Objective: To establish normative electroglottography (EGG) data in the pediatric population.

Design: Clinical study with EGG data gathered on children with normal voices.

Setting: Major children’s hospital and specialty eye and ear hospital.

Patients: A total of 164 children, 79 girls and 85 boys, aged 3 to 16 years.

Methods: Children with normal voices, determined through subjective evaluation and a voice use history questionnaire, underwent EGG recording. The EGG data were analyzed with commercially available software for fundamental frequency, jitter, open quotient, closing quotient, and opening quotient.

Results: Normative EGG data were established for children aged 3 to 16 years. Jitter, open quotient, closing quotient, and opening quotient were all found to have no significant dependence on age.

Conclusions: Children as young as 3 years can easily tolerate EGG, making it possible to establish this initial set of normative pediatric EGG data. These preliminary results suggest that EGG may have potential to assist clinicians with noninvasive documentation of vocal function in the pediatric population. This may be particularly important for tracking treatment-related changes in the vocal function of children who are difficult to examine endoscopically.


Methods used in the diagnosis of a pediatric voice disorder typically include questioning the patient and parent on voice use history and history of airway compromise, subjectively assessing the patient’s voice quality, and directly visualizing the glottis. Unfortunately, methods of laryngeal evaluation used in the adult population, such as laryngeal mirror or fiberoptic telescope examinations, may not be readily accepted by a pediatric patient, and may in certain instances even require the use of general anesthesia. Once a definitive diagnosis has been established and a serious pathological problem is not suspected, a noninvasive method for assessing vocal function may reduce the need to subject pediatric patients to repeated endoscopic recordings. Such a method would be especially useful to obtain an objective baseline measure of vocal function during the initial examination, then to help track the patient’s progress during vocal therapy.

Electroglottography (EGG) may provide an appropriate noninvasive, objective way to assess vocal function in the pediatric population. The electroglottograph is an electrical device that was first described by Fabre and later implemented as a “larynograph” by Fourcin and Abbott. The EGG waveform represents vocal fold vibration and has been reported to relate to vocal function. The electroglottograph may be especially suitable for use in a clinician’s office since it is immune to environmental acoustic noise, is portable, is relatively inexpensive, and software is commercially available for analysis of EGG signals.

There is a paucity of information in the literature describing objective measures of EGG in the pediatric population. Zajac et al, in their review of laryngeal airway resistance and EGG, stress the “need . . . to obtain developmental data for normal children” for these two techniques. This study sought to establish normative data on 5 objective measures of EGG for children with normal voices, aged 3 through 16 years.
SUBJECTS AND METHODS

Electroglottographic data were collected from 164 children aged 3 to 16 years who were being evaluated for reasons unrelated to any voice disorder in the pediatric otolaryngology clinic at Massachusetts Eye and Ear Infirmary or Children’s Hospital, Boston, between May 1995 and August 1997. Each subject and parent or guardian completed a questionnaire to provide informed consent and information on the following: age, sex, medications, allergies, exposure to tobacco smoke, voice disorder history, history of laryngeal injury or surgery, vocal demands, speech therapy history, pubertal stage, and whether the subject had experienced a voice change with puberty. This study was reviewed and approved by the hospitals’ institutional review boards.

Subjects’ EGG waveforms were obtained with a laryngograph (Kay Elemetrics, Lincoln Park, NJ) using surface electrodes that were gently held in contact with the skin underlying the subject’s larynx. The electrodes were positioned to provide a waveform of maximal amplitude. The output of the laryngograph was monitored on an oscilloscope (model LS 8020; Leader Instruments Corp, Hauppauge, NY), to provide instantaneous visual feedback on the EGG waveform quality. The EGG signal was recorded on the right channel of a digital audiotape recorder (Tascam model DA-30 MKII, Tasc America Inc, Montebello, Calif). An acoustic reference signal, uncalibrated for intensity, was recorded on the left channel of the digital audiotape recorder using a lapel microphone (Radio Shack model 33-3003; Tandy Corp, Fort Worth, Tex) amplified by a mixer (model M267; Shure Brothers Inc, Evanston, Ill).

Each subject was instructed to sustain the vowel /a/ for six 3-second utterances during the recording; the first 3 in a comfortable or conversational voice and the second 3 in a loud voice. The digital audiotape recordings were edited, displayed, and analyzed using commercially available software6 and hardware7 on an IBM-compatible personal computer. First, each utterance was redigitized and the signal was processed with the EGG software’s default high-pass and low-pass digital filters. A 0.5-second portion of the utterance: fundamental frequency (F0), jitter, open quotient, and closing quotient. Then the mean for each subject (ie, across each subject’s comfortable or loud utterances) was calculated. Figure 1 shows a representative EGG waveform to graphically define 4 of the EGG measures: QO, percentage of each period in which the glottis is open; opening quotient, the percentage of each period in which the vocal folds are moving apart while the glottis is closed; closing quotient, the percentage of each period in which the vocal folds are moving together while the glottis is closed; and F0. The points A, C, and D in Figure 1 are marked where the waveform crosses its DC value, represented by the time axis, which is positioned so that the areas under the EGG curve above and below the axis are equal. Schematized coronal sections through the larynx show the corresponding glottal configurations for points A, B, and C.9-10 Jitter, a measure of the frequency variability over every 3 consecutive periods of the EGG waveform, has been previously defined in the literature as relative average perturbation.11

To determine if there were significant differences between the comfortable and loud conditions, t tests (P ≤ .01) were performed on the 5 EGG measures for each age and sex. Subsequently, correlation coefficients (r, P ≤ .01) were calculated to evaluate whether there was a significant relationship between each EGG measure and age within the 2 separate male and female groups. Then, for any EGG measure that was not significantly correlated with age for both boys and girls, the data were averaged across age and a t test (P ≤ .01) was used to determine if there was a significant difference between the average female and male values. Lastly, for any measure that did not show significant age or sex effects, the overall mean and SD (ie, across age and sex) was computed as an estimate of that measure’s mean and SD for the normal population. It was decided a priori not to use measures that were significantly correlated with age to estimate normative values due to the relatively small size of each age group.

RESULTS

A total of 927 utterances were recorded and analyzed from 164 children with normal voices aged 3 to 16 years. Ten of the comfortable voice condition utterances were removed from this data set for 1 of 3 reasons: (1) a discontinuous EGG signal, (2) octave errors in the software’s marking of the EGG waveform, or (3) unsteady phonation. The number of children with normal voices recorded and analyzed of each age and sex is given in Table 1.

The normative data on the 5 EGG measures for the boys and girls are summarized in Figures 2, 3, 4, 5, and 6. Each figure shows the mean values of the measures for each subject. Values in these figures are from analyses of the comfortable level EGG waveforms only (479 utterances), because t tests (P ≤ .01) at each age demonstrated that none of the measures except F0 consistently differed between the comfortable and loud conditions. Two unusually high jitter values appear in Figure 3, one for a 9-year-old boy and the other for a 10-year-old girl. Given that these children’s voices were subjectively assessed as normal and that their utterances could not be excluded for any of the 3 reasons mentioned above, their data were included in the normal population and the high jitter must be attributed to errors in the algorithm that computes jitter.

The correlation coefficients and P values for each EGG measure are summarized in Table 2. As expected, F0 was found to be significantly correlated with age and so was not subjected to the significance testing for sex. Jitter, QO, closing quotient, and opening quotient were all found to have no significant correlation with age and to not be significantly different for sex by t test (P ≤ .01). Thus, the overall mean ± 1 SD for these measures across age and sex was calculated as 0.76% ± 0.61% for jitter, 54.8% ± 3.3% for QO, 14.1% ± 3.8% for closing quotient, and 31.1% ± 4.1% for opening quotient. These values are viewed as estimates of the mean and SD for jitter, QO, closing quotient, and opening quotient for the entire normal group.
Aside from F0, EGG measures as they were defined in this study have not been previously reported. However, similar measures of jitter have been described using acoustic techniques. The trends of F0 values across age as shown in Figure 2 follow those described by Wilson: both boys and girls have approximately equal F0 until puberty, after which the male F0 drops to a lower level than the female F0. Linders et al measured F0 using EGG in 7- to 15-year-old boys and girls, and found the mean values across age to be 250 Hz for boys and 244 Hz for girls. These mean F0 values are not significantly different from the values found in this study, except for the 5-year-old male category. The difference in the 5-year-old male data may be due to the small sample size. The number of vocally healthy subjects at each age and sex is shown in Table 1. The open quotient (OQ) and closing quotient (CQ) are shown in Figures 4 and 5, respectively.
CONCLUSIONS

An electroglottograph such as the laryngograph is a safe and nonthreatening instrument that was well accepted by most children. Four measures on the EEG signal—jitter, OQ, closing quotient, and opening quotient—are independent of age and sex for children aged 3 to 16 years, which enables the establishment of initial normative data for these measures. The mean jitter of children appears to be slightly higher than that of adults, while children’s OQ is more comparable to adult male OQ than adult female OQ. Closing quotient and opening quotient data have not been previously reported.

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REFERENCES


Table 2. Correlation Coefficients and P Values for Testing the Relation Between Age and Each EGG Measure

<table>
<thead>
<tr>
<th>EGG Measure</th>
<th>Comparison</th>
<th>r²</th>
<th>P</th>
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<tr>
<td>F0</td>
<td>Age (female group)</td>
<td>0.295</td>
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<td>Jitter</td>
<td>Age (male group)</td>
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<td>Age (male group)</td>
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<td></td>
<td>Age (male group)</td>
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<td></td>
<td>Female vs male</td>
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<td>.74</td>
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<tr>
<td>OQ</td>
<td>Age (female group)</td>
<td>0.0003</td>
<td>.98</td>
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<td></td>
<td>Age (male group)</td>
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<td>.24</td>
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<tr>
<td></td>
<td>Female vs male</td>
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<td>.47</td>
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<tr>
<td>Closing quotient</td>
<td>Age (female group)</td>
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<td>.14</td>
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<tr>
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<td>Age (male group)</td>
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<td></td>
<td>Female vs male</td>
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<tr>
<td>Opening quotient</td>
<td>Age (female group)</td>
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<td>Age (male group)</td>
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<td>.87</td>
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</table>

*P values for follow-up t tests between average female and male values are also shown. EGG indicates electroglottographic; F0, fundamental frequency; OQ, open quotient; and ellipses, data not applicable.

size in this study (n = 3) compared with that of the Hasek et al study (n = 15).

Jitter, or relative average perturbation, measurements were reported by Takahashi and Koike and summarized by Baken for adult males and females with normal voices. Their mean (SD) jitter results of 0.61% (0.056%) for women and 0.57% (0.134%) for men are both slightly lower than the mean value of 0.76% found for children. This difference may suggest that children exercise slightly less control over cycle-to-cycle variability in their voices than do adults, but it also could be an artifact of differences in the method for marking fundamental periods.

Jitter, OQ, closing quotient, and opening quotient were all found to be independent of age and sex for the normal group, allowing calculation of a mean children’s value for each of these measures. This suggests that certain aspects of vocal fold vibratory timing are maintained even with growth of the laryngeal structures, perhaps as a way of maintaining normal voice quality. Further study of EGG signals from adolescence through early adulthood is needed to determine how jitter and OQ may change between children and adults. Future research will focus on questions such as whether EGG has the potential to differentiate between normal voices and pathological voices, through the measures used here (jitter, OQ, closing quotient, and opening quotient) or other more sophisticated signal processing of the EGG signal.