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Dominant frequency content of ocular microtremor from normal subjects

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Abstract

Ocular microtremor (OMT) is a high frequency tremor of the eyes present during fixation and probably related to brainstem activity (Coakley, D. (1983). *Minute eye movement and brain stem function*. CRC Press, FL.). Published observations on the frequency of OMT have varied widely. Ocular microtremor was recorded in 105 normal healthy subjects using the Piezoelectric strain gauge technique. The dominant frequency content of a signal was determined using the peak counting method. Values recorded ranged from 70 to 103 Hz, the mean frequency being 83.68 Hz (S.D. ± 5.78 Hz).

Keywords: Ocular microtremor; Piezoelectric strain gauge; Peak counting

1. Introduction

Ocular microtremor (OMT) is a small high frequency tremor of the eyes present even when the eyes are at rest. Originally thought to have a role in the prevention of retinal image decay, this now seems unlikely, Steinman, Cushman and Martins (1982). The most recent published estimate of ocular microtremor amplitude is that of Eizenman, Hallett and Frecker (1985) who put the mean extent at 6 s of arc. The peak to peak rotation involves a displacement of the surface of the eye of between about 150 and 2000 nm (Sheahan, Coakley, Hegarty, Bolger & Malone, 1993). The OMT signal appears as an irregular oscillatory movement with intermittent burst-like components. The function of OMT, if any, remains obscure. Published observations on the frequency of OMT have varied widely.

In 1934 Alder and Fliegelman estimated the frequency to be between 50 and 100 Hz. This estimate was revised to between 30 and 80 Hz by Ratcliff and Riggs (1950) and Ditchburn and Ginsborg (1953). In the past two decades authors' estimates of frequency have tended to focus around 100 Hz, summarised in Table 1. The largest series to date is that of Coakley (1983) who estimated the normal frequency at 101 Hz in 41 subjects. However, Michalik (1983) estimates the frequency at 87.4 Hz in 34 normal subjects. Both estimates were based on peak counting of records obtained with the piezo-electric technique.

In latter years it has been recognised that recording of OMT may be of value in clinical situations, particularly as an objective method of assessing brain stem function (Coakley & Thomas, 1977). All of those who have applied the recording of OMT to clinical situations have used the piezoelectric strain-gauge technique as described by Bengi and Thomas (1968).

Given the clinical interest and speculation about its role in visual function, the large discrepancy between the extremes of tremor frequencies reported, that is 30–150 Hz, the normal frequency of OMT activity requires further assessment. Our present system has a flat frequency response over the 20–150 Hz range and produces displacement versus time wave forms.

The purpose of this study was to determine the dominant frequency content of OMT in the normal

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Table 1
Summary of previous investigations and measurement of ocular microtremor

Investigation	Number of subjects	Method	OMT frequency (Hz)
(Alder & Fliegelman, 1934)	1	Horizontal component of deflection of mirror placed on eye; monocular fixation	50–100
(Ratcliff & Riggs, 1950)	5	Horizontal and vertical component of deflection of mirror attached to contact lens; monocular fixation	30–70
(Ditchburn & Ginsborg, 1953)	2	Horizontal and vertical component of deflection of contact lens flat	30–80
(Riggs et al., 1954)	6	Horizontal component of deflection of mirror attached to contact lens	60–80
(Matin, 1964)	1	Horizontal, vertical and torsional components of deflexion of mirrors embedded in contact lens using infra-red light	85
(Shaknovich & Thomas, 1973)	7	Piezoelectric strain gauge	100
(Abakumova, 1975)	7	Piezoelectric strain gauge	96
(Davies & Plant, 1978)	1	Piezoelectric strain gauge	100
(Coakley, 1981)	41	Piezoelectric strain gauge	101
(Michalik, 1983)	34	Piezoelectric strain gauge	87.4
(Bolger et al., this paper)	105	Piezoelectric strain gauge	83.68

healthy population, using the piezoelectric transducer technique and the manual peak counting method of record assessment.

2. Methods

2.1. Subjects

A total of 105 normal healthy subjects were recruited for study. Informed consent was obtained from all subjects. All subjects underwent full history and clinical examination. Exclusion criteria included any history or evidence of neurological, ocular or systemic disease. In addition subjects with a history of neurological or ocular trauma were excluded. There were 70 males and 35 females. Mean age of the subjects was 49 years (S.D. ± 20.1 years), median age was 42 years (Skew 0.65, Kurtosis -0.72). The age range was 21–88 years. Subjects under 21 years were not studied because of concern regarding informed consent as defined by the Hospital Ethics Committee. At least 5 s of OMT record was obtained and analysed by a single experienced observer, Bolger, Sheahan, Coakley and Malone (1992).

2.2. OMT recording apparatus

The recording technique and apparatus have been described in detail elsewhere, (Sheahan et al., 1993). Some salient details are summarised here.

A piezoelectric biomorph consisting of two strips of piezoelectric material (piezoelectric lead Zirconium-Tilamate PZT5BN) is attached to a central metal plate and electrodes attached to the outer faces (Van Randeraat & Setterington, 1974; Smith, 1984). A schematic figure of the probe is given in Fig. 1. The biomorph is constructed constructed as a cantilever with one end embedded in a solid mount and the other free. The dimensions of the biomorph are $26 \times 1.6 \times 0.6$ mm.

A rubber strip is fixed to the biomorph tip and electric leads are fixed to the biomorph electrodes. The ensemble is encased in a hollow Perspex cylinder and 1 cm of the tip protrudes from this. The protruding tip is coated with Silicone rubber. The probe is mounted on a headset so that the rubber tipped protrusion is in contact with the sclera. Each probe when constructed is tested for fateful reproduction of signal using an OMT vibrating plate simulator as described by Sheahan (1991).

The performance of the system is reported with regard to three requirements for faithful reproduction of a measured event (Geddes & Baker, 1989): amplitude linearity and freedom from frequency and phase distortion. The amplitude linearity is generally quoted in terms of the maximum non-linearity within the dynamic range of the instrument (van Putten, 1988). In the case of the probes, all probes used have a linear amplitude response (maximum non-linearity < 21 mm), a flat frequency response (< 1 dB deviation from peak re-

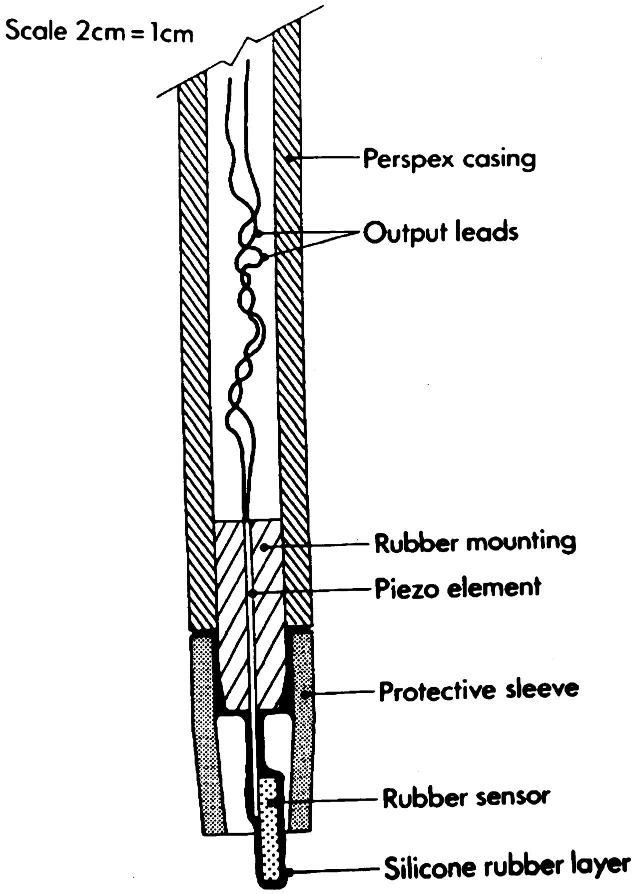

Fig. 1. Cross section of a piezoelectric strain gauge transducer.

sponse) between 20 and 150 Hz and no phase difference between the probe and simulator reference signal.

The signal from each probe is passed to a conditioning unit consisting of a differential amplifier with 40 dB common mode rejection ratio. Amplification factor is 10. The signal passed from the conditioning unit is recorded on an audio-cassette recorder (Sony D3) (Fig. 2). The record is later played back and analysed on an ECG tape analyser (Reynolds Medical (RM) Pathfinder 3 and RM TP-Thermal Printer).

This system shows a frequency response between 20–150 Hz which deviates less than 2 dB from peak response. The system filters out inputs below 20 Hz, in particular, any drift movements. The system has a signal/noise ratio of >23 dB and the resolution is less than 1% of the dynamic range, or 12 nm.

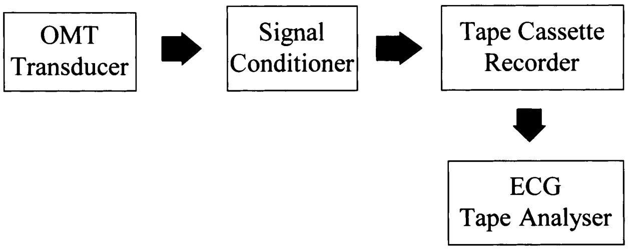

Fig. 2. Schematic diagram of OMT measuring system. The amplified signal is recorded on tape and then replayed using standard ECG tape analysis facilities.

2.3. Record analysis

The peaks occurring per unit time on a printed record are counted. This provides a good estimate of the high frequency component of any random signal (Kay & Sudhaker, 1986; Kedem, 1986; Smith, 1989), particularly OMT (Sheahan, 1991). Sheahan (1991) compared the relative merits of peak counting and the mean frequency of the high frequency resonance of the Fourier and linear predictive spectrum in the analysis of OMT signals. She found the Fourier index showed more variation, both in terms of its reproducability under static conditions, and in its correlation with changes in the spectrum, than either of the other two indices. Peak counting is also the method of obtaining frequency information favoured by Coakley who, to date has published the largest series on OMT (Coakley, 1983).

2.4. Recording session

The subject lies supine in a normally lit room. The subject is advised to keep their eyes fixating straight ahead at the same point throughout the recording. However, Bolger (1994) has shown there is no significant over all variation in OMT activity when comparing the fixational and non-fixational states. Movements of the head can represent a source of noise and this problem is overcome by mounting the transducer onto the head by means of a headset. The subject is then asked to keep the head still throughout the recording but no means of restraint are used. The scleral surface is anaesthetised with 0.5% proxymethacaine hydrochloride solution topically. The eye lids are retracted using adhesive tape. The rubber-tipped piezoelectric probe is lowered so that the probe is just touching the scleral surface. The amplitude frequency and phase response of each probe remain as quoted above regardless of the probe surface contact pressure after contact is first established. Probe placement is judged by visual inspection and by listening to the signal being recorded, using audio cassette headphones.

A recording of between 30 s and 1 min of activity is taken and processed as already described. An example of a normal OMT recording is given in Fig. 3.

Following a recording session the probes are soaked in sodium hypochlorite (concentration 500 ppm) for 10 min, for sterilisation purposes, prior to being used again (Nagington, Sutehall & Whipp, 1983).

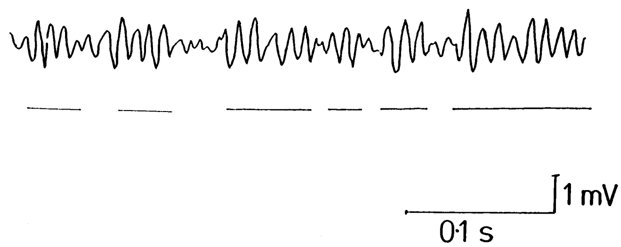

Fig. 3. Example of a normal OMT record. Bursts are underlined and are detected by eye when examining the record. The period between bursts is the terminal baseline. The peak to peak rotation involves a displacement of the surface of the eye of between 150 and 2000 nm.

3. Results

There were no complications associated with the procedure. The mean frequency of OMT as determined by manual peak counting was 83.68 Hz, S.D. ± 5.78 Hz. The mode frequency was 83 Hz and the median was 83.8 Hz. Values recorded ranged from 70 to 103 Hz. A t test showed no significant difference between males and females ($P = 0.7$). However, in comparing subjects above and below the age of 70 years the mean peak count frequency fell from 86.69 Hz (S.D. ± 7.29, range 74.4–103 Hz) in the under 70 age group to 80.54 Hz (S.D. ± 4.73, range 70–88.4 Hz) in the over seventies ($t = 3.00$, $P < 0.008$).

A frequency distribution of the values of OMT among the population studied is provided in Fig. 4. This demonstrates a good fit to a normal distribution of the data with the mean and standard deviation of 83.68 and 5.78 Hz, respectively (Skew 0.22 SE Skew ± 0.24, Kurtosis 0.39 SE Kurtosis ± 0.47).

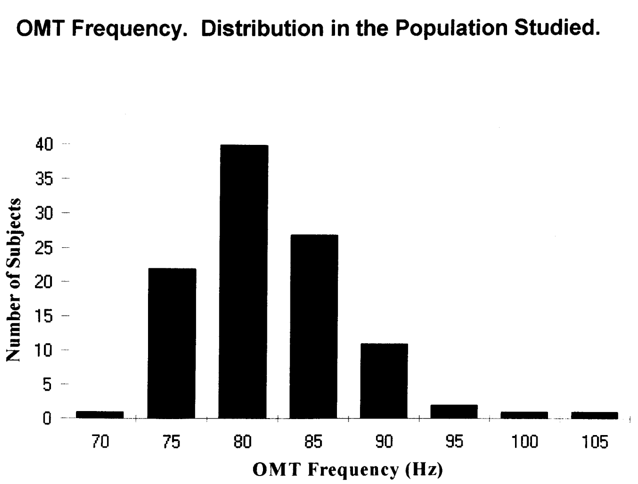

Fig. 4. Frequency distribution of OMT among the population studied.

4. Discussion

Estimates of the frequency of ocular microtremor have varied between 30 and 150 Hz since Alder and Fliegelman's (1934) original estimate of 50–100 Hz. In the 1950s the estimate was generally put at between 30 and 80 Hz (Ratliff & Riggs, 1950; Ditchburn & Ginsborg, 1953; Riggs, Armington & Ratcliff, 1954). In 1964, Matin put the frequency at 85 Hz.

However, in the last two decades, authors' estimates of frequency have tended to focus around 100 Hz: thus Abakumova, Shakhnovich and Thomas (1975) 96 Hz, Shakhnovich and Thomas (1973) 100 Hz, and Davies and Plant (1978) 100 Hz. The largest series to date of 41 subjects is that of Coakley (1983) who found a frequency of 101 Hz. More recently Michalik (1983), has reported a mean frequency of 87.4 Hz on 34 subjects.

Much of this discrepancy may be explained on the basis of differences in recording technique and filtration since all of the authors quoted would appear to have analysed sufficient record lengths to provide a reliable estimate of OMT frequency, Bolger (1992). Analysis of sample tremor records, provided in the earlier papers, reveals a high degree of contamination of records with drift movement. Also, as Coakley (1983) has rightly indicated, other methods of measuring OMT such as corneal contact methods, could be expected to add significant inertia to the oculomotor system while the piezoelectric technique used by more recent authors does not. These factors might reasonably explain some of the lower tremor frequencies reported.

However, Michalik (1983) also used the piezoelectric transducer and reported a mean frequency of 87.4 Hz. Coakley's (1983) analysis and also those of Shakhnovich and Thomas (1973) and Davies and Plant (1978) have been based on velocity, rather than displacement waveforms. Velocity against time analysis will enhance the contribution of higher frequency components to the overall, measured, frequency. The present system has a flat frequency response between 20 and 150 Hz and provides displacement relative to the time records. Frequency analysis is based on the peak counting method which Sheahan (1991) reports that although the least technical method, is the best way to determine the dominant frequency content of a signal, being superior to both Fourier and linear predictive analysis. Further, the analysis here is based on the records of 105 subjects, and thus our estimate of 83.68 Hz is probably more accurate. The value of 83.68 Hz is very closed to that of Michalik (1983) at 87 Hz who also used displacement versus time records obtained with a piezoelectric transducer. This further indicates the consistency of OMT activity, even between two different series once they are using the same methodology.

Interestingly, in this study we found a significant difference in the mean peak count frequency when comparing subjects under and over 70 years of age. A previous study by Coakley in 1976 (Coakley & Thomas, 1976) compared OMT in 26 young adults and 15 subjects over 70 years of age. He could find no significant change in OMT frequency associated with age in this group. We are currently investigating the effect of age on OMT in greater detail.

Given the nature of the literature published to date, the consistency between different centres using the same technique, the known flat frequency response of the present method and a series of 105 normal subjects; we can begin to consider in confidence the concept of a normal OMT frequency. This is an essential pre-requisite to the application of OMT recordings to the pathological state or any investigation of possible physiological function.

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