

# AN IMPROVED METHOD FOR QUANTIFYING THE STIFFNESS OF RUNNING SHOES

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## INTRODUCTION

A running shoe aims to protect a runner's foot from injury by stabilizing motion and cushioning impact. As material technology and product testing develop, shoes can offer more protection through advanced designs. A typical test for running shoes is a flexion test in which the shoe is bent through a fixed angle and the applied force is measured. A popular method for flexion testing consists of bending a shoe that has been fixed such that bending occurs at a particular point in the shoe, usually the forefoot, and then determining the stiffness in that region from the measured force [1,2,3]. While this method provides one measure of shoe stiffness, the method characterizes stiffness over a limited portion of the shoe. In actual use, a running shoe bends over a much larger area during a typical footstep. An improved test would permit shoe bending, and the determination of stiffness, for different sections of the shoe.

The goal of this study is to develop an improved flexion test for evaluating and quantifying the stiffness of running shoes in both the forefoot and mid-foot sections. The results generated with the new test method will be used to better evaluate shoe design and to assess shoe performance for injury prevention. This paper describes the experimental setup and method for the improved test, and also discusses the preliminary data collected for two different shoe architectures.

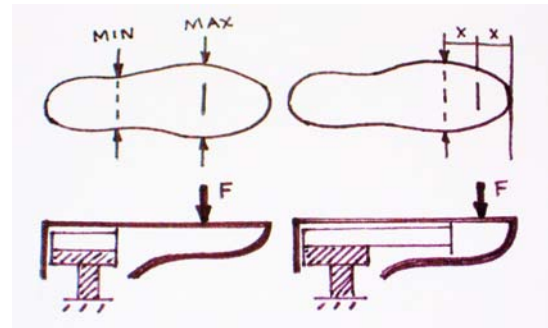
## METHODS

To facilitate the measurement of shoe flexion at various locations, an apparatus was designed so that the distance between the loading actuator and the shoe fixture column is adjustable (Fig. 1). This distance is adjusted by sliding the apparatus base within the test frame. This adjustability allows testing a range of shoe sizes and allows for a custom bend length. The apparatus also features interchangeable supports, mounted to the shoe

fixture column, that offer a flexible length inner support in the shoe (Fig. 2).



**Figure 1:** Testing rig with adjustable base and experimental setup in the MTS machine

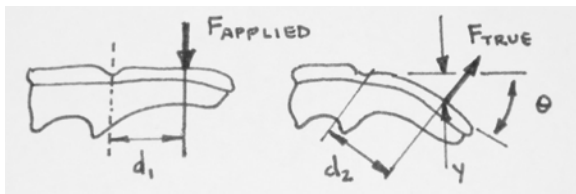


**Figure 2:** Diagram of shoe inserts, bend locations (dotted line), and force application points (solid line)

A cushioned shoe and a stability shoe, with a noticeable tactile difference in stiffness, were chosen for evaluation with the new apparatus in order to determine if the method could be used to quantify the difference in stiffness. Two regions of each shoe sole were tested: the mid-foot, located at the narrowest part of the shoe, and the forefoot, located at the widest part. To keep bend lengths proportional to the shoe size, the actuator was positioned on the forefoot line for the mid-foot test and at a distance halfway from the bend zone to the end of the shoe for the forefoot test.

For the flexion test, the apparatus was mounted in an MTS Q-Test 150 load frame and the shoes were clamped to the shoe fixture column (Fig. 1) For each test, the supports in the shoe extended far enough to keep part of the shoe rigid, and allow it to bend in the desired location. The actuator was positioned at the appropriate bend location and then lowered at a rate of 1 inch per minute until each shoe had been bent to an angle of at least 15 deg. The applied force and actuator displacement were recorded and used for calculating the stiffness. After the desired flexion was achieved, the actuator was raised and load was removed.

Oleson et al. defined stiffness as “the ratio of ground reaction moment to the angular deflection” of the shoe, producing a quantity with the units of lbf-in/deg [3]. Following Oleson’s method, the ground reaction moment was calculated by multiplying the true bend length ( $d_2$ ) by the true force (Fig. 3). The true force was found using the applied force and bend geometry ( $y$  and  $d_1$ ). The stiffness is plotted versus the bend angle and a value was selected based on where the curves leveled off.

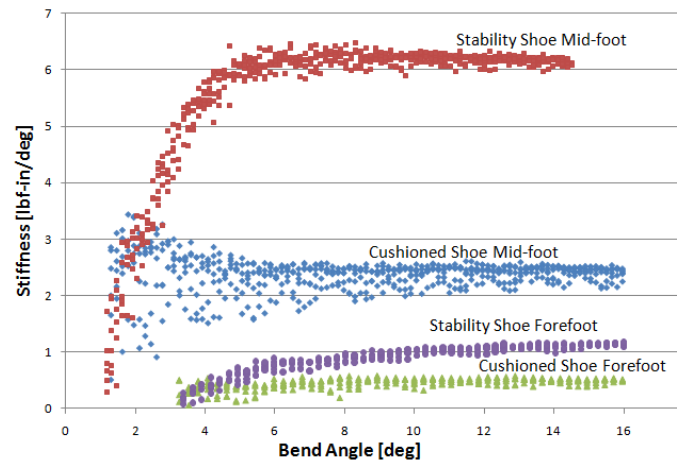


**Figure 3:** Bend geometry of tested shoes

## RESULTS AND DISCUSSION

Figure 4 illustrates the calculated stiffness of both shoes in the mid-foot and forefoot sections. The stability shoe exhibits a higher stiffness than the cushioned shoe in both sections. The cushioned shoe had a measured stiffness of 2.5 lbf-in/deg in the midsole and 0.5 lbf-in/deg in the forefoot while the stability shoe had values of 6 lbf-in/deg and 1.2 lbf-in/deg, respectively.

The stiffness was higher in the stability shoe, regardless of where the bending occurred, supporting the tactile difference that was noticed during shoe selection. A trend seen in both bend locations is that the stability shoe resists the applied force longer, presenting a delayed flex, as shown by the curve leveling off at a higher bend angle. Another interesting outcome of this test is that both



**Figure 4:** Comparison of stiffness vs. bend angle in the midfoot and forefoot sections of a stability shoe and a flexible shoe

shoes differ in stiffness amounts, yet both have a mid-foot / forefoot stiffness ratio of 5.0. Further testing may demonstrate that a certain ratio is a favorable design factor in shoes. Oleson et al. measured values of forefoot stiffness in the range of about 0.8 to 1.7 lbf-in/deg while data from this study range from 0.5 to 1.2 lbf-in/deg, showing that the test concepts remain consistent [3].

The initial results obtained with this new apparatus indicate that shoe stiffness is a function of both the shoe architecture and the location of measurement. Since there is a measurable difference in the stiffness values in the forefoot and mid-foot regions of the shoe, future work will focus on determining the optimal locations for testing to determine the most appropriate measure of shoe stiffness. Eventually, this information will be correlated with impact forces exerted on a foot during the gait cycle to examine the influence of shoe design on injury prevention.

## REFERENCES

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3. Oleson, M. et al. *Journal of Biomechanics* **38**, 1886–1894, 2005.