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Comparison of Laryngographic Waveforms of an Adult and Child

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COMPARISON OF LARYNGOGRAPHIC WAVEFORMS OF AN ADULT AND CHILD

Communicative Disorders

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EDUCATION

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By Elaine Hicken 1st Place

Statement of the Problem

The ability to accurately identify and differentially diagnose voice disorders is an important concern for the speech-language pathologist. This need has resulted in the development of methods which focus on identifying "objective, reliable, valid procedures for assessing voice disorders" (Costello, 1985). Several methods that allow direct observation of the laryngeal mechanism are invasive and time consuming. A method that is noninvasive and that provides valuable information about the vocal fold movement pattern is needed for clinical use.

Incidence studies have found that between 7-23.4% of elementary school aged children have had a voice disorder characterized by chronic hoarseness, and that more boys than girls exhibit this disorder (Baynes, 1966; Silverman, Zimmer,1975). A relatively simple, noninvasive method for detecting voice disorders among this younger population is much needed.

The laryngograph or electroglottograph (EGG),is a noninvasive devise that gives information about vocal fold contact area (Gilbert, Potter, Hoodin, 1984). This relatively recent addition to the voice scientist's instrumentation has been used to obtain data on the characteristics of normal vocal fold functioning. Normative data is needed before the laryngograph can be an effective tool in identifying disorders. The majority of the literature found which discuss expected characteristics of normal vocal fold functioning, have focused on adult male voices (Abberton, Howard, Fourcin, 1989; Gilbert et al., 1984; Baer, Titze, Yoshioka, 1983; Baken, 1987; Robb and Simmons, 1990). Reasons for this focus include the fact that adult males tend to have a much larger larynx, which may facilitate proper electrode placement. In the Kay Elemetrics, June 1990, Instructions Manual, it mentions that women with fleshy necks produce a poor Lx signal. This may also be a reason studies have used adult males. Hirano, Kurita, and Nakashima (1983), found that the growth, development, and aging of the human vocal folds, affects changes in the tissue structure of the vocal folds. These changes in length, mass, tissue layers, and structure may effect the movement patterns of the vocal folds. If these changes do effect movement patterns then the differences would effect the results obtained when using the laryngograph on children. "Taking developmental differences into account, there exists a need to examine EGG characteristics in younger as well as post pubescent children" (Robb and Simmons, 1990).

The proposed study will compare the laryngograph waveform (Lx) or EGG signal obtained with a male prepubescent child with a perceptually normal voice with the Lx waveform of a male adult with a perceptually normal voice to see if differences between the two exist.

Review of Literature

Anatomically, the larynx is situated in an area which makes direct examination and visualization difficult. These problems have led to the development of several methods for indirectly studying laryngeal vibration (Berke, Moore, Hantke, Hanson, Gerrantt, Burstein, 1987). The laryngograph is a method designed to allow vocal fold closure to be monitored, and give a basis for the measurement of certain aspects of vocal fold vibration during phonation (Abberton et al., 1989). This instrument operates by measuring the electrical conductance between two electrodes that are placed on either side of the client's neck, on the thyroid lamina, at the approximate position of the vocal folds. When the folds close, impedance across the glottis decreases and the current flow will be at a maximum. As the vocal folds open, the impedance increases and the ease of flow decreases. When displayed oscillographically, the signal is called larynx excitation or Lx waveform. (Abberton et al., 1989). This indirect measure of vocal fold movement is a "noninvasive technique that neither disrupts phonation nor requires uncomfortable illuminating and photographic equipment to be positioned in the vocal tract" (Gilbert, et al., 1984). This method also allows the client to use uninterrupted speech and remain able to participate in the monitoring activity (Gilbert et al., 1984).

Electroglottography has been used to gain insight into vocal fold closure in both the normal and pathologic voice. A broad understanding of the way normal vocal folds function is important when looking at the laryngographic waveform. "The Lx waveform is not of interest in itself: Its importance lies in the vocal fold behavior it represents" (Baken et al.,1987). It is expected, due to the Bernoulli effect, to see a steeper rise in the waveform when the vocal folds are closing. This rise indicates that the electrical impedance is decreasing. Fourcin (1981) believes that the initial contact of the vocal folds is formed by mucous connecting the two folds. As the folds continue to close in a vertical manner, the wave also rises to a peak. This vertical wave of vocal contact area begins to diminish as the lower end of the folds start to open. This corresponds with the more gradual opening phase we see on a normal adult Lx waveform. As the folds open the resistance to flow increases until the vocal folds are separated. At this point we see the lowest portion, or highest, depending on the machine, of the point of our waveform cycle. The relatively flat area across the graph indicates the time the vocal folds remain open. This description corresponds with Abberton's (1989), description of the slope of the waveform with a normal adult voice: (I) a steep rising edge, (II) a maximum peak, (III) a shallow falling edge, and (IV) a trough essentially constant with time. These features represent the position of the vocal fold at: (I) closing phase, (II) maximum closure, (III) opening phase, and (IV) open phase. The lengths of these phases will differ with voice quality (Abberton et al., 1989).

Robb and Simmons (1990), conducted a study which compared the EGG duty cycle of the Lx waveforms of normal voiced boys to those obtained from normal voiced girls. The EGG duty cycle is a measurement introduced by Rothenberg and Mahshie (1988), and is obtained by "dividing the total opening time of a single EGG waveform into the period." The children used Robb and Simmons' study were between the ages of 4 years and 6 years. Their findings suggested minimal differences between the gender groups. This study is among the few that exist which use the laryngograph on children. "Aside from limited accounts in the literature, an absence of child-based EGG research exists...additional information is needed regarding the characteristics of normal EGG waveforms specific to both boys and girls before applying it to examine the vocal characteristics of disordered groups" (Robb et al,. 1990).

As mentioned previously, the length, structure, and mass of the vocal folds are very different in children versus adults (Hirano, Kurita, Nakashima, 1983). These differences may result in data that shows distinguishing characteristics between the two. A study done by Colton and Conture, (1990) suggest that children produce smaller EGG signal levels than adults. The smaller waveforms may be a result of the previously mentioned morphological factors, physiological factors, such as the magnitude of vocal fold contact, or both. The magnitude of vocal fold contact is discussed by Robb (1990) as he sites Titze's work (1989), on gender differences among adult mathematical models. Titze's findings suggest that the difference in shape of the glottis between men and women, effects the vocal fold contact per glottal cycle. "Among males, the medial surface of the vocal folds is curved as a result of tissue bulging, whereas female vocal folds are more triangular shaped. Accordingly, the vocal fold differences are reflected in the opening and closing phases of EGG waveforms, with males displaying "knee"-shaped waveforms, representing more vocal fold contact per glottal cycle."

There have been many studies that have attempted to validate the laryngograph. Gilbert (1984), lists many such attempts. These, including his own, which measured subglottal pressures simultaneously with the laryngographic signal during phonation, support the view that the Lx waveform reflects vocal fold activity. Gilbert reports "... the Lx waveform is generated directly by the change in conductance due to alterations in the area of vocal fold contact during phonation. The present findings, when combined with the data reported by Fourcin (1982) and others, contribute to our understanding of the laryngograph as a noninvasive measure of vocal fold contact area."

The laryngograph, like other methods of voice assessment, has several factors that may present problems during application. Baker (1987) mentions five of these important considerations. (1) Electrode placement - the most accurate reading will occur only if the electrodes are placed at the level of the vocal folds. (2) Skin-electrode resistance - This can usually be compensated by placing clean electrodes fixed firmly at a properly prepared site. (3) Fat tissue is a very poor conductor - If a substantial fatty layer exists under the skin the Lx signal will not be representative of vocal fold activity. (4) Vertical larynx height changes for different phonemes and articulations, will change the relationship of the electrode to vocal fold position. This will also influence the Lx waveform. (5) Head movement alters the neck structures and may complicate the electrode to vocal fold positioning. This will affect the data output. Kay Elemetrics Instruction Manual (1990) estimates that between 5-10% of people are unable generate a usable Lx signal.

The laryngograph is an important instrument in the study of vocal fold activity, especially when used in conjunction with other phonatory function measures. Although there is a lack of baseline normative data for both children and adults (Robb et al., 1990), the laryngograph and its waveform has proved helpful in the qualitative understanding of normal vocal fold closure. and about deviations from this pattern, among adults. Data is needed about the Lx waveform in children in order for the laryngograph to be a helpful tool in the assessment and monitoring of children voice

Purpose and Objectives

The general purpose of this proposed study is to collect vocal fold functioning data on a male child with a perceptually normal voice using a laryngograph. The Lx waveforms will then be analyzed and compared to the data obtained from an adult male with normal vocal functioning. The overall shape, quasi-open phase measurement, and the characteristic effects of vocal fry and breathy voice of the Lx waveform of a child's Lx waveform will be compared to that of an adult. Once the two Lx waveforms have thus been analyzed, a determination of their similarities or differences will be possible.

Research Questions

The following research questions have been formulated to guide this study:

1. Do differences exist between the overall shape of the four identified phases of a Lx waveform of a male child with a perceptually normal voice to that of a male adult with a perceptually normal voice?

2. Do differences exist between the quasi-open phase measurement of the Lx waveform of a male child with a perceptually normal voice to that of a male adult with a perceptually normal voice?

3. Do similar wave characteristics exist between the Lx waveform produced during vocal fry by a male child with a perceptually normal voice and that produced by a male adult with a perceptually normal voice?

4. Do similar characteristics exist between the Lx waveform produced with breathy voice by a male child with a perceptually normal voice and that produced by a male adult with a perceptually normal voice?

Procedures

Sample

One adult male between the ages of 37 years and 39 years and one male child between the ages of 8 years and 10 years will be used to conduct this study. They will meet the following criteria: (1) No history of a speech or voice disorder. (2) A perceptually normal voice using Dr. D. Kenneth Wilson's Voice Profile Scale (Wilson, 1972, p. 70) (see Appendix B. (3) Normal perturbation level on sustained vowel production on the phonemes, /a/, /i/, /u/, using the Kay Elemetrics Visi-Pitch analysis. Normal values of pitch perturbation for this screening will be based on the Koike's formula which determines values below 1% as normal (Kay Elemetrics Corporation, 1990).

Instrumentation

The Kay Elemetrics Portable Laryngograph will be used to measure the electrical conductance across the vocal folds. A set of gold plated custom designed adult and pediatric sized electrodes fitted to a Hypertac Plug type DO2P708 MRT, consisting of a transmitting electrode and a receiving electrode, will be used to send and receive the electrical current across the vocal folds. Kay Elemetrics Waveform Display System model #6091 with a GoldStar IBM compatible computer model #1450 will be used to display and analyze the laryngographic signal.

Data Collection

The Lx waveforms will be obtained individually for both clients using the above mentioned instrumentation in the following manner:

1. The electrodes will be placed on the neck of the subject, on the thyroid lamina, in the approximate position of the vocal folds. The subject, using modal voice will produce a prolonged /a/ , while the electrodes are moved slightly to achieve best waveform signal amplitude as monitored.

2. The electrodes will be held in place while the subject produces, in modal voice, a sustained /a/. The resulting Lx waveform will then be stored on a 5 1/2 inch floppy disk, having been assigned the appropriate label name using the User Input option on the Kay Elemetrics waveform display main menu.

3. The subjects will produce the /a/ phoneme using vocal fry quality in their voice. The resulting Lx waveform will be saved to floppy disk after being labeled appropriately.

4. The subjects will produce the /a/ phoneme with a breathy voice quality. The resulting Lx waveform will be saved to floppy disk after being labeled appropriately.

These steps will be followed for each of the subjects. While producing the three vowels /a/, /i/, /u/ three times each.

Analysis

Using the cursors on the waveform display, the quasi-open phase quotient, the ratio of time vocal folds are open divided by the vocal period, will be obtained in the following manner:

Quasi-open Phase

1. A normalized signal will be acquired.

2. The open phase of vocal fold movement will be bracketed using the solid cursors. Each will be placed at the 40% level on the waveform signal.

3. The period of vocal fold movement will be bracketed with the dotted cursors at the 40% level on the waveform signal.

4. Using the Statistical Calculations option on the waveform display software, the quasi-open quotient will be calculated.

The overall shape will be analyzed by visual inspection. The four main phases of a Lx waveform, described in the literature, will be considered: 1) a steep rising edge, II) a maximum peak, III) a shallow falling edge, and IV) a trough essentially constant with time.

The characteristics between vocal fry and breathy qualities will be analyzed by visual inspection. General similarities and differences between the Lx waveforms will be determined.

Results

The research questions used to guide this study are followed by a detailed explanation of our findings.

Question #1

1. Do differences exist between the overall shape of the four identified phases of a Lx waveform of a male child with a perceptually normal voice to that of a male adult with a perceptually normal voice?

The shape of both the child's and the adult's Lx waveforms on the sustained vowels /a/,/i/, and /u/ using modal voice, can be describe using the four identified phases of a Lx waveform discussed in the literature: (1) a steep rising edge, representing vocal fold position during closing phase, (2) a maximum peak, corresponding with vocal fold maximum closure, (3) a shallow falling edge, representing the vocal folds position during opening phase, (4) a trough essentially constant with time, which represents the vocal folds during open phase. These four characteristics can be identified on both the adult and child Lx waveforms produced during the three sustained vowel sounds. These waveform displays should be read with open phase being represented by the lowest point on the waveform and the closure phase rising upward (see Figures 1-6. All figures are in Appendix A.)

The difference in the number of cycles produced in the 24 milliseconds represented, is due to the difference in vocal pitch, or fundamental frequency between the adult and child. Several other differences between the Lx waveform displays of the adult and child can be identified by visual inspection. The adult waveform shows a more gradual slope during the opening phase. The "knee" discussed in the literature is seen consistently in the waveforms of the adult during opening phase. This is not present in the child's waveform. Titze's work (1989) indicated that this "knee" represented more vocal fold contact per glottal cycle. The child's Lx waveform demonstrates a scattering of points, while the adult's Lx waveform is shown as a quasi-continuous line. The reasons behind this very noticeable difference is not clearly understood. This pattern is consistent across all the child samples obtained during the study.

Differences in the overall shape of the Lx waveforms of the adult and child do exist, however, the four identified phases discussed in the literature to be common among normal voiced male adult Lx waveform patterns are present in both the adult subject and the child. The general shape of the adult and child Lx waveforms are very similar.

Question #2

2. Do differences exist between the quasi-open phase measurement of the Lx waveform of a male child with a perceptually normal voice to that of a male adult with a perceptually normal voice?

The quasi-open phase measurement is determined by dividing the time the vocal folds are represented as being open by the total time of one cycle. The measure is figured as a ratio value. The ratio can be converted to the percentage of time the vocal folds are open during the measured cycle. For instance a quasi-open quotient of .43, would mean that during the measured cycle, the vocal folds were open 43% of the total time it took for vocal folds to complete a full cycle during their vibration. The values obtained from the Lx waveforms produced during one sample of the sustained vowel sounds /a/, /i/, and /u/ using modal voice are shown in Figures 7-12.

A more accurate picture of the quasi-open quotient measure, and how the child's values compared to the adult's is given below. The values obtained on each sample is shown in Figure 13 along with the average of these values.

Figure 13 shows the similarity in quasi-open quotient measurements between the adult and child waveforms. It is interesting to note the narrow range of values (.33 - .56 adult and .41 - .58 child). While differences in values do exist, they are small.

Question #3

3. Do similar wave characteristics exist between the Lx waveform produced during vocal fry by a male child with a perceptually normal voice and that produced by a male adult with a perceptually normal voice?

The Lx waveforms produced by both the adult and child during vocal fry on the sustained vowels /a/, /i/, and /u/ are characterized by irregularity in their cycles. This irregular pattern gives the voice its creaky quality. The time taken for each cycle is generally longer than that found for modal voice. It is interesting to note in figures 14-19 that the adult signals have a longer closed phase then open phase while in the child's signals this is just the opposite with the open phase dominating the cycle period. The child's waveform display of the /i/ looks similar to the display obtained when he was using modal voice. This is thought to be due to the difficulty he had producing this phoneme using a vocal fry quality. This waveform is included in the figures to show the comparison between a modal voice Lx waveform and production of vocal fry or a creaky quality.

Similar wave characteristics do exist between the Lx waveforms of the adult and child. The irregular pattern that characterizes the creaky voice is clearly present in both the child's and the adult's Lx waveform.

Question #4

4. Do similar wave characteristics exist between the Lx waveform produced with breathy voice by a male child with a perceptually normal voice and that produced by a male adult with a perceptually normal voice?

The adult and child waveform displays produced during sustained phonation of the vowels /a/, /i/, and /u/ using a breathy quality had similar characteristics. A larger quasi-open quotient measurement was obtained on each of the samples as compared to modal function. As the open phase in each cycle is extended, more air is allowed to escape giving the "breathy" quality. Visually, the child's open phase does not appear to be as extensive as the adults, however when divided by the total cycle time, the values are very similar. Figures 20-25 show the quasi-open quotient measurement of the breathy quality waveform as well as the quasi-open quotient measurement obtained during the sustained phonation of the vowel sound using modal quality.

Similar characteristics exist between the child's and adult's Lx waveforms using breathy voice during phonation of the vowels /a/, /i/, and /u/ from an adult and child. The extended open phase was clearly present in each as demonstrated when compared to the values of the quasi-open quotient measurement during normal phonation.

Conclusions

Similarities between the Lx waveforms of a child and adult included comparable overall waveform shape, during modal, and characteristic waveform configuration during breathy, and vocal fry phonation. Quasi-open quotients of the adult and child were within a range of .23 for the adult and .17 for the child. Differences included the presence of a "knee" in the adult Lx waveform which was absent in the child's waveform. The distribution of data points varied in the child's waveform with a "thicker" trace evident. Vocal fry phonation demonstrated a predominate closed phase for the adult and longer open phase for the child. The stability of both similarities and differences across a large sample of normal speakers needs to be investigated before generalizations can be made. We stress the preliminary nature of this data. An ongoing study will hopefully amass normative data and further explore the differences identified in this pilot study.

This indirect method of examining vocal fold vibration has potential as a screening tool. It is both time and cost efficient and may aid in more appropriate referral patterns to otolaryngologists. As a component of a full diagnostic battery it may provide important information on the vertical contact pattern of the folds only obtained by invasive methods such as photoglottography (PGG). As a tool in therapy it has some capability as a biofeedback method.

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Appendix A

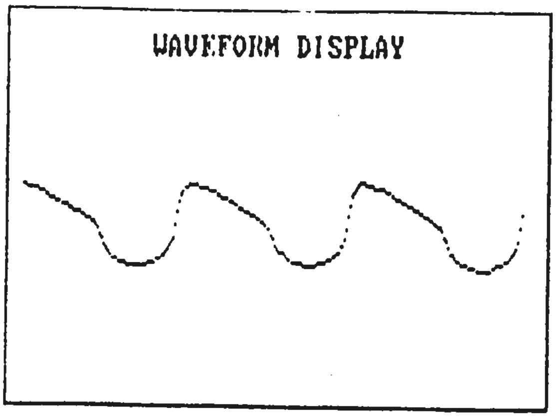


Figure 1 ADULT LX WAVEFORM /a/

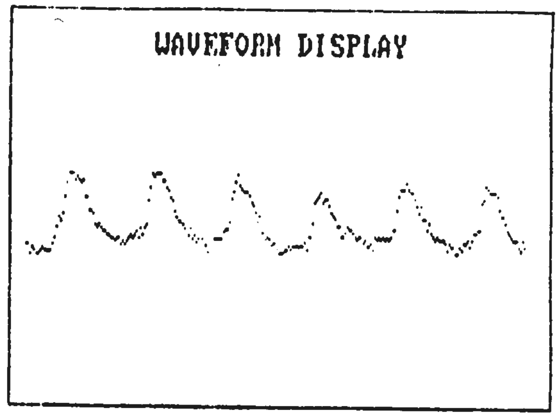


Figure 2 CHILD LX WAVEFORM /a/

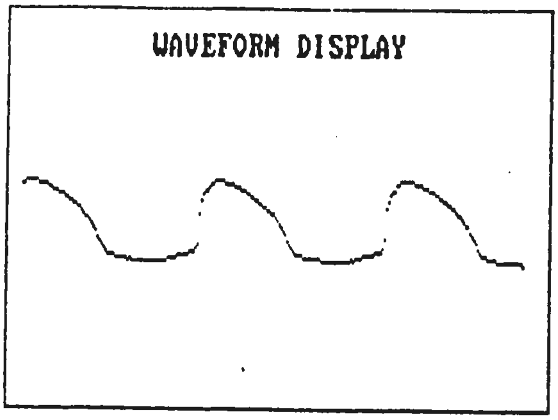


Figure 3 ADULT LX WAVEFORM /i/

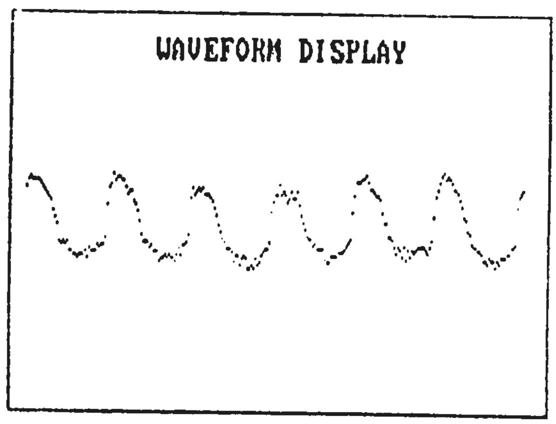


Figure 4 CHILD LX WAVEFORM /i/

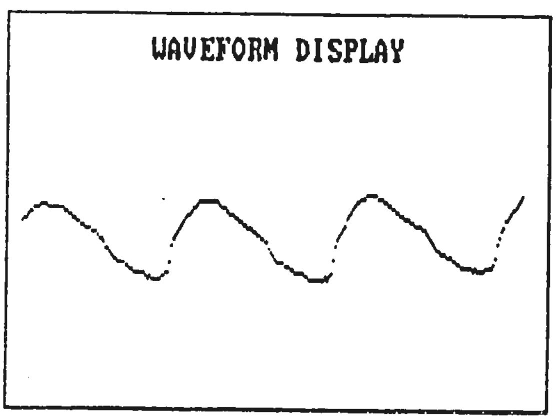


Figure 5 ADULT LX WAVEFORM /u/

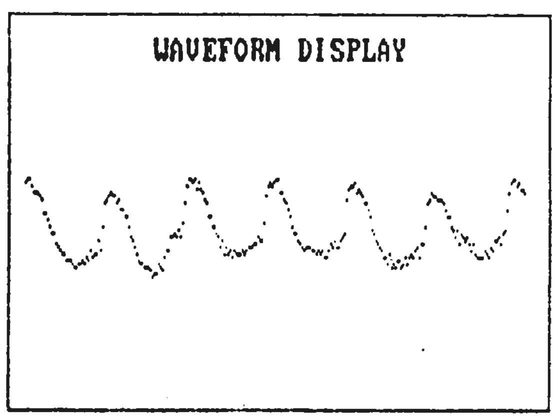


Figure 6 CHILD LX WAVEFORM /u/

Time axis = 24 milliseconds

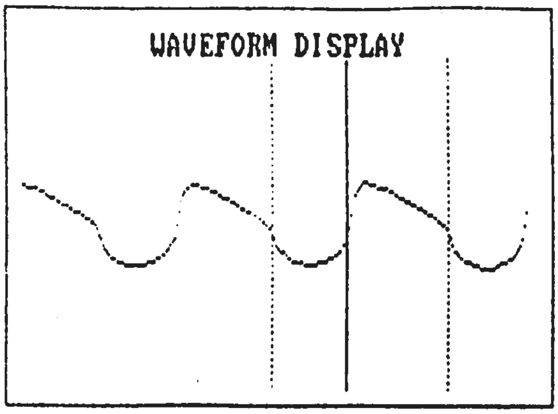


Figure 7 ADULT LX WAVEFORM /a/
QUASI-OPEN QUOTIENT =.43

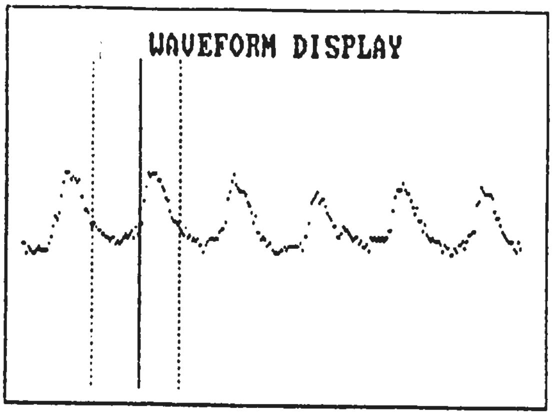


Figure 8 CHILD LX WAVEFORM /a/
QUASI-OPEN QUOTIENT =.55

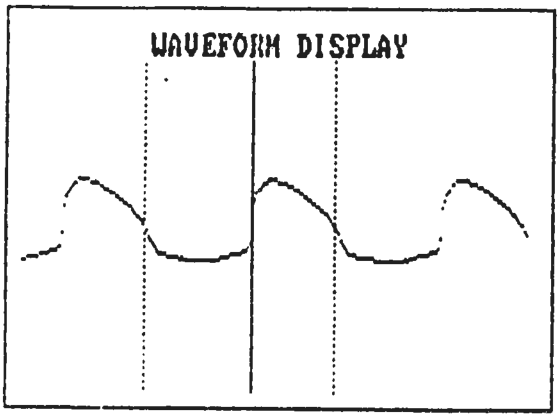


Figure 9 ADULT LX WAVEFORM /i/
QUASI-OPEN QUOTIENT =.56

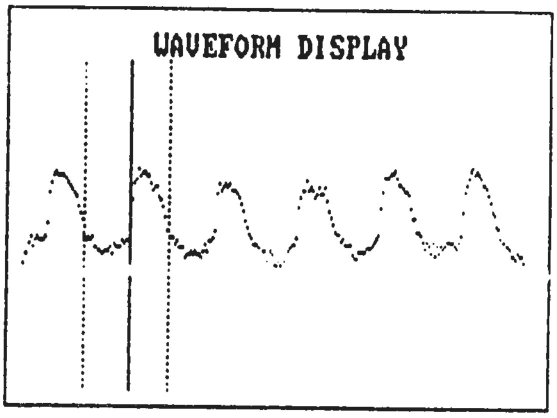


Figure 10 CHILD LX WAVEFORM /i/
QUASI-OPEN QUOTIENT =.55

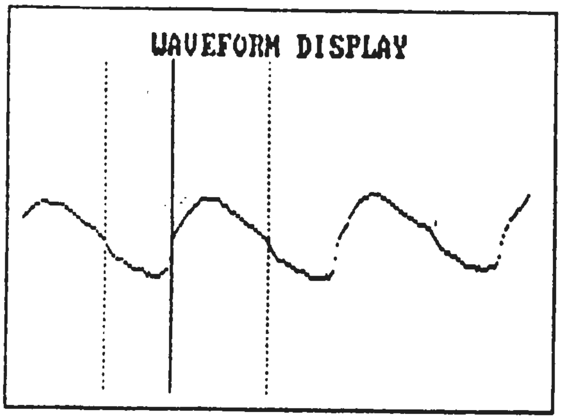


Figure 11 ADULT LX WAVEFORM /u/
QUASI-OPEN QUOTIENT =.41

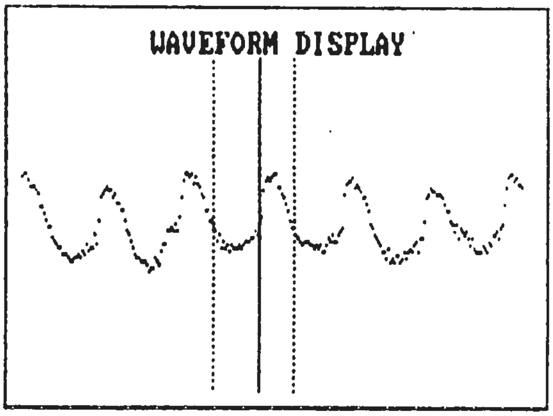
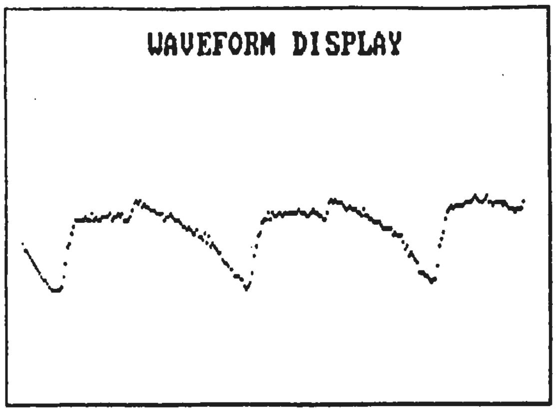


Figure 12 CHILD LX WAVEFORM /u/
QUASI-OPEN QUOTIENT =.58

Time axis = 24 milliseconds

ADULT'S QUASI-OPEN QUOTIENTS	CHILD'S QUASI-OPEN QUOTIENTS
/a/1 = .42	/a/1 = .47
/a/2 = .33	/a/2 = .48
/a/3 = .43	/a/3 = .55
AVERAGE = .39	AVERAGE = .50
/i/1 = .56	/i/1 = .45
/i/2 = .43	/i/2 = .41
/i/3 = .52	/i/3 = .55
AVERAGE = .50	AVERAGE = .47
/u/1 = .41	/u/1 = .48
/u/2 = .41	/u/2 = .58
/u/3 = .41	/u/3 = .46
AVERAGE = .41	AVERAGE = .51

Figure 13 Adult and child quasi-open quotient measurements of the Lx waveforms produced using modal voice for the sustained vowel sounds /a/, /i/, and /u/.



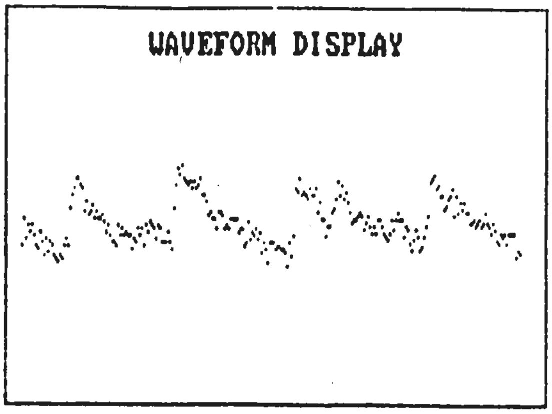
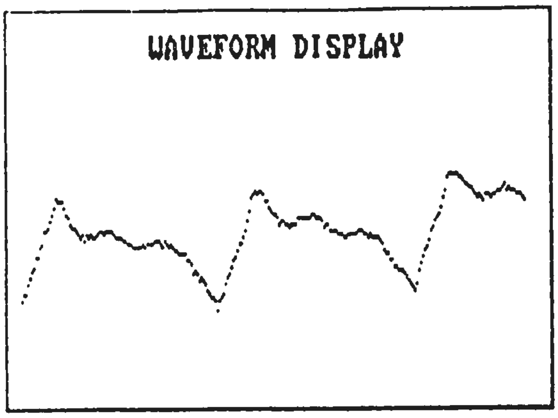


Figure 14 ADULT LX WAVEFORM /a/ VOCAL FRY

Figure 15 CHILD LX WAVEFORM /a/ VOCAL FRY



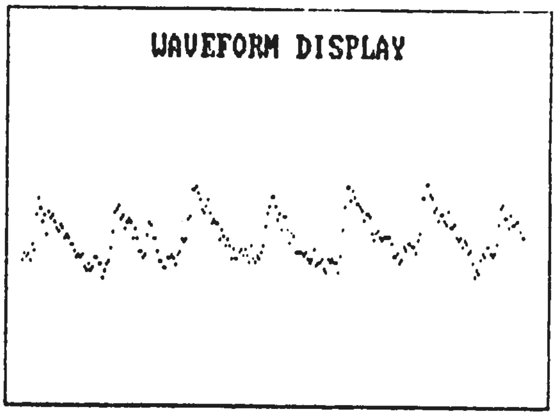
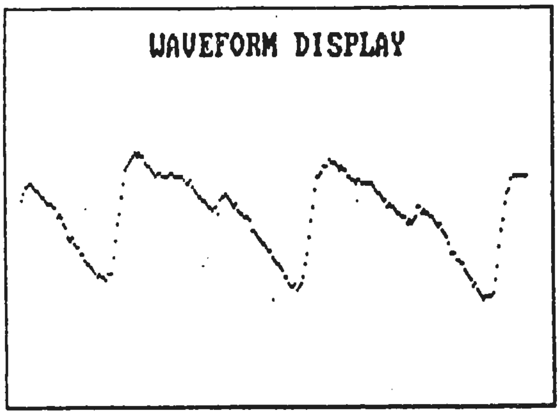


Figure 16 ADULT LX WAVEFORM /i/ VOCAL FRY

Figure 17 CHILD LX WAVEFORM */i/ VOCAL FRY



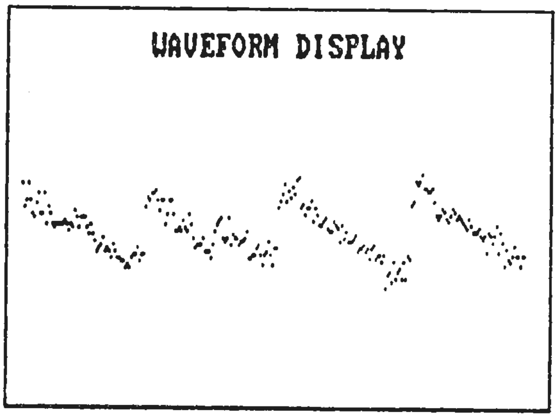


Figure 18 ADULT LX WAVEFORM /u/ VOCAL FRY

Figure 19 CHILD LX WAVEFORM /u/ VOCAL FRY

* NOT A GOOD REPRESENTATION OF VOCAL FRY QUALITY DURING SAMPLING.

Time axis = 36 milliseconds

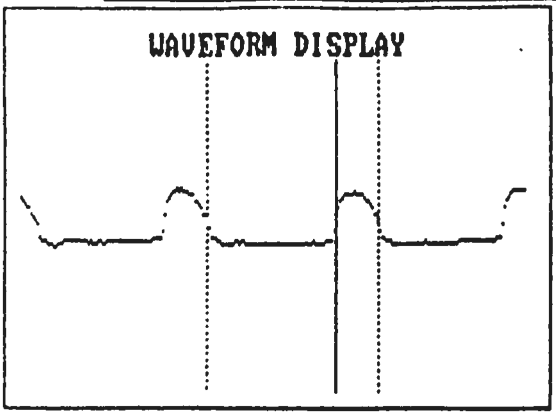


Figure 20 ADULT LX WAVEFORM /a/
BREATHY OQ = .75
MODAL OQ = .43

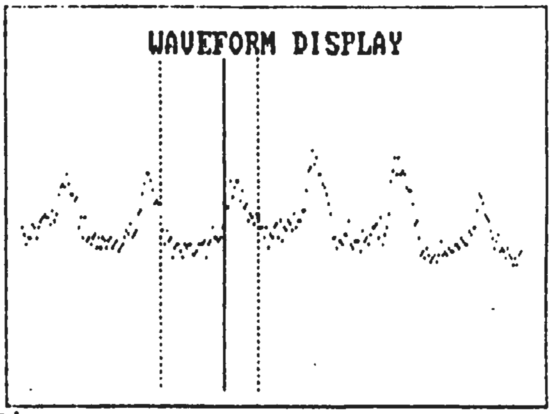


Figure 21 CHILD LX WAVEFORM /a/
BREATHY OQ = .65
MODAL OQ = .55

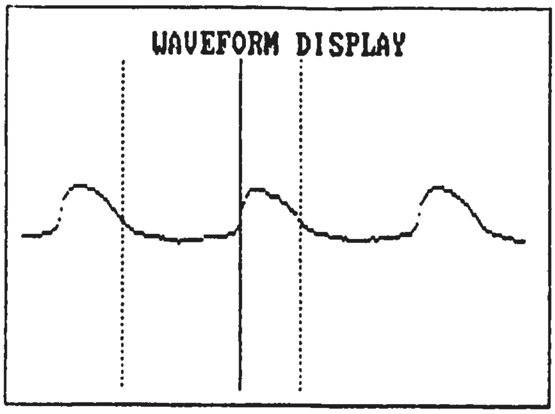


Figure 22 ADULT LX WAVEFORM /i/
BREATHY OQ = .66
MODAL OQ = .56

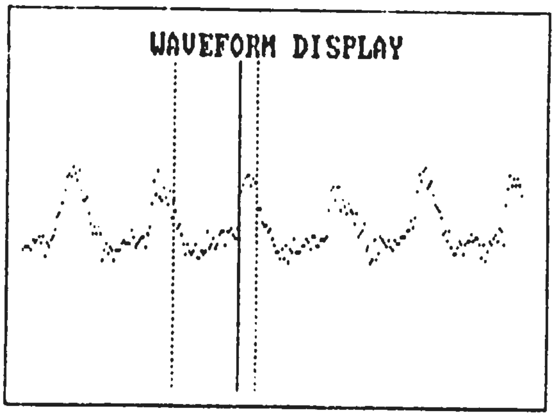


Figure 23 CHILD LX WAVEFORM /i/
BREATHY OQ = .79
MODAL OQ = .55

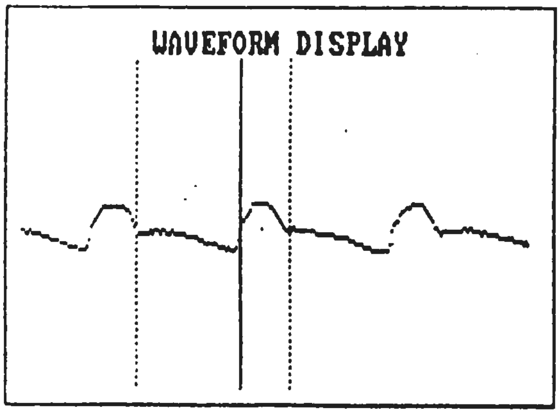


Figure 24 ADULT LX WAVEFORM /u/
BREATHY OQ = .68
MODAL OQ = .41

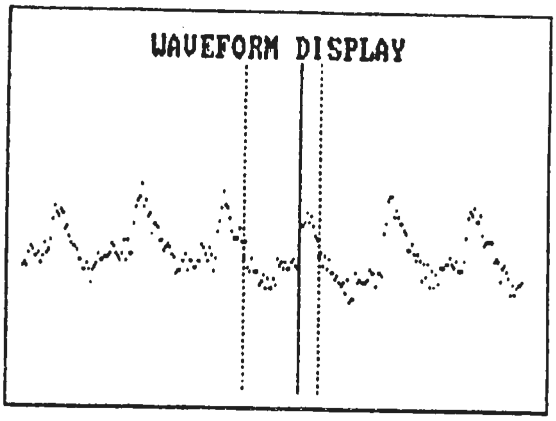


Figure 25 CHILD LX WAVEFORM /u/
BREATHY OQ = .74
MODAL OQ = .58

Time axis = 24 milliseconds

Appendix B

Wilson Voice Profile Scale

Name____________________ Birth Date__________ Age________ Sex______
Rater____________________ Date__________ Time of Day_____ Place_____

1. PITCH
    - Normal
    - High 1 2 3 4 5 6 7
    - Low
2. VOCAL INFLECTIONS
    - Normal
    - Monotone 1 2 3 4 5 6 7
    - Excessive
3. LARYNGEAL TONE
    - Normal
    - Breathy 1 2 3 4 5 6 7
    - Harsh
    - Hoarse
4. LARYNGEAL TENSION
    - Normal
    - Hypertense 1 2 3 4 5 6 7
    - Hypotense
5. VOCAL ABUSE
    - No
    - Yes 1 2 3 4 5 6 7
6. RESONANCE
    - Normal
    - Hypernasal 1 2 3 4 5 6 7
    - Hyponasal
7. NASAL EMISSION
    - No 1 2 3 4 5 6 7
    - Yes
8. LOUDNESS
    - Normal 1 2 3 4 5 6 7
    - Too Loud
    - Too Soft
9. RATE
    - Normal 1 2 3 4 5 6 7
    - Fast
    - Slow
10. OVERALL VOICE EFFICIENCY
    - Adequate 1 2 3 4 5 6 7
    - Inadequate

COMMENTS:

INSTRUCTIONS:

A. Circle the appropriate descriptive term under each item.
B. For each item not normal or adequate, circle a number on the scale for that item.

Do not mark between numbers.

Key: 1 = slight deviation 7 = severe deviation