A CLINICAL METHOD OF VOCAL FREQUENCY ANALYSIS FOR NORMAL AND VOCALLY DEVIANT CHILDREN

by

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ABSTRACT

Modal vocal frequency characteristics of normal speaking and voice defective children were compared via striation counting (Magna See) and oscillographic measurement procedures. The results of the experiment suggest that the striation counting procedure is a useful, valid and reliable method for estimating fundamental frequency values from sustained vowels, a simple counting task, or from sentence contexts. The use of the Magna See technique is an inexpensive alternative to more costly instruments for clinical assessment of vocal frequency characteristics of voice disordered patients.

The increasing demands for accountability by the speech-language pathologist have led to an increased interest in the quantitative assessment of laryngeal function. This interest is centered upon the need to correlate acoustical and physiological characteristics of laryngeal action with perceptual attributes of the voice.

One important part of a voice evaluation is the determination of modal vocal frequency and vocal frequency range. Many sophisticated instruments and analysis techniques are available to determine vocal frequency (Hollein and Tamburrino, 1965; Horii, 1975; Davis, 1981). However, for most evaluations, the cost, time, and technology necessary to operate these computer-assisted instruments are unrealistic for the clinician in a hospital, rehabilitation center, or school setting.

Less complicated instruments have also been developed to measure fundamental frequency. Some of the earlier models, such as the Purdue Pitch Meter (Dempsey, *et al.*, 1950) or Florida I (Holbrook and Meador, 1969) are not currently commercially available. Some instruments currently marketed employ a bandpass filter system to analyze frequency. These devices typically operate within rather broad frequency bandwidths and display a frequency signal on a meter that is not designed to yield a precise visual representation of the fundamental frequency. Other instruments (Visipitch; Vocal II) correct many of the problems of earlier "pitchmeters" by using a digital display, but are still relatively expensive for a speech pathologist's budget.

The determination of the patient's most appropriate pitch range is a difficult task to perform for many musically naive speech pathologists. One solution to this problem is to teach the professional how to estimate vocal frequency by making comparative perceptual judgments concerning the pitch of the voice from a chromatic pitch pipe and then convert these musical notes to frequency values within the talker's appropriate pitch range. While relatively simple to perform, this pitch matching technique presents its own unique problems. That is, for many musically unsophisticated students and professionals, the use of an auditory-perceptual vocal pitch matching procedure via piano keyboard or pitch pipe may lead to errors in judgements of the appropriate pitch range by as much as one octave. Boone (1971) recognized the problem and stated that "... fundamental frequency values will be more or less gross, depending upon our techniques such as those suggested by Fairbanks (1960) and Moncur and Brackett (1975)."

Another solution to the problem is to find an easily obtainable, inexpensive, and reliable method of obtaining fundamental frequency of the voice. Such a method was first described by Black (1949) when he introduced a procedure for obtaining fundamental frequency by counting the vertical striations on magnetic recording tape. These striations appeared after immersion of the tape in a compound of iron filings. The vertical striations represented individual cycles of the basic vocal frequency recorded on the tape. More recently, Kelly and Sansone (1981), using a modern version (3M Plastiform Magnetic Tape Viewer) of Black's technique, analyzed the vocal frequency of normal adults and children. Their procedure utilized a small, flat, sealed disc filled with liquified iron fillings. This disc, when placed over a portion of magnetic tape upon which some signal had been recorded, produced a facsimile of the vertical striations placed on the tape from a transduction of the voice signal from the microphone to the recording head of the tape recorder. These striations were converted to frequency and/or musical notation by the researchers and were compared with vocal frequency measurement obtained from another frequency analysis system (Kay Sonograph). Kelly and Sansone (1981) reported vocal frequency values for normal adults and children that correlated well with previous research with more sophisticated instruments. They suggested that further research using this technique needed to be conducted with children and adults with voice deviations.

School age children commonly present voice deviations and would profit from more objective analysis by the physician and speech clinician (Leeper, Leonard and Iverson, 1980). Leeper (1976) and Leeper and Iverson (1977) have also suggested that children with vocal nodules possess voice characteristics that differ significantly from normal. These authors have indicated that children with vocal fold pathologies may demonstrate a restricted vocal frequency, hard glottal attack, inefficient glottal closure, and intermittent laryngeal hyperfunction.

While some preliminary data are available to describe aerodynamic and acoustic characteristics of the voices of normal children, to date only Leeper, Iverson and Horii (1978) have reported speaking fundamental frequency data for both normal speaking children and children with vocal nodules and accompanying voice problems. Further, no data have been reported to support the use of a clinical method of measuring vocal frequency in voice defective children without the aid of expensive computer-assisted equipment. The present investigation was designed to describe a simple, inexpensive striation counting procedure (Magna See) for obtaining fundamental frequency values from sustained vowel and contextual speech samples for normal children and vocally deviant children with vocal nodules.

METHOD

Subjects

A total of 16 male children ranging in age from 8 years to 10 years with a mean age of 9.2 years served as subjects for this experiment. Eight of the children were outpatients seen in an otolaryngology clinic by one physician and had medically diagnosed vocal nodules. They were described by two speech pathologists as having a voice quality that deviated from normal. Eight children comprised the normal speaking group and were selected from a local public school to match the children with vocal nodules in chronological age and physical size. These children had no past histories of laryngeal problems and had vocal qualities within normal limits. Both groups of children had hearing sensitivity within normal limits. None of the children had oral language or speech difficulties as determined by two clinically competent speech pathologists.

Procedure: Speech Sample

Each child was directed to a guest room in the clinic and seated comfortably in a chair. Each was instructed to count to four and then immediately sustain the vowel /a/ at a comfortable pitch and intensity. This procedure was repeated three times for each child. The sustained vowel productions were tape recorded at 19.05 cm/sec. with a Sony, model TC 650 tape recorder and associated microphone. These samples were later reassembled into a master tape of vowel production for frequency analysis purposes.

Additional samples of connected speech were also collected during the same recording session. These samples consisted of two tasks designed to explore the feasibility of using the Magna See technique with more complex speech samples. The first sample, the *Counting* task, was elicited by asking the children to count from one to ten following a deep inhalation. For analysis purposes, all 10 words from the counting task were rerecorded and reassembled on another master audio tape. During the second sample, the *Reading* task, the subjects read a one paragraph story entitled "Limpy". In each case, the children practiced reading the passage before the sample was recorded for data analysis purposes. The sentences "... When he hears them coming he begins a loud, excited quacking. (and) The children always bring bread or corn for Limpy ..." were recorded and reassembled onto a master tape.

Instrumental Analysis

The instrumentation used in the frequency analysis included a high quality tape recorder (Sony, model TC 650), a light writing oscillograph (Honeywell Visicorder, model 1508C), and an iron filled liquid material (Magna See).[1] The oscillographic instrumentation was used as a reference measure of vocal frequency because of its high reliability and excellent response characteristics. The measures from this instrument were used to compare the direct striation counting procedure for accuracy of measurement. This traditional approach has been used previously (Horii, 1975) for comparison with other more sophisticated computer approaches.

In order to compare the data, the recorded vowel samples were fed into the oscillograph from the tape recorder. Paper tape output exiting the machine at 1500 mm/sec. was used for measurements of segment by segment estimates of fundamental frequency.[2] Each of the segments were measured, summed, and multiplied by ten to equal the requisite time base. Data for all three vowel productions for each subject were combined to one mean value for each subject and then summed for group analysis.

The material (Magna See) was originally developed for use by audio engineers for visual representation of head azimeth, track uniformity, balance, and head wear. The material is a non-toxic liquid which is an iron filing base in a suspension solution. It may be applied by artist's paint brush directly from the can to the audio tape. When applied and left to dry, it is seen as a whitish-grey powder covering the tape. The powder may be removed from the tape by wiping with tissue paper and will leave a greyish, graphite-looking smudge on paper or fingers when removed.[3] The tape may then be remeasured for reliability purposes or simply reused for other patients.

[1] Trademark: Soundcraft – A product of CBS Records, Columbia Broadcasting system, Danbury, Connecticut 06810.

[2] By definition, at 7.5 inches per second, each one inch frame is equal to a separate analysis segment and is approximately equal to 125 milliseconds in duration.

[3] A comparable liquid (Magna View) is now available in a pressurized spray (Mag View Nortronic Co., Inc., Minneapolis, Minnesota 55427).

TABLE 1

Average fundamental frequency characteristics of normal speaking children and children with vocal nodules compared by two measurement techniques, ("Magna See" and Oscillographic) (Values in Hz)

NORMAL			VOCAL NODULE		
Ss	Magna See	Oscillographic	Ss	Magna See	Oscillographic
1.	258.0	255.0	1.	232.5	222.5
2.	225.0	227.5	2.	270.0	268.0
3.	247.5	240.0	3.	255.0	232.5
4.	277.5	260.0	4.	247.5	240.0
5.	225.0	217.5	5.	315.0	320.0
6.	255.0	245.0	6.	232.5	227.5
7.	262.5	270.0	7.	225.0	218.0
8.	337.5	332.5	8.	240.0	240.0
	$\bar{X}$ = 261.0	$\bar{X}$ = 256.0		$\bar{X}$ = 252.0	$\bar{X}$ = 246.0
	S.D. = 35.7	S.D. = 35.3		S.D. = 29.0	S.D. = 34.0

Application of the Magna See material for measurements of fundamental frequency was as follows: (1) A section of the master tape containing the sequential vowel segments was played through the speaker of a research quality reel-to-reel tape recorder operating at 19.05 cm/sec. At the audible onset of the vowel the experimenter stopped the tape and marked the tape with a water proof pen. (2) The experimenter continued to play the vowel segment until the end of the utterance and then marked the tape with the felt pen to signify the end of that particular vowel. (3) Each vowel segment was then removed manually from the feed and takeup reel and placed in front of the experimenter on a level surface. (4) The Magna See material was painted ("dabbed") onto the tape from beginning to end of the sample. (5) One inch segments of the tape were measured with a quality ruler and marked with a felt tip pen. (6) From the application of Magna See, vertical striations appeared within each segment and represented the subject's vocal frequency. (7) The experimenter then counted the number of striations occurring in each one inch segment and then multiplied the number of striations by the playback speed of the tape recorder. For example, if the experimenter counted twenty-two (22) striations in a one inch segment he would multiply this value by the tape speed (7.5 inches per second) [(22 × 7.5) = 165 Hz] to provide the measurement of vocal frequency for that segment. The frequency values for each of the segments were recorded and stored for later statistical analysis.

Since the methodology of using the new striation counting procedure (Magna See) was initially established by comparison with the oscillographic records from the sustained vowel samples, the word (counting) and sentence contexts were examined at a later time with the Magna See technique alone.

Both the oscillographic trace and the direct striation counting procedure were prepared from the vocal frequency material for sustained vowels, such that reliability estimates could be made from the same material. Each of the experimenters (HAL; GWL) re-evaluated a one second sample of each vowel phonation from the oscillographic trace and from the vertical striations on the magnetic tape for estimates of reliability.

TABLE 2

Average fundamental frequency characteristics of normal speaking children and children with vocal nodules compared on the basis of a Counting task and a Reading task employing the Magna See technique (values in Hz)

NORMAL			VOCAL NODULE		
Ss	**Counting**	**Reading**	**Ss**	**Counting**	**Reading**
1.	241.1	240.0	1.	250.0	280.7
2.	236.4	235.3	2.	223.4	222.8
3.	249.0	248.4	3.	236.8	251.0
4.	268.0	268.0	4.	201.1	210.5
5.	246.1	244.7	5.	283.0	285.0
6.	259.0	257.8	6.	248.8	287.4
7.	262.3	261.6	7.	280.5	218.8
8.	328.0	326.3	8.	268.0	252.0
	$\bar{X}$ = 261.2	$\bar{X}$ = 260.3		$\bar{X}$ = 249.0	$\bar{X}$ = 251.0
	S.D. = 29.1	S.D. = 28.9		S.D. = 28.3	S.D. = 31.3

Results

A single factor repeated measures analysis of variance (ANOV) (Winer, 1962) was used to determine differences in modal frequency level (in Hz). This analysis indicated no statistically significant difference ($F = 1.99$, $df = 3, 28$, $P > .10$) in modal frequency level for the two measurement techniques (Magna See – oscillographic) for the sustained vowel samples. Further, separate ANOV's indicated no significant differences ($F = 454$, $df = 1, 7$, $P > .10$) between vocal groups (normal – vocal nodules) for either of the methods of measurement employed for the vowel productions.

From the data in Table 1, it may be seen that there is a numerical difference in modal vocal frequency with children with normal voice having slightly higher fundamental frequency (Magna See = 261 Hz; oscillographic = 256 Hz) than do the children with vocal nodules (Magna See = 252 Hz; oscillographic = 246 Hz). Interestingly, the frequency variability of these two groups is of similar magnitude, regardless of measurement method examined.

Since contextual aspects of speech do have an effect on vocal fundamental frequency, statistical analyses of the *Counting* task and *Reading* task were performed via the Magna See technique alone. A one way analysis of variance (ANOV) (Winer, 1962) was performed with the three contexts (vowel, counting, reading) employed to estimate vocal frequency. The results of the analysis revealed no significant differences ($F = .520$, $df = 2, 21$, $P > .10$) between the three contexts for normal speaking children. Similar non-significant results were found for the children with vocal nodules ($F = .261$, $df = 2, 21$, $P > .10$). Further, no significant differences were found for any context (vowel, counting, reading) when comparisons were made between the two groups (normal – nodule). As with the sustained vowel data, the more complex contexts (See Table 2) showed numerically lower modal fundamental frequencies for the children with vocal nodules. In addition, there was a slight reduction in variability in vocal frequency for both groups of children as the context increases in complexity.

Remeasurement of the data was performed by the two examiners for the middle one-second segment of each vowel for both techniques of analysis. A Pearson Product-Moment correlation coefficient of .96 was obtained for the comparison of the vocal frequency measures employing the two techniques. Inter-judge reliability for the Magna See method and the oscillographic measurements was .90 or better (r = .90 – Magna See; r = .94 – oscillographic) for the sustained vowel data. Reliability coefficients for the more complex contexts were .86 or better. Intra-judge reliability for the Magna See method was .91 and for the oscillographic method, .95. The slightly lower coefficients for the striation counting procedure was largely because of the more irregular spacing between striation events with the vocal nodule group.

Discussion

This study was designed to evaluate the usefulness of the Magna See technique for estimating vocal frequency in simple and complex speech contexts with normal speaking children and children with vocal nodules and accompanying voice deviations. The results support the use of the technique as an inexpensive, valid, and reliable method for obtaining vocal frequency data in a clinical setting. Further, the results suggest that the average modal vocal frequency values of children with vocal nodules do not differ significantly from normal children in the same age group. Numerical differences between these two groups do occur, and these slight differences may be related to the complexity of the vocal task or to the sample of children selected for study.

The modal frequency values for both groups of children (250–260 Hz) in the present study are within the range of frequencies usually reported for 8–10 year old children as suggested by Fairbanks, *et al.*, (1949, a, b) (284 Hz), Eguchi and Hirsh (1969) (262 Hz), and Leeper and Iverson (1977) (230 Hz). The relative differences in the present modal frequency data and those of past researchers should be viewed with respect to sustained vowel or contextual speech elicitation procedures. That is, it has generally been noted that modal frequency values from sustained vowel samples are usually slightly higher in frequency value than are those obtained from sentence length or longer connected speech samples (Horii, 1975; Leeper and Iverson, 1977; Wellen and Wilson, 1980). These reports could explain some of the differences between the findings of the present study and past experiments which used contextual samples as speech material.

However, it should be noted that since the *Counting* task and *Reading* task in this study were in the same modal frequency region as the sustained vowel, it is more likely that the vocal frequencies recorded reflect the vocal characteristics of the subject sample selected. Since this study was directed toward the methodological aspects of the Magna See or striation counting technique, the absolute vocal frequency values are simply a convenient vehicle for expressing the usefulness of this technique.

The results of this investigation have also indicated that the use of the striation counting procedure (Magna See) is highly accurate (r = .96) when compared to more sophisticated oscillographic measures. This accuracy measure is also in agreement with a report by Siler (1977). Siler found no significant differences in modal vocal frequency of sustained vowel samples when examined by separate analysis employing an oscillographic, Magna See, and an alternate striation counting procedure (3M) Plastiform Tape Viewer; Kelly and Sansone, 1981).

Further, intra- and inter-judge reliability were also quite high (r = .95), supporting the usefulness of the Magna See method in a clinical evaluation of vocal frequency. Similar findings were reported by Mueller, et al., (1979) for normal speaking male and female adults using the Florida I pitchmeter and the Magna See technique.

The present data also suggest that more complex material (words, sentences) may be analyzed by employing the Magna See technique. This will allow the clinician to evaluate vocal frequency characteristics in contextual speech for more naturalness of production.

Caution needs to be exercised, however, when the speech pathologist uses the Magna See technique or similar methods. First, the clinician must be aware that this method is only one part of the complete voice evaluation. In addition to modal vocal frequency, many other functional aspects of vocal production are important; for example, measuring basal frequency, highest sustainable frequency, duration of maximum phonation, frequency and intensity flexibility measures, method of glottal initiation, vocal fold diadochokinesis, and estimates of glottal efficiency (Wilson, 1979). Second, the clinician must have a reel-to-reel tape recorder that records and replays at least at 19.05 cm/sec. to make the Magna See procedure feasible for visual discrimination of striations from the tape. The use of a language master or cassette recorder is not feasible with the Magna See method since neither record or reproduce at speeds approximating 19.05 cm/sec. Their slow speeds compress the individual striations into an unreadable unit. Further, compact cassette tape recorders and associated tapes may be difficult to rewind and/or unwind. Third, the clinician must be willing to spend time gathering, analyzing, and reporting various fundamental frequency values (basal, modal, falsetto) for the voice patients in the case-load.

Although the present study found no significant differences in average modal vocal frequency between normal speaking children and children with vocal nodules, the numerical trend reported is supported by similar findings by Leeper and Iverson (1977). These experimenters reported no significant differences in modal vocal frequency data for normal speaking and voice deviant children. They did report significant differences between groups for basal frequency values employing computer analysis techniques to obtain the frequency data. Since the Magna See procedure has proven useful in the present study of normal and voice deviant children, further research should be completed to evaluate basal, modal, and upper limit range of vocal frequencies in simple and complex contexts using the Magna See procedure. Such data should be evaluated in normal children and children with medically documented vocal fold deviations before and after behavioural management.

In sum, the authors believe that this tool (Magna See) is an inexpensive, valid, reliable technique for measuring vocal frequency characteristics of normal and vocally deviant school children. It is a technique that should be added to the speech pathologist's diagnostic battery in clinical settings where more elaborate equipment is not available.

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