Effects of Tinnitus on Posture: A Study of Electrical Tinnitus Suppression

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Abstract: We investigated the effects of tinnitus on postural responses using posturography. Thirty-three tinnitus patients (19 female and 14 male) ranging in age from 33 to 67 years (mean age, 53) were selected randomly at our outpatient clinic. Nobody complained of dizziness. Posturographic examination was given before and after 30-minute electrical stimulation. Items tested were envelope area, area (root mean square), total length, total length-area, mean amplitude of lateral body sway (*mx*), and anteroposterior sway (*my*). Those parameters did not improve in patients without tinnitus relief. Two postural measures (envelope area and *mx*) showed significant improvement in patients with tinnitus relief. These effects appeared only on positions involving restricted visual feedback. In a comparison of postural measures in patients with and without tinnitus relief, all parameters except total length and *mx* improved significantly in patients with eyes open. Our study showed that aside from the auditory system, tinnitus can affect balance, implying that tinnitus may be a factor in increasing unsteadiness in patients with tinnitus.

Keywords: body sway, electrical stimulation, posturography, tinnitus

Although we often speak of tinnitus as if it were a single entity, tinnitus consists of sensory and affect components [1]. Affects of tinnitus include insomnia, annoyance, anxiety, and interference in communication capability [2]. Tinnitus relief was obtained after electrical stimulation of the ear [3–5], and we investigated affects of tinnitus [6–9]. Although few reports address the balance system in which tinnitus provokes affect [10], we were interested in the effects of tinnitus on the balance system. We focused on movements in several parts of the body to analyze dynamic equilibrium [11]. Patients with dizziness tend to resist moving their heads because of malfunction of the peripheral vestibular organ, suggesting that head movement during locomotion may be one indicator that shows vestibular disorders.

Our previous study showed that without perceiving it, tinnitus patients suffered from disturbance in head movement during stepping [12]. Tinnitus relief after electrical stimulation [13] and occipital nerve block by lidocaine (Xylocaine) injection to the tender area [14] caused improvement in head movement during stepping. The positive relationships between tinnitus and disturbance in dynamic balance may produce susceptibility to dizziness in tinnitus patients. Abnormal head movement during stepping in such patients may give aberrant information about prior dysfunction of the peripheral vestibular system.

Regarding the background of dizziness, ascertaining effects of tinnitus on balance is very important. The objective assessment of the functional aspects of static balance by modern posturography has been well established. To support the relationship between tinnitus and imbalance, assessing the effects of tinnitus on static balance is becoming increasingly important for patients with dizziness and tinnitus. The aim of our study is to show positive relationships between tinnitus and imbalance by using posturography.

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SUBJECTS AND METHODS

Thirty-three tinnitus patients (19 female and 14 male), ages 33–67 years, (mean age, 53 years) were selected randomly at our outpatient clinic for a study of relationships between body sway and tinnitus relief. Patients exhibited no dizziness. All patients had hearing loss of various degrees in the ears in which they experienced tinnitus. The etiologies of hearing loss were sudden deafness (n = 3), chronic otitis media (n = 1) and unknown other causes. Three patients had suffered from head trauma.

Patients were asked to stand on a platform (IG06, San-Ei) with their feet close together. The output from the platform was stored simultaneously in a data recorder (TEAC MR30). For analysis of the output of a platform, the sampling time interval was 10 msec. Measurements were obtained under the condition of gazing at a red circle 1 cm in diameter and 3 m ahead when eyes were opened. Recording time was 60 seconds each (eyes closed and eyes open). Parameters on posturographic study included envelope area, area (root mean square), total length, total length-area, mean amplitude of right-left body sway (*mx*) and anteroposterior sway (*my*). Statistical analysis was performed using the Mann-Whitney *U*-test.

ELECTRICAL TREATMENT

Tinnitus was treated with electrical stimulation. We used three stimulation methods. The most popular method was external stimulation. Two plate electrodes for electrocardiography (ECG) were attached to the skin at the tragus and behind the ear. The intensity of electrical stimulation was approximately 200 μA. The duration of stimulation was 30 minutes. Twelve patients underwent this method.

In three patients, a steel needle with a diameter of 250 μm along its length was placed on the promontory through the ear drum after local anesthesia with iontophoresis. The stimulation intensity level was fixed at approximately 100 μA, and the duration of stimulation was 30 minutes. A return electrode—a plate electrode for recording the electrocardiogram—was attached to the postauricular skin.

Electrical stimulation was supplied by an oscillator and a current amplifier. We used a 10-kHz frequency modulated at 100 Hz in the form of charge-balanced sinusoidal waves. The wire was connected to a stainless steel lead wire attached to an electromagnetic coupling system. In eight patients, negative DC of 0.5 mA was delivered through Xylocaine in the external ear canal for 20 minutes.

RESULTS

For normalization, the ratio of values after treatment versus before standard was compared. Table 1 shows mean value and standard deviation of postural measures before and after electrical treatment in patients who experienced tinnitus relief. In comparing this ratio, we found significant improvement in envelope area and mean amplitude of lateral position (*mx*) with eyes closed in patients who had tinnitus relief. However, no significant improvement in the ratio of each item was observed in patients tested with eyes open.

Table 2 shows mean value and standard deviation of postural measures after treatment versus before electrical treatment in patients who had no tinnitus relief. No significant improvement in the ratio of such parameters was observed in patients when tinnitus was not relieved. A comparison of the ratio of such parameters as envelope area, area (root mean square), total length, total length-area, and mean amplitude of x and y between patients who had tinnitus relief and those who had no tinnitus relief revealed that the ratio of all parameters except for total length, mean amplitude of x (*mx*) with eyes open, and mean amplitude of y (*my*) with eyes

Table 1. Summary of Body Sway in Patients Experiencing Tinnitus Relief

	Total Length		Length-Area		Envelope Area		Area (rms)		Amplitude of x		Amplitude of y	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Eyes open												
Before	78.60	29.86	18.42	9.10	5.80	4.30	2.95	2.11	3.05	1.46	3.76	1.39
After	67.77	23.42	20.33	9.57	3.89	2.70	2.17	1.66	2.56	1.07	2.56	1.07
Probability	NS		NS		NS		NS		NS		NS	
Eyes closed												
Before	124.07	46.91	17.39	7.78	10.51	10.18	4.38	4.27	4.42	1.88	4.54	2.14
After	103.69	41.48	21.21	7.62	5.90	4.80	3.03	2.83	3.00	1.12	3.78	1.59
Probability	NS		NS		$p = .0098$		NS		$p = .0044$		NS	

rms = root mean square; x =right-left sway; y = antero-posterior sway; NS = not significant ($p > .05$).
Note. Values are the mean and standard deviation of postural measures before and after electrical treatment in patients with tinnitus relief

Table 2. Summary of Body Sway in Patients Without Tinnitus Relief

	Total Length		Length-Area		Envelope Area		Area (rms)		Amplitude of *x*		Amplitude of *y*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Eyes open												
Before	67.77	21.39	23.13	10.40	3.30	1.60	1.90	1.37	2.58	0.71	2.79	1.14
After	68.95	20.03	21.23	9.51	3.59	2.11	2.21	1.69	2.24	0.52	2.95	1.20
Probability	NS		NS		NS		NS		NS		NS	
Eyes closed												
Before	109.31	38.70	19.03	8.26	6.38	4.34	2.74	1.47	3.13	0.94	3.75	1.45
After	108.57	40.08	19.88	9.89	6.34	4.02	2.78	1.62	3.20	0.96	3.67	1.52
Probability	NS		NS		NS		NS		NS		NS	

rms = root mean square; NS = ($p > .05$).
Note. No significant improvement in body sway was observed in patients without tinnitus relief after stimulation.
Values are the mean and standard deviation of postural measures before and after electrical treatment in patients without tinnitus relief

closed improved in patients with tinnitus relief, as shown in Table 3.

Significant improvement in the ratio of envelope area with eyes closed was observed in patients who had tinnitus relief. To know which parameters affected improvement in envelope area, mean amplitude of *x* and *y* and total length in patients with eyes closed were compared. Table 4 shows the correlation among these values and demonstrates that improved area of body away with tinnitus relief was affected by decreased amplitude of *x* ($p = .0003$) and *y* ($p = .0001$) after electrical stimulation. Envelope area, however, was not related to total length ($p = .8666$). Total length was not affected by mean amplitude of *x* ($p = .8265$) and *y* ($p = .8775$). A positive correlation ($r = .576$, $p = .0123$) between the ratio of the mean amplitude of *x* and *y* was seen in patients with tinnitus relief with eyes closed. No correlation between the mean amplitude of *y* and envelope area, however, was observed even in patients who had tinnitus relief with eyes open, as shown in Table 4. Table 4 shows a positive correlation between the mean amplitude of *x* and area in patients who had tinnitus relief with eyes open.

Table 3. Statistics Separating Patients Experiencing Tinnitus Relief and Without Tinnitus Relief

	Eyes (*p* value)	
Test paramenters	**Open**	**Closed**
Area	.042	.0019
Area (rms)	.0027	.0359
Total length	.0798*	.0159
Length-area	.0192	.0302
Mx	.5876*	.0009
My	.0017	.2472*

* $p > .05$.
Note: For statistical analysis, ratio (values after treatment and before treatment) for each parameter were compared between patients who had relief and those who had no tinnitus relief. Probability less than .05 shows that each parameter improved in patients who had tinnitus relief after treatment.
rms = root mean square; *mx* = mean amplitude of right-left sway; *my* = mean amplitude of forward-backward sway.

DISCUSSION

The posturographic study showed a positive relationship between tinnitus relief and improvement in balance, as demonstrated in the previous study using assessment of head movement. Envelope area with eyes closed was most sensitive to improvement in static balance with tinnitus relief. Significant effects of tinnitus relief on static balance appeared only when subjects were under restricted visual feedback. This finding was in accordance with a study of effects of fatigue and stress, showing that significant differences appeared only when subjects were under the same conditions (i.e., simultaneously restricted somatosensory and visual feedback) [15]. A comparison of postural measures between patients who did and did not have tinnitus relief revealed that all parameters except total length of body sway and mean amplitude of lateral sway (*mx*) improved, even in positions involving no visual feed-

Table 4. Relationships Among Mean Amplitude of Right-Left and Antero-Posterior Sway, Total Length, and Envelope Area in Patients Experiencing Tinnitus Relief

	Eyes (*R* value)	
	Closed	**Open**
Area		
mx	.752 $p = .003$	.787 $p = .0001$
my	.833 $p = .0001$	.428 $p = .0764$*
Total length	.043 $p = .866$*	.420 $p = .0829$*
Total length		
mx	.056 $p = .8265$*	.324 $p = .1899$*
my	.039 $p = .8775$*	.079 $p = .7561$*

mx = mean amplitude of right-left sway; *my* = forward-backward sway.
* = $p > .05$.

back. This finding showed that balance in tinnitus patients may be more disturbed than that in patients without tinnitus. Therefore, we should pay more attention to disturbance in balance as an affect of tinnitus.

Although the three main postural control mechanisms (visual, somatosensory, and vestibular) could attribute to improvement in balance, a study based on the power of sway frequencies showed that the vestibular mechanism was affected most by fatigue. Because in the present study the power of sway frequencies was calculated according to international rules, frequencies were divided into three ranges: –0.2 Hz, 0.2–2 Hz, and 2–10 Hz [16]. Therefore, we could not conclude that postural sway was susceptible to vestibular involvement in our new study. Emotional responses play a part in motor integration [17]. The increased sympathetic nerve tone due to stress may evoke the tightening of muscles around the neck and shoulders in response to noxious stimuli [18]. That anxiety, one of the affects, causes an increased discharge of gamma efference, which probably explains the hyperactive tendon reflexes sometimes seen in anxious patients [19].

According to Hinoki's theory on psychogenic dizziness [20], stress-induced imbalance may be due also to the increased sympathetic nerve tone in the amygdala-hippocampus, hypothalamus, and balance center of the brainstem. The increased sympathetic nerve tone in the balance center would induce disorders of eye movement and balance. Our method of electrical treatment for tinnitus patients is speculated to be a kind of relaxation therapy [9] because a close relationship between tinnitus relief and the increased parasympathetic nervous tone was shown in tinnitus patients after electrical stimulation [7]. R-R interval study by ECG also showed that the parasympathetic nerve tone became predominant when tinnitus was relieved after electrical stimulation [21]. Reducing the increased sympathetic nerve tone and anxiety improved muscle stiffness, eventually improving static balance in the present study.

When tinnitus chronically annoyed patients, it also could induce stress, resulting in lack of concentration. Concentration may be a kind of attention, so that tinnitus may disturb attention. Our previous report showed that occipital nerve block improved selective attention and tinnitus [14]. Head movement also improved with tinnitus relief at that time. The result appeared to support the hypothesis that improved selective attention is highly related to tinnitus relief and imbalance. Previous results showing that electrical stimulation of the ear improved attention [6] and head movement [13] bolstered, the hypothesis. Posturographic study [15] showed a relationship between fatigue due to shift work and imbalance. Fatigue induces lack of attention and bad moods. We should be aware that emotions and moods may be important to our allocation of effort and attention to incoming stimuli and to how we process, retain, and recall information. Thus, lack of allocation of efforts and attention would affect the balance system. Increased attention accompanying tinnitus relief may promptly respond to change in posture on the platform, irrespective of visual feedback.

Our current posturographic study showed imbalance in tinnitus patients who did not experience dizziness. Therefore, in patients having dizziness, existence of tinnitus may make imbalance worse than in patients without tinnitus. The benefit of relieving tinnitus is greater to such patients than we imagined.

CONCLUSION

Our posturographic study showed that tinnitus can affect balance as well as the auditory system. Statistically significant improvement in the envelope area and mean amplitude of lateral sway with eyes closed was observed in patients who had tinnitus relief. In comparing postural measures between patients who had tinnitus relief and those who had no tinnitus relief, we observed significant improvement in postural measures in patients who experienced tinnitus relief, irrespective of visual feedback. On the basis of our previous studies, increased attention or reducing the increased sympathetic nerve tone (or both) may be attributable to improvement in balance on tinnitus relief.

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