COMPARISON OF SPRINT STRIDE KINEMATICS BETWEEN THREE DIFFERENT CARBON SPIKES – A CASE STUDY

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The aim of this study was to compare the effect of three different carbon spikes that have different carbon plate and foam placement upon stride-by-stride kinematics during short and long sprints. An international leveled 400m (52.60 s) master athlete performed several 50 and 200m sprints, while wearing three different carbon spikes types in which stride kinematics and angular foot velocity were measured. The main findings were that in the 50m sprints with Puma spikes peak velocity and step frequency were lower with longer contact times than with the other spikes and during the 200m Saucony had a shorter average step length than Adidas. The largest changes in kinematics were found in the angular foot velocities in both sprints thereby it was concluded that placement of carbon plate can influence step kinematics particularly during the short sprint for this athlete.

KEYWORDS: Contact times, flight times, step frequency, step length.

INTRODUCTION: In recent years running performance has changed by the introduction of the carbon plate in the midsole. (Healey et al., 2022). Many new records are set in recent years in the long distances like the half and whole marathon, while wearing these carbon plated shoes. The inclusion of carbon fiber plates in the midsole of the shoes, increases the bending stiffness, and thereby, reduce the loss of energy of the metatarsophalangeal joint during the midstance phase (Stefanyshyn & Nigg, 2000). To the best of our knowledge only a few studies have analyzed performance based on carbon spikes. Healey et al. (2022) discussed if we could quantify the benefits of the carbon spikes in track running and showed the effects of carbon spikes vary based on several factors like event (100, 200, to 10,000 m), characteristics of the athlete wearing them, and force application. Furthermore, they discussed the difficulty of testing the carbon spike, due to the metabolic energy demands in the short and middle distances. Herrero et al. (2023) reported that female sprinters decreased 40m times significantly by 0.031 s (0.6%), while wearing carbon spikes compared to the conventional spike. This was mainly caused by the increase in leg and vertical stiffness and a reduction in the ground contact time during the 30-40m of the sprint. However, they have only investigated kinematics in two phases 0-10m and 30-40m and used only one type of carbon spike (Nike Air Zoom Maxfly). Nowadays there are several carbon spikes on the marked with different placement of the carbon plate and the foam (foam under or above carbon plate) with perhaps different effects upon sprint kinematics. Therefore, this study compares the effect of three different carbon spikes that have different carbon plate and foam placement upon step-by-step kinematics during short and long sprints.

METHODS: An international leveled 400m (52.60 s) master athlete (Age: 47, height: 1.79m, body mass: 86kg) in his age group participated in the study. The athlete had four test sessions separated by one week each at 11AM of the day. The warm-up was individualized, but similar every test session. In the first two test sessions the athlete performed nine maximum 50m sprintswith 6 min rest between each sprint in each session indoors in which the three types of spikes were alternated in the order 1-2-3-3-2-1-1… In the second session the order of the three shoes was changed. In the last two sessions three 200m with 12 min rest between each run were performed outdoors in which the athlete ran one 200m with each pair of spikes at 400m max pace to mimic the first 200m of the 400m. The three pair of shoes all had a carbon plate, but differed in where it was placed: under or above the cushioning in the front of the spikes. The spikes were the Saucony Endorphin Cheetah, Puma evoSPEED Distance Nitro Elite and Adidas Adizero Prime SP2. On top of the shoelaces of each spike an IMU with an integrated 3-axis gyroscope with maximal measuring range of 2000°s−1 ± 3% at 1000 Hz (Ergotest

Technology AS, Langesund, Norway) was attached (Figure 1). The athlete was familiar with all three types of spikes.

Figure 1: The three different types of spikes with the IMUs attached on two of them.

Step-by-step kinematics (step length, rate, contact and flight time), together with angular foot velocity (plantar-dorsal flexion) at touch down, minimal and toe off (Martín-Fuentes & van den Tillaar, 2022) were automatically recorded for each step by a combined laser+IMU system as part of the MUSCLELAB system (Ergotest Technology AS, Langesund, Norway) during each sprint using a CMP3 Distance Sensor laser gun (Noptel Oy, Oulu, Finland). All recordings of the IMUs and laser were synchronized with MUSCLAB v10.232 (Ergotest Technology AS, Langesund, Norway). All kinematics per step was recorded during each sprint, while each step of the last 90m (straight line of the 200m was recorded with the laser. Kinematics (velocity, contact and flight time, step length and frequency) were averaged per stride as the average of two following steps. 50m sprint times were recorded with the laser, while the first and second 100m of the 200m were clocked manually by the athlete and the average velocity of the last 90m to calculate the last 100m times.

To assess the effect of carbon spike on sprint times, velocity and kinematics a two-way ANOVA (strides and spike type) on each of the variables was performed, with pairwise comparison post hoc. The level of significance was set at $p < 0.05$.

RESULTS: No significant differences were found in the times of the 50 and 200m sprints between the three spike conditions (Table 1).

Table 1. Average sprint times on 50m and 200m (first and second test day) with the spikes.

	Laser measured	Manually clocked			Laser measured
	50m	**First 100m**	**Second 100m**	**Total 200m**	**Second 100m**
Saucony	6.51±0.07	12.34-12.17	12.39-12.23	24.73-24.40	12.47-12.37
Puma	6.56±0.06	12.34-12.15	12.32-12.40	24.59-24.55	12.41-12.43
Adidas	6.56±0.07	12.39-12.13	12.31-12.21	24.70-24.34	12.37-12.39

However, when evaluating stride kinematics of the 50m, peak velocity and stride frequency were significantly lower with longer contact times, while sprinting with Puma spikes compared with the other two spikes (Table 2). Furthermore, significant interaction and spike type effects were found in which minimal angular foot velocity and at touch down were significantly different between all three carbon spikes and significantly lower at toe off with the adidas spike compared with the other two. Pairwise comparisons revealed that minimal angular foot velocity was the highest with the Saucony spikes, followed by Puma and Adidas and that over the strides these differences increased. Whilst, at touch down Adidas had the highest velocity, followed by Saucony and Puma, in which over strides these differences also increased. At toe off angular foot velocity was the lowest with Adidas compared with the others, especially in the later steps (Fig. 1).

Table 2. Average kinematics (±SD) over 50m sprint with the three spikes.

	Peak velocity (m/s)	Contact time (s)	Flight time (s)	Step length (m)	Step Frequency (Hz)
Saucony	9.06±0.04	0.106±0.018	0.126±0.017	1.76±0.33	4.39±0.29
Puma	8.91±0.06*	0.108±0.017*	0.125±0.019	1.75±0.33	4.36±0.28*
Adidas	9.01±0.08	0.106±0.018	0.124±0.020	1.76±0.34	4.38±0.28

* indicates a significant difference with the other two on a p<0.05 level.

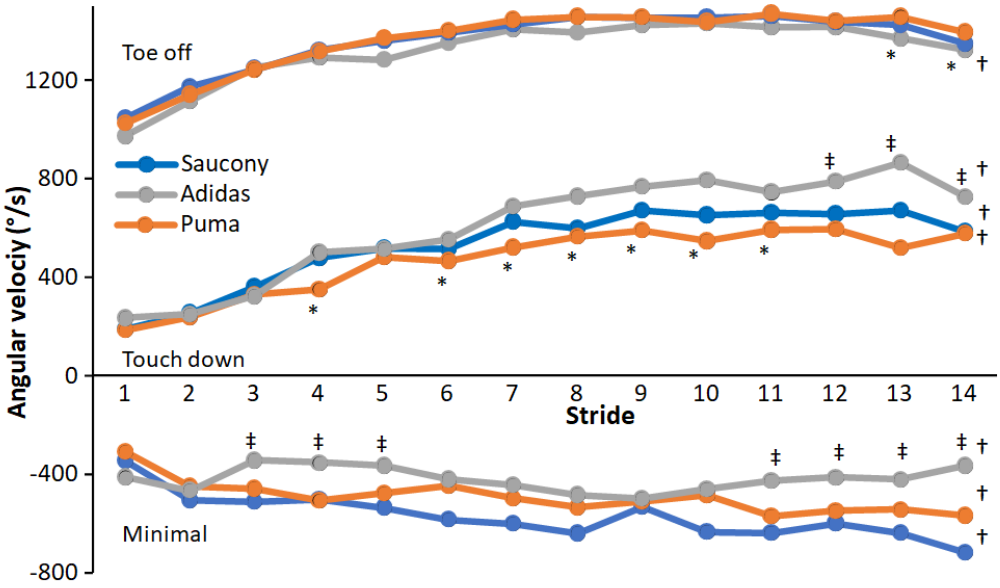

Figure 1. Average angular foot velocity per stride averaged per spike.
† indicates a significant difference with the other two spikes for the entire 50m. * indicates a significant difference with between Adidas and Puma for the stride. ‡ indicates a significant difference between all three spikes for the stride.

Also in the last 90m of the 200m sprint significant differences in minimal angular foot velocity and at touch down were found. At touch down Puma had the highest velocity, followed by Adidas and Saucony. The minimal angular foot velocity was higher with Saucony and Adidas compared with Puma (Fig. 2).

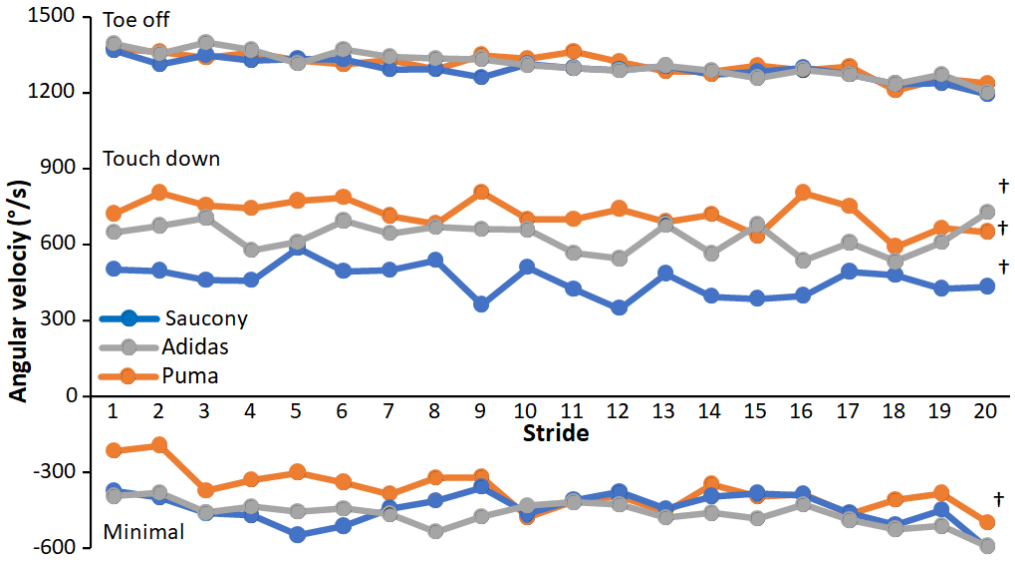

Figure 2. Average angular foot velocity per stride averaged per spike over last 90m of 200m.
† indicates a significant difference with the other two spikes for the entire run.

Only a significantly shorter stride the Saucony spikes with the Adidas was found when evaluating stride kinematics of the last 90m of the 200m sprint (Table 3).

Table 3. Average kinematics (±SD) over last 90m of 200m sprint with the three spikes.

	Velocity (m/s)	Contact time (s)	Flight time (s)	Step length (m)	Step Frequency (Hz)
Saucony	8.07±0.32	0.107±0.004	0.146±0.006	2.04±0.03*	3.96±0.13
Puma	8.15±0.34	0.107±0.004	0.145±0.005	2.05±0.03	3.97±0.13
Adidas	8.14±0.34	0.107±0.004	0.148±0.009	2.07±0.04*	3.94±0.17

***** indicates a significant difference between these two on a $p<0.05$ level.

DISCUSSION: The aim of this study was to compare the effect of three different carbon spikes with different carbon plate and foam placement upon stride-by-stride kinematics during short and long sprints. The main findings were that no times differences in short and long sprints were found between the three spikes. However, some kinematics were affected. In the 50m sprints with Puma spikes peak velocity and stride frequency were lower and had longer contact times than in with the other spikes. During the 200m Saucony had a shorter average step length than Adidas. The largest changes in kinematics were found in the angular foot velocities in both sprints.

The lower peak velocity with the Puma spikes are probably caused by the longer contact times, which also caused a lower step frequency compared with the other spikes. This is also visible in the lower angular foot velocity at touch-down, which correlates with lower 50m sprint velocities (Martín-Fuentes & van den Tillaar, 2022). However, during the long sprint the angular foot velocity at touchdown was higher than the other two spikes that could indicate other characteristics of the spikes. This was then also shown in less minimal angular foot velocity during the 200m sprints (Fig. 2). That the spikes have different cushioning and recoil is also visible with the Adidas spike during the 50m. The spike has a higher angular foot velocity at touch down and less minimal angular foot velocity, which could result in higher leg stiffness (Herrero et al., 2023) and positive effect for the sprint. However, angular foot velocity at toe off was lower, which again is negative for maximal velocity (Martín-Fuentes & van den Tillaar, 2022) resulting in similar stride kinematics as with Saucony spike (Table 2).

The main limitation of this study was that it was tested by one athlete and the results could be different in other athletes as shown by Healey et al. (2022). Therefore, this should be tested also by other athletes to investigate if the findings are generalizable.

CONCLUSION: Based upon the findings it was concluded that the type of carbon spikes influences step kinematics and especially angular foot velocity during short and long sprints in this athlete. Thereby, it seems that the way the placement of carbon plate in combination with the cushioning foam can have a positive effect upon sprint performance, especially for the 50m sprint. For this athlete it should be recommended to use the Saucony spike in the 50m as this results in faster peak velocity and thereby faster sprints.

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