INTER-LIMB COORDINATION DURING SPRINT ACCELERATION

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Bilateral coordination is inherent to running motions but has not been investigated during sprint acceleration. The purpose of the study was to examine inter-limb thigh coordination during the first four steps of sprint acceleration in elite and sub-elite athletes. Anti-phase coordination patterns predominated in each step, but the proportion of anti-phase motion was higher in elite athletes (85.9 ± 10.8%) than sub-elite athletes (76.8 ± 10.9%, ES 0.83). Coordination profiles suggest that sub-elite athletes exhibit longer periods of the trailing (+) pattern around the time of touchdown (swing thigh flexing, stance thigh fixed) and the leading (-) pattern in the latter part of stance (stance thigh extending, swing thigh fixed) compared with elite athletes. These results provide preliminary empirical support for the emphasis placed on the switching of the limbs by coaches.

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

INTRODUCTION: Sprint acceleration performance is dependent on the application of force against the start blocks and ground in order to accelerate the centre of mass forwards. In order to accomplish this, athletes must achieve body configurations that will facilitate an effective direction of force application (von Lieres und Wilkau, Irwin, Bezodis, Simpson & Bezodis 2018). Kinematic analyses of the sprint start and early acceleration have identified joint and segment angles that are related to these effective external force characteristics (von Lieres und Wilkau, et al., 2018). These are typically reported as univariate segment orientations or joint angles at the instance of touchdown or toe-off, or as an angle-time series. However, this type of analysis does not easily allow for the assessment of the relative motion of different segments and joints, that is, movement coordination. To date, only one study has examined intra-limb coordination during the sprint start and early acceleration, for trunk-thigh, trunk-shank, and thigh-shank segment couples (Bezodis, et al., 2019). Bilateral coordination of the limbs is inherent to running motions, including sprint acceleration, and coaches emphasise technical drills and cues that are related to the cycling of the limbs. However, biomechanical studies of the sprint start have not investigated inter-limb coordination patterns. This study therefore aimed to quantify inter-limb thigh coordination during early acceleration, and to identify any differences in coordination strategies between elite and sub-elite sprinters.

METHODS: Eleven competitive sprinters participated in the study and were classified as elite based on a personal best (PB) 100m 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) athletes and the sub-elite group consisted of three male (10.56 ± 0.08 s) and three female (11.91 ± 0.29 s) athletes.
Testing was conducted during a training session on an outdoor athletics track, where athletes performed three maximum effort 30m trials from a block start with at least five minutes rest between each trial, following their accustomed warm up routine. Prior to starting the trials, a tri-axial inertial measurement unit (IMU) (Myomotion, Noraxon, USA) with a sampling frequency of 200 Hz was affixed to the distal half of the lateral aspect of both thighs using double-sided tape and secured with a velcro strap. Calibration was performed in an upright standing posture that established a 0° segment angle. Sagittal plane deviation from this position was defined as positive for flexion and negative for extension. A video camera sampling at 100 Hz was positioned in the sagittal plane and synchronised with the IMUs. Video

and IMU data was acquired using myoResearch 3.12 software (Noraxon, USA). Each athlete's best trial (defined as the fastest 30m time) was included in the subsequent analysis.

Instances of touchdown and toe-off were identified from the video. Sagittal plane thigh orientation data was normalised to 101 data points from toe-off to toe-off for each of the first four steps, beginning with toe-off of the front foot in the starting blocks (block clearance). Limbs were identified as "trailing" or "leading" at the instance of toe-off for each step, to account for alternating right and left lead limbs (e.g. the leading limb at toe-off for step 1 became the trailing limb at toe-off for step 2).

Coupling angles for trailing thigh-leading thigh were calculated at each time normalised data point by applying vector coding techniques to the angle-angle series (Chang, Van Emmerik & Hamill, 2008). The coupling angles were classified into one of eight coordination patterns (Needham, Naemi & Chockalingam, 2015) and colour coded for visual representation of each athlete's coordination profile (Figure 1) (Bezodis, et al., 2019).

To quantify differences between the elite and sub-elite groups, a coupling angle difference score (CA_{diff}) between the group means, ranging from 0 (same bin) to 4 (opposite bin), was assigned for each data point, as a positive integer in either direction (Figure 1). These scores were then summed for each step to give a total CA_{diff} which is expressed as a percentage of the maximum possible score of 404 (Bezodis, et al., 2019). In addition, the proportion of each step where the athlete was classified in an anti-phase pattern (AntiPhase%) was calculated. Group means, standard deviations (SD) and effect sizes (Cohen's d) were calculated.

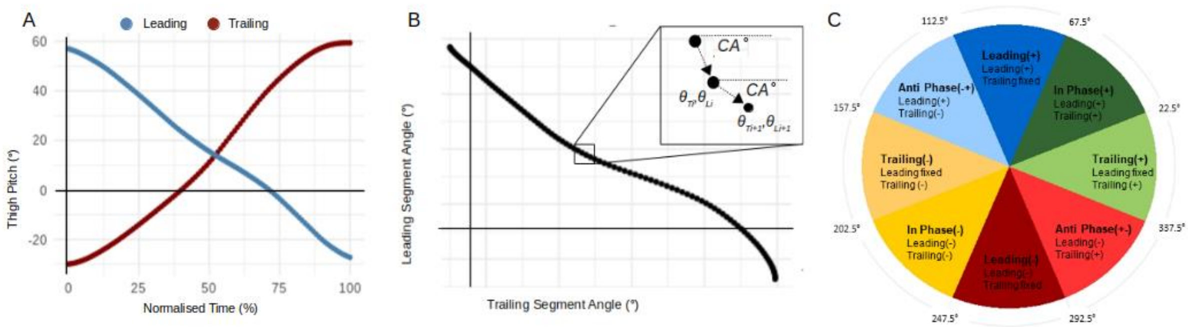

Figure 1: Definition of the coupling angle from angle-angle plots (A) and classification of coordination pattern bins based on the relative motion of each segment (B).

RESULTS: Angle-angle diagrams for individual athletes and elite and sub-elite groups are presented in Figure 2. Anti-phase patterns dominate each step, with sub-elite athletes tending to display larger periods of trailing (+) and leading (-) patterns (Figure 3) than elite athletes. The AntiPhase% was higher in all four steps for elite athletes compared with sub-elite athletes (ES = 0.34 to 1.61; Table 1), and the CA_{diff} between the groups was 3.2%, 2.0%, 3.7% and 3.0% for steps 1 to 4 respectively.

Table 1: Proportion of anti-phase coordination pattern of the thighs for each of the first four steps, for elite and sub-elite sprinters (Mean ± SD)

		Step			
		1	**2**	**3**	**4**
AntiPhase%	**Elite**	86.9 ± 8.1	81.2 ± 11.5	85.9 ± 10.6	89.5 ± 9.5
	Sub-elite	71.9 ± 9.7	78.2 ± 6.1	78.4 ± 11.9	78.7 ± 6.6
	Effect size (90% CI)	1.61 (0.50 – 2.73)	0.34 (-0.92 – 1.60)	0.67 (-0.45 – 1.79)	1.27 (0.11 – 2.43)

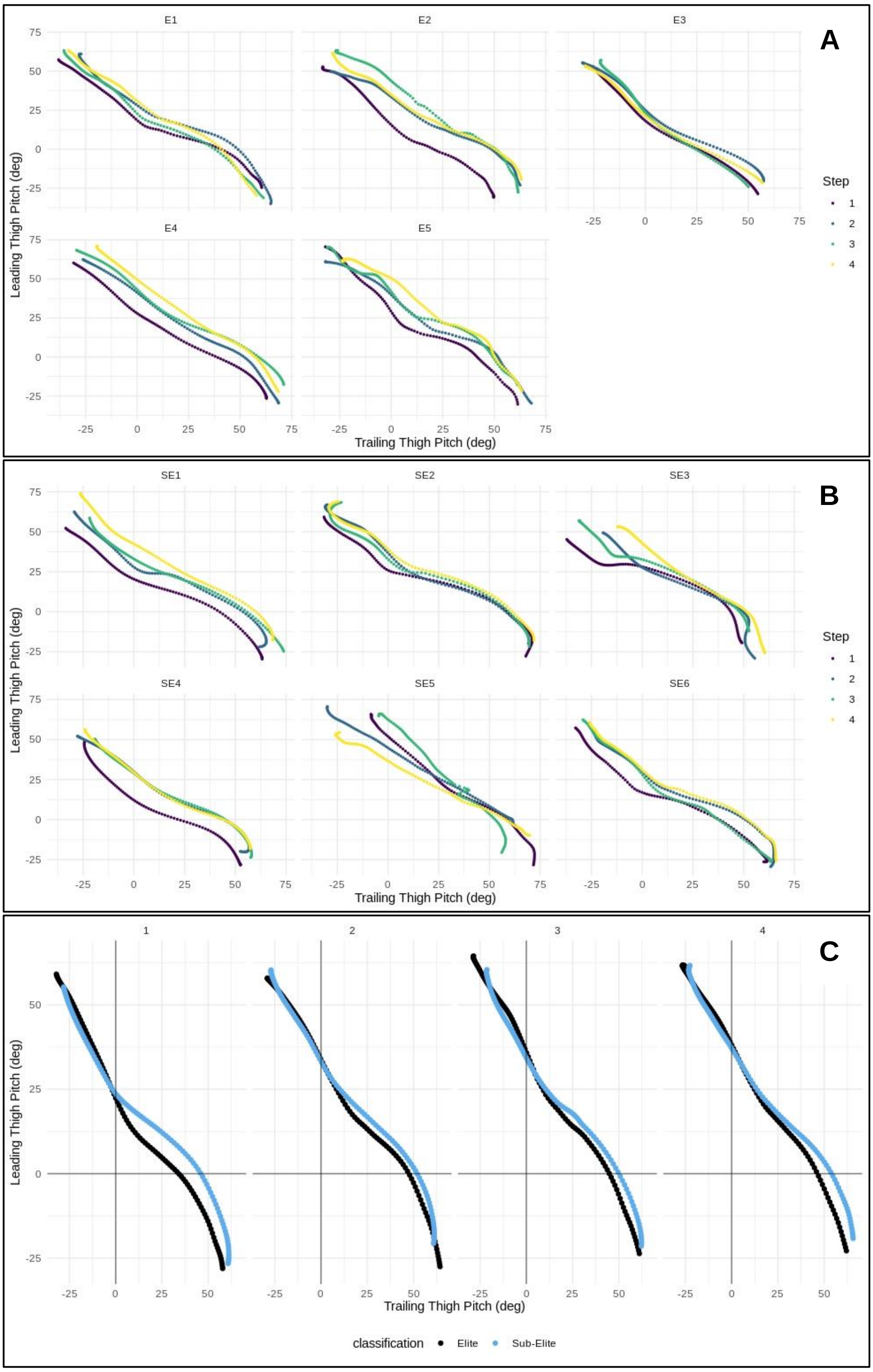

Figure 2: Angle-angle diagrams of the leading and trailing thighs for each of the first four steps for individual elite athletes (A), sub-elite athletes (B) and group means (C). Toe-off (the start of each step) occurs at the upper left most data point.

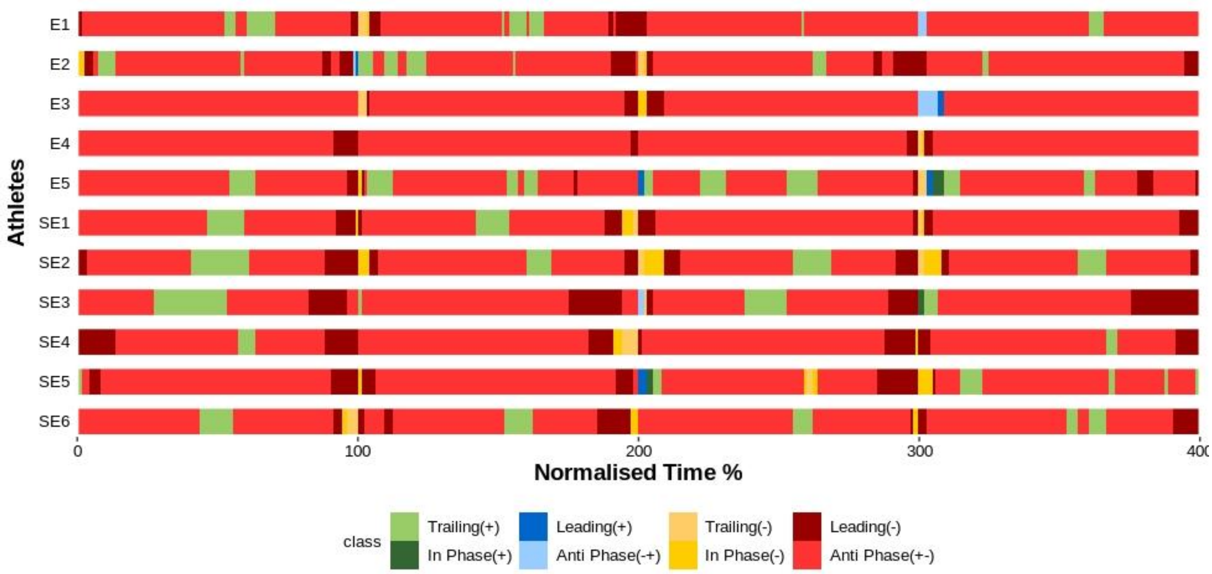

Figure 3: Individual coordination profiles for the trailing and leading limb thighs during the first four steps of sprint acceleration. Colour coding represents the coupling angle classification at each time point.

DISCUSSION: Inter-limb thigh coordination profiles during sprint acceleration display predominantly anti-phase patterns. A CA_{diff} of 2-4% was observed between elite and sub-elite sprinters across the first four steps; elite athletes spent relatively more time in the anti-phase pattern than sub-elites (Table 1; Figure 3). Visual inspection of the angle-angle series (Figure 2) show that elite athletes tend to have a more linear anti-phase pattern in comparison with the sub-elite athletes that display some decoupling in the mid portion of the plot and around the instance of toe-off. The individual coordination profiles suggest that the sub-elite athletes exhibit longer periods of the trailing (+) pattern around the time of touchdown (swing thigh flexing, stance thigh fixed) and the leading (-) pattern in the latter part of stance (stance thigh extending, swing thigh fixed) compared with elite athletes.

Whilst these data were from a small population, high-level athletes were analysed. Potentially important coordination patterns which differentiate elite from sub-elite sprint acceleration performance were therefore identified, and these provide preliminary empirical support for the coaching emphasis placed on the switching or cycling of the limbs. Further investigation is needed to understand the interaction between these patterns and other technical elements, such as touchdown distance, and the timing and duration of contact, which may influence the “fixing” of one limb and the deviation from anti-phase thigh motion.

CONCLUSION: Elite sprinters exhibit a more linear anti-phase pattern of inter-limb thigh coordination during early acceleration than sub-elite sprinters.

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