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Original Article

A Non-invasive Method to Assess Tensor Tympani Muscle Contraction in Response to Tactile Stimulation

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BACKGROUND: The function of the tensor tympani muscle and its effects, as well as a universal testing procedure, is not yet known. The purpose of this study is to investigate the effect of tactile stimulation on the tensor tympani muscle activity in an attempt to evaluate the functional status of the muscle.

METHODS: In this study, 20 healthy adults aged between 18 and 30 years were included. All participants had their history taken, as well as the evaluation of otoscopy, audiometry, and tympanometry. A modified reflex decay paradigm was used to evaluate the tensor tympani muscle activity, in both humans and a fresh-frozen cadaver. The tactile stimulation was applied by thumb tappings on different forehead areas.

RESULTS: Reflex decay responses were in the form of the absence of a response or either a positive or negative waveform. Tactile stimulation had no impact on reflex decay recordings obtained from the cadaver. There was no significant difference between the waveforms obtained from both ears, at different stimulation frequencies, tactile stimulation areas, or the 3 successive stimuli for 1 individual in 1 ear ($P > .05$). Changes observed in the reflex decay test upon tactile stimulation seem to be due to tensor tympani muscle activity as supported by the previous findings in the literature.

CONCLUSION: The application of a tactile stimulus on the forehead is a non-invasive test method to assess tensor tympani muscle contraction. Understanding the function of the tensor tympani muscle using a non-invasive method will be helpful during the decision-making process in the practice of otology.

KEYWORDS: Acoustic reflex decay, tactile stimulus, tensor tympani

INTRODUCTION

Tensor tympani (TT) muscle is approximately 25 mm in length with a surface area of 6 mm^2. The TT is a striated muscle innervated by the mandibular branch of the trigeminal nerve. The muscle attaches to the greater wing of the sphenoid connecting to the bony and cartilaginous eustachian tube. It inserts onto the malleus neck in the middle ear after exiting from the cochleariform process. Contraction of this muscle opens the eustachian tube and pulls the malleus anteromedially, thereby reducing the range of movement of the tympanic membrane by increasing its stiffness while also decreasing the propagation of sound throughout the ossicular chain.[1]

Both TT and stapedius muscles are involved in the acoustic reflex to protect the inner ear. Although the TT muscle is thought to decrease the intensity of sounds entering the middle ear, especially during mouth movements such as eating, chewing, or speaking, its effects on hearing are not fully understood.[2] Although TT spasm or myoclonus can be associated with some otologic disorders like tinnitus, aural fullness, and eustachian tube dysfunction, there is no unique test to evaluate the function of TT.

A saw-tooth-like pattern in long-term tympanometry can represent tympanic membrane movements which can support TT spasms.[3] In some cases, movement of the tympanic membrane may be observed via otomicroscopy during symptomatic muscle

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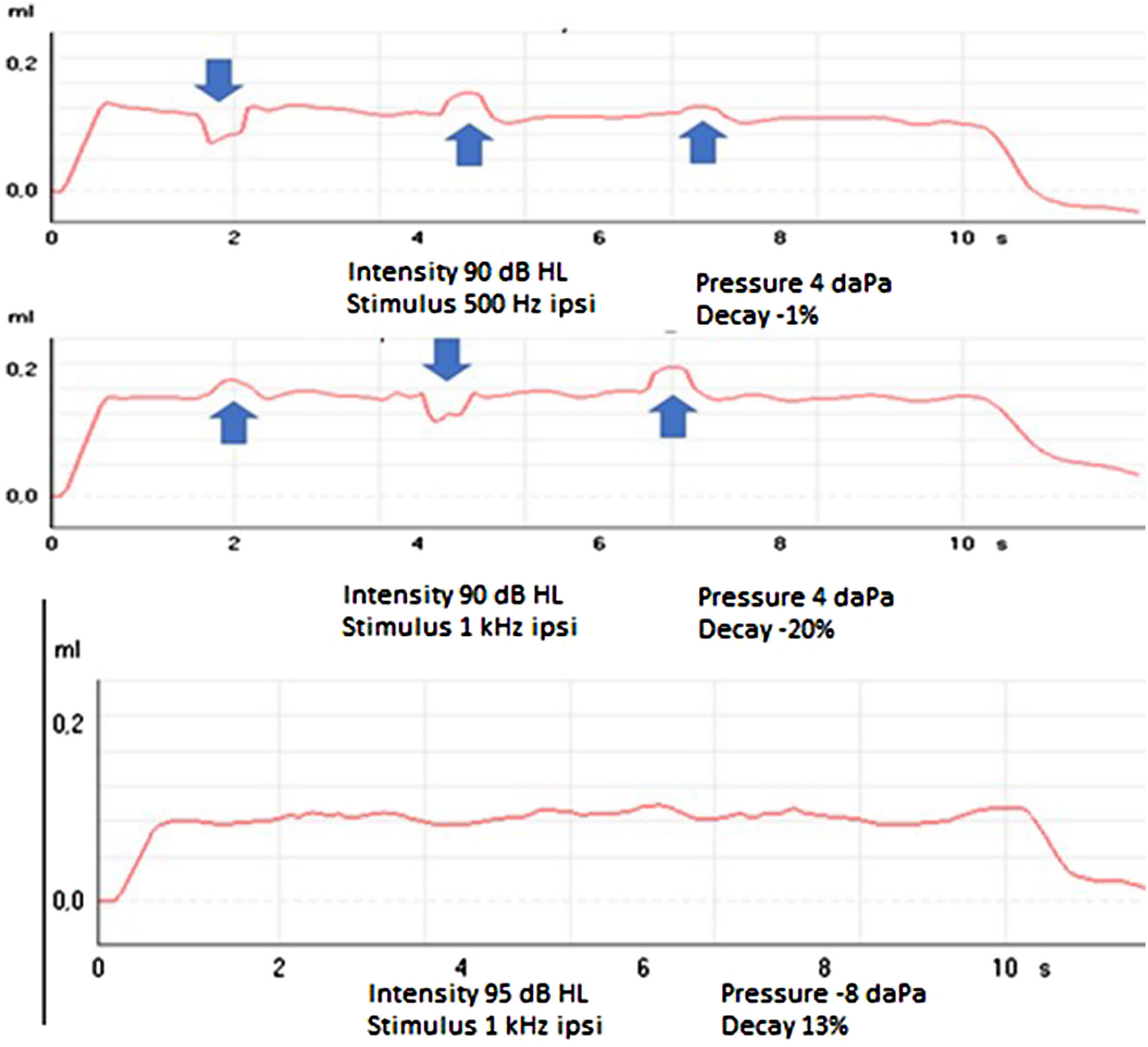

Figure 1. Positive and negative waveforms recorded after tactile stimulation over the right eyebrow at frequencies of 500 and 1000 Hz on reflex decay testing in a subject.

contractions. In other cases, a presumed diagnosis of middle ear myoclonus is based purely on patient history.[4] Markers of a contracted TT include a decrease in peak static compliance, negative middle ear pressure, asymmetry in the tympanometry curve during a pressure sweep from positive to negative pressure reversal of the positive deflection on modified reflex decay testing, a lower-frequency conductive hearing loss with a possible smaller lower-frequency sensorineural hearing loss component, or mixed lower-frequency sensorineural hearing loss.[5,6]

A tactile stimulus applied to the face may lead to an activity in the trigeminal nerve, as well as its mandibular branch, which innervates the TT muscle. Reflexive contraction of the TT muscle has been reported to be elicited by tactile stimulation of facial areas. At the same time as the said tactile stimulus, a modified acoustic reflex decay, which keeps the stapedius muscle contracted, can be performed. This may help to record the changes in the middle ear mechanics via tympanometry, which may reflect TT muscle activity.[6]

In this study, we aimed to investigate the effect of a tactile stimulation applied on the forehead by thumb tappings on TT muscle activation in an attempt to evaluate the function of the muscle.

MATERIALS AND METHODS

In this study, 20 healthy adults (16 females and 4 men) aged between 18 and 30 (22 $\pm$ 2) years were included. All participants had their history taken, as well as an evaluation of otoscopy. Pure tone and speech audiometry, as well as tympanometry, were performed to exclude any otologic problem. Impedance audiometry was performed to evaluate the middle ear compliance using static

tympanometry. A modified reflex decay paradigm, which allowed the measurement of acoustic admittance changes during a 10-second window, was conducted to evaluate TT muscle activity as described previously.[5,6]

The same researcher tapped their thumb on the target areas on the forehead to elicit the tactile stimulation. The tactile stimuli were applied twice on each of the 3 forehead areas, which were over right and left eyebrows and in the midline. Meanwhile, the acoustic reflex decay test was performed recording at 4 different frequencies, which were 500, 1000, 2000, and 4000 Hz. These procedures were repeated for both ears separately. The tactile stimulus was applied successively to each target area 3 times to evaluate the reproducibility of the recordings.

In an attempt to replicate live human studies with comparable conditions, 1 fresh-frozen cadaver was used to compare the tympanometric changes observed in living individuals.[5,6] The static tympanometry was performed during tappings on the forehead areas in an attempt to understand whether they would lead to artifacts or have a significant impact on recordings. We presumed that the vibrations on the bone conduction caused by the tappings may be the cause of the positive/negative deflections. To rule out this effect, we performed the same measurements on a fresh-frozen cadaver and observed if there are any possible positive/negative deflections on the baseline.

An ethical committee approval was obtained from the Clinical Research Ethics Committee of Istanbul Medipol University (October 10, 2019/708). Before testing, written informed consent was obtained from all participants. The study was conducted according to the guidelines of the Helsinki Declaration.

Statistical Analysis

The data were analyzed using Statistical Package for the Social Sciences version 20.0 for Windows (IBM SPSS Corp.; Armonk, NY, USA), and the chi-square test was applied. The reflex decay changes recorded in different stimulation areas, different frequencies, and both ears were compared.

RESULTS

All subjects had normal otoscopy, normal acoustic reflex responses, and type A tympanograms, and they had pure tone average scores better than 15 dB HL. In total, 1440 tactile stimuli were applied to 3 different stimulation areas on the forehead at 4 different test frequencies on both ears. The reflex decay responses were in the form of absence of a response or either a positive or negative waveform.

There was no impact of knocking on the forehead on the recordings of reflex decays either as positive or negative amplitudes as seen in the recordings obtained in the cadaver. The effects of all 3 tapping locations have been evaluated. The results originating from the tappings above the right eyebrow have been shown (Figure 1 and Figure 2). Furthermore, from our findings, we can also see that tappings on the forehead do not cause changes in the tympanometric measurements caused by propagated sound.

A positive or negative waveform was indicative of TT muscle contraction.[5] There was no significant difference between the waveforms obtained in both ears, at different stimulation frequencies and different forehead areas, and for the 3 successive stimuli for 1 individual at 1 ear ($P > .05$) (Figure 3). Overall, there were 812 (56.4%) positive and 549 (38.1%) negative waveforms, whereas no response was obtained in 79 (5.5%). Thus, either a positive or negative waveform indicative of TT contraction could be obtained in 94.5% of the subjects (Figure 4).

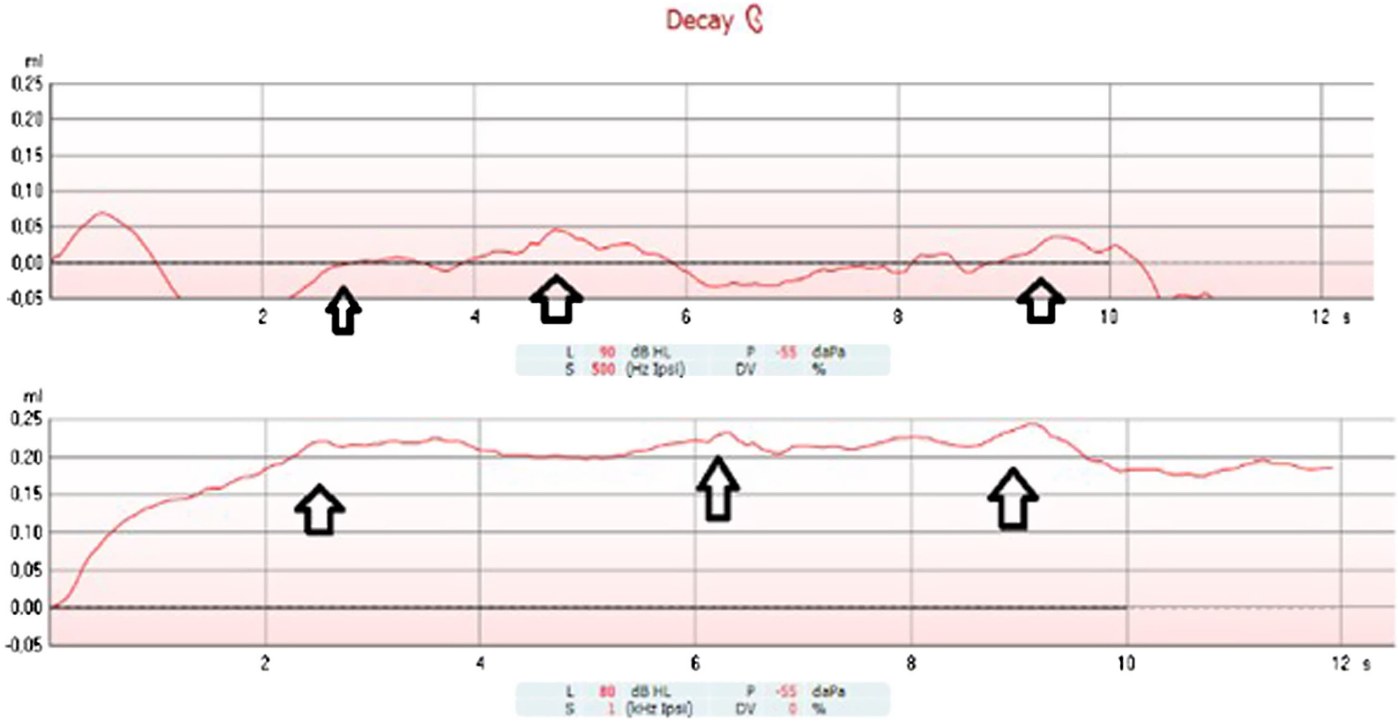

Figure 2. Positive and negative wave fluctuations after tactile stimulation over the right eyebrow at frequencies of 500 and 1000 Hz on reflex decay testing in a cadaver.

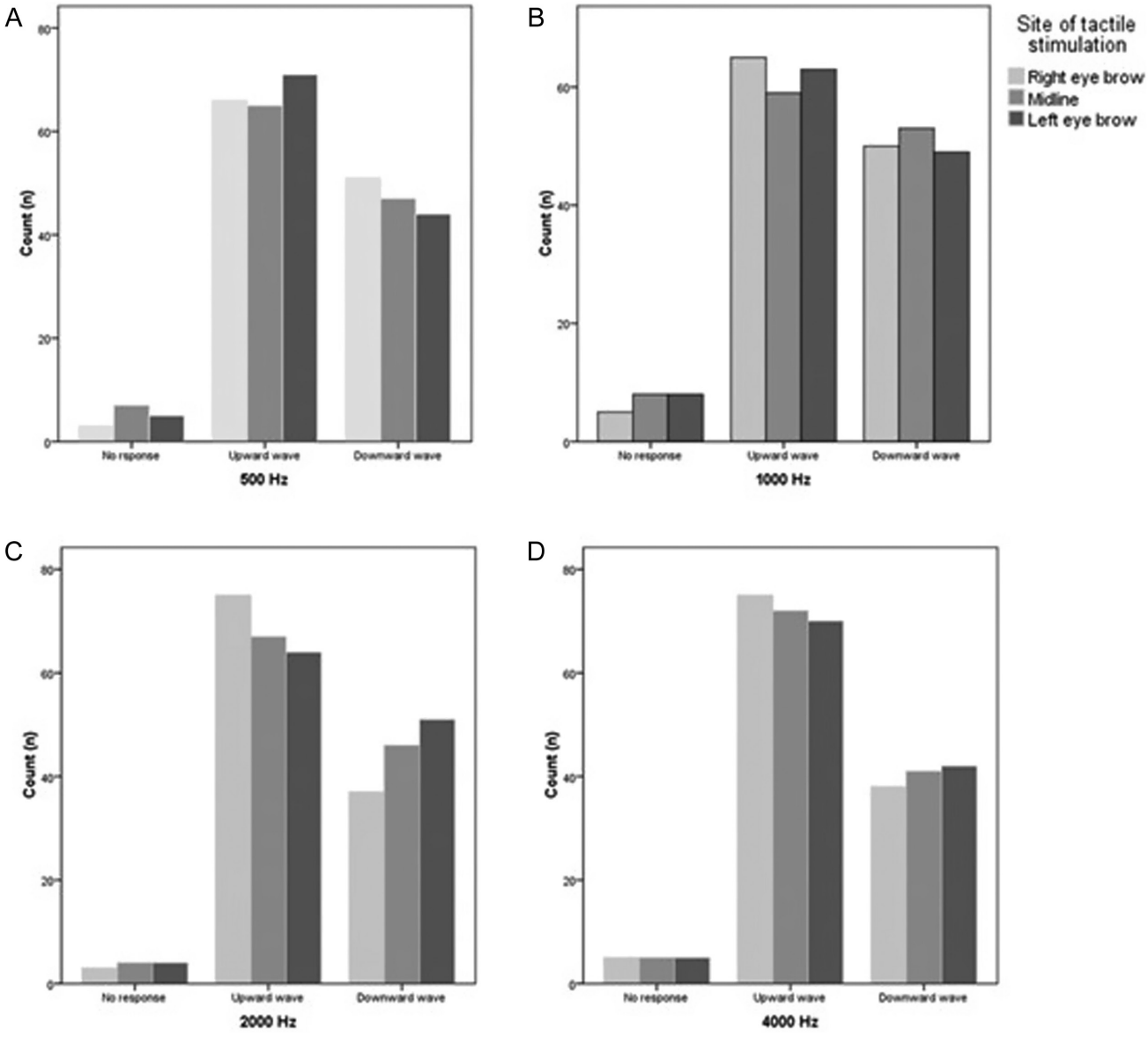

Figure 3. Waveforms obtained in reflex decay tests at (A) 500 Hz, (B) 1000 Hz, (C) 2000 Hz, and (D) 4000 Hz ($P > .05$).

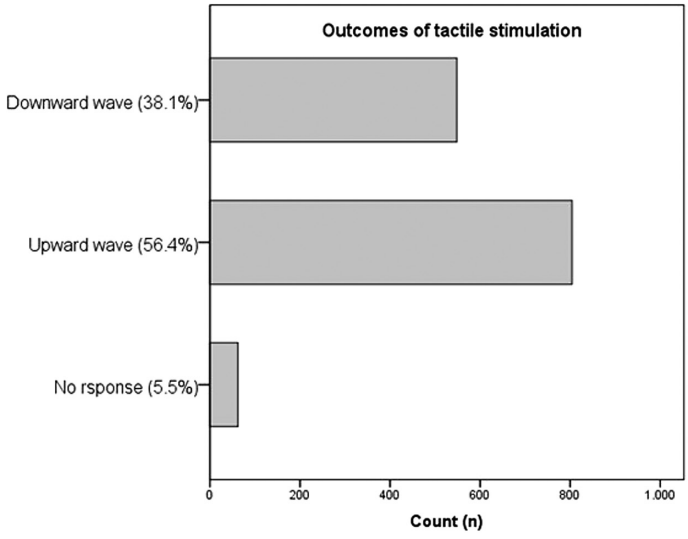

Figure 4. Overall waveforms obtained in the reflex decay test ($P > .05$).

DISCUSSION

Although studies on TT muscle date back to the beginning of the 20th century, clear findings regarding the function of this muscle have not yet been revealed. In some studies, during the presentation of an acoustic stimulus to both ears, the activity of the TT muscle was recorded by electromyography (EMG), and it was observed that the TT showed minimal electrical activity in response to sound.[7-9] In subjects with sectioned stapedius muscle as a result of stapes surgery, acoustic reflexes could not be obtained.[10] These findings support the contention that the TT response to acoustic stimuli is ignorable or acoustic stimuli may not play a role in the TT reflex.

In a study performed to evaluate the TT muscle reflex contraction in response to a touch stimulus to the cornea, head movements or closing of the eyes caused a number of artifacts on recordings.[8] In another study aiming to show the contraction of TT muscle in response to electrical stimulation to the tongue, an outward movement of the tympanic membrane with positive waveforms was observed with

immitansmetry, while negative waveform recordings are thought to be due to a tympanic membrane movement in the reverse direction.[11] Similar studies were performed on the patients with facial paralysis to eliminate the stapedius muscle responses while testing the TT muscle activity.[6,12,13]

Electromyography in conjunction with immitansmetry can be used to test TT muscle activity. However, the EMG needles can be misplaced on the tendon of the muscle rather than the abdomen muscle. The other drawback can be the invasiveness of this method.[14] Therefore, a non-invasive and reliable method is needed to test the TT muscle activity. At this point, the utilization of a tactile stimulus can be promising.

It is claimed that the reflex contractions of the TT muscle occur as a result of tactile stimuli to the facial region, electrical stimulation to the tongue, blowing air to the eye, swallowing, and muscle activities in the face and neck, as well as during speech.[11,14-16] In our study, the tactile stimulus elicited with thumb tappings while performing a reflex decay test led to reproducible recordings of TT muscle contractions in almost 95% of the subjects. It is also evident that the responses obtained are independent of the stimulation area on the forehead.

The reflex decay test was also used in some of the previous studies to assess the TT activity, and similar direction changes in the waveforms were observed just like in our study. The difference was in the stimulation applied. A stimulation by blowing into the eye leads to downward (negative), upward (positive), and no response in a range of 57%-65%, 23%-30%, and 5%-17% of the subjects, respectively,[6,17] which are comparable with our results.

The association between upward and downward waveforms with impedance changes is unclear. We would expect purely positive or negative reflex decay curves rather than their combination. However, these positive and negative changes might have occurred due to contraction and relaxation characteristics of the TT muscle upon stimulation. This raises the question of whether TT muscle acts in the form of 2 different functional units as 1 portion relaxes while the other portion contracts in response to stimuli. The second takeaway might be that the TT muscle may be contracting intermittently.

CONCLUSION

In conclusion, the changes observed in the reflex decay test upon tactile stimulation seem to be due to TT muscle activity as supported by the previous findings in the literature. The application of a tactile stimulus on the forehead is a non-invasive test method to assess TT muscle contraction. Understanding the function of TT muscle using a non-invasive method will be helpful in decision-making in the practice of otology.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Istanbul Medipol University (October 10, 2019/708).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

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