

Auditory steady-state evoked potentials at carrier frequencies above 4000 Hz

Potencial evocado auditivo de estado estável em frequências portadoras acima de 4000 Hz

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ABSTRACT

Introduction: The auditory steady-state evoked potentials (ASSEPs) has been identified as a promising technique for assessing hearing in patients who do not cooperate spontaneously in determining auditory thresholds. Although studies report decreased performance at carrier frequencies above 4000 Hz, technical advancements to determine its clinical utility is necessary because the use of these frequencies can contribute to a better audiological diagnosis. **Purpose:** Aimed to analyze the general auditory steady-state response at carrier frequencies above 4000Hz. **Methods:** Evaluation of ASSEPs combined and isolated at the intensities of 50 SLpPe and 80 SLpPe at the carrier frequencies 6000 Hz to 8000 Hz, with the signal acquisition and analysis system MASTER. **Results:** Analysis of variance (two-way ANOVA), which found decreased amplitudes when related to the intensity and the stimulus conditions. **Conclusion:** It was possible to evaluate the carrier frequencies 6000 Hz and 8000 Hz, either alone or combined. There were no interactions between the carrier frequencies 6000 Hz to 8000 Hz in both forms of presentation (combined and isolated) and intensity, for the sample.

Keywords: Auditory evoked potentials; Hearing; Audiometry

RESUMO

Introdução: O potencial evocado auditivo de estado estável (PEAEE) tem sido apontado como uma técnica promissora para avaliar a audição de pacientes que não cooperam espontaneamente na determinação dos limiares auditivo. Embora estudos relatem desempenho diminuído nas frequências portadoras acima de 4000 Hz, são necessários avanços técnicos para determinar a sua utilidade clínica, pois o uso dessas frequências pode contribuir para um melhor diagnóstico audiológico. **Objetivo:** Analisar os potenciais evocados auditivos de estado estável, em frequências portadoras acima de 4000 Hz. **Métodos:** A avaliação dos PEAEE foi realizada de forma isolada e combinada, nas intensidades de 50 dBNPSpe e 80 dBNPSpe, nas frequências portadoras de 6000 e 8000 Hz, com o sistema de aquisição e análise MASTER. **Resultados:** Foi realizada análise de variância (ANOVA *two-way*), em que se encontrou diminuição das amplitudes, quando relacionadas às intensidades e às condições do estímulo. **Conclusão:** Foi possível avaliar as frequências portadoras de 6000 e 8000 Hz, tanto de forma isolada, quanto combinada. Não houve interações entre as frequências portadoras de 6000 Hz e 8000 Hz, quanto à forma de apresentação (combinada e isolada) e intensidade, para a amostra estudada.

Palavras-chave: Potenciais evocados auditivos; Audição; Audiometria

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INTRODUCTION

Assessment of auditory steady-state evoked potentials (ASSEPs) is widely indicated as a tool to determine electrophysiological thresholds, allowing the objective detection of responses, using statistical analysis. With modulation frequencies of 80 Hz or more, ASSEP proved to be a reliable method to estimate electrophysiological thresholds^(1,2).

However, there is still no consensus regarding the clinical diagnostic protocols used. Furthermore, reports of conducting ASSEPs with carrier frequencies above 4000 Hz are scarce. Studies have reported a decline in amplitude and performance in determining electrophysiological thresholds when carrier frequencies below 500 Hz⁽³⁾ and above 4000 Hz⁽⁴⁾ were used.

Previous research has suggested a qualitative model of carrier frequencies following the U pattern, possibly reflected on the minimum auditory curve. For this operational model, a decrease in amplitude and accuracy in determining thresholds was observed when the carrier frequency declined or rose beyond the ideal range (500 Hz to 4000 Hz), that is, towards audiometric extremes^(3,4,5,6,7).

To better define the operational model, this study assessed carrier frequencies above 4000 Hz, determining whether or not there is a systematic difference in ASSEP accuracy and amplitude.

As such, to standardize results, the technique needs protocols that can be reproduced in clinical populations. The primary aim of this study was to analyze auditory steady-state evoked potentials at carrier frequencies above 4000 Hz. The specific objective was to determine whether there is a relationship between carrier frequencies of 6000 Hz and 8000 Hz in terms of the form of presentation (combined and separate) and intensity.

METHODS

This cross-sectional, prospective, organizational and analytical study was approved by the Research Ethics Committee of the *Universidade Federal de Pernambuco*, under protocol number 165.922. All the participants gave their informed consent.

The sample included ten individuals (20 ears), selected according to the following inclusion criteria: age between 18 and 45 years and auditory thresholds less than or equal to 20 dBNA, with differences in frequencies between ears less than or equal to 10 dB. Excluded were those who were exposed to occupational or leisure noise, had undergone middle and/or inner ear surgery, suffered from more than three middle ear infections, used ototoxic drugs, exhibited hormonal alterations, ringing in the ears, vertigo, dizziness or other cochleovestibular disorders.

Participants were initially screened by completing a medical history and auditory function questionnaire. Next, the following procedures were applied: otoscopy, pure-tone threshold audiometry and steady-state auditory evoked potentials.

The ASSEP examination was applied using the Multiple Auditory Steady-State Response (MASTER®) technique. The electrode region was prepared with 70% alcohol and abrasive paste (Nuprep®) was used for exfoliation. Next, disposable electrodes (3M®) were placed on the right clavicle (ground electrode) at Cz (active electrode) and below the hairline (reference electrode). Assessments were conducted only when impedance between electrodes connected to the skin was less than 5kΩ.

The volunteers were comfortably seated in a reclining chair, in dorsal decubitus, to allow adequate muscle relaxation. They kept their eyes closed during the examination and were not sedated.

Up to 32 scans were averaged to obtain a value of $p < 0.05$. When the expected significance level was reached, it was confirmed in at least two subsequent stimuli. The automatic rejection of outliers was established at 40nV and collection was interrupted when a high rate of stimuli was rejected.

We used a pure tone, at a frequency of 6000 and 8000 Hz, and modulated at a range between 80 Hz and 85 Hz. The stimuli were presented continuously through TDH 39 P audiometric earphones.

Carrier frequencies of 6000 Hz and 8000 Hz were assessed separately (binaural stimulation of a single frequency) and in combination (simultaneous and binaural stimulation of multiple frequencies - 6000 Hz + 8000 Hz), at intensities of 50 SLPpe and 80 SLPpe.

To interpret the findings, we considered the presence of a response to statistical identification of the spectral peak, at the modulation frequency of carrier stimulation, with the amplitude statistically higher than that of background noise on the Fast Fourier Transform (FFT). Significance was calculated using T² and F statistical tests, conducted by the MASTER system.

Statistical method

The data were tabulated and processed by Predictive Analytics Software 22.0 (PASW® STATISTIC). Data were described as a tabular and graphical representation of the means, standard deviations and percentiles.

To determine the interaction between carrier frequencies of 6000 Hz and 8000 Hz, in terms of stimulation (separate or combined), amplitudes were evaluated using analysis of variance (two-way ANOVA). The values were considered significant for $p \leq 0.05$.

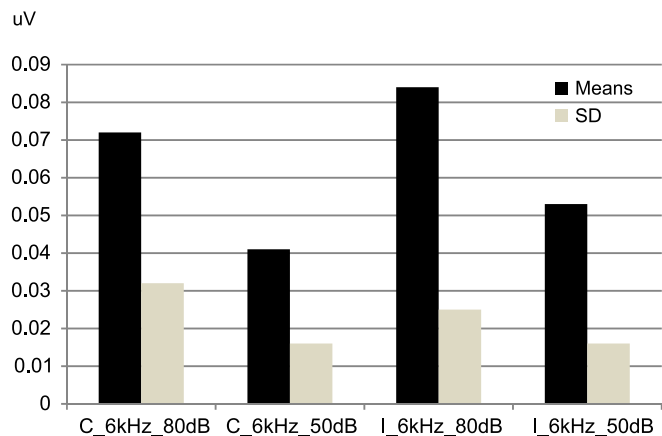
RESULTS

Ten patients (20 ears) of both sexes, aged 27.3 ± 2.26 years, were assessed. All the subjects exhibited ASSEP at the frequencies investigated.

The means and standard deviations of amplitudes by frequency, intensity and condition (separate or combined) are described in Figures 1 and 2. The relationship between

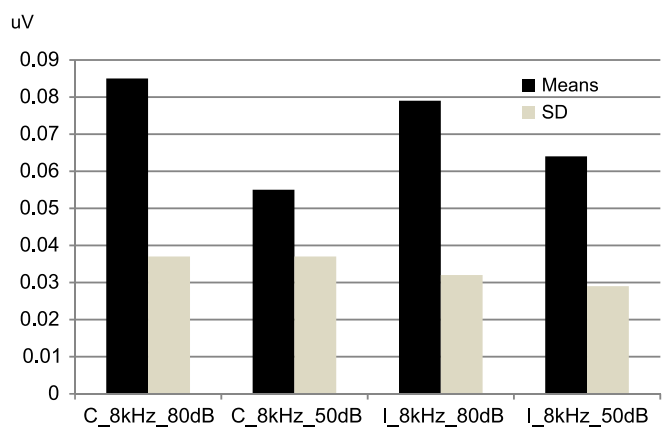
amplitudes by frequency, intensity and condition is demonstrated in Figure 3.

There was a slight difference in response amplitudes in relation to intensity and stimulation, but there were no significant effects or interactions involving the frequencies.



Subtitle: C = condition combined; I = condition isolated; SD = standard deviation

Figure 1. Means and standard deviation of amplitudes by intensity and condition (isolated or combined) at the frequency of 6000 Hz



Subtitle: C = condition combined; I = condition isolated; SD = standard deviation

Figure 2. Means and standard deviation of amplitudes by intensity and condition (isolated or combined) at the frequency of 8000 Hz

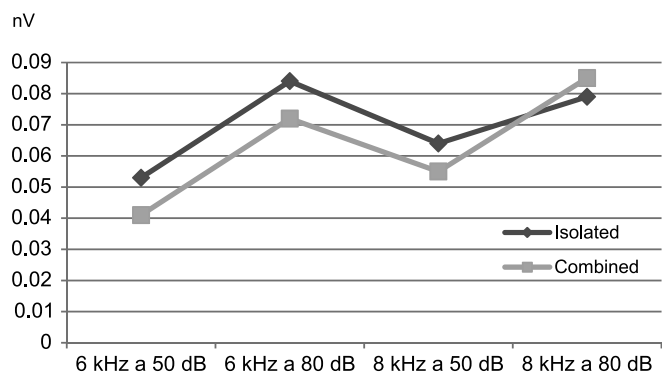


Figure 3. Ratio of amplitudes by frequency, intensity and condition

DISCUSSION

ASSEPs can be recorded separately (a single stimulus is presented to one or both ears) or in combination (two or more stimuli are presented to one or both ears). Although clinical data for the combined presentation are more limited^(8,9,10), they can potentially provide more information over a short period of time, thereby accelerating test time^(11,12,13). If there are no interactions between responses when several stimuli are presented, the time to obtain them is reduced by the number of stimuli presented simultaneously⁽¹⁴⁾. Even if there is a reduction in amplitude (interactions), combined, rather than separate presentation may still be more effective.

Authors report that ASSEP amplitudes are lower due to interactions and that more scans should be averaged to detect these responses^(13,14), which was not done in the present study. Despite the slight decline in amplitudes, when a combined presentation was used, there were no interactions (based on the ANOVA test) or increase in the number of scans.

Research has shown that combined presentation in adults does not cause a decrease in amplitude when the stimuli are presented at 60 dB NPS or lower, in one or both ears, provided that the carrier frequencies are separated by at least one octave^(11,12,15).

The present study demonstrated that it is not necessary to establish one octave between carrier frequencies to obtain ASSEPs, and that there is no statistical difference in response amplitude. However, some studies report that significant interactions occur between responses for 75-80 dB NPS, such that the amplitudes at the combined presentation decrease to 52-58 % when the stimulus is presented separately^(11,16,17). This was not observed in the present study, since the amplitudes remained unchanged, for both the separate and combined presentations.

The study of carrier frequencies of 6000 Hz and 8000 Hz was an innovative aspect for the national literature, since it demonstrated the viability of assessing frequencies, both separately and in combination, without the need to be separated by one octave. These measures are potentially interesting for a more detailed investigation of electrophysiological thresholds.

CONCLUSION

It was possible to assess carrier frequencies of 6000 Hz and 8000 Hz, both separately and in combination. There were no significant interactions between carrier frequencies of 6000 Hz and 8000 Hz for the sample studied, only a decline in amplitude when they were presented in combination.

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