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ORIGINAL PAPER

# INVESTIGATING CHANGES IN BRAINSTEM AUDITORY EVOKED POTENTIAL (BAEP) WAVES FOLLOWING ACUPUNCTURE AT SELECTED ACUPOINTS: A CROSS-SECTIONAL STUDY

**Ngoc Chi Lan NGUYEN[1], Thi Son NGUYEN[2], Diem Ai DUONG[1], Bao Duy NHAN[1], Minh Hoang LE[1]✉**

[1] Faculty of Traditional Medicine, Can Tho University of Medicine and Pharmacy, Can Tho city, Vietnam
[2] Faculty of Traditional Medicine, University of Medicine and Pharmacy at Ho Chi Minh City, Ho Chi Minh City, Vietnam

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## Abstract

**Introduction.** Although acupuncture is being used more frequently to treat auditory disorders, the neurophysiological mechanisms behind its effectiveness are still not fully understood. Brainstem Auditory Evoked Potentials (BAEP) offer a non-invasive, objective method to investigate the effects of acupuncture on the functional integrity of the auditory pathway.

**The objectives of this study** were to investigate and compare changes in BAEP parameters following acupuncture at five distinct acupoints, selected based on their anatomical location and their meridian associations with the ear.

**Materials and methods.** In this cross-sectional study, 150 healthy volunteers were randomized into five groups (n=30 per group). Each group received manual acupuncture at a single designated acupoint: Tinggong (SI-19), Wangu (SI-4), Yangchi (SJ-4), Qiuxu (GB-40), or Taixi (KI-3). BAEP wave latencies, interpeak latencies, and amplitudes were recorded pre- and post-intervention.

## Résumé

**Étude des modifications des ondes des potentiels évoqués auditifs du tronc cérébral (PEATC) après une séance d'acupunction à des points d'acupunction sélectionnés : une étude transversale**

**Introduction.** Bien que l'acupuncture soit de plus en plus utilisée pour traiter les troubles auditifs, les mécanismes neurophysiologiques sous-jacents à son efficacité restent encore mal compris. Les potentiels évoqués auditifs du tronc cérébral (PEATC) offrent une méthode non invasive et objective pour étudier les effets de l'acupuncture sur l'intégrité fonctionnelle de la voie auditive.

**L'objectif de cette étude** visait à examiner et comparer les modifications des paramètres des PEATC après une séance d'acupuncture sur cinq points d'acupuncture distincts, sélectionnés en fonction de leur localisation anatomique et de leurs associations avec les méridiens de l'oreille.

✉ Address for correspondence: Minh Hoang LE
Faculty of Traditional Medicine, Can Tho University of Medicine and Pharmacy, Can Tho, Vietnam
Address: 179 Nguyen Van Cu, Can Tho 900000, Vietnam
Email: lmhoang@ctump.edu.vn

**Results.** Within-group analysis revealed significant, acupoint-specific changes. Stimulation at Qiuxu (GB-40) significantly increased Wave I amplitude (p=0.035), while Taixi (KI-3) reduced I-III interpeak latency (p=0.043). Conversely, Wangu (SI-4) and Yangchi (SJ-4) significantly decreased Wave V and Wave III amplitudes, respectively (p=0.024 for both). However, between-group comparisons of these changes showed no statistically significant differences, suggesting that while acupuncture induced effects, a differential impact among the acupoints was not statistically confirmed.

**Conclusions.** Acupuncture induced specific, measurable neurophysiological changes in the auditory pathway. Although a statistically significant differential effect among acupoints was not confirmed, distinct modulatory patterns were observed, including opposing effects on wave amplitudes. These preliminary findings suggest unique neuromodulatory mechanisms that warrant further investigation to optimize acupuncture protocols for auditory disorders.

**Keywords:** acupuncture, acupoint, brainstem auditory evoked potentials, auditory.

**List of abbreviations:**
BAEP – Brainstem Auditory Evoked Potentials
TM – traditional medicine
IPL – interpeak latencies

**Matériel et méthodes.** Dans cette étude transversale, 150 volontaires sains ont été répartis aléatoirement en cinq groupes (n=30 par groupe). Chaque groupe a reçu une séance d'acupuncture manuelle sur un point d'acupuncture désigné: Tinggong (SI-19), Wangu (SI-4), Yangchi (SJ-4), Qiuxu (GB-40) ou Taixi (KI-3). Les latences des ondes, les latences inter-pics et les amplitudes des PEATC ont été enregistrées avant et après l'intervention.

**Résultats.** L'analyse intra-groupe a révélé des modifications significatives et spécifiques à chaque point d'acupuncture. La stimulation du point Qiuxu (GB-40) a augmenté significativement l'amplitude de l'onde I (p = 0,035), tandis que celle du point Taixi (KI-3) a réduit la latence inter-pics I-III (p = 0,043). À l'inverse, les points Wangu (SI-4) et Yangchi (SJ-4) ont diminué significativement les amplitudes des ondes V et III, respectivement (p = 0,024 pour les deux). Cependant, les comparaisons inter-groupes de ces modifications n'ont montré aucune différence statistiquement significative, suggérant que, bien que l'acupuncture ait induit des effets, un impact différentiel entre les points d'acupuncture n'a pas été statistiquement confirmé.

**Conclusions.** L'acupuncture a induit des modifications neurophysiologiques spécifiques et mesurables au niveau de la voie auditive. Bien qu'un effet différentiel statistiquement significatif entre les points d'acupuncture n'ait pas été confirmé, des profils de modulation distincts ont été observés, notamment des effets opposés sur les amplitudes des ondes. Ces résultats préliminaires suggèrent des mécanismes neuromodulateurs uniques qui justifient des recherches plus approfondies afin d'optimiser les protocoles d'acupuncture pour les troubles auditifs.

**Mots-clés:** acupuncture, point d'acupuncture, potentiels évoqués auditifs du tronc cérébral, auditif.

## Introduction

Acupuncture, a therapeutic modality with roots extending over two millennia in some Asia countries, is founded on the principle of modulating bodily functions through the stimulation of specific points on the skin with needles[1]. Traditionally, acupuncture's therapeutic effects are attributed to the stimulation of specific acupoints located along meridians—intricate pathways believed to conduct vital energy, thereby modulating the physiological state of both local tissues and distant organs. Building on centuries of empirical success, particularly in the realm of neurological and sensory disorders, the field of acupuncture is currently undergoing significant modernization on multiple fronts. This includes both the refinement of pedagogical methods, such as the development of vision-based learning systems to improve training accuracy, and a deeper scientific inquiry into its neurobiological underpinnings[2].

Moreover, clinical evidence shows that acupuncture can improve symptoms of certain neurological diseases[3–5]. A growing body of evidence from reviews and studies now corroborates that acupuncture can significantly modulate activity within the central and peripheral nervous systems. These effects are mediated through complex mechanisms, including the release of endogenous opioids, regulation of neurotransmitter levels, and the activation of specific brain regions involved in sensory processing[6–9]. However, despite this progress in both training and research, the precise mechanisms by which acupuncture

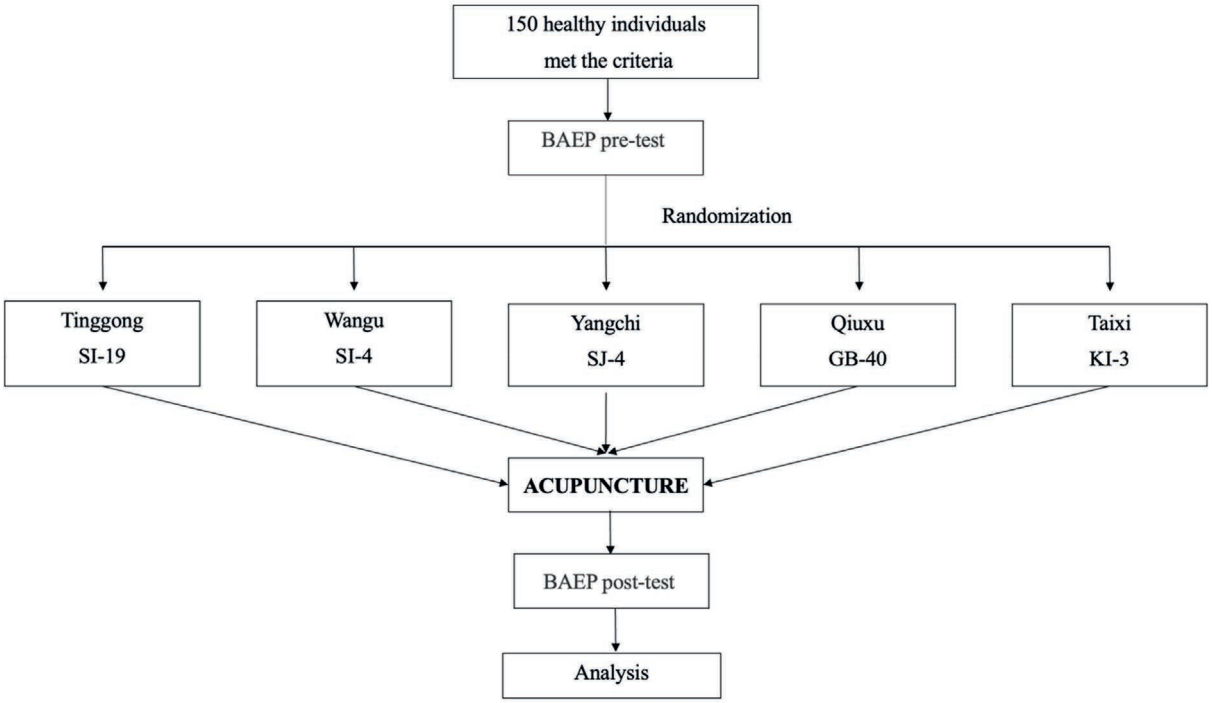



**Figure 1.** Study flow chart

influences distinct sensory pathways, such as the auditory system, remain to be fully characterized. This knowledge gap highlights the need for objective, physiological investigations to bridge traditional theories with modern evidence-based medicine.

Brainstem Auditory Evoked Potentials (BAEP) is a non-invasive and painless diagnostic method that assesses the integrity of the auditory pathway and brainstem transmission[10]. This technique is highly sensitive in detecting brainstem auditory nerve tumors and is widely used to differentiate various types of hearing impairment[11]. It offers several advantages, including ease of implementation, rapid and objective results, cost-effectiveness, and minimal dependence on patient cooperation[12,13]. BAEP is particularly valuable for determining hearing thresholds in non-cooperative patients, such as children, psychiatric patients, individuals feigning deafness, and comatose patients[12,14–16]. In addition, BAEP has been investigated as a useful prognostic tool for long-term neurological outcomes in patients after poor-grade subarachnoid hemorrhage[17].

Therefore, this study was designed to utilize BAEP to systematically investigate the immediate neurophysiological effects of acupuncture at distinct acupoints related to auditory function. This study presents a secondary analysis of a dataset from our previously published work in Vietnamese[18]. The primary publication provided a descriptive overview of the data, whereas the present analysis employs a comparative statistical approach to specifically investigate the differential effects among the five acupoints.

**The main objective of the study** was to determine whether acupuncture induces specific, quantifiable changes along the auditory pathway and to explore the potential correlation between these observed effects and the principles of traditional meridian theory.

## Material and methods

### Study design

The cross-sectional study was conducted over a six-month period, from January to June 2017, in the Department of Functional Examination, Can Tho University of Medicine and Pharmacy Hospital, Vietnam. A total of 150 participants were recruited for the study. The research protocol received ethical approval from the Ethics Council for Medical Research of the University of Medicine and Pharmacy in Ho Chi Minh City (approval No. 359/HDĐD-DHYD). The steps of the study are presented in Figure 1.

### Participants

Healthy volunteers were recruited for the study. All participants provided written informed consent after receiving a detailed explanation of the study's objectives and procedures.



**Figure 2.** Procedure for acupuncture at the Tinggong (SI-19) acupoint on a participant

The inclusion criteria were: (1) age between 18 and 30 years; (2) no self-reported hearing impairments or otological complaints; and (3) no use of medications or dietary supplements that could affect the central nervous system for at least one week prior to the study. The exclusion criteria were any abnormalities detected during the screening examination.

Prior to enrollment, all potential participants underwent a preliminary hearing assessment performed by a trained researcher. This assessment included a whisper test and the Rinne and Weber tuning fork tests to screen for hearing deficits or lateralization.

### Randomization and intervention

A total of 150 eligible participants were randomly allocated into one of five intervention groups (n=30 per group). Each group was assigned to receive acupuncture at a single, specific acupoint: Group 1: Tinggong (SI-19); Group 2: Wangu (SI-4); Group 3: Yangchi (SJ-4); Group 4: Qiuxu (GB-40); Group 5: Taixi (KI-3).

Acupuncture was performed by a qualified acupuncturist. Sterile, single-use stainless steel needles (0.30×25 mm) were used. Needles were inserted to the appropriate depth and angle as per traditional guidelines and manipulated to elicit the Deqi sensation (a sensation of soreness, numbness, or distension). Needles were retained in place for the duration of the second BAEP recording (approximately 5-7 minutes). The auditory stimulation consisted of sounds at an average hearing threshold, and its safety, as well as its lack of impact on health, has been well-documented in numerous prior studies. The procedure of acupuncture is illustrated in Figure 2.

### BAEP recording procedure

All BAEP recordings were conducted in a quiet, temperature-controlled room with participants seated comfortably. Surface Ag/AgCl electrodes were placed with the active electrode (+) at Cz and reference electrodes (-) at the ipsilateral (A1) and contralateral (A2) mastoids, maintaining skin impedance below 5 kΩ. Monaural stimulation was delivered via headphones using 0.1 ms clicks at 10 Hz, with an intensity of 40-90 dB nHL. The non-stimulated ear was masked with 40 dB white noise. Signals were amplified and filtered (bandpass 5-15 Hz). For each ear, responses to 2000 clicks were averaged, and the procedure was repeated twice to ensure waveform clarity. The resulting traces yielded five primary waves (I-V) for analysis.

### Outcome measures

The primary outcome measures, extracted from the BAEP waveforms before and during acupuncture, were:

- Absolute latencies of waves I, III, and V (ms).
- Interpeak latencies (IPLs) for the I-III, III-V, and I-V intervals (ms).
- Amplitudes of waves I, III, and V (μV), measured from the peak to the subsequent trough.

### Data analysis

Data were entered and managed using Microsoft Excel, and statistical analyses were conducted using JASP (version 0.19.2). The paired sample t-test was employed to compare mean values within related groups, while the ANOVA test was utilized to assess differences in mean values across the five independent groups. A p-value of less than 0.05 was considered significant.

**Table 1.** Baseline characteristics and BAEP parameters

| *Parameters* | *Tinggong (SI-19)* | *Wangu (SI-4)* | *Yangchi (SJ-4)* | *Qiuxu (GB-40)* | *Taixi (KI-3)* |
|---|---|---|---|---|---|
| Age (Median, IQR) | 23, 0.75 | 23, 1 | 22, 0.75 | 22, 1 | 22, 1.5 |
| Gender (Male/Female) | 15/15 | 15/15 | 15/15 | 15/15 | 15/15 |
| ***Latency (ms; mean ± SD)*** | | | | | |
| Wave I | 1.16 ± 0.54 | 0.74 ± 0.28 | 0.80 ± 0.37 | 1.43 ± 0.37 | 1.20 ± 0.58 |
| Wave III | 3.35 ± 0.60 | 3.60 ± 0.51 | 3.62 ± 0.50 | 3.27 ± 0.50 | 3.27 ± 0.75 |
| Wave V | 5.70 ± 0.96 | 6.12 ± 0.55 | 5.87 ± 0.65 | 5.23 ± 0.69 | 5.30 ± 0.79 |
| ***IPL (ms; mean ± SD)*** | | | | | |
| I-III | 2.35 ± 0.90 | 3.03 ± 0.55 | 2.92 ± 0.67 | 1.84 ± 0.43 | 2.18 ± 0.89 |
| III-V | 2.35 ± 2.77 | 7.75 ± 4.06 | 2.23 ± 0.46 | 1.96 ± 0.49 | 2.03 ± 0.53 |
| I-V | 4.70 ± 1.37 | 5.55 ± 0.64 | 12.90 ± 60.1 | 3.80 ± 0.69 | 4.20 ± 1.08 |
| ***Amplitude (μV; mean ± SD)*** | | | | | |
| Wave I | 0.067 ± 0.06 | 0.099 ± 0.07 | 0.089 ± 0.08 | 0.047 ± 0.03 | 0.08 ± 0.07 |
| Wave III | 0.041 ± 0.02 | 0.032 ± 0.02 | 0.046 ± 0.04 | 0.029 ± 0.02 | 0.04 ± 0.03 |
| Wave V | 0.038 ± 0.03 | 0.026 ± 0.02 | 0.036 ± 0.02 | 0.029 ± 0.12 | 0.03 ± 0.02 |

*All BAEP parameters represent the average of both ears.*

**Table 2.** Within-group comparison of BAEP parameters

| *Parameter (mean ± SD)* | *Pre-Intervention* | *Post-Intervention* | *p-value* |
|---|---|---|---|
| ***Wangu (SI-4)*** | | | |
| Amplitude Wave V (μV) | 0.033 ± 0.017 | 0.026 ± 0.02 | 0.024 |
| ***Yangchi (SJ-4)*** | | | |
| Amplitude Wave III (μV) | 0.046 ± 0.035 | 0.036 ± 0.021 | 0.024 |
| ***Qiuxu (GB-40)*** | | | |
| Amplitude Wave I (μV) | 0.047 ± 0.032 | 0.30 ± 0.08 | 0.035 |
| ***Taixi (KI-3)*** | | | |
| IPL I-III (ms) | 2.18 ± 0.89 | 2.16 ± 0.87 | 0.043 |

*Values are presented as mean ± standard deviation (SD). All BAEP parameters represent the average of both ears; p-values were calculated using the paired sample t-test.*

## Results

### Participant characteristics and baseline BAEP parameters

The baseline demographic and neurophysiological characteristics of the 150 participants, stratified by intervention group, are presented in Table 1. The study population consisted of young adults with a median age ranging from 22 to 23 years. Gender distribution was balanced evenly across all five groups, with each group comprising 15 males and 15 females. The table also details the initial mean values for the BAEP parameters, including absolute latencies, interpeak latencies (IPLs), and wave amplitudes, which serve as the baseline for subsequent post-intervention analysis.

### Within-group changes following acupuncture intervention

The within-group analysis of BAEP parameters before and after acupuncture revealed several statistically significant changes, as detailed in Table 2. Notably, the effects on wave amplitude varied considerably depending on the acupoint stimulated. For the Wangu (SI-4) and Yangchi (SJ-4) groups, a statistically significant decrease in the amplitude of Wave V (from 0.033 to 0.026 μV, p=0.024) and Wave III (from 0.046 to 0.036 μV, p=0.024) was observed, respectively.

In stark contrast, stimulation at Qiuxu (GB-40) resulted in a significant and substantial increase in the amplitude of Wave I, which rose from 0.047 to 0.30 μV (p=0.035). Furthermore, the Taixi (KI-3) group exhibited a significant, albeit modest, reduction in the I-III interpeak latency (IPL), decreasing from 2.18 to 2.16 ms (p=0.043), suggesting an acceleration of neural conduction in the early segment of the brainstem auditory pathway. No other parameters reached statistical significance for pre-post comparison within the groups.

**Table 3.** Between-group comparison of changes in BAEP parameters

| *Change in Parameter (mean ± SD)* | *Tinggong (SI-19)* | *Wangu (SI-4)* | *Yangchi (SJ-4)* | *Qiuxu (GB-40)* | *Taixi (KI-3)* | *p-value* |
|---|---|---|---|---|---|---|
| | | | *Δ Latency (ms)* | | | |
| ΔL – Wave I | 0.001± 0.55 | 0.034 ± 0.34 | 0.005 ± 0.48 | -0.007 ± 0.52 | -0.03 ± 0.28 | 0.91 |
| ΔL – Wave III | 0.058 ± 0.69 | -0.046 ± 0.70 | 0.065 ± 0.63 | -0.064 ± 0.61 | -0.04 ± 0.67 | 0.72 |
| ΔL – Wave V | -0.027 ± 0.87 | -0.138 ± 0.76 | 0.001 ± 0.70 | -0.049 ± 0.74 | 0.023 ± 0.63 | 0.80 |
| | | | *Δ IPL (ms)* | | | |
| ΔIPL – I-III | 0.014 ± 0.67 | -0.083 ± 0.64 | 0.043 ± 0.66 | -0.005 ± 0.53 | -0.02± 0.57 | 0.85 |
| ΔIPL – III-V | -0.08 ± 0.82 | -5.32 ± 40.56 | -0.05 ± 0.53 | 0.025 ± 0.66 | 0.055 ± 0.67 | 0.39 |
| ΔIPL – I-V | -0.07 ± 0.92 | -0.18 ± 0.75 | -7.77 ± 59.97 | -0.07 ± 0.78 | 0.038 + 0.73 | 0.42 |
| | | | *Δ Amplitude (μV)* | | | |
| ΔA – Wave I | -0.006 ± 0.03 | -0.016 ± 0.07 | 0.002 ± 0.08 | -0.01 ± 0.04 | -0.014 ± 0.08 | 0.59 |
| ΔA – Wave III | 0.0002 ± 0.03 | 0.004 ± 0.03 | -0.011 ± 0.04 | -0.003 ± 0.02 | -0.009 ± 0.03 | 0.09 |
| ΔA – Wave V | -0.005 ± 0.07 | -0.006 ± 0.03 | -0.002 ± 0.03 | 0.002 ± 0.02 | -0.006 ± 0.03 | 0.07 |

*Values are presented as mean ± standard deviation (SD). All BAEP parameters represent the average of both ears; p-values were calculated using the ANOVA test.*

### Between-group comparison of acupuncture-induced changes

The acupuncture-induced changes in BAEP parameters were compared between the five groups to investigate acupoint specificity, with the results presented in Table 3. An analysis of variance (ANOVA) indicated that there were no statistically significant differences in the mean change for any absolute latency (Wave I, III, V) or interpeak latency (I-III, III-V, I-V) parameter across the five acupoint groups (all $p > 0.3$).

Similarly, for changes in wave amplitudes, the differences among the five groups did not reach statistical significance. It is worth noting, however, that the comparisons for the change in amplitude of Wave III ($p = 0.09$) and Wave V ($p = 0.07$) approached the threshold for significance, suggesting a potential, albeit non-significant, trend. Overall, the data do not provide statistical evidence to support a differential effect among the tested acupoints on the auditory pathway.

## Discussion

This study provides preliminary neurophysiological evidence that acupuncture induces specific, measurable modulations within the human auditory pathway. The principal finding is that the observed effects were highly acupoint-specific, a specificity that appears to align with both anatomical principles and traditional meridian theory, thus offering a potential bridge between these two paradigms.

Our results suggest differentiated mechanisms of action based on acupoint location and meridian association. A key finding was the opposing effect on wave amplitudes. Stimulation at distal upper limb points, Wangu (SI-4) and Yangchi (SJ-4), led to a statistically significant decrease in the amplitudes of central waves V and III, respectively. Wave V reflects activity in the inferior colliculus (midbrain) and Wave III in the superior olivary complex (pons). This reduction in amplitude may be interpreted as a central neuromodulatory or inhibitory effect, potentially downregulating neural hyperexcitability and restoring homeostatic balance within the brainstem. This interpretation is consistent with acupuncture's role in regulating central nervous system activity, as observed in studies on conditions like primary depression, where BAEP wave latencies were also shown to be modulated by acupuncture[19,20]. In stark contrast, stimulation at Qiuxu (GB-40), a distal point on the lower limb, produced a significant and substantial increase in the amplitude of Wave I. Wave I represents the synchronous firing of the auditory nerve, and its enhancement suggests an improved peripheral neural response. While Wave I amplitude is known for its variability, the six-fold increase observed here is statistically significant and likely represents a true physiological effect. This indicates that GB-40 may primarily act by augmenting the peripheral signal, a distinct mechanism from the central modulation observed with the upper limb points.

Furthermore, stimulation at Taixi (KI-3) resulted in a significant reduction of the I-III interpeak latency (IPL). This shortening of the conduction time from the cochlear nerve to the pons provides direct evidence of enhanced neural transmission efficiency in the early stages of the auditory pathway. As the primary original-source point of the Kidney meridian, KI-3 is traditionally used for auditory disorders linked to Kidney essence deficiency. This finding

offers a remarkable neurophysiological correlate to the fundamental TCM principle that "the Kidney opens into the ears," suggesting that stimulation at this point strengthens the foundational integrity of the auditory pathway[21].

The capacity for acupuncture to influence neural activity at these different levels may be linked to its documented effects on neurogenesis and nerve repair mechanisms, which could contribute to enhancing both peripheral and central neural integrity[7,22]. Overall, the observed modulations align with established theories on acupuncture's broad effects on the nervous system, which involve the activation of sensory nerves that trigger complex responses throughout the central and autonomic nervous systems[23].

This study's findings must be interpreted within its limitations. The investigation was conducted on a healthy cohort, and the observed acute effects—particularly the decrease in amplitude—may have different implications in clinical populations with pre-existing auditory deficits. Furthermore, the absence of a sham acupuncture control group, a common challenge in acupuncture research, means a potential placebo effect cannot be entirely ruled out.

## Conclusions

This investigation provides preliminary evidence that acupuncture can induce immediate and measurable neurophysiological changes within the auditory pathway. The effects observed were complex and varied by acupoint. Specifically, stimulation at Taixi (KI-3) was associated with an acceleration of peripheral-to-central neural conduction (reduced I-III IPL), while Qiuxu (GB-40) was linked to an enhanced peripheral signal (increased Wave I amplitude). In contrast, stimulation at upper limb points Wangu (SI-4) and Yangchi (SJ-4) resulted in a significant reduction in the amplitude of central brainstem waves. While a direct statistical comparison between the groups did not confirm a differential effect, these distinct patterns of modulation suggest that different acupoints may engage unique neuromodulatory mechanisms. These findings offer a potential neurophysiological basis for the principles of acupoint selection in Traditional Medicine and support the rationale for designing targeted acupuncture protocols. Further research, particularly in clinical populations with auditory disorders, is warranted to validate these observations and explore their therapeutic implications.

### Author Contributions:

*Conceptualization, N.C.L.N and M.H.L; methodology, N.C.L.N, T.S.N; investigation, N.C.L.N, B.D.N, D.A.D; data curation, D.A.D and M.H.L; writing–original draft preparation, M.H.L., N.C.L.N, D.A.D.; writing–review and editing, N.C.L.N, B.D.N, D.A.D.; supervision, T.S.N.*

*All the authors have read and agreed with the final version of the article.*

### Compliance with Ethics Requirements:

*"The authors declare no conflict of interest regarding this article"*

*"The authors declare that all the procedures and experiments of this study respect the ethical*

*standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law.*

*Informed consent was obtained from all the patients included in the study"*

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