[Regular Papers]

ACCOMMODATIVE MICROFLUCTUATION IN ASTHENOPIA
CAUSED BY ACcommodative SPASM

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Abstract: [Background] Although many patients complain of eye fatigue caused by accommodative spasm, there have been no reports of a good objective examination method to diagnose it. [Purpose] The spectral power of the high frequency component of the accommodative microfluctuation (spectral power of HFC) differs according to the constrictive degree of the accommodation. In this paper, we expatiated upon our previously reported analyzing processes of the spectral power of HFC, and we investigated the relationship between normal subjects and subjects with asthenopia. [Method] The accommodative microfluctuation were recorded when the subjects were looking at a stable target. The waves of the accommodative microfluctuation were analyzed by FFT. [Results] The spectral power of HFC for the distant target was 50–60 in the subjects with normal vision, but it was higher in the subjects with asthenopia. [Conclusion] Our results suggested that the ciliary muscle was also actively working in asthenopia caused by accommodative spasm even if the patient was looking at a distant target.

Key words: accommodation, accommodative microfluctuation, asthenopia, accommodative spasm, refraction

INTRODUCTION

Although there are many patients who complain of eye fatigue caused by accommodative spasm\(^{1-3}\), to date, no good objective examination to diagnose asthenopia has been reported. An oscillation–like sine wave known as an accommodative microfluctuation can be observed in an objective refraction when a subject is looking at a stable target\(^{4-11}\). Low (<0.6 Hz) and high frequency components
(1.0–2.3 Hz) have been identified\textsuperscript{12–18}, and it is considered that the latter results from a fluctuation of refractive power in crystalline lens.

It is known that the spectral power of the high frequency component (spectral power of HFC) differs according to the constrictive degree of accommodation\textsuperscript{16–18}. In this study, we compared the relationship of spectral power of HFC in normal subjects and in subjects with asthenopia caused by accommodative spasm.

SUBJECTS

Our subjects were three normal subjects and four subjects with asthenopia. The normal subjects were two males and one female, aged 29, 26 and 24 years old, respectively. All three subjects had good corrective visual acuity of more than 1.2. No subjects experienced retrobulbar ache, headache or shoulder stiffness. The subjects with asthenopia were three females and one male, aged 28, 25, 21 and 24 years old, respectively. Although they also had same good visual acuity, they all had a chief complaint of asthenopia was retrobulbar ache (Table 1).

METHODS

Accommodative microfluctuation was recorded by an infrared optometer (AA2000, NIDEK) when the subjects were looking at stable targets provided by the optometer. The sampling time was 80 milliseconds. The target was set every 0.5 D in steps from +0.5 D to −3.0 D to a refraction measured by an auto-refractometer (AR1100, NIDEK) for 20 seconds.

The spectral power of the accommodative microfluctuation was analyzed by Fast Fourier Transformation (FFT). The spectral power of HFC was analyzed using the following processes:

1) Abnormal sampling dots made by blinking, which were easily identified by simultaneously a pupillometry performed were removed (Fig 1a).

2) Spectral power at a point of data was calculated from data for 8 seconds (4 seconds before and 4 seconds after the point). The data in the 8 seconds

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Fig. 1.  

a. an example of original data. Points shown by the arrow were removed from the data, since it was confirmed that they were recorded during blinking.  
b. an example of an 8-second record by a cubic spline function; 1,024 points on the curve were used for the following analysis. Average of real value (right scale) was reset as 0 (left scale).  
c. Hanning's window expressed with an equation $F(x) = 0.5 - 0.5 \cos(2\pi T/t)$; $T = 8$ sec.  
d. data directly used for FFT analysis, obtained by b×c.

range consisting of 100 dots were superposed by cubic spline function (Fig. 1b); 1,024 points on the curve was used for FFT analysis.

3) To simplify calculation, mean refraction was reset at 0 (Fig. 1b, right vs. left scales).

4) Since FFT analysis is influenced by values at both ends of the data, Hanning’s window (Fig. 1c) was used to establish balanced data for the analysis of FFT (Fig. 1d).

5) Spectral power was calculated by FFT (Fig. 2a).

6) To simplify the value, the values of spectral power were then converted to the common logarithmic values. Summation of the logarithmic values between 1.0–2.25 Hz (black columns in Fig. 2b) was defined as Spectral power value of HFC (Fig. 2b).

7) The same analysis was performed for 11 points, 1 second apart from each other, in the original 20 second data. The whole process was repeated for the data obtained when the subjects looked at the target from different distances.
Fig. 2. An example of the results of FFT analysis (a), re-expressed after the ordinates were changed to logarithmic scale (b). Summation of the values between 1 and 2.25 Hz (black bars in b) was used as the spectral power value of HFC.

RESULTS

Fig. 3a shows the accommodative response in the subjects looking at the targets set at 0.5 D intervals from +0.5 to −3.0 D. In one patient with asthenopia, the accommodative responses were almost the same for every target. The accommodation in the other subjects responded according to the distance of the target: their focusing points were less than the distance of the target when the target was −0.5 D or greater (Fig. 3a, left side), and their focusing points were greater than the distance of the target when the target was set at −1.0 D or less except in one subject whose accommodative response to the −3.0 D target was markedly strong. In normal subjects and subjects with asthenopia, the distance at which the accommodative response was almost the as the distance of the target was −0.5 and 0.0 D, respectively. The dispersion of accommodative response for the +0.5 D target was markedly wide in the subjects with asthenopia.

Fig. 3b shows the relationship between the Spectral power value of HFC and the targets, which were displayed at different distances. There was no difference in the Spectral power of HFC between normal subjects and subjects with asthenopia when
Fig. 3. Focusing points (accommodative response) (a) and Spectral power value of HFC (b) when each subject looked at the target at different distances (+0.5 to −3.0 D). Open circles, subjects with asthenopia. Closed circles, normal controls. Each mark is average and S.D. of 11 results obtained from 8-second data (Fig. 1a).

the targets were displayed closer than −2.0 D. However, the Spectral power value of HFC in subjects with asthenopia was higher than that in normal subjects, when the target distance was −0.75 D or greater.

We speculated that the degree of accommodative microfluctuation does not relate to the target distance, but to the degree of the actual accommodation. Based on this hypothesis, the relationship between the Spectral power value of HFC and the accommodative response was plotted (Fig. 4) and we found that the Spectral power value of HFC in subjects with asthenopia was higher than that in normal subjects when the accommodative responses were between 0.0 and −0.75 D. When the t-test was used for the accommodative responses between 0.0 and −0.75 D, there was significant difference between normal subjects and subjects with asthenopia (P < 0.01). No other significant difference was found between normal subjects and subjects with asthenopia in the other degrees of accommodative responses.
DISCUSSION

It is hypothesized that the Spectral power value of HFC is caused by an oscillation in refractive power in crystalline lens and that this is shown in the degree of activity in the ciliary muscle. We previously reported the relationship between the Spectral power value of HFC and the constrictive degree of the accommodation\textsuperscript{19} and in this study we found that the Spectral power value of HFC in normal subjects showed a pattern similar to that described in our previous report. However, in subjects with asthenopia, the Spectral power value of HFC was different from that in normal subjects. In distant targets, the Spectral power value of HFC in subjects with asthenopia was higher than in normal subjects, but there was no difference between the Spectral power value of HFC in normal subjects and in subjects with asthenopia using the $-3.0$ D target ($t$-test : $p=0.61$). Since subjects did not always focus on a target correctly, we divided targets into two groups: in the low accommodation group the subjects accommodation was between 0.0 and 0.75 D, which is the accommodation used for looking into the distance; and in the high accommodation group the subjects accommodation was between $-1.0$ and $-3.0$ D, which in the accommodation used for deskwork. We then defined the mean Spectral power value of HFC in the low and high accommodation group targets as HFC1 and HFC2, respectively.

The Spectral power value HFC1 was low (40-60) in normal subjects, suggesting
that the ciliary muscle is relaxed when focusing on a distant object (Table 2). However, the HFC1 in subjects with asthenopia showed high values (60–70), suggesting that the ciliary muscle is not relaxed in subjects with asthenopia when the patient is looking at a distant object. The difference was significant (t-test: p < 0.01). No differences were observed in the HFC2s between the normal subjects and the subjects with asthenopia.

Although, it is necessary to confirm this tendency in a larger study, we also speculate that the high HFC1 between 0.00 and 0.75 D's constriction of accommodation could be a useful indication in the diagnosis of asthenopia caused by strain of the ciliary muscles.

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REFERENCES


