Curve Sprinting With A Split-Toe Running Specific Prosthesis: A Pilot Study

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Introduction

For athletic track events like the 400 m sprint, over half the race is completed along a curve. Sprinting along a curve imposes different force production requirements [1] and elicits slower maximum sprinting velocity compared to a straightaway [2]. Faster curve sprinting may improve overall performance in these athletic events. Sprinters with transtibial amputations use a passive-elastic running-specific prosthesis (RSP) that is typically made with a solid piece of carbon fiber and torsionally stiff, and thus resists frontal plane rotation during running. Fillauer Composites (Salt Lake City, UT) manufactures an RSP with a "split-toe" design, where a distal portion of the RSP is cut longitudinally, which allows the medial and lateral sides of the RSP to bend independently, reduces torsional stiffness, and potentially increases traction when running on a curve (Fig. 1).

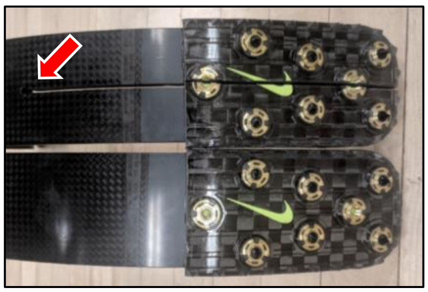

Figure 1. Split-toe (top) and solid (bottom) RSPs. Arrow indicates the proximal end of the split.

We hypothesized that maximum sprinting velocity would be faster using the split-toe compared to solid RSP on curves but would be similar between RSP designs on the straightaway. We also hypothesized that participants would elicit greater affected leg stance-average centripetal ground reaction forces (GRFs) on a curve when using the split-toe compared to solid RSP to achieve faster velocities.

Methods

Three individuals (2 M, 1 F; mean ± SD mass: 72.92 ± 10.72 kg; height: 1.80 ± 0.06 m; age: 25 ± 9 yrs) with a right transtibial amputation participated. Subjects had at least one year of experience competing using an RSP in a sprint event (400 m or shorter) within the past two years. The split-toe and solid RSP had identical shapes, height, and sagittal plane stiffness.

Participants completed a randomized series of 40 m sprints on a flat indoor track. We instructed participants to run as fast as possible for each trial and provided ≥8-min rest between trials. Participants performed clockwise and counterclockwise sprints along curves with radii of 36.5 m and 17.2 m and straightaway sprints over 40 m. Athletes ran across two adjacent force plates (1000 Hz) embedded beneath the track surface. We recorded 3D kinematics using high-speed motion capture cameras (100 Hz). The force plates and capture volume were located halfway along the runway. Trials were repeated until athletes successfully landed on the force plates at least once. Participants were not blinded to the RSP designs.

We measured maximum sprinting velocity using average pelvis marker velocity over the length of the force plates (2.4 m). We calculated stance-average centripetal force for the affected leg. We constructed linear mixed-effects models to determine the effect of RSP design on sprinting velocity and centripetal force production.

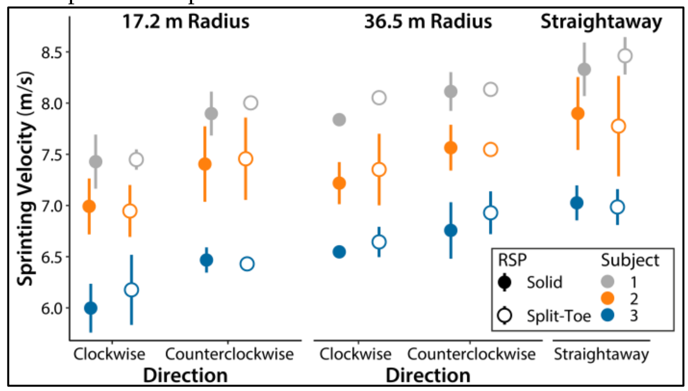

Figure 2. Mean ± SD velocity across conditions. Sprinting velocity using the split-toe running-specific prosthesis (RSP) was 0.13 m/s faster than the solid RSP across curve conditions and directions, but similar during the straightaway. Velocity was 0.34 m/s slower when sprinting in the clockwise compared to counterclockwise direction and 0.33 m/s faster with increased curve radius across directions.

Results and Discussion

Mean (± SE) sprinting velocity with the split-toe RSP was 0.13 ± 0.04 m/s faster compared to the solid RSP for a given curve radii and direction ($p < 0.001$; Fig. 2). Using the split-toe RSP did not affect maximum sprinting velocity on the straightaway compared to the solid RSP ($p = 0.705$).

Stance-average centripetal force was significantly affected by curve condition ($p < 0.001$) and sprinting velocity ($p < 0.001$), but not RSP design ($p = 0.180$) or running direction ($p = 0.746$). Mean stance-average centripetal force for the affected leg on the 17.2 m radius curve was 0.43 ± 0.15 BW and decreased by 0.19 ± 0.02 BW in the 35.2 m radius curve for both directions.

Centripetal (radial) force (Fc) equals mv^2/r, where m is mass, v is tangential velocity, and r is curve radius. Sprinters running on a curve must apply Fc to stay within their lane and achieve a fast velocity. We observed statistically significant increases in sprint velocities with the split-toe RSP, but no change in Fc. Although participants ran along 36.5 m and 17.2 m curve radii, the 1.22 m lane width allows athletes to vary their path traveled for a given curve condition. We suspect that participants decreased the effective radius of the curve they traveled along within the lane when using the split-toe compared to solid RSP, which may potentially explain the faster sprinting velocity without significant increases in Fc.

Significance

Sprinters with a unilateral transtibial amputation may be able to achieve faster curve sprinting velocities using an RSP with a split-toe design compared to a traditional, solid RSP.

References

1. Luo & Stefanyshyn *J Exp Biol* **215**, 4314-21, 2013.
2. Greene *J Biomech Eng* **107**, 96-103, 1985.