INTRODUCTION

The most feared lower extremity problem among patients with diabetes is amputation, and the sequences of events leading to amputation are initiated by skin ulceration combined with sensation loss (Birke, J.A. et.al. 1995). Therefore, it is essential to detect the foot at risk of plantar ulceration, at an early stage of sensation loss, so as to prevent complications and amputation, (Armstrong, D.G. et.al 1998). It is found that the foot pressure parameters are functions of the mechanical properties of foot sole soft tissue and also different levels of sensation loss. Therefore, this paper presents the results of the research study undertaken to find the relationship between the foot pressures characterized by a new parameter known as Power Ratio, PR (the ratio of high frequency power to the total power in the power spectrum of the foot pressure image) at different levels of sensation loss and the foot sole mechanical property (in terms of hardness of foot sole soft tissue characterized by its Shore level, Sh).

METHODS

In this study, the foot pressures are measured using the optical pedobarograph. The sensation levels on the foot sole are measured by scanning ten standard areas of the foot sole (Figure 1 a) using the Semmes-Weinstein nylon monofilaments of specified diameters to determine quantitatively the degree of neuropathy (characterized by sensation levels S, ranging from 3 gm to 10 gm). The mechanical properties of foot sole, in the above ten foot sole areas, are measured using the Shore meter which measures the hardness of the foot sole soft tissue- lesser the Shore value, softer is the soft tissue (Pigassesi, A. et.al 1999). The Shore meter works on the principle of indentation using a truncated cone tipped indenter; indentation depth being inversely proportional to the modulus of elasticity.

The standing foot pressure images are obtained from the optical pedobarograph. Spatial frequencies (cycles per degree, cpd) and their distributions in these images are analyzed by performing the 2-D Discrete Fourier transform (DFT) using MATLAB. The magnitudes of the power spectrum, in each of the foot sole areas, are obtained by squaring the absolute magnitudes of Fourier spectrum of light intensity variations of foot images. Now, the power ratio PR is calculated by using the equation as follows.

$$PR = \left(\frac{HFP}{TP}\right) \times 100$$

where, HFP- High Frequency Power and TP – Total Power in Foot pressure image. Multiplication by 100 is to express the PR value as a whole number. The parameter, PR is evaluated for normal and diabetic feet.
with different levels of loss of sensation and different hardness values of the soft tissue.

RESULTS AND DISCUSSION

Analysis of the standing images of foot on 7 normal and 18 diabetic subjects show that in diabetic neuropathy, as the sensation loss increases from diminished light touch (sensation level $S=4.5$ gm, early stage of sensation loss) to loss of protective sensation (sensation level $S=10$ gm), the foot pressure parameter PR, increases in all the foot sole areas (Figure 1b). The increase in PR values for diabetic subjects in the upper sensation loss region ($S=7.5$ to $10\text{gms}$) compared to the corresponding increase in lower sensation loss ($S=3$ to $4.5\text{gms}$) are of the order of 5 times in lateral heel and big toe and 4 times in the first metatarsal regions of the foot sole. Figure 2 presents the variations of mean PR values in the ten foot sole areas for different Shore levels. The increase in PR values for diabetic subjects in the upper Shore value regions ($30$ to $40$) compared to the corresponding increase in lower Shore value regions ($20$ to $25$) are of the order of 4 times in lateral heel, 5.4 times in the first metatarsal regions and 2 time in big toe.

![Figure 1. (a) Areas of foot. (b) PR values vs areas of foot with sensation levels ‘S’.](image)

![Figure 2. PR values vs areas of foot with different Shore levels](image)

SUMMARY

It is seen that the foot pressure parameter PR values in diabetic subjects increase by (i) 4 to 5 times in higher sensation loss regions and (ii) 2 to 5.4 times in higher Shore regions compared to the corresponding lower sensation loss and Shore regions of the foot sole, respectively that are ulcer prone (namely areas of lateral heel, big toe and first metatarsal heads). Therefore, it may be concluded that both the increase in sensation loss and Shore (hardness) levels of the foot sole soft tissues may be responsible for plantar ulcers.

REFERENCES

