THE MEDIOLATERAL CENTER OF PRESSURE MOVEMENT DIFFERS BETWEEN TRAINING AND RACING SHOES: A CASE STUDY

Stephanie R. Moore[1], Aaron Martínez[1,2], Hermann Schwameder[1], Thomas Stöggl[1,2]

Department of Sport and Exercise Science, University of Salzburg, Austria[1]
Red Bull Athlete Performance Center, Thalgau, Austria[2]

Athletes that compete on an elite level often employ running shoes specifically for racing that contain carbon plating. The purpose of this case study was to compare one female athlete's mediolateral COP while she ran in racing and training shoes. SPM analyses revealed several regions where significant differences existed ($p<0.05$) for both left and right footfalls. While the magnitude of the differences observed in the right foot appear to be minimal, the difference in the left footfalls indicate that the athlete is experiencing a lesser magnitude of medial COP displacement with the training shoe. The athlete therefore appears to be compensating by limiting foot pronation when using her training shoe. As a result, it is important to investigate mediolateral COP when characterizing movement patterns and compensations of athletes using multiple shoes.

KEYWORDS: carbon plate, super shoe, running, elite performance

INTRODUCTION: With the help of footwear developments, elite athletes have been consistently improving the top times performed in long distance running races in the recent years (Bermon et al., 2021). Further, the carbon plated running shoe has gained popularity as a racing shoe and been associated with top international performances since 2016 (Burfoot, 2020). Evidence suggests that carbon plated running shoes can elicit changes in sagittal plane motion especially at the ankle (Ortega et al., 2021) and increase energy return (force) applied at the heel during propulsion (Nigg et al., 2021). Considering this, it can be expected that any frontal plane motion of the foot outside neutral (i.e. supination/pronation) would not be optimal for the energy return properties of the "teeter-totter effect" of a carbon plate (Nigg et al., 2021). Foot pronation during the early ground contact phase, with the forefoot contacting the ground sequentially from the 5th metatarsal to the 1st, can be characterized by a medial shifting of the center of pressure (COP) (De Cock et al., 2005, 2008). However, limited information has been provided about the mediolateral COP of the foot while using carbon plates. Because many elite athletes perform the bulk of their training in a different type of shoe than is used for racing, it is important to understand whether the athletes are in fact training the movement patterns that they are using for racing. Therefore, the purpose of this case study was to compare the mediolateral COP path during running of one elite female athlete using her training shoe and her carbon-plated racing shoe.

METHODS: Following a self-selected warm-up, one elite female endurance athlete (VO_{2max}= 76.3 ml·kg^{-1}·min^{-1}; forefoot striker) performed two bouts of 180 s running on a motorized treadmill at 16 km·hr^{-1}. For each bout, the athlete ran in a different pair of shoes (training shoe: heel drop = 8 mm, weight = 220 g; racing shoe: heel drop = 8 mm, weight = 210 g, carbon-plated). An h/p/cosmos instrumented treadmill (200 hz; zebris Medical GmbH, Allgäu, DE) was used to record the two-dimensional (2D) pressure between the shoe outsole and the treadmill running surface. Only the last 60 s of each trial were used for the subsequent analyses.
Initial contact and toe off were determined for each footfall within the 60 s measurement window using the pressure measurements for both the left and right steps. Using these gait events, the stance phase of both the anteroposterior and mediolateral plane motion of the center of pressure path was extracted for each step. Eighty-eight steps for each side and shoe type were included for the subsequent statistical analysis (i.e. total footfalls for each shoe = 176). Each step was then normalized to the average length of the contact time (200 ms) using Piecewise Cubic Hermite Interpolating Polynomial interpolation to allow for continuous

statistical comparison. Each COP was then aligned to the same origin point (i.e. initial contact = origin: [0,0]) in order to compare the mediolateral COP components.
One Dimensional (1D) Statistical Parametric Mapping (SPM) was performed (spm1d MATLAB package; Pataky, 2019) to compare the mediolateral COP path while the athlete ran in the training and racing shoes. The left and right footfalls were analyzed separately in the event of bilateral dissimilarities. Both SPM comparisons were two-tailed paired samples t-tests (α = 0.05), with the null hypothesis that no difference exists between shoes. Therefore, when the critical thresholds (t^*) were exceeded, the null hypothesis was rejected and the p-value for each cluster region (i.e. consecutive data points that exceed the t^*) was reported.

RESULTS: The 2D pressure paths of the athlete wearing her training and race shoes can be seen in Figure 1 for both the left and right footfalls (n = 88 each). In all instances, the initial contact (i.e. origin) is the lateral-most point in the COP path.

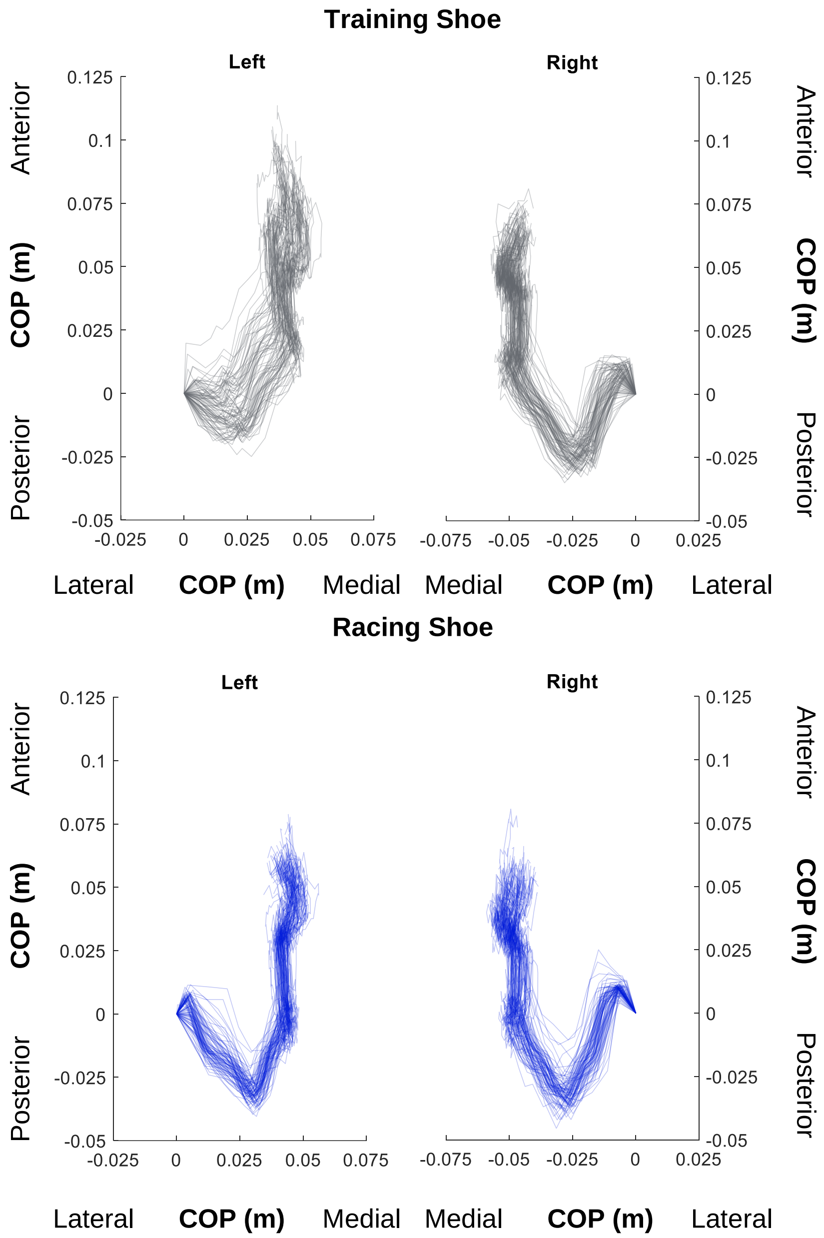

Figure 1. The 2D center of pressure (COP) path of the contact phase of 88 footfalls is displayed for both left and right footfalls, in two types of shoe: training (gray) and racing (blue; with carbon plate). Initial contact for all graphs = origin [0,0]; Mediolateral and Anteroposterior movement is described from the origin (i.e. anterior COP > 0, posterior COP < 0).

The SPM comparison of the mediolateral component of the stance phase between the two shoes can be seen in Figure 2. Two significant cluster regions were observed in the left foot, with differences totaling 93.7% of the stance phase (2.5-5.6%, $p = 0.048$; 7.4-98%, $p < 0.001$). Four significant regions were observed in the right foot comparison (3.5-8.9%, $p = 0.041$; 10.2-16.4%, $p = 0.039$; 20.1-29.5%, $p = 0.028$; 87.9-93.8%, $p = 0.039$).

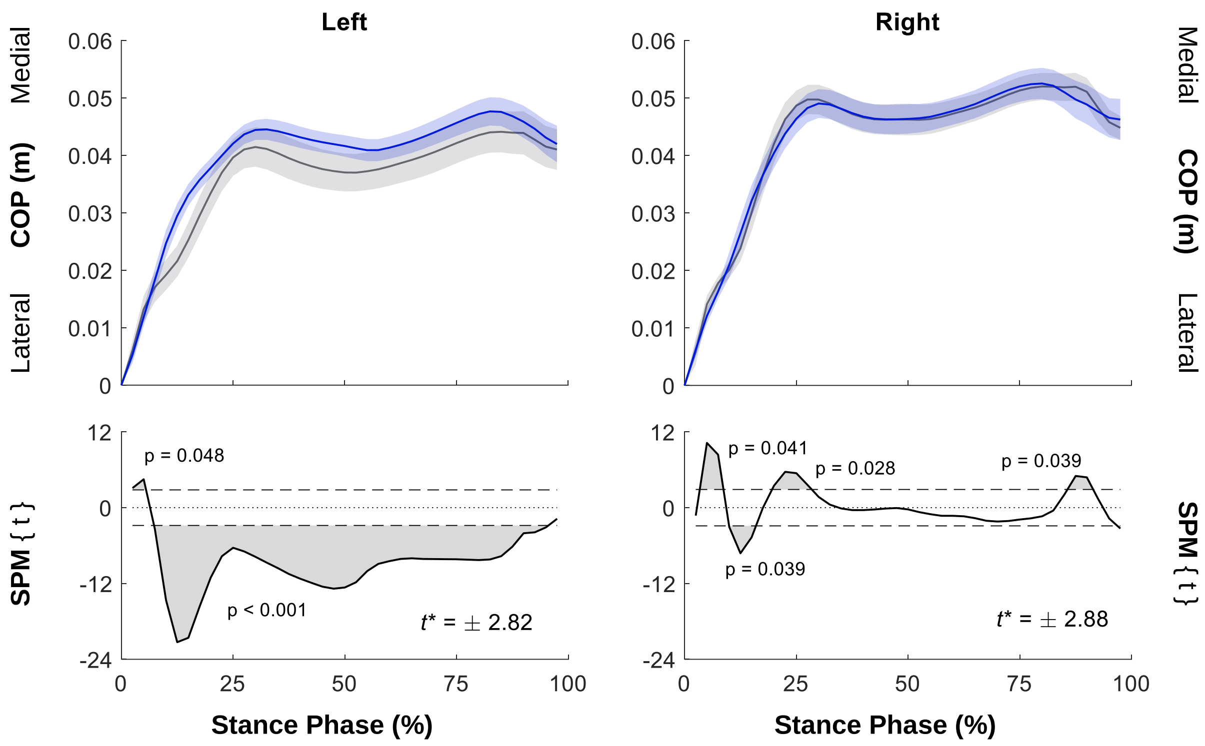

Figure 2. The mean ± SD of the continuous mediolateral component of the stance phase center of pressure (COP) measured during running (n = 88 steps for each leg) is displayed for the training shoe (gray) and the racing shoe (blue). The COP paths are compared statistically in the SPM {t} figures for the left and right footfalls separately. The t-score continuum of the SPM analysis (solid line) and the critical thresholds (*t**; dashed lines) are included for both comparisons. Significant differences ($\alpha = 0.05$) between the mediolateral COP component of the two shoes are indicated by the shaded areas above and below the critical thresholds. COP motion is defined as medial > 0 and lateral < 0 in relation to the initial contact (i.e. origin = 0).

DISCUSSION: Significant cluster regions were observed in both left and right legs, which indicates differences in mediolateral COP motion between the two types of shoes. However, the magnitudes and duration of these regions for the right foot are small in the relative comparison to the left foot. It is important to note that by imposing an origin of [0,0], the authors have removed the potential influence of the location of the initial contact (within the base of support; i.e. the foot). However, this analysis does not affect the magnitude of the medial COP displacement relative to the initial contact.

The descriptive plot of the 2D COP (Figure 1) supports visually what was observed in the SPM comparison of the mediolateral COP component of the athlete's stance phase; when the training shoe was employed, the athlete performed a lesser magnitude of medial COP motion from the point of origin toward the mid-line with the left foot (Figure 2). Although, the greater magnitude of medial displacement from the origin is apparent from 7.4-98% of the stance, it also appears that the rate (i.e. slope) of the medial drop is greater for the racing shoe. Visually observable differences in the 2D COP of the left foot also included a greater amount of variability and less posterior displacement in the left foot pattern using the training shoe as compared to the racing shoe (left foot) or the right foot (either shoe condition; Figure 1).

A researcher or coach's first instinct may be to conclude that by employing the racing shoe, the athlete's symmetry has improved and the COP pattern has exemplified a typical front-foot strike pattern. However, the athlete in the current case report reports subjective pain and discomfort during and after running with the racing shoe and has experienced a previous injury on her left side. Considering the visual results in Figure 1 showing that the right side is generally consistent between both shoes, it supports that there could be an asymmetry or compensatory mechanism (potentially to avoid the reported pain) occurring in the left foot movement pattern when using the training shoe. The medial COP movement suggests that the athlete employs some pronation during the initial contact phase (De Cock et al., 2005, 2008) while using both shoe types. As De Cock and colleagues (2008) discussed, this pronation may serve to support short absorption during the early contact of the foot. Thus, a reduction in the medial movement of the COP in the left foot using the training shoe may imply that the athlete is preventing the pronation and shock absorption to reduce the experience of pain.

CONCLUSION: Ultimately, the athlete in question spends the bulk of her training performing a movement pattern that is not the same as her racing movement pattern. As a result, it is not only important to investigate the racing conditions of athletes, but also their training conditions. Although the initial conclusions from the shoe comparison might be to recommend more usage of the racing shoe, this case study supports that it is important to consider the influence of carbon-plated shoes on individual responses. Specifically, the athlete appears to avoid medial displacement of the COP while using her training shoe in her afflicted limb, thereby potentially limiting the full pronation movement and altering the shock absorption characteristics to avoid pain. Finally, when considering the implications of an athlete's selection of running shoes, this study supports that it is important to consider the mediolateral COP movement in order to identify potential compensatory movement patterns, pain or associated weaknesses.

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