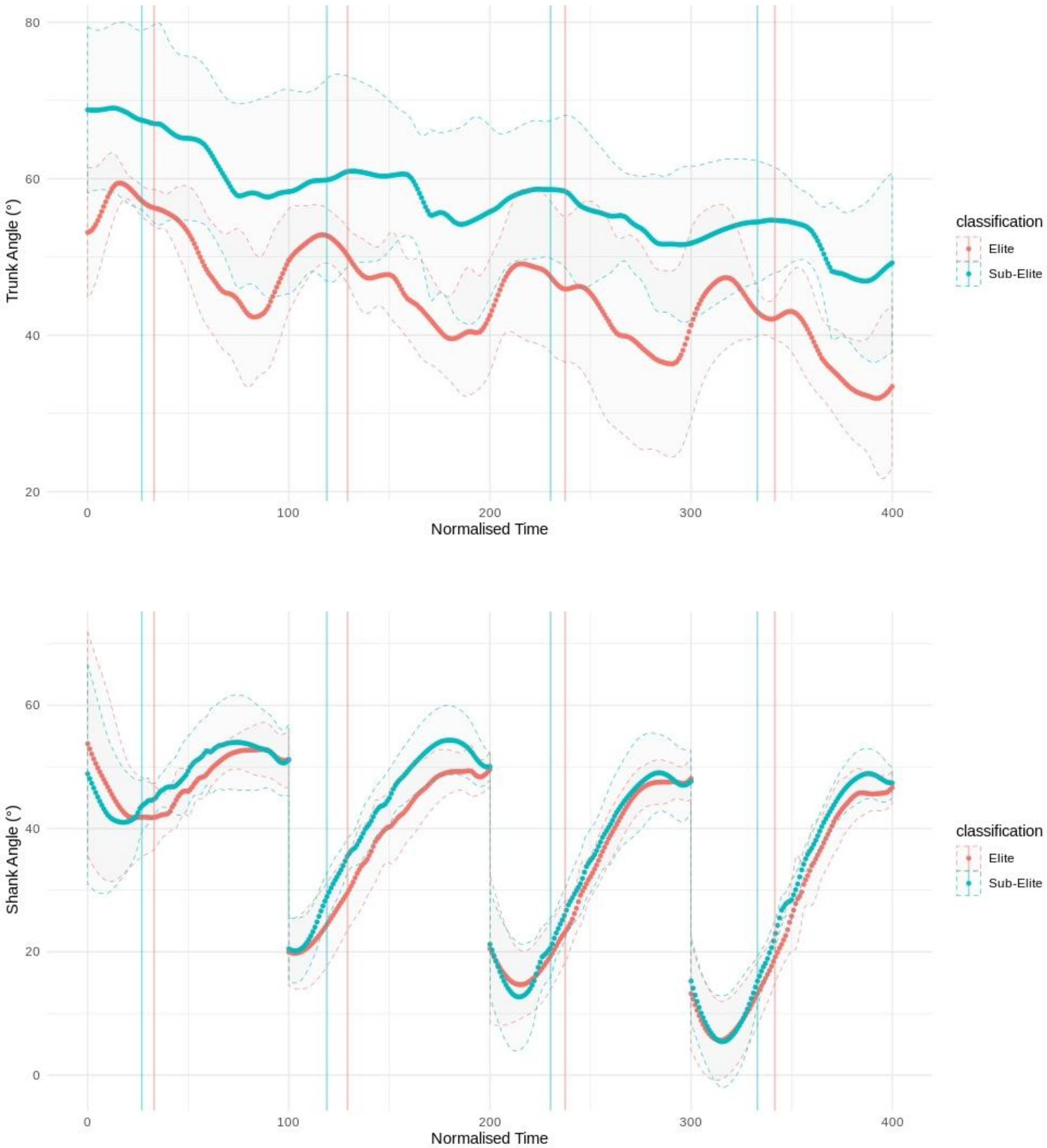

Figure 1: Mean trunk (top) and shank (bottom) angles over first four steps (toe-off to toe-off) for Elite and Sub-elite sprinters. Vertical lines indicate mean touchdown %. 100%, 200%, 300% and 400% represent toe-off of each subsequent step and therefore a change in the shank of interest

DISCUSSION: Elite sprinters were found to have a more vertical trunk position than sub-elite at all instances throughout the first four steps (Figure 1), with approximately 9-15° difference between groups at each of the discrete time points (Table 1). This appears contrary to previous research which suggested greater forward lean of the body was associated with increased propulsive forces and better acceleration, although this was represented by centre of mass position and not trunk lean (Kugler & Janshen, 2010). These observations provide evidence in support of coaching observations that too much forward lean of the trunk may be a suboptimal body position and compromise lower limb positioning and force application during acceleration (McMillan, 2020). Further, trunk and shank angles at touchdown decreased over the four steps in both groups, which supports previous observations of large step to step kinematic changes

during the first steps of acceleration (von Lieres und Wilkau et al., 2018). Differences in shank angles between the groups were less pronounced, with small to moderate effect sizes at touchdown, but only trivial to small differences at toe-off (Table 1). In both groups, shank angle at touchdown became more vertical over the four steps, however the angle at toe off remained consistent (Table 1). Touchdown occurred earlier in the normalised step cycle in sub-elite sprinters, with the shank in a slightly more vertical position (Table 1). Thus elite sprinters exhibited a forward lean of the shank at initial contact which sub-elite sprinters only achieved after contact. This may have implications for the preparation of the ankle joint for contact.
At touchdown, neither group showed parallel orientations of the trunk and shank. However, the difference between trunk and shank angle was greater in sub-elite sprinters where the trunk was more horizontal and the shank more vertical than elite sprinters. Hence, while trunk and shank segments did not approach parallel at touchdown, a large difference between the segment orientations may not be desirable. Given that this hypothesis was based on coaching observations it is possible that the segments would appear parallel or near parallel to a real time observer. Also, as the trunk is not a rigid segment, the definition of it from a single IMU may differ from the visual or two-dimensional video methods that would typically be used by coaches to assess trunk angle. Although the sample for this study was small, high level sprinters were studied. These results indicate that less horizontal trunk lean is a characteristic of higher level sprinters, suggesting that there may be an upper threshold beyond which forward trunk lean is not advantageous during acceleration. It is possible that excessive forward trunk lean may influence the athlete's ability to achieve the necessary hip joint motion. Further studies should investigate the interaction between trunk and shank angles and other segment motions, as well as spatiotemporal parameters.

CONCLUSION: The aim of this study was to compare trunk and shank orientations in elite and sub-elite sprinters. Elite sprinters demonstrate more vertical trunk orientations compared to sub-elite sprinters during early acceleration. Parallel trunk and stance limb shank segments were not observed at touchdown in either group. Practitioners should be wary of encouraging excessive forward lean of the trunk.

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