THE EFFECT OF OUTSOLE PATTERN ON BASKETBALL SHOE TRACTION

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The traction needs of basketball shoes are actually twofold: translational traction and rotational traction. Torg and Quedenfeld (1971) contend that the increased rotational traction characteristics of some football shoes are related to an increase in significant knee injuries. On the other hand, Bowers and Martin (1975) recognize that the increased translational traction of cleated shoes allows for sharper cutting angles which can lead to enhanced performance. There is no similar research related to basketball, but it can be assumed that too little traction is a detriment to a basketball player's performance, and too much traction will potentially put the athlete in an injurious situation. This thus creates a compromise between performance and protection in the design of a basketball shoe outsole. However, this compromise may be avoided by designing an outsole that develops maximum traction in translation to aid the athlete in performing some of the skills of the game of basketball, but which allows for minimum traction in rotation so as to protect the athlete from the high rotary forces that can occur at the knee joint.

Considerable research has been conducted during the last decade in the area of athletic footwear, but little has dealt with the traction needs of shoes, particularly basketball shoes. Rheinstein, Morehouse, and Niebel (1978) showed that the resistances to rotation about a vertical axis for elastomer type and for polyurethane basketball shoe outsoles were not appreciably different. However, as the hardness of the outsole increased, its resistance to rotation about a vertical axis decreased. The purpose of this study was to make a more specific determination of the traction characteristics of different basketball shoe outsoles, and primarily to determine the effect that the pattern of the outsole has on traction.

METHODS

A device was constructed that is capable of measuring coefficients of friction for different shoe outsoles under conditions that closely resemble typical loading situations. The major components of the device are a force platform, a footform, and a compressed air system. The footform closely resembles a shoemaker's last but has the bottom portion of the rear part cut away and angled upward such that the test shoe, when pulled over this footform, is in contact with the test surface with only the anterior 50% of the outsole. A vertical shaft is attached to the footform in a location corresponding to the heads of the first and second metatarsals. Steel weights can be supported on this shaft such that the shoe is loaded vertically with loads exceeding typical body weights.

Both translational traction measures and rotational traction measures of shoe outsoles can be made with this device. In the translation test, the shoes are pulled at a rapid rate by the piston of an air cylinder, which is connected to the vertical shaft that loads the shoe. The shear force measured by the force platform is a direct measure of the frictional force. By controlling the flow of air at the exhaust ports of the cylinder, the velocity of the piston can be adjusted to speeds approaching footstrike velocities. In the rotation test, the shoe is rotated about the vertical shaft by a set of gears connected to a rotary actuator which is pressurized by the same air supply that activates the air cylinder. Thus, the axis of rotation is a vertical axis passing through the location corresponding to the heads of the first and second metatarsals. The force platform measures the free moment generated during the rotation. Continuous measurement of the normal force is also made by the force platform during both test conditions.

A varnished maple test surface was firmly bolted to the force platform and nine different shoes, whose outsoles are shown in Figure 1, were tested with the device. In the translation test, the shoes were pulled anteriorly over the surface through a distance of 35 cm at an average velocity of 0.38 m/s. For the rotational test, the shoes were rotated medially through 2.1 radians at an average angular velocity of 6.7 rad/s. For both conditions, an average normal load of 840 N was distributed beneath the forefoot region of the shoes. Each shoe was tested a minimum of 5 times for each condition. Testing order of shoes and conditions was randomized. The shoe outsoles were cleaned with acetone prior to each test and the surface was wiped with water and allowed to dry before each shoe was tested.

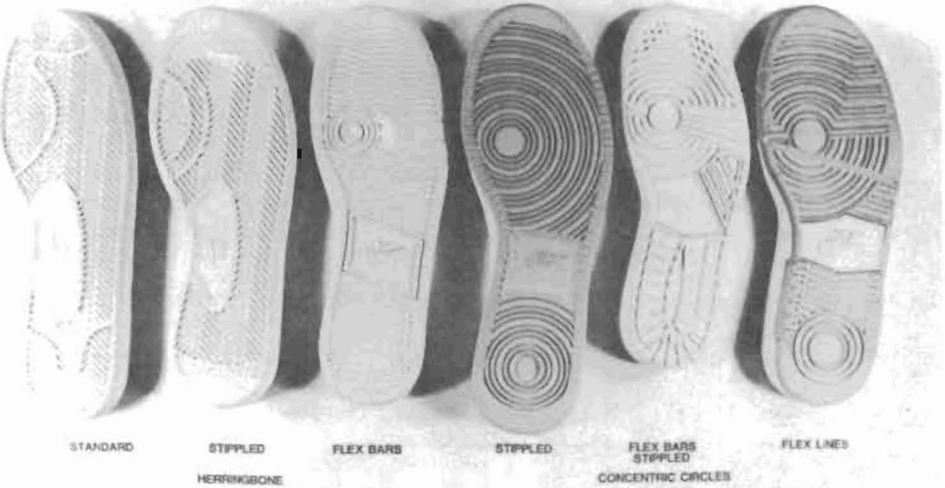

Figure 1. Six different basketball shoe outsole patterns tested for translational and rotational friction characteristics. Three other shoes were included in the study, a second shoe with the standard herringbone pattern composed of a different rubber formulation, and two shoes with flat outsoles.

RESULTS

Figure 2 shows the mean forces measured on one of the shoes during the translation test. The friction coefficient, mu, is the ratio of shear, or friction force, to normal force. It rises rapidly to a peak, falls off slightly, and then remains constant during constant velocity motion. The constant value of mu during this interval is the coefficient of kinetic friction.

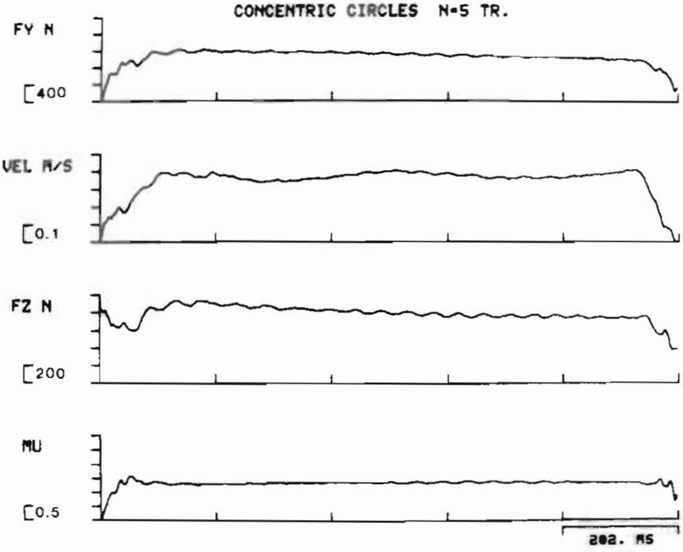

Figure 2. An example of the frictional forces created during anterior translation on a varnished maple playing surface by one of the shoes. The frictional, or shear force, Fy, linear velocity, normal force, Fz, and coefficient of friction, mu, are averaged over 5 trials.

Shown in Figure 3 are the mean kinetic coefficients for all nine shoes. The first four outsoles are composed of either a standard rubber formulation combining SMRL, SBR, and PBR, or of a rubber compound from the Goodyear Tire Company, and they have either a flat pattern or a herringbone pattern. There was a significant difference ($p < 0.05$) between the two different compounds in the flat outsole pattern. Also, the flat outsole, which is an outsole with no pattern, develops considerably higher friction forces in translation than does the herringbone pattern.

The stippled herringbone outsole has a pattern that is basically the same as the first two herringbone patterns, however, this outsole also has a very rough stipple which appears to be responsible for a considerable increase ($p < 0.05$) in the friction forces. The similarity in herringbone patterns is evident from the photos in Figure 4, with the bottom outsole having a very rough stipple pattern around the perimeter of the forefoot.

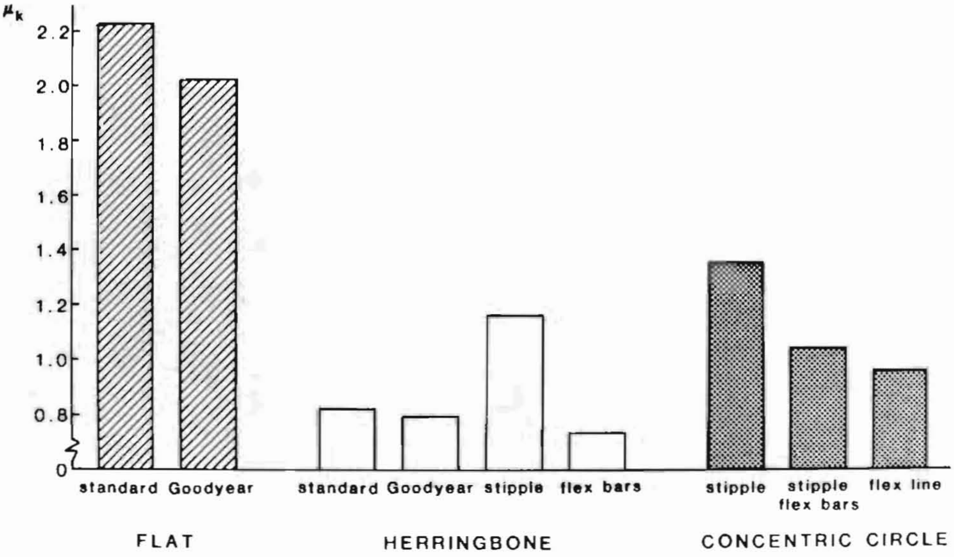

Figure 3. Mean kinetic coefficients of friction for nine different basketball shoe outsoles measured during anterior translation.

The 1st two concentric circle pattern outsoles have the identical stipple to the stippled herrringbone pattern, and consequently develop high frictional forces. The last concentric circle outsole has a different stipple, not as large and not raised as much, and has a lower kinetic coefficient.

Plotted in Figure 5 is an example of the mean torque measured about a vertical axis as a loaded shoe is rotated. The torque is directly related to the normal load and is therefore divided by the normal load, giving a variable in units of length. Peak torque was determined for each trial and then averaged for each shoe. Mean peak torques for each shoe are plotted in Figure 6.

The two flat outsoles developed significantly higher torques ($p < 0.05$) than the two herringbone outsoles of the same material. These results agree with the kinetic coefficient of friction results measured during the translation test. The data for the four herrringbone outsole patterns reveals that the one with the stipple created more torque ($p < 0.05$) than the herringbone pattern on the standard and Goodyear outsoles. These patterns are virtually identical, except for the large, rough stipple along the perimeter of the forefoot of the stippled shoe. The fourth herringbone pattern created even higher moments ($p < 0.05$). It did not have as large a stipple pattern (refer to Figure 1), but it did have some bars radiating out from the medial edge. The purpose of the bars is to increase the flexibility of the outsole in the forefoot region, but a consequence is an increase in the resistance to rotation.

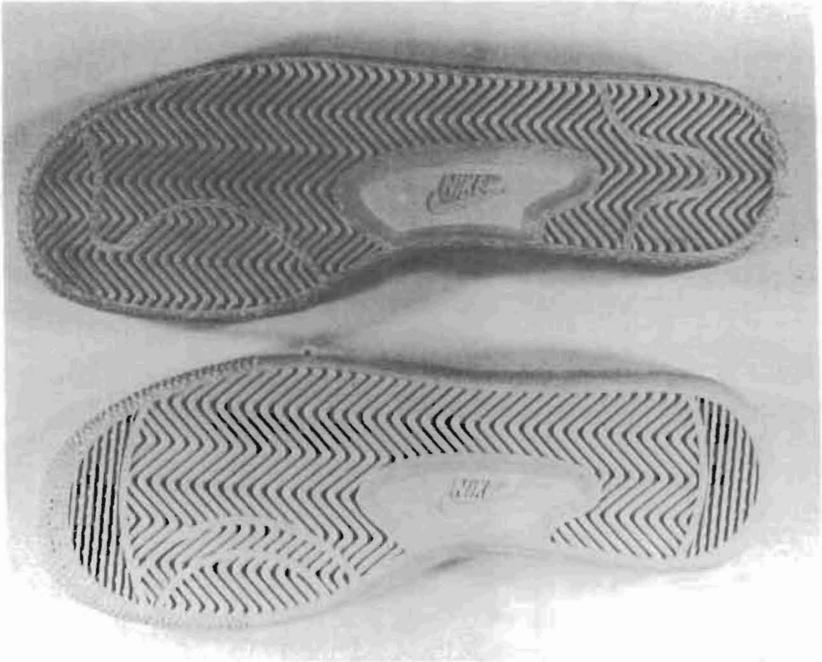

Figure 4. A standard herringbone pattern (top) and a very similar herringbone pattern with a rough stipple around the perimeter of the forefoot (bottom). The mean kinetic coefficients of friction were 0.83 and 1.16 for the standard pattern and the stippled pattern respectively.

Two of the three concentric circle patterns that were tested also created high torques, even though the original intention of the concentric circle design was to decrease resistance to rotation. The first concentric circle pattern has the identical stipple pattern around its perimeter to that of the stippled herringbone pattern, and its developed torque is the same. The second concentric circle pattern has a stipple pattern very similar to the first, but it also has a number of radiating bars which interrupt the concentric circle pattern and create a large surface area. The third pattern was the only one of the three concentric circle patterns tested that was successful in reducing the resistance to rotation ($p < 0.05$). This outsole pattern is shown in Figure 7. A stipple is not absent from this shoe, but it is the least rough of all stipple configurations. Also, this shoe has an absence of radiating bars in the forefoot. The shoe achieves its flexibility from two radiating channels which are recessed, and thus not subject to any pressure distribution, and whose enclosed area is made up, not of bars, but of a continuation of the concentric circle pattern.

DISCUSSION

Friction characteristics are shown to be dependent on material, as there is a 10% difference between the Goodyear rubber formulation and the combination of SMRL, SBR, and PBR. This finding is not surprising since other studies on the traction characteristics of rubber outsoles suggest

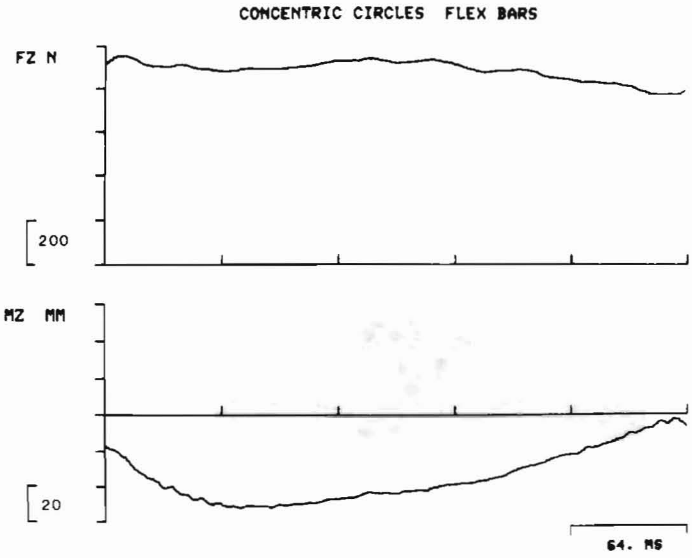

Figure 5. An example of the mean normal load, Fz, and the mean free moment of rotation, Mz, measured during medial rotation of one of the shoes on a varnished maple surface. The free moment is normalized in time with respect to normal load and multiplied by 1000 to be expressed in units of mm.

that the material out of which a shoe outsole is composed can possibly have a greater effect on traction than variables such as tread design and cleat height (Cavanagh, Williams, and Clarke, 1979; Valiant, McGuirk, McMahon, and Frederick, 1985).

The increased forces, both translational and rotational, developed by the flat outsoles seem to be a result of an increased outsole surface area that is in contact with the playing surface. This is demonstrated by the ink impressions in Figure 8. The outsoles that made these impressions were identical in composition, were loaded with the same vertical force, but were moulded in two different patterns. There is a greater area supporting the load under the flat outsole than under the herringbone outsole. This is not the first study to present data that challenges the 18th century friction relations described by Charles Coulomb. Schlaepfer, Unold, and Nigg (1983), when testing tennis shoes on an artificial grass surface, found that the coefficient of friction decreased with increasing normal loads, up to about 200 N. At normal loads greater than 200 N, the grass was pressed down sufficiently to make the surface smooth enough for the friction coefficient to be independent of normal load. Valiant, McGuirk, McMahon, and Frederick (1985) tested cleated rubber samples on a synthetic turf and also found that the static coefficient of friction decreased with increasing normal loads. However, the coefficient was found to continually decrease for loads as high as 1125 N. They also found that the static coefficient decreased with decreasing surface area. Since decreasing area and increasing normal load are directly related to increasing pressure

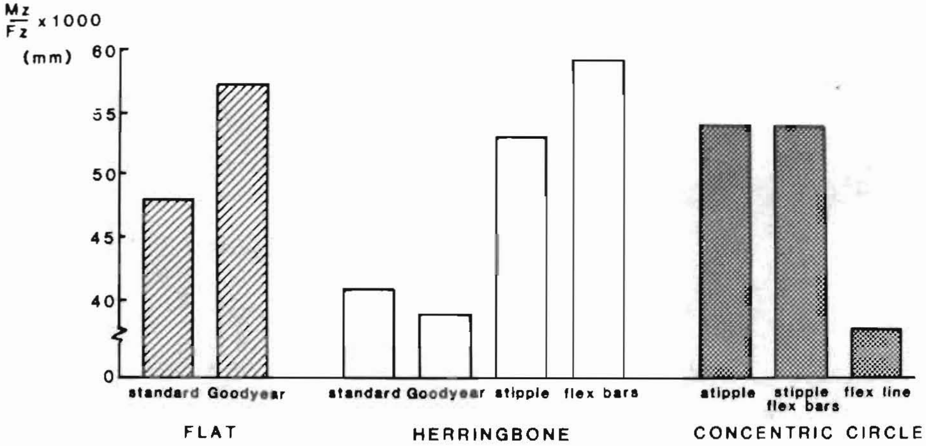

Figure 6. Mean torques created by nine different basketball shoe outsoles during medial rotation.

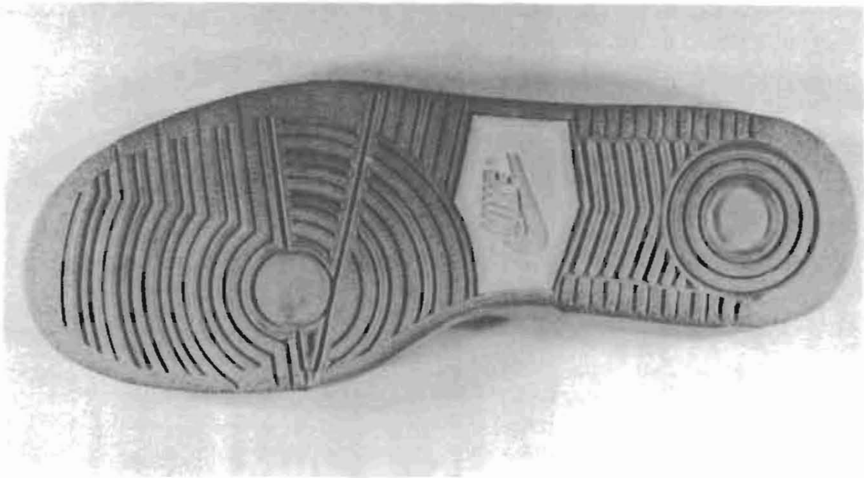

Figure 7. An outsole which creates low torque (38 mm) during medial rotation. The two radiating channels are for the purpose of enhancing forefoot flexibility. They only minimally interrupt the concentric circle pattern and are recessed into the outsole and are thus not in contact with the playing surface when the shoe is loaded.

distributions, the effects on friction of area and of normal load are likely related. The findings of this study suggest that this same relation exists for rubber samples on a smooth basketball playing surface.

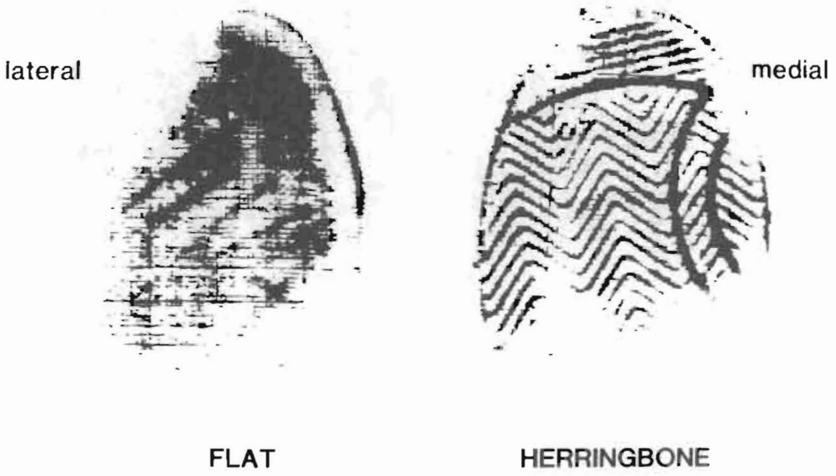

Figure 8. Ink impressions left by a flat shoe outsole and a herringbone shoe outsole, showing the surface area that is in contact with a test surface when loaded in the forefoot region with 880 N.

A stipple pattern is generally added to a basketball shoe outsole for cosmetic reasons. However, it appears that if the stipples are large and the pattern is very rough, the frictional forces can actually be increased, both in translation as well as in rotation. By varying the size, location, and orientation of the stipple pattern on the outsole, the ability to develop high translational friction forces or to reduce free moments of rotation may be regulated to some extent.

The addition to a basketball shoe's outsole of bars in a radial pattern for the purpose of increasing the flexibility of the forefoot region can sometimes be a detriment to a shoe's ability to minimize resistance to rotation about a vertical axis passing through the forefoot. One reason for this may be that the radiating bars interrupt the concentric circle pattern. A more likely reason is that if the surface of the bars is flush with the rest of the outsole, the area in contact with the playing surface is increased, and an increase in friction will occur. However, as demonstrated by the shoe in Figure 7, it is possible to incorporate an outsole pattern to enhance forefoot flexibility without adversely affecting free moments of rotation.

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