Thomas Shipp,[1] *Ph.D. and Krzysztof Izdebski,*[2] *Ph.D.*

Current Evidence for the Existence of Laryngeal Macrotremor and Microtremor

REFERENCE: Shipp, T. and Izdebski, K., **"Current Evidence for the Existence of Laryngeal Macrotremor and Microtremor,"** *Journal of Forensic Sciences,* JFSCA, Vol. 26, No. 3, July 1981, pp. 501-505.

ABSTRACT: To test for the existence of laryngeal "microtremors" two experiments were conducted on humans. The first analyzed the acoustic characteristics of observable tremors (macrotremors) in the voice of singers using vocal vibrato and in pathologic subjects producing vocal tremor. In both of these groups acoustic oscillations between 4 and 8 Hz were found. The second study, using a normal subject, sampled electromyographic (EMG) activity from laryngeal and arm muscles during isometric contraction to determine if a periodic component (microtremor) was present in either muscle's contraction pattern. A 9-Hz signal was detected in limb muscle contraction, whereas no periodicity was found in signals from laryngeal muscles. The application of these findings to the theory behind voice "stress" analyzers is discussed.

KEYWORDS: pathology and biology, larynx, speech

The publicity and promotion surrounding the use of instruments designated as "stress" evaluators report that the presence or absence of laryngeal tremor in the voice is the basis for the determination of deception. Some of these instruments purport to perform this tremor analysis "on-line," presenting the results in a light display, while others record the voice signal and the resultant *x-y* chart printout is "analyzed" by someone using criteria set up by the manufacturer [*1*]. According to the developers' information, an unstressed voice has "normal" microtremors, while a stressed voice exhibits changes in the frequency of these rhythmic contractions. It seems implicit in the information provided by the manufacturers that these so-called normal laryngeal microtremors affect the voice output of the subject, and, though inaudible to the human ear, their presence or absence or a tremor frequency change can be detected by the "stress analysis" instrument. The physiologic basis for the existence of certain large types of oscillatory muscle behavior in the larynx is well known, while the presence of smaller tremor-like activity in this region is not well documented. This paper is intended to review the relevant evidence on laryngeal muscle tremor and to determine the reality of the acoustic and physiologic existence of such large and small tremors in the human larynx.

The phenomenon of rhythmic oscillations known as tremor is well described in both normal and pathologic subjects. The physical characteristics of limb tremor are the tremor's rate, amplitude, and overall waveform or pattern [*2*]. Normal tremor is described as having a fast rate of from 8 to 12 Hz, relatively small amplitude, and a continuous but rather irregular

Received for publication 21 July 1980; revised manuscript received 25 Oct. 1980; accepted for publication 29 Oct. 1980.

[1]Chief, Speech Research Laboratory, VA Medical Center, San Francisco, Calif., and associate professor, Department of Otolaryngology, University of California at San Francisco.

[2]Assistant professor, Department of Otolaryngology, and director, Voice Science Laboratory, University of California at San Francisco.

Copyright © 1981 by ASTM International

waveform. In contrast, abnormal tremor rate is from 3 to 8 Hz with variable amplitude and a waveform that can range from regular and rhythmic to irregular. Marshall [3] reported that tremor rate depends heavily on the anatomic site; tremor amplitude is related to muscle load and tension [4] and, therefore, is a misleading quantifier of tremor. Muscles in midline structures such as the larynx are subject to possible oscillatory or tremor behavior, as are the more common limb muscles.

The nature of the nerve-muscle function in the larynx is so divided that alterations in nerve efferent impulses to one set of muscles will influence only vocal frequency while impulses to the others will principally influence the amplitude. This arrangement of muscle to function allows independent study of each acoustic parameter, for example, voice frequency changes during vocal vibrato in singers and voice amplitude changes in patients with vocal tremor.

The present study was designed to compare and contrast acoustic measures derived from the sustained vocalization of singers, patients with vocal tremor, and a normal nonsinger. In addition, electrical activity from limb and several laryngeal muscles during isometric contraction was also investigated in the normal subject. It was felt that such a combined investigation would define the characteristics of tremor when present in the voice and determine the presence or absence of small, rhythmic contractions in sampled limb and laryngeal muscles.

Study 1

The first portion of the study was concerned with specifying the rate, amplitude, and regularity of vocal vibrato in singers since this behavior can be considered caused by "normal" muscle contraction oscillations. The subjects were five men and five women who were members of an internationally known opera company. Each subject was tape-recorded while sustaining vocalization on the vowel |a| for 7 to 12 s at each of three pitch levels: low, medium, and high. At each pitch, vocalization was produced with high and low effort; thus, six vocalizations were analyzed for each subject for a total of 60 samples. The singers were instructed to produce their best quality vocalization for each trial. The exact frequency and relative effort level were not dictated; the singer selected a representative pitch and produced sustained phonation at that frequency using two distinctly different effort levels.

The pathologic subjects were 20 females and two males with a vocal disorder of unknown cause known as spastic dysphonia who, along with the primary symptom of a "strangled" voice, had an accompanying pronounced vocal tremor. These subjects were recorded sustaining the vowel |a| for as long as possible at low, medium, and high pitch within their range, but only at one comfortable effort level at each pitch.

The recordings for both groups of subjects and the normal nonsinger were played back through a graphic-level recorder, an instrument that makes sensitive measures of amplitude variations, and through a sound spectrograph displaying the acoustic spectrum with a special amplitude display. The recorded samples were also analyzed from an oscillographic display and by computer analysis [5] that provided a calculation of each pitch period from which any pattern of voice frequency change could be detected. Figure 1 shows typical graphic outputs produced by the analyzing instruments.

Results of Study 1

The results of Study 1 demonstrated that the principal difference in the acoustic output of the singer and vocal tremor groups was that frequency variation was responsible for vocal vibrato while amplitude was the primary variable in vocal tremor. As shown in Table 1, when all subjects and conditions were pooled for the singers the average vibrato rate was 5.4 Hz with a range from 4.7 to 6.6 Hz with little or no discernible amplitude fluctuation. Figure 2 shows that for pathologic subjects the tremor rate ranged from 3 to 10 Hz, with the dominant

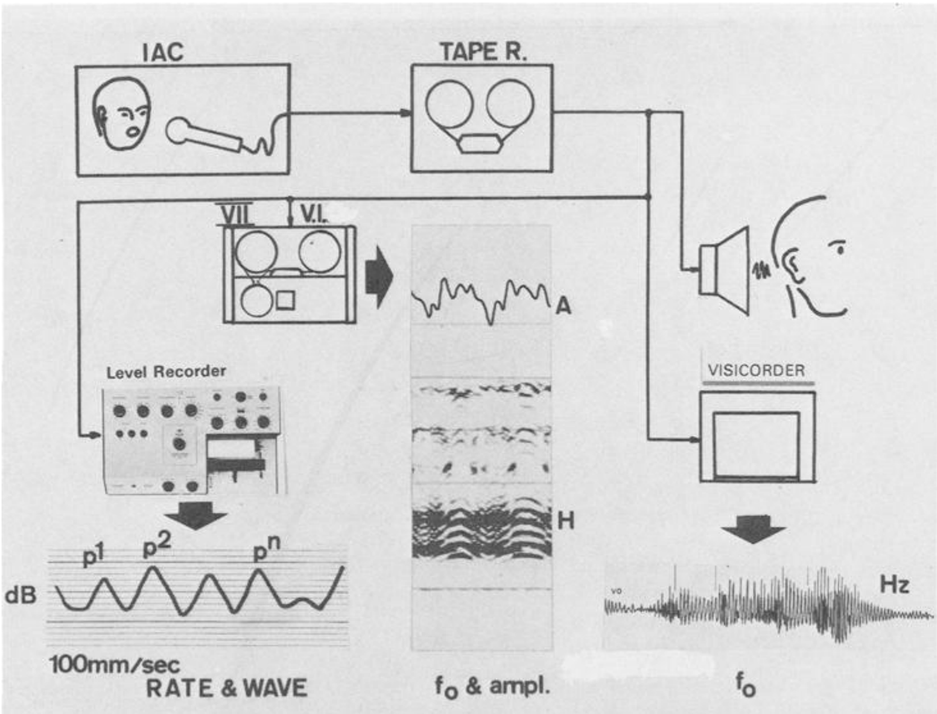

FIG. 1—*Instrumentation for recording and playing back subjects' voices to analyze vocal intensity* (dB), *amplitude* (A), *acoustic spectrum* (H), *and fundamental frequency* (f_0).

TABLE 1—*Mean vibrato rate, in hertz, for five male and five female singers sustaining phonation at low, medium, and high pitch.*

Subjects	Low Pitch	Medium Pitch	High Pitch	Pooled
Males	5.5	5.4	5.4	5.4
Females	5.7	6.1	6.0	5.9

rate at 5 to 6 Hz (each tremor cycle = 151 to 200 ms) independent of pitch, with the oscillation occurring predominantly in the signal amplitude. In other words, the average rate of vocal oscillations in both singers and pathologic subjects, whether in frequency or amplitude, fell within the same value of 5 to 6 Hz. Moreover, in both groups the rate of oscillations was not affected by the pitch produced. Sustained phonation by the single nonsinger subject showed random nonrhythmic variations in both voice frequency and amplitude.

Study 2

One young adult male volunteer underwent electromyographic (EMG) assessment of laryngeal muscle activity. The purpose was to sample electrical activity directly from critical muscles in the larynx to determine if there were periodic muscle contractions buried beneath the large electrical interference pattern picked up from these muscles as the subject produced phonation.

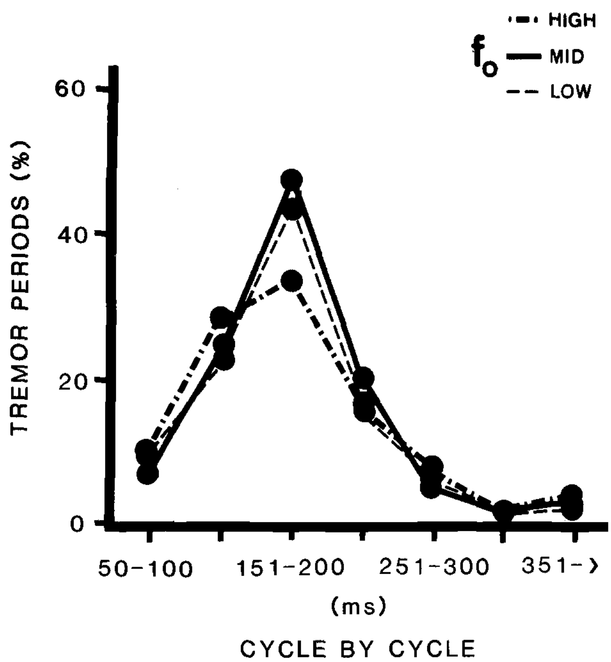

FIG. 2—*Percentage of each tremor cycle duration (in ms) at low, medium, and high fundamental frequency* (f_0) *for 24 patients with vocal tremor during sustained phonation.*

Intramuscular hooked-wire electrodes were introduced to the target muscles [*6*]. Two hours after electrode insertion, EMG signals were recorded on frequency-modulated tape from the cricothyroid and the posterior cricoarytenoid muscles during conversational speech and during sustained phonation (isometric muscle contraction). Long before this time, the subject had adjusted to the experimental situation and produced voice and speech easily with no subjective or objective indications of stress. To verify the system's capability to discern normal tremor, EMG activity was also sampled from the biceps muscle while the subject maintained an isometric contraction with his forearm supinated at 90°.

The EMG recordings from larynx and limb muscles were subjected to fast Fourier analysis that revealed the spectrum of energy in the complex electrical signal. It was anticipated that normal physiologic tremor (microtremor), if present, would show up in the EMG analysis as an energy peak somewhere between 8 and 12 Hz. It was found that EMG activity during conversational speech changed so rapidly over time (to accommodate normal speech phonation patterns) that at the present sampling rate no Fourier analysis could be made of these signals. Analysis of a 1-s segment of the EMG activity from both the posterior cricoarytenoid and cricothyroid muscle during nonstressful sustained vowel phonation failed to reveal any periodic component in the frequency band from 1 to 20 Hz; the electrical energy was randomly distributed throughout the spectrum. A 1-s segment of the EMG activity from the biceps revealed a prominent energy peak at 9 Hz, indicating periodic contraction within the range of normal physiological tremor rate.

Discussion

The rate of vocal vibrato in singers and of vocal tremor in this study is consistent with values generated in other studies of these parameters [*7,8*]. It would appear that oscillatory contraction of laryngeal muscles, whatever the cause, averages about 6 Hz with considerable variability between 3.5 and 7 Hz. The finding of a periodic muscle contraction at around 9 Hz in a limb muscle is consistent with the neurophysiologic data on normal physiologic tremor and validates the instrumentation and analysis techniques used in this study. The failure to find a similar tremor-like muscle pattern in the laryngeal muscles is contrary to the study of Inbar and Eden [*9*], who reported tremors of 10 to 20 Hz in muscle activity generated during sustained phonation. Their use of surface electrodes placed on the neck makes it difficult to be precise about the origin of the obtained EMG signals and, therefore, casts doubt on their conclusion that the obtained muscle patterns were, indeed, samples from a critical laryngeal muscle for phonation. Further evidence that their obtained signals were nonlaryngeal in origin lies in their correlations of obtained EMG with the frequency of the third formant, the location of which has little to do with laryngeal activity. Perhaps these investigators were presuming to sample some type of muscle activity that altered the shape of the supralaryngeal vocal tract instead.

Summary

These investigations demonstrate that laryngeal muscles can oscillate at rates between 4 and 7 Hz to produce frequency changes associated with vocal vibrato. Further, periodic muscle oscillations somewhere along the vocal tract in patients with vocal tremor produces a marked, rhythmic variation in amplitude of the voice signal at a rate from 3 to 7 Hz. The failure to find physiologic evidence of normal tremor in sampled laryngeal muscles casts some doubt on the assumption made by the manufacturers of stress analysis instruments that they are, indeed, detecting the presence of laryngeal muscle tremor.

Acknowledgments

The reported research was supported in part by National Institutes of Health Research Grants NS 14199 and 14729 and by the Veterans Administration Research and Development Service.

References

[*1*] Rice, B., "The New Truth Machines," *Psychology Today*, Vol. 12, No. 1, June 1978, pp. 61-78.
[*2*] Brumlik, J. and Yap, C-B., *Normal Tremor: A Comparative Study*, Charles C Thomas, Springfield, Ill., 1970.
[*3*] Marshall, J., "Tremor," in *Handbook of Clinical Neurology*, P. J. Vinken and G. W. Bruyn, Eds., Vol. 6, North Holland Publishing Co., Amsterdam, 1968, pp. 809-825.
[*4*] Freund, H. J. and Dietz, V., "The Relationship Between Physiological and Pathological Tremor," in *Physiological Tremor, Pathological Tremor and Clonus*, Vol. 5 of *Progress in Clinical Neurophysiology*, J. E. Demsmedt, Ed., Karger, Basel, 1978, pp. 66-89.
[*5*] Horii, Y., "Some Statistical Characteristics of Voice Fundamental Frequency," *Journal of Speech and Hearing Research*, Vol. 18, No. 1, March 1975, pp. 192-201.
[*6*] Shipp, T., Fishman, B. V., Morrissey, P., and McGlone, R. E., "Method and Control of Laryngeal EMG Electrode Placement in Man," *Journal of the Acoustical Society of America*, Vol. 48, No. 2, Pt. 1, Aug. 1970, pp. 429-430.
[*7*] Vennard, W., *Singing: The Mechanism and the Technique*, Carl Fischer, Inc., New York, 1967.
[*8*] Seashore, C. E., *Psychology of Music*, Dover Publications, Inc., New York, 1967.
[*9*] Inbar, G. F. and Eden, G., "Psychological Stress Evaluators: EMG Correlation with Voice Tremor," *Biological Cybernetics*, Vol. 24, No. 3, Nov. 1976, pp. 165-167.

Address requests for reprints or additional information to
Thomas Shipp, Ph.D
Speech Research Laboratory (126)
Veterans Administration Medical Center
San Francisco, Calif. 94121