FORCE PROFILE OF FUNCTIONAL LEG MUSCLE GROUPS IN CURVE SPRINTING - PRELIMINARY RESULTS

Johannes Funken[1], Marvin Zedler[1,2], Svea Lüdorff[1,2], Tobias Alt[3], Kai Heinrich[4], Wolfgang Potthast[1,2]

Institute of Biomechanics and Orthopaedics, German Sport University Cologne, Cologne, Germany[1]
German Research Centre of Elite Sport Cologne, German Sport University Cologne, Cologne, Germany[2]
Department of Biomechanics, Performance Analysis and Strength & Conditioning, Olympic Training and Testing Centre Westphalia, Dortmund, Germany[3]
Institute of Occupational Safety and Health, German Social Accident Insurance, Sankt Augustin, Germany[4]

Research on lower extremity joint and muscle kinetics in athletic curve sprinting is under-represented in the scientific literature. This is an issue due to its importance for training and rehabilitation protocols as well as for injury prevention. In this study, we analysed six male sprinters regarding their force profile of functional lower extremity muscle groups in curve sprinting. Three-dimensional motion capture (Vicon) and four force plates (Kistler) were used to capture kinematic and kinetic data. Inverse dynamic calculations (Anybody), including muscle forces, provide first insights into potential side differences of leg muscle group force profiles between the inside and the outside leg in submaximal curve sprinting (9.48 ± 0.26 m/s). However, a differentiated analysis of individual muscles is necessary in the future as grouping might overlay the side-specific effects in particular muscles.

KEYWORDS: kinetics, bend running, athletics, adaptation, performance, injury prevention

INTRODUCTION: In athletic sprint disciplines longer than 100 m, more than 50% of the distance is covered in the curve. Although sprinting in a curve is particularly relevant, it has received insufficient attention in sports biomechanical research compared to linear sprinting.

Previous research on athletic curve sprinting revealed that the left and right leg have different functions during curve sprinting (Alt et al., 2015). While the curve inside leg (left) stabilises the movement in the frontal plane (eversion-adduction strategy), the curve outside leg (right) is more responsible for movement control in the horizontal plane (rotation strategy) (Alt et al., 2015). Furthermore, the research group amongst Churchill and colleagues has investigated other kinematic aspects of track and field curve sprinting and associated technique adaptations (Churchill et al., 2015), as well as kinetic aspects (Churchill et al., 2016), related to ground reaction force. They suggest that curve sprint-specific technique and strength training may have a positive effect on athletic performance. In addition, in athletes specialised in running disciplines between 400 and 5000 m, muscular adaptation effects were shown to result in an asymmetry of volume in some muscles between the inside vs. outside leg (Tottori et al., 2016).

The specific motor demands in athletic curve sprinting differ from those in linear sprinting (Alt et al., 2015; Churchill et al., 2015, 2016). As outlined in a study by Pollock and colleagues (Pollock et al., 2016), these demands affect not only movement execution but also local and structure-specific musculoskeletal demands. The characteristics of ground reaction force (GRF) differ in expression or orientation in curve sprinting not only from linear sprinting but also between the inside and outside leg (Churchill et al., 2016). This inevitably directly influences the orientation of the GRF vector relative to the respective joint centres and will thus condition the externally applied torques to the structures and, consequently, the internal loading of the muscle-tendon complex.

Therefore, the current analysis aimed to gain insights into muscle force profiles specific to curve sprinting. Based on the available literature, we hypothesise that peak muscle forces differ between the curve inside and outside limb in submaximal curve sprinting.

METHODS: Six male sprinters on national competitive level (mass: 76.3 ± 8.2 kg; height: 186 ± 6 cm; 200 m personal record at the time of study: 22.60 ± 0.33 s) voluntarily participated in the study. Ethical approval was granted (184/2016). A three-dimensional motion capture system (250 Hz, VICON^{TM}, Oxford, UK) and four force plates (1250 Hz, Kistler^{TM}, Winterthur, CH) mounted flush with the floor were used to record kinematic and kinetic data. All athletes wore sprint spikes and force plates were covered with the same polyurethane surface as the runway. Retro-reflective markers were attached to anatomic reference points. Kinematic and kinetic data were filtered the same way (Butterworth, fourth order, 50 Hz cut-off, recursive), and served, together with athlete-specific anthropometrics, as input for an anatomic landmark scaled rigid body model (Anybody Modeling System, Anybody Technology, Aalborg, DK, modified from Lund et al., 2015) to calculate muscle forces. Ground contact was defined by using the filtered vertical GRF and a threshold of 20 N. Results were time normalised to the stance time of the ground contact. Force outputs of individual muscles were combined into functional groups (Table 1). After an individual warm-up, the athletes performed straight and curve (radius = 36.5 m) sprints with constant submaximal velocity, which should be attained after a 40m approach run. To avoid the influence of fatigue, the number of trials was limited, resulting in a varying number of trials per athlete with valid force plate strikes, which included both the left and right leg. Here we present data including each athlete's fastest curve sprint trial, including valid strikes for the left and right leg. We calculated sprinting velocity within the measuring volume (approx. 8 m) from the centre of mass (CoM) velocity using the resultant vector of the antero-posterior and medio-lateral components Wilcoxon sign rank test was used to identify differences between legs with a level of significance of 5%.

Table 1: Composition of functional muscle groups.

Hip Extensors	Hip Flexors	Hip Adductors	Hip Abductors
Biceps femoris caput longum	Iliacus	Adductor brevis	Gluteus medius
Gluteus maximus	Tensor fasciae latae	Adductor longus	Gluteus minimus
	Sartorius	Adductor magnus	
		Gracilis	
Hip External Rotators	**Knee Extensors**	**Knee Flexors**	**Ankle Plantar Flexors**
Gemellus	Rectus femoris	Biceps femoris caput breve	Gastrocnemius lateralis
Piriformis	Vastus intermedius	Semitendinosus	Gastrocnemius medialis
Quadratus femoris	Vastus lateralis	Semimembranosus	Soleus
Obturator	Vastus medials		Tibialis posterior
			Peroneus longus
			Flexor hallucis
			Flexor digitorum longus

RESULTS AND DISCUSSION: Running velocity was 9.48 ± 0.26 m/s. Peak inward GRF was 56% higher for the left inside than the outside leg (Figure 1, Table 2). Based on the first analysis, we only partly accept our hypothesis, that peak muscle forces differ between the curve inside and outside limbs in submaximal curve sprinting.

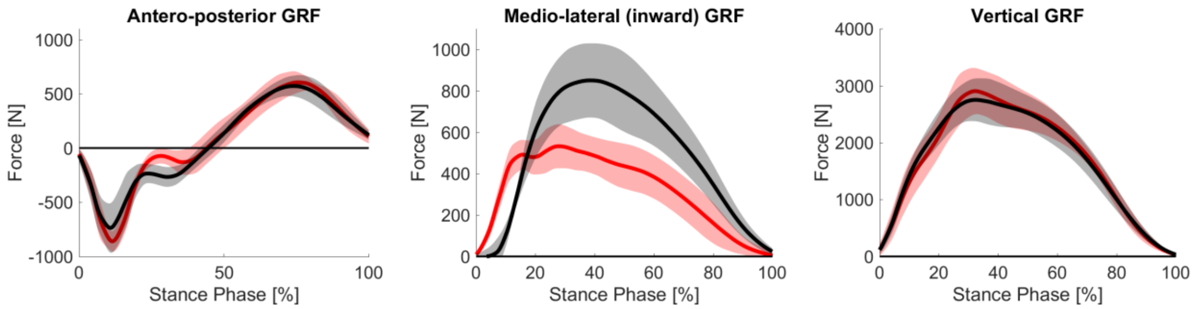

Figure 1: Mean values (solid line) and standard deviation (shaded) of ground reaction force (GRF) in submaximal athletic curve sprinting. Antero-posterior, medio-lateral (inward relative to the curve) and vertical GRF for the right (red, outside) and for the left (black, inside) leg.

Peak forces of the hip abductor and of the external rotator muscle groups were higher (35% and 29%, respectively) in the left leg compared to the right leg. On the other hand, peak forces of the hip extensor and of the knee flexor muscle groups were lower (30% and 16%, respectively) in the left leg compared to the right leg (Table 2). In all other muscle groups peak values were not different between the inside and the outside leg. Similar to the force profiles presented by Schache and colleagues (Schache et al., 2012) for linear sprinting, knee flexors are mainly inactive during mid-stance (40 – 80% of ground contact) for both legs (Figure 2). During initial ground contact, sum of muscle forces (semimembranosus, semitendinosus, biceps femoris short head) as presented by Schache and colleagues match well with the force of the knee flexor group presented here.

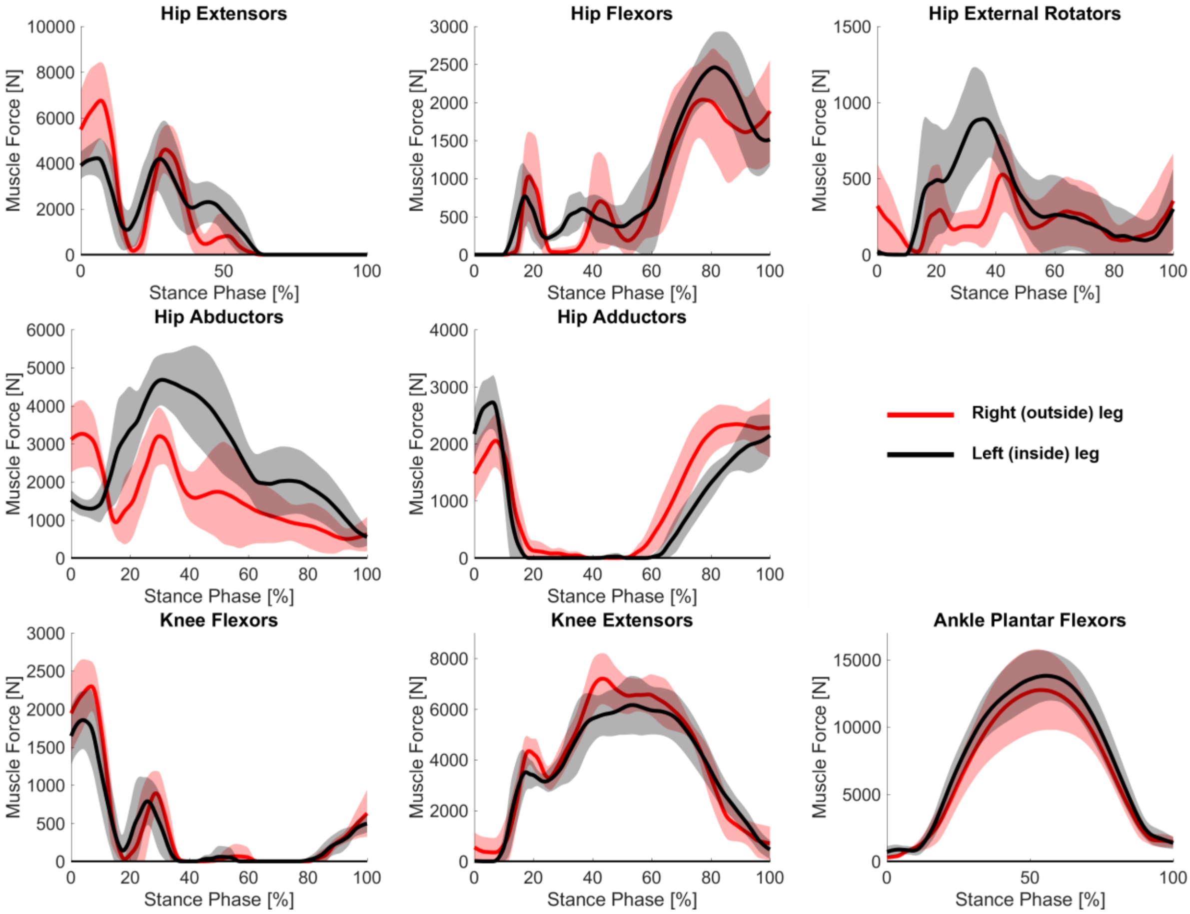

Figure 2: Mean values (solid line) and standard deviation (shaded) of muscle group forces in submaximal athletic curve sprinting for the right (red, outside) and for the left (black, inside) leg.Top row: Hip extensors, hip flexors and hip external rotators. Middle row: Hip abductors and hip adductors. Bottom row: Knee flexors, knee extensors and ankle plantar flexors.

There are some limitations to this preliminary results which will be addressed in future in-depth analyses: As per Table 1, we assigned each muscle only to one functional muscle group even if it contributes to other functional tasks. To which extent a re-grouping might alter muscle group force profiles and, in particular, might affect side-specific effects was not investigated. As data capturing also included linear sprinting (not presented here), we asked athletes to run in submaximal velocity to have the same velocities between linear and curve sprints and to make the comparison between the conditions meaningful. Therefore, some muscular features that might occur only during maximum sprinting may not be detected. For this first analysis, and because the focus was on muscle force, the presented horizontal GRFs were not rotated into the direction of travel. Even though the expected differences to the current representation will be minor, in future analysis, we will account for CoM direction of travel for GRF analysis – muscle force calculations, however, are unaffected.

Table 2: Mean values (standard deviation) for peak ground reaction forces (GRF) and peak muscle forces of muscle groups (as of Table 1) for the left (inside) and right (outside) leg in submaximal athletic curve sprinting. Significant differences (p < 0.05) between left and right leg are indicated (+).

	left (inside) leg	right (outside) leg	p < 0.05
Peak Muscle Force (kN)			
Hip Extensors	4.76 (1.48)	6.81 (1.71)	+
Hip Flexors	2.51 (0.50)	2.38 (0.73)	
Hip Adductors	2.82 (0.46)	2.55 (0.42)	
Hip Abductors	5.11 (0.84)	3.79 (0.68)	+
Hip External Rotators	0.97 (0.31)	0.75 (0.18)	+
Knee Extensors	6.44 (1.01)	7.35 (0.87)	
Knee Flexors	1.96 (0.38)	2.33 (0.35)	+
Ankle Plantar Flexors	13.96 (1.78)	12.81 (2.98)	
Peak GRF (N)			
Antero-posterio (propulsive)	581.4 (95.0)	626.6 (83.3)	
Antero-posterior (braking)	767.7 (240.1)	868.0 (95.1)	
Medio-lateral (inward)	871.3 (166.5)	559.6 (85.0)	+
Vertical	2792.5 (350.9)	2962.1 (402.9)	

CONCLUSION: This study provides a first insight into the effect of leg side (curve inside versus outside) on leg muscle force profiles in athletic curve sprinting. However, a differentiated consideration of the individual muscles seems necessary since muscles partly take over several propulsion and/or stabilisation tasks across planes of motion, and a grouping could overlay the side-specific effects of individual muscles.

REFERENCES:

Alt, T., Heinrich, K., Funken, J., & Potthast, W. (2015). Lower extremity kinematics of athletics curve sprinting. *Journal of Sports Sciences*, *33*(6), 552–560. https://doi.org/10.1080/02640414.2014.960881

Churchill, S. M., Salo, A. I. T., & Trewartha, G. (2015). The effect of the bend on technique and performance during maximal effort sprinting. *Sports Biomechanics*, *14*(1), 106–121. https://doi.org/10.1080/14763141.2015.1024717

Churchill, S. M., Trewartha, G., Bezodis, I. N., & Salo, A. I. T. (2016). Force production during maximal effort bend sprinting: Theory vs reality. *Scandinavian Journal of Medicine & Science in Sports*, *26*(10), 1171–1179. https://doi.org/10.1111/sms.12559

Lund, M. E., Andersen, M. S., de Zee, M., & Rasmussen, J. (2015). Scaling of musculoskeletal models from static and dynamic trials. *International Biomechanics*, *2*(1), 1–11. https://doi.org/10.1080/23335432.2014.993706

Pollock, N., Dijkstra, P., Calder, J., & Chakraverty, R. (2016). Plantaris injuries in elite UK track and field athletes over a 4-year period: A retrospective cohort study. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(7), 2287–2292. https://doi.org/10.1007/s00167-014-3409-3

Schache, A. G., Dorn, T. W., Blanch, P. D., Brown, N. A. T., & Pandy, M. G. (2012). Mechanics of the Human Hamstring Muscles during Sprinting: *Medicine & Science in Sports & Exercise*, *44*(4), 647–658. https://doi.org/10.1249/MSS.0b013e318236a3d2

Tottori, N., Kurihara, T., Otsuka, M., & Isaka, T. (2016). Relationship between lateral differences in the cross-sectional area of the psoas muscle and curve running time. *Journal of Physiological Anthropology*, *35*. https://doi.org/10.1186/s40101-016-0086-6