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The effectiveness of shock-absorbing insoles during normal walking

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Abstract

This paper describes a study of the effectiveness of commercially available shock absorbing insoles when used in four different pairs of shoes during normal walking. The measurement method was based on the use of the Fourier Transform of the axial acceleration of the leg measured by an accelerometer mounted at the ankle. The magnitude of shock was measured by the "Shock Factor" which has been defined as the rms acceleration between 50 Hz and 150 Hz expressed as a proportion of that between 10 Hz and 150 Hz. Nine insoles were tested in each pair of shoes and the Shock factor for each combination was compared with the value obtained for the shoes alone. Statistically significant reductions of Shock Factor were noted in 58% of cases; the largest improvement (30% reduction in Shock Factor) was achieved by lightweight Sorbothane. The experimental technique has now been further developed to allow the measurement of Shock Factor by a portable Shock Meter.

Introduction

The existence of transient accelerations and the associated skeletal stress waves at heelstrike in normal gait was demonstrated by Light et al (1980) and a possible association between degenerative joint disease and impact loads has been proposed by Radin and colleagues (1973). This background knowledge together with the increased popularity of jogging and running has led to the current interest in the measurement of skeletal shock and the development of footwear to reduce it. This paper will describe a method for assessing such footwear and present results from a number of proprietary shock absorbing inserts.

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Work has been carried out previously at a number of centres (Perkins, 1983). Wilson (1985) at the Shoe and Allied Trades Research Association has performed both drop tests and walking experiments to evaluate shock absorption and his results suggested that sports shoes can be particularly effective in reducing acceleration peaks. Pratt and colleagues (1986) carried out similar assessments and showed that peak acceleration could be reduced by up to 30% with a Poron insole. This paper describes a study to measure the acceleration of the tibia during walking and presents a novel method of signal analysis which allows the rapid comparison of different footwear.

Experimental equipment and method

The accuracy of acceleration measurements is entirely dependent upon the use of a suitable method of mounting the accelerometer. Since direct bone mounting by a pin was regarded as unacceptable the accelerometer was attached to a moulded polypropylene splint, manufactured from an accurate plaster cast, fitting around the malleoli. This arrangement has the advantage that the skin is loaded predominantly in compression leading to a stiffer mounting; the natural frequency of the assembly has been kept as high as possible by the use of a lightweight accelerometer (Kistler model 8620). The initial testing and development of this mounting has been described elsewhere (Johnson 1986).

The experimental arrangement consisted of the accelerometer connected, via a signal conditioning unit carried in the trouser pocket, to a spectral analyser (Nicolet Model 660B) by a trailing cable. The accelerometer was fitted to the left leg and identical footwear was worn on each foot. All of the tests were carried out in a laboratory with a wooden block floor laid over concrete. The analyser, controlled from a host microcomputer, was configured to sample the acceleration signal in the range 0 to 200 Hz over a period of 16s, equivalent to approximately 20 steps. It was programmed to allow a time delay between the start of the test walk and sampling of the data to eliminate spurious data during the first few steps. Similarly a bleep was sounded after sampling had finished to tell the subject to stop. At the end of a test walk the rms spectrum was stored on the microcomputer; for any given footwear configuration the experiment was performed 5 times and the mean spectrum calculated. It was this mean spectrum which was used to compare footwear. Experiments were carried out by the author wearing 4 types of footwear with and without each of the following shock absorbing inserts:

1. Sorbothane[1] heel insert
2. Viscolas insole
3. Sorbothane[1] walking insole
4. Sorbolite insole
5. Red Sorbothane[1] insole
6. Nonshock insole
7. Soft blue Sorbothane[1] insole
8. Hard blue Sorbothane[1] insole
9. Lightweight Sorbothane[1] insole

The types of shoe used for the study were as follows:

1. Trainer with Velcro fastening
2. Leather casual with leather sole and heel
3. Similar to (2) but a rather looser fit
4. Lace up shoe with soft rubber sole and heel

Signal analysis

The severity of a skeletal stress wave is determined by both the amplitude and the frequency content of tibial acceleration. The effectiveness of a shock absorbing shoe could, therefore, be judged by its ability to reduce both the high frequency content and the amplitude of the acceleration. In addition, it must be taken into account that much of the low frequency acceleration is associated with the swing phase of gait and is, therefore, unlikely to be influenced by footwear. For these reasons it was decided to measure two aspects of the rms spectrum. The first measurement was that of the rms acceleration over the frequency range 10 Hz to 150 Hz. The upper limit had been

1. Sorbothane is a trade name of BTR plc.

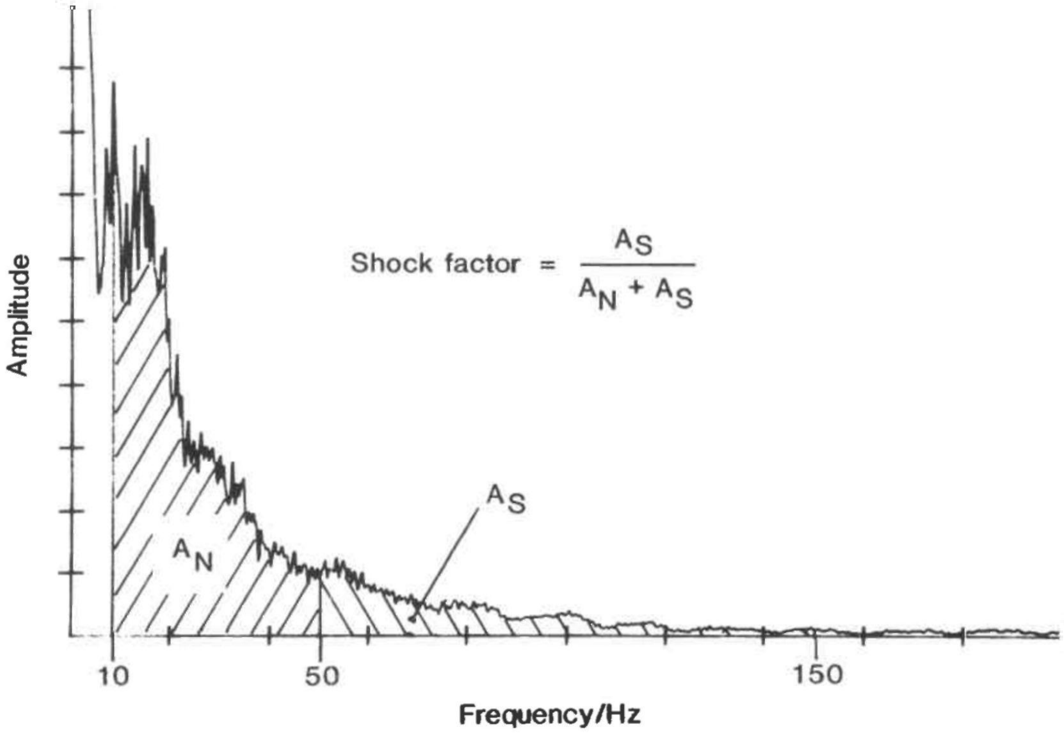

Fig. 1. Definition of Shock Factor

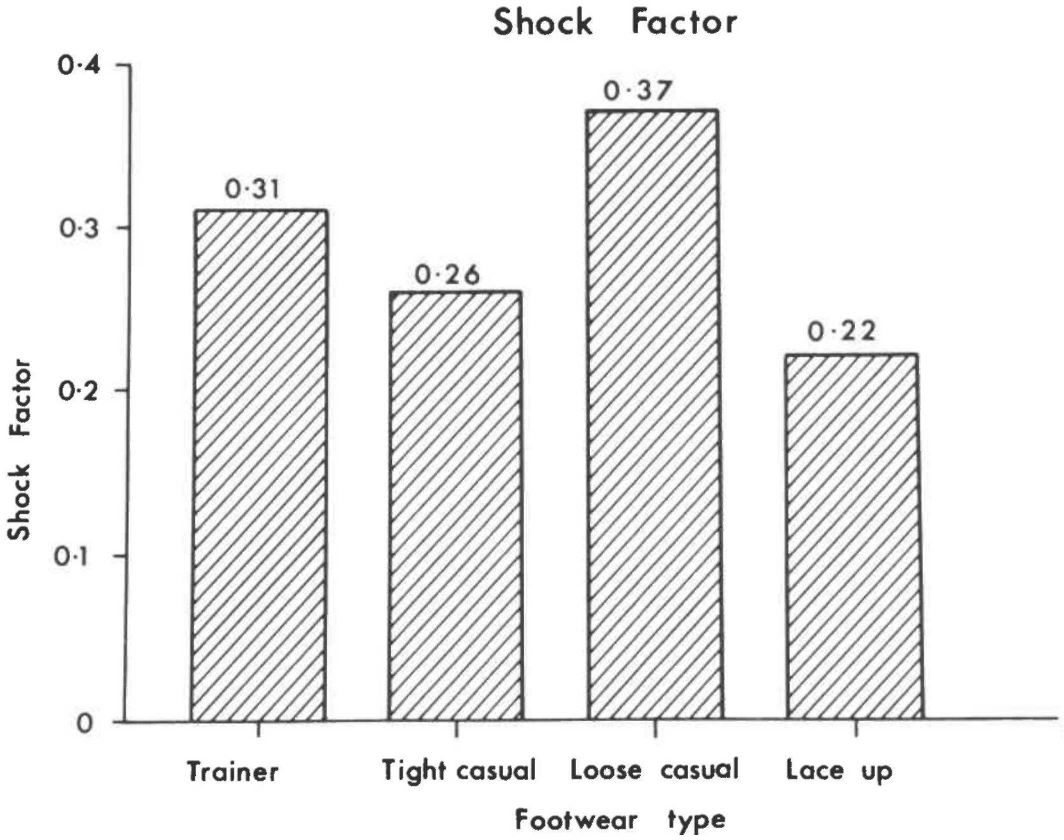

Fig. 2. Variation of Shock Factor for different shoes without insoles.

chosen after inspection of the data had shown the signal to be small at higher frequencies. The second measurement was concerned with the proportion of the signal which could be considered to represent shock loading making it necessary to determine a cut off frequency distinguishing between "normal movement" and "shock"; when studying the frequency content of the ground reaction force in normal gait Simon and colleagues (1981) found the highest frequency to be 50 Hz and so this has been chosen as the cut-off frequency for this particular study. In addition, data at less than 10 Hz has been ignored because of the poor response of piezoelectric accelerometers at low frequencies. The rms values of the "normal" and "shock" signals may be calculated as the integrals represented by the areas An and As shown in Figure 1. A shock factor S may then be defined as:

$$S = As/(An + As)$$

This factor, which can vary between 0 and 1, can be used to compare the effectiveness of an insert used in different types of footwear by different users whose acceleration spectra may have personal distinctions. The relevant integrations were carried out on the mean spectrum using Simpson's rule.

Results

Figure 2. shows the average shock factor measured while walking in the four types of footwear without shock absorbing insoles. Figure 3. shows results for various insoles in which the improvement was statistically significant ($p<0.05$) using the student t-test. Shock improvement has been defined as the percentage reduction in Shock Factor resulting from the use of an insole. The most impressive shock reduction has been achieved by the Lightweight Sorbothane and the Soft Blue Sorbothane each of which reduce shock by over

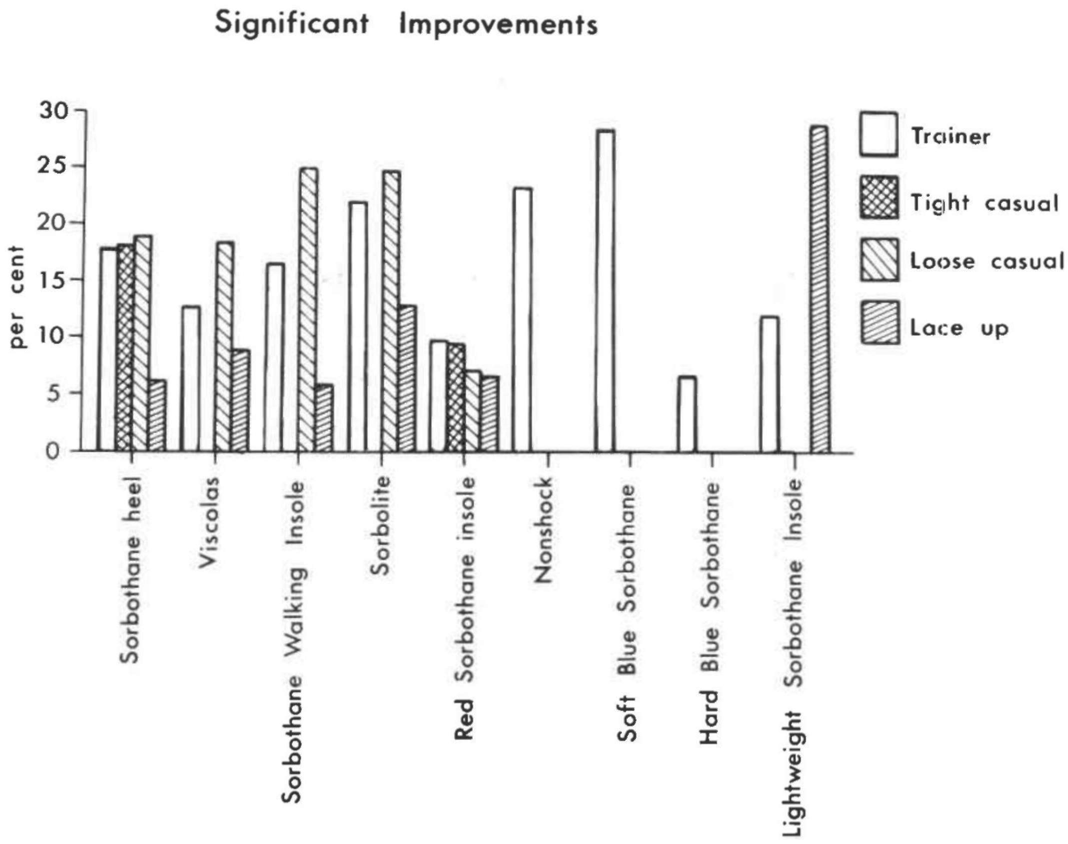

Fig. 3. Statistically significant shock improvement afforded by different insoles.

30%. These are followed by Sorbolite, Nonshock and the Sorbothane walking insole all achieving better than 20% shock reduction. The results can be summarized as follows: On average, across footwear and insoles, a Shock Improvement of 8% was achieved with a maximum of 29% (Soft Blue+type 1, Lightweight Sorbothane+type 3). The overall best performer was Sorbolite (average 15.5%). In only three cases was a significant deterioration observed although some deterioration occurred in eight (22%) of the tests. In 21 cases (58%) a significant improvement was observed.

Discussion and conclusions

With the exception of the work of Pratt and colleagues (1986) this is the only comparative study of a range of insoles. Whereas their work was based on the measurement of peak acceleration, the present study uses the Shock Factor which it is suggested is a more representative measure of shock. This work has shown that statistically significant shock reductions can be achieved by insoles and that their effectiveness is greatly influenced by the footwear in which they are used. Indeed, it is interesting to note the large variations between the different shoes when used without insoles particularly since the two pairs of casual shoes were very similar except that one pair was a rather tighter fit than the other. This suggests that the fit between the shoe and foot can have a major influence over shock transmission.

This study has not been concerned with measurement of the mechanical properties of insoles; this must be a priority if they are to be designed in a scientific manner. However, the author has suggested in an earlier paper (Johnson, 1986) that shock reduction may be largely a function of compressive stiffness. This idea is borne out by the results from the Hard and Soft Blue Sorbothane which are of identical geometry; the softer insole affords greater shock reduction. Other studies by the author confirm this impression.

The method described here suffers from two major limitations—it requires expensive (non-portable) spectral analysis equipment and this must be connected to the subject by a trailing cable. However, these problems have now been overcome by the development of the Shock Meter[2] consisting of two major components—a universally fitting ankle cuff with accelerometer and a meter unit which is worn on a waist belt. This unit analyses the acceleration over a period of one minute and displays the Shock Factor on a digital readout. Being completely portable, the meter is ideally suited to the measurement of shock in both running and walking. A repeatability study has shown that the meter is repeatable to within 10% for a single 1 minute test and this may be further improved by averaging several tests. Now that this instrument is available more exhaustive testing of different insoles and footwear during both running and walking becomes possible. The author has already commenced such work.

Acknowledgements

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[2] J. P. Biomechanics. A division of J. C. Peacock and Son Ltd.