A SYSTEM FOR THE MEASUREMENT OF IMPACT FORCE IN FOOTWEAR

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The purpose of the research was to develop a mechanical device to measure the effectiveness of the Energy (J) absorption in materials used for the construction of the soles of athletic footwear. Mean Ground Reaction Force curves were used to calculate energy during impact loading in the materials used for the soles of six different brand-name running shoes. Results indicated a range of variability in energy absorption in the soles of the shoes and the relationship to shoe quality assessed on retail cost. The measurement system provided a reliable and alternate measure of performance in shoe materials and demonstrates a need for the provision of more accurate and alternative test measures for the consumer.

KEY WORDS: force, energy, footwear, materials

INTRODUCTION: The development of new materials and designs for activity footwear has created an extremely competitive market for shoe design. One of the challenges in shoe design for running and jogging shoes is to maximize attenuation of reaction forces during foot strike. The effect will be an increase in the energy absorbed in the shoe materials and less energy referred upwards into the foot, and lower extremity. The use of light weight, durable, energy absorbing materials is a critical factor for functional design in shoes. Ethylene vinyl acetate, moulded polyurethane, air cushions and various forms of gel capsules are common features promoted in shoe design. The consumer is rarely provided with test measures to indicate design effectiveness. The literature indicates a variety of claims demonstrating the effectiveness of shoe design to reduce energy cost (Frederick, 1980), the effect on red cell counts (Burke, 1983; Falsetti, 1983) and the reduction of the overall incidence of stress injury (Schwellnus, 1990). The performance of the sole of the shoe is generally measured using the peak vertical reaction force or the time to peak force from a force plate reading during normal gait .This study was designed to provide an alternative measure of energy absorption in the sole materials. For practical purposes the measures were then related to shoe quality based on the local retail value of the footwear.

METHODS: The testing device included an adjustable inclined track fitted with a loaded sled mounted with a force absorbing prosthetic leg and foot. Foot position was adjustable to control for contact areas. The vertical ground reaction force (GRF) was measured using a force plate set for impact at 90 degrees to the base of the inclined sled. The sled was calibrated to provide GRF's for a 75 kg subject jogging at 2.0 m/s and 3.0 mls. Repeated trials for reliability indicated an error of +/- 2% for peak vertical GRF. An Analogue to Digital (A/D) interface and signal processing software provided impulse curves (N/s). Impact tests were conducted on six brand name running shoes plus the prosthetic foot with no shoe. Twenty trials for each shoe at both speeds for both heel strike and toe strike were completed. The trial data was then averaged to produce a mean impulse curve for each shoe. The calculation of energy absorption in the sole of the shoe (e) is outlined in Figure 1. Net force absorption of the shoe (fm) is calculated by subtracting shoe impact force (fs) from no shoe impact force (fb) at each sampling point. Changes in velocity (v) are calculated from the impulse momentum relationship (fm*dt=mass*v/2-v/1). The compression velocity of the sole material (v) is calculated by the sum of all the changes in velocity over the total contact time (T). Power is then calculated using the product of the net force absorption of the shoe (fm) and the sum of all the changes in velocity over the total contact time (T). The final calculation of energy absorption (e) in the sole of the shoe is based on the sum of the product of power output (p) in the sole of the shoe and the sampling rate for data collection (dt).

$$fm = fb - fs$$

$$v = \int_{t=0}^{T} fm * dt \div mass = \sum_{t=0}^{t} \Delta v$$

$$p = fm * \sum_{t=0}^{T} \Delta v$$

$$e = \int_{t=0}^{T} p * dt = \sum_{t=0}^{T} p * dt$$

fm=net force absorption of shoe at impact.
fb=no shoe impact force.
fs= shoe **impact** force.
Mass=mass of the sled plus shoe and prosthetic.
v=compression velocity of the sole material.
p=power output of the sole material.
e= energy absorption of the sole material.
dt=sampling rate for data collection.
T=total contact time.

Figure 1 - Energy Calculations for Sole Materials in Running Shoes

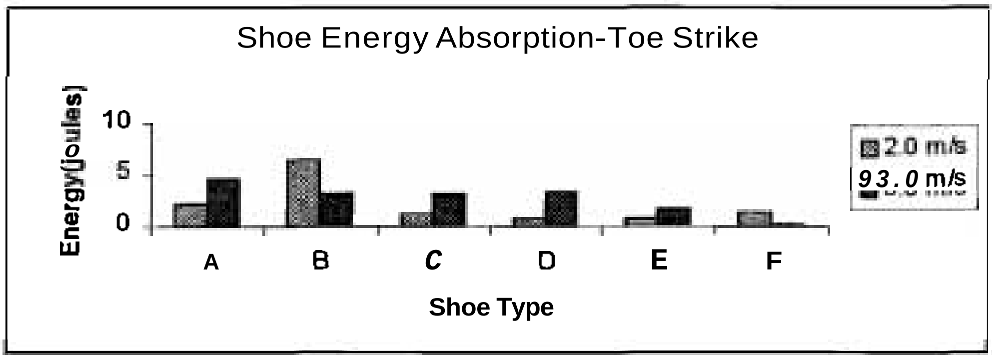

Figure **2 -** Shoe Energy Absorption- Toe Strike at **2.0 m/s** and **3.0 m/s**

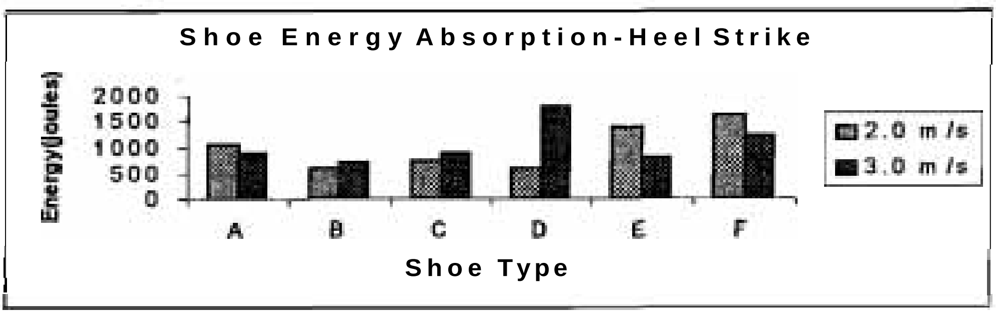

Figure 3 - Shoe Energy **Absorption-Heel** Strike at **2.0 m/s** and **3.0 m/s**

Table 1 Elastic Energy (J) in Brand Name Running Shoe Materials Types A-F at Velocities 2m/s and 3m/s for Heel (H.S.) and Toe Strike(T.S.) Retail Cost (R.C. $100's)

Variable	Brand Name Running Shoes					
	A	B	C	D	E	F
H.S. 2m/s	(J)1063	601	710	589	1363	1614
Rating	3	5	4	6	2	1
H.S. 3m/s	(J) 893	680	893	1761	798	1216
Rating	3	6	4	1	5	2
T.S. 2m/s	(J) 2.2	6.5	1.3	0.9	0.8	1.4
Rating	2	1	4	5	6	3
T.S. 3m/s	(J) 4.6	3.2	3.3	3.5	1.8	0.3
Rating	1	2	4	5	6	3
R.C.$100	1.1	1.3	2.1	1.5	2	1.5

RESULTS AND DISCUSSION: This study is suggesting that a measure of energy absorption in the sole of running shoes may be an effective indicator of functional shoe design. These results are limited to impact loading only and give no indication of the loading taking place in the shoe afler initial impact. The measurement system effectively controlled for gait speed and impact point accuracy and proved to be a reliable instrument. The results demonstrated considerable variability between shoes for different speeds and for both toe and heel strike. Discussion here is based on the shoes which score well for both heel and toe strike energy measures and how these results relate to retail cost. Shoe F for example is the highest performing shoe for heel strike at both speeds but rates low for toe strike. The shoe is moderately priced but rates high for energy and would be more appropriate for low intensity joggers or walking where heel strike is predominant. Shoe D is also well priced and performs well for fast heel and toe strike and is therefore more appropriate for a higher performance runner. Shoes A and B are effective for toe strike at both speeds but performance is relatively low on heel strike. These shoes are more appropriate for the more competitive runners who perform at higher velocities and require more effective fore foot energy absorption. Shoes D and E both perform well on heel strike over toe strike but vary with speed.

CONCLUSION: Although shoe testing and performance evaluations are common there is currently no formally recognized rating system for consumers to compare and evaluate footwear for different applications. Retail cost may also vary depending on the market and based on these results is probably not a good indicator of performance. Commercial manufacturers promote functional designs and market their products without providing test results for public consumption. Energy absorption in the sole of the shoe may be one of many effective measures for running shoe performance and could form the basis of a consumer evaluation system. Consumers should also consider cost and the application of the shoe rather than general appearance that often masks the functional aspects. Functional foot disorders oflen require prescription orthotics and or shoes to correct the disorders and without effective shoe performance information the clinician is also limited. More effective tests are required to identify the best measures for shoe effectiveness for a particular user application and to provide a measure of the shoe deterioration over time. Public exposure to reliable test results will improve consumer knowledge, promote appropriate pricing and maximize the use of activity footwear, both as a functional treatment modality and for the prevention of injuries.

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