THE EFFECTS OF CYCLING SHOE OUTSOLE MATERIAL ON PLANTAR STRESS

Nathan E. Jarboe, Peter M. Quesada

Department of Mechanical Engineering
University of Louisville
Louisville, KY

INTRODUCTION

Published reports have mentioned localized ischemia, paraesthesia, and metatarsalgia as being common problems among cyclists [12,17]. Elevated local pressure during cycling has been specifically linked to metararsalgia [5], and is likely a contributing factor in other foot problems.

Several studies have examined in-shoe plantar pressure [17,20]. Several aspects of footwear related to comfort and to biomechanical abnormalities have been discussed [6,9,11,20] and typical pressure profiles during cycling [17,19] and running are also documented.

Ultra-stiff carbon fiber composites are now being placed in the midsole and/or outsole of both road and mountain bike racing shoes. According to popular cycling magazines and cycling-related advertisements, stiffer cycling shoes made from composite materials are designed to transfer energy more efficiently from the legs and feet to the pedals, although this is not well documented.

The current study attempted to determine whether: (a) carbon fiber composite cycling shoes result in higher forefoot plantar pressure than traditional plastic-soled cycling shoes; and (b) carbon fiber shoes are quantifiably stiffer than more traditional plastic-soled shoes. Plantar stress data were collected with in-shoe plantar pressure measurement insoles and material testing techniques were used to quantify shoe stiffness.

MATERIALS AND METHODS

Subjects

Ten healthy male subjects were recruited to participate in plantar pressure data collection. Subjects had mean age, height, and weight of 28.3 ±5 years, 1.75 ± 0.04 meters, and 747 ± 85 Newtons, respectively. No subjects were competitive cyclists, but several had recreational cycling experience (1.3 ± 1.2 years). All subjects signed a human subject informed consent form reviewed by the University of Louisville Human Subjects Committees prior to participation.

Shoes

Two pairs of shoes were tested in this study: *Shimano* model SH-M152 and SH-M220 (Shimano Corporation, Irvine, CA). The M152 is constructed with a homogeneous plastic sole while the model M220 has a carbon fiber composite sole. Shoe stiffness values were measured in two ways: per ASTM F-911 test standard, and with a custom three-point bending arrangement.

Plantar Pressure

A bicycle mounted to an indoor magnetic-resistance trainer was used to test all subjects under identical conditions. Plantar pressure data were recorded separately in both shoe types using *Pedar* insoles (Novel Electronics, Minneapolis, MN). Insoles were calibrated using the manufacturer's air bladder technique in a range from 0-250 kPa, rather than the more typical 0-600 kPa range [16], to achieve increased sensitivity within the expected range of pressures.

Data were collected in ten-second intervals while subjects pedaled steadily at 90 RPM and 400 Watts. Peak values of pressure were recorded then averaged across each ten-second trial to determine an overall average peak pressure for that particular trial. An example of this process is seen in Figure 1. Three ten-second trials were examined for each subject in the plastic shoes and three in the carbon fiber shoes. Two-way balanced analysis of variance (ANOVA), with repeated measures on both factors (shoe type and side), was performed on plantar pressure data using the *Minitab* statistical software package.

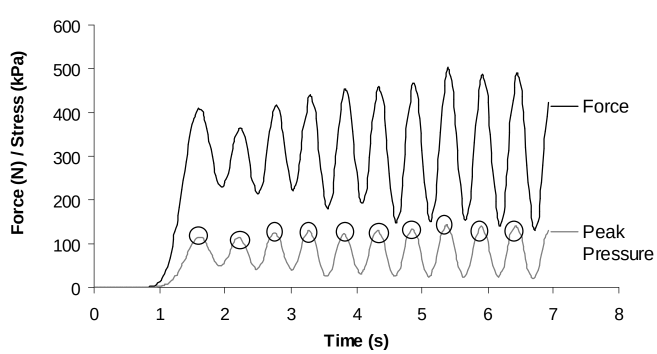

Figure 1. Force and Peak Plantar Pressure.

RESULTS

Plantar Pressure Results

Mean peak pressure recorded in shoe type M152 (plastic sole) was 103.0 kPa and the mean for the M220 (carbon sole) shoe was 121.2 kPa. Overall plantar pressure results are shown in Figure 2. Peak pressures recorded in this study were consistent with published reports related to running [6], cycling [17,19], and walking [7,9,11,15,16].

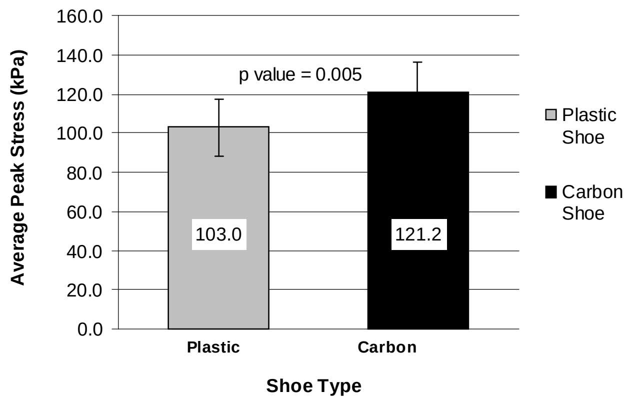

Figure 2. Plantar pressure comparison.

Shoe Stiffness Results

Mean values for shoe stiffness in longitudinal bending per ASTM standard F-911 and three-point bending are shown in Table 1. The carbon shoe produced mean stiffness values of approximately 10,500 N/m in longitudinal bending while the plastic shoes produced stiffness values of 7420 N/m. In three-point bending, the carbon shoe produced mean stiffness values of approximately 6.0×10^5 N/m while the plastic shoes produced stiffness values of 0.93×10^5 N/m.

Shoe Type	Longitudinal Bending Stiffness (per ASTM F-911) (N/m)	Three-Point Bending Stiffness (N/m)
M220	10512	607,750
M152	7422	93,200

Table 1. Average Stiffness of two cycling shoe models.

DISCUSSION

Shoes with carbon fiber composite midsole/outsole produced significantly higher peak plantar pressures in the forefoot region than did cycling shoes made with a more traditional plastic sole. Dynamic mechanical testing indicated that carbon fiber shoes were stiffer than plastic shoes in both longitudinal bending and three-point bending. Large stiffness discrepancies, especially between shoes that are otherwise identical, lead one to believe that stiffness differences are responsible for the increased peak plantar pressures. Increased plantar pressure with the use of the carbon fiber shoes occurred in almost all subjects tested, in contrast to other reports, in which differences based upon shoe stiffness were either inconclusive [13] or subject dependent [4,8].

Results indicate that plantar pressures during seated cycling can be within the range encountered during walking and should not be ignored as a potential source of foot pain. Results of this study, and other literature [17], indicate that the inability of certain cycling shoes to flex under load, and conform to foot contours, may increase peak plantar pressure, which has been associated with foot problems. Perhaps the drawbacks of stiffer cycling shoes could be counteracted while preserving the desired flexural properties of the soles. Manufacturers could consider producing carbon fiber composite cycling shoes either with different insole geometries than those of the corresponding plastic-soled models, or with thicker more pliable insoles that provide more cushioning.

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