CLINICAL RESEARCH

# Variability in vibration perception threshold among sites: a potential source of error in biothesiometry

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## Abstract

**Vibration perception threshold was measured with a biothesiometer by a single observer at both medial malleoli and both big toes in 110 diabetic patients aged 15-65 selected at random and in 64 non-diabetic subjects aged 20-65. The vibration perception threshold showed appreciable individual variation both between contralateral sites and between ipsilateral sites, differing by at least 30% between the big toes in 26 (24%) of the diabetic patients and 16 (25%) of the non-diabetic group. Variability between sites was significantly greater in the diabetics than the normal subjects. The vibration perception threshold exceeded published normal values at one or more sites in 22 of the diabetic patients but at all four sites in only four.**

**The wide variability in vibration perception threshold among sites may be due to the tissue characteristics locally and, in diabetic patients, possibly to asymmetric neuropathy. Biothesiometer readings at single or unilateral sites may be unrepresentative or misleading.**

## Introduction

Objective assessment of peripheral nerve function, whether by traditional neurological examination or by sophisticated techniques using computers,[1] is laborious and time consuming, and a simple, rapid, and reliable test is needed to diagnose peripheral neuropathy in busy outpatient clinics. Measurement of the vibration perception threshold with electromechanical devices such as a biothesiometer has been claimed to fulfil this need.[2-4] Normal ranges based on the vibration perception threshold in over 500 subjects have been published with the suggestion that they could be used clinically to diagnose and monitor peripheral neuropathy.[4]

While screening for diabetic neuropathy by measuring the vibration perception threshold at both big toes and both medial malleoli we found several patients who had abnormal values (compared with the centile charts of Bloom *et al*[4]) at one or more sites but normal values elsewhere. These abnormalities did not follow the distal symmetric pattern classically attributed to peripheral neuropathy in diabetes. Wide variability in vibration perception threshold at different sites in the same subject might reduce the diagnostic value of this variable, especially as many investigators have taken measurements at single or unilateral sites. This possible source of error has not been systematically studied before; we therefore examined variability in vibration perception threshold among sites in diabetic and non-diabetic subjects on a single occasion.

## Subjects and methods

A total of 124 diabetic patients aged less than 65 were randomly selected from the diabetic clinic at Ealing Hospital; the upper age limit was chosen because of the difficulty in interpreting data on vibration perception threshold in older subjects.[2-4] Patients were excluded if they admitted to a heavy intake of alcohol; were being treated with psychotropic drugs or drugs recognised as causing peripheral neuropathy as a side effect; had had a foot injury or an operation to their feet; or had ankle oedema. Fourteen patients, in whom the measurements of vibration perception threshold were inconsistent (that is, the range of values exceeded 5 volts) after full familiarisation with the stimulus (see below), were also excluded. Data are presented for the remaining 110 patients (51 men and 59 women), who were aged 15-65 (mean 48·3 (SD 12·3) years) and had had diabetes for from two months to 31 years (mean 9·3 (9·1) years). Eleven were treated with diet alone, 41 with diet and oral hypoglycaemic agents, and 58 with insulin. Patients were systematically questioned about symptoms of neuropathy, but comprehensive neurological examination was not performed.

Sixty four healthy non-diabetic subjects were also examined, comprising eight men and eight women from each of the age groups 20-29, 30-39, 40-49, and 50-65. None had diabetic or neurological symptoms or was taking any drug that was likely to affect the measurements; a random capillary blood glucose concentration was <8 mmol/l in each case.

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MEASUREMENT OF VIBRATION PERCEPTION THRESHOLD

Measurements were taken in a quiet room at a comfortable temperature (22-24°C). The subject removed shoes and socks or thick stockings but not thin nylon stockings, which do not impair measurements,[4] and lay supine on a couch. All measurements of vibration perception threshold were performed in a standardised way by one observer familiar with the technique, who used the same handheld biothesiometer (Bio-Medical Instrument Company, Newbury, Ohio, United States). The biothesiometer tactor, which vibrates at 100 Hz with an amplitude proportional to the square of the applied voltage, was applied perpendicularly to the test site with constant firm pressure. Vibration perception threshold was measured at the most prominent part of each medial malleolus and the distal plantar surface of each big toe. The applied voltage was slowly and steadily increased, and the voltage was recorded when the subject first felt the vibration.

Each subject was familiarised with the sensation by first holding the tactor against the anterior tibial border and then by taking three readings at each of the four test sites in turn; this cycle of readings was disregarded. Two more cycles of three measurements at each site were then recorded; vibration perception threshold at each site was expressed as the mean of these last six readings. The whole procedure generally took four to six minutes.

STATISTICAL ANALYSES

The variability in vibration perception threshold between the diabetic and normal groups and among sites was examined by analysis of covariance of logarithmically transformed data[3,4] adjusted for age; the BMDP statistical package was used.[5]

## Results

Table I shows the mean vibration perception threshold at each site adjusted for age. Values at the four sites varied considerably in individual subjects in both the diabetic and normal groups. Analysis of covariance (table II) showed that site made a highly significant contribution to variability in the study population as a whole; variability among sites was significantly greater in the diabetic than the normal group. The variability showed no consistent distribution; in many subjects there were appreciable differences in vibration perception threshold between the same site on opposite sides of the body or between different sites on the same side. Figure 1 shows the considerable scatter in values recorded at the left and right big toes. Although there was a highly significant positive correlation between the two sides, in 26 diabetic patients (24%) and 16 normal subjects (25%) a difference of at least 30% was seen between the two sides. Figure 2 shows the scatter of readings between the right big toe and right medial malleolus. Both diabetic and non-diabetic groups showed a significant positive correlation between the two sites, with an overall tendency for higher values at the medial malleolus, as previously reported[2-4]; but wide individual variation was again apparent, and 28 diabetic patients (26%) and eight normal subjects (13%) had lower values at the malleolus than at the big toe.

TABLE I—*Mean vibration perception threshold at each site adjusted for age*

| Site | Diabetic patients | Non-diabetic subjects |
|---|---|---|
| Big toe: | | |
| Left | 1·2223 | 1·0623 |
| Right | 1·2328 | 1·0517 |
| Malleolus: | | |
| Left | 1·2602 | 1·1727 |
| Right | 1·2473 | 1·1586 |

TABLE II—*Source of effects by analysis of covariance examining for effects of group and site after adjusting for age*

| Source | Degrees of freedom | Mean square | F Ratio | Significance |
|---|---|---|---|---|
| Group | 1 | 2·43 | 20·4 | <0·0001 |
| Covariate (age) | 1 | 8·54 | 71·8 | <0·0001 |
| Error | 171 | 0·12 | | |
| Site | 3 | 0·24 | 31·5 | <0·0001 |
| Site by group | 3 | 0·09 | 11·9 | <0·0001 |
| Error | 516 | 0·01 | | |

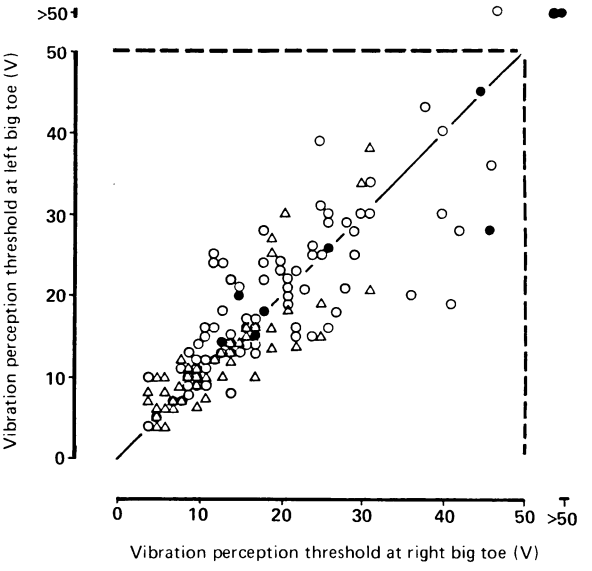


FIG 1—Vibration perception threshold in right and left big toes in 110 diabetics (○) and 64 non-diabetic subjects (△). ●=Diabetics with appreciable symptoms of neuropathy.
Diabetics: r=0·89, p<0·001. Normal subjects: r=0·85, p<0·001.

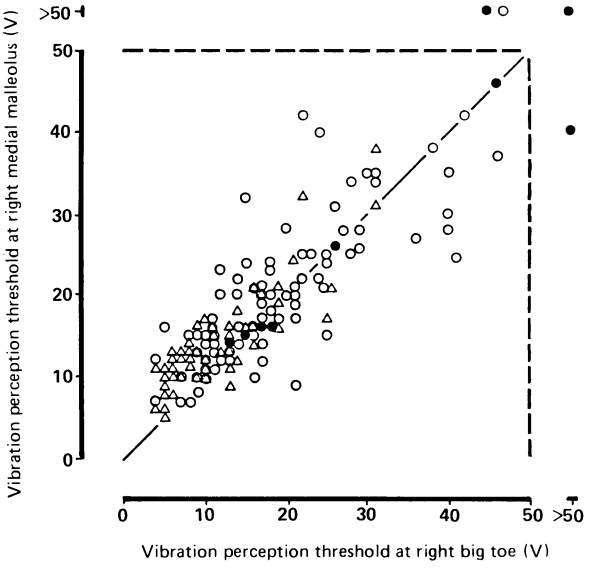


FIG 2—Vibration perception threshold in right big toe and right medial malleolus in 110 diabetics (○) and 64 non-diabetic subjects (△). ●=Diabetics with appreciable symptoms of neuropathy.
Diabetics: r=0·85, p<0·001. Normal subjects: r=0·85, p<0·001.

The distribution of abnormal measurements was examined by comparison with the centile charts of Bloom *et al*,[4] values being judged abnormal if they exceeded the upper 95% confidence limit of the normal range for age interpolated from the data of Bloom *et al*.[4] Values were abnormally high at one or more sites in 22 diabetic patients but at all four sites in only four. Six diabetic patients had an abnormally high value at a single site, seven at two sites, and five at three sites. A symmetric pattern of abnormality consistent with the classical distribution of diabetic polyneuropathy was seen in only a few patients (both big toes, five patients; all four sites, four). Of the normal subjects, one had an abnormally high vibration perception threshold at a single site and one at two sites.

Nine diabetic patients reported appreciable neuropathic symptoms as defined by Ward.[6] Of these, six had abnormal values at two or more sites. Neuropathic symptoms were not present in any of the six patients with abnormal values at a single site.

The vibration perception threshold at each site and in both groups was related to age—for example, right big toe in diabetic patients, r=0·47, p<0·001; right big toe in normal subjects, r=0·65, p<0·001), as previously reported,[2-4] but apparently not to the known duration of diabetes—for example, right big toe, r=0·15, p>0·1).

## Discussion

Enthusiastic claims for the simplicity, reliability, and reproducibility of the biothesiometer[2-4] have led to its wide use in diagnosing peripheral neuropathy and in studying the epidemiology, natural course, and response to treatment of this condition.[1 7-9] The extent to which vibration perception threshold varies at different sites in the same person is obviously important when this measurement is used to diagnose peripheral neuropathy but has not, to our knowledge, been systematically examined. Our results show considerable and unpredictable variability at the big toes and medial malleoli, both in randomly selected diabetics and in a group of non-diabetic subjects stratified by age. Such variability may partly be due to the physical characteristics of the tissues at the test sites, which affect damping of the vibratory stimulus.[10] Greater variability in the diabetic than the non-diabetic group may have reflected neuropathic damage, which was presumably patchy and asymmetric in most cases.

In this study vibration perception threshold exceeded the largest published normal range[4] at one or more sites in a fifth of the diabetic patients, but only a few of these had the symmetric distal pattern suggesting classical diabetic polyneuropathy. Because of variability among sites, which is present in normal subjects but accentuated in diabetic patients, the diagnosis of abnormality may be difficult. Most patients with a generalised abnormality of the vibration perception threshold probably have peripheral neuropathy, but there remains the diagnostic dilemma of deciding whether a subject with abnormal values at some sites but not others has neuropathy or not. The practice followed in many studies of taking measurements only at a single site or on one side of the body may produce unrepresentative or misleading results.

Biothesiometry may be criticised for several other reasons. Firstly, as with all sensory measurements the technique may be unsuitable for the large proportion of cases (11% in this study) in which readings at each site are inconsistent; variability within sites may be due to psychological factors such as lack of motivation, easy distractibility, fatigue, and poor comprehension[2 3 11] rather than to a genuine defect in the perception of vibration. Secondly, the immense variability of values with time[11] must be considered when interpreting longitudinal studies of the evolution of neuropathy or its response to treatment.[7-9] Thirdly, the currently available biothesiometer has several drawbacks, including unsatisfactory standards of electrical safety[12] and poor sensitivity at the upper end of the voltage scale (>40 volts).

In conclusion, wide and previously unreported variability in the vibration perception threshold among different anatomical sites must be recognised when using biothesiometry to diagnose neuropathy, especially when interpreting data based on measurements at single or unilateral sites. Bilateral readings should always be taken, and all sites examined should be considered when deciding whether neuropathy is present.

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# Effective lipid lowering diets including lean meat

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## Abstract

**The plasma lipid and lipoprotein responses to two modified isoenergetic diets including meat were studied in 15 free living men with hyperlipidaemia (mean plasma cholesterol and triglyceride concentrations 8·1 and 3·4 mmol/l). A reference diet (diet A, 42% energy from fat, ratio of polyunsaturated to saturated fatty acids (P:S ratio) 0·2) was compared with a fat reduced diet (diet B, 35% energy from fat, P:S ratio 0·5) and with a further fat modified diet supplemented with fibre (diet C, 27% energy from fat, P:S ratio 1·0). Daily intake of meat and meat products (180 g/day) was the same in each dietary period; that in diet A had a fat content typical of the average British diet, whereas that in diets B and C was based on very lean meat and meat products. During consumption of diet B the plasma cholesterol concentration fell by 8·6% and low density lipoprotein cholesterol by 11%. During consumption of diet C plasma cholesterol fell by 18·5% and low density lipoprotein cholesterol by 23·8%. Triglyceride and high density lipoprotein cholesterol concentrations and body weight did not change appreciably during the study.**

**A modified diet including a moderate amount of lean meat and meat products is compatible with a reduced lipoprotein mediated risk of atherosclerotic heart disease.**

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## Introduction

Atheroslcerotic coronary heart disease is the main cause of death in most industrial communities.[1] There is compelling evidence that