ABSTRACT

REPEATABILITY OF AERODYNAMIC MEASURES IN CHILDREN, AGES 4.0-5.11 YEARS

by Shelley May

The purpose of this study was to determine the short-term repeatability of average airflow in children, ages 4.0 – 5.11 years. Thirty participants with healthy voices and normal hearing sustained the vowel /a/ for 5 seconds at their comfortable frequency and intensity for 3 consecutive productions during 2 separate trials, using the Phonatory Aerodynamic System. The trials were separated by performance of additional acoustic tasks. Results indicated that average airflow measurements were repeatable in young children with no significant difference in average airflow values.
REPEATABILITY OF AERODYNAMIC MEASURES IN CHILDREN, AGES 4.0-5.11 YEARS

A Thesis

Submitted to the

Faculty of Miami University

in partial fulfillment of

the requirements for the degree of

Master of Arts

Department of Speech Pathology and Audiology

by

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2010

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Introduction and Review of the Literature

What Is a Voice Disorder?

The ability to communicate through speech is a precious skill that relies on an individual’s use of language, articulation, and voice. If there is a disturbance in vocal function, an individual’s speech may become compromised. This vocal function disturbance, or voice disorder, can occur following functional or structural changes in the larynx, as well as any changes that affect the three subsystems of voice (respiration, phonation, resonance). Such changes may impact an individual’s pitch, vocal quality, and loudness, thus causing a disordered voice (Stemple, Glaze, & Klaben, 2000).

There are many types of voice disorders, and individuals of every age can be affected. Voice disorders can arise from a variety of etiologies and pathologies, and can be congenital, acquired, or idiopathic. Trauma to the vocal folds, such as poor vocal hygiene, smoking, and shouting, may result in laryngeal pathologies such as vocal fold nodules, polyps, Reinke’s edema, and contact granulomas (Boone, McFarlane, Von Berg, & Zraick, 2010; Colton, Casper, & Leonard, 2006; Seikel, King, & Drumright, 2005; Stemple et al., 2000). Congenital disorders that affect the function of the laryngeal structures include congenital web, laryngomalacia, and cardiac anomalies (Filter, 1982). Acquired pathologies of the laryngeal mechanism include cysts, polypoid degeneration, and sulcus vocalis. Nerve paralysis of the recurrent and superior laryngeal branches of the vagus nerve, physical and emotional stress/tension, neurogenic diseases, and systemic diseases are other causes of voice disorders (Stemple et al.). According to a 2000 retrospective study by Dobres, Lee, Stemple, Kummer, and Kretschmer, the most common laryngeal pathologies in children were vocal nodules, vocal fold paralysis, subglottic stenosis, and laryngomalacia.

Anatomy and Physiology

The larynx marks the boundary between the upper airway and the lower airway. Sitting opposite the fourth, fifth, and sixth cervical vertebrae in adults, and the third cervical vertebrae in children, the larynx separates the pharynx and trachea (Boone et al., 2010). A total of one bone, nine cartilages, eight extrinsic muscles, and six intrinsic muscles compose the larynx and work together to produce voice and to protect the airway (Boone et al.; Colton et al., 2006).
The laryngeal structures in children are smaller than those of adults, and sit higher in the throat (as previously discussed), and the layers of the vocal folds are not prominent until puberty (Boone et. al., 2010; Kent & Ball, 2000; Stathopoulous & Sapienza, 1997). In addition, children have shorter, thicker vocal folds than adults (2.5 to 3.0 mm at birth compared to 11 to 21 mm in adults), and smaller lung volume (Boone et al.; Keilmann & Bader, 1995; Koenig, 2000; Weinrich, Salz, & Hughes, 2005). With age, they also develop the 3-layer lamina propria (Hirano, Kurita, & Nakashima, 1983; Kahane, 1982; Keilmann & Bader; Koenig).

To produce voice, adequate respiration, phonation, and resonance are needed. In normal voicing, as the air rises from the lungs, it is temporarily blocked by adducted, or closed, vocal folds. The pressure of the air under the vocal folds (subglottic pressure) pushes the folds open, and they begin a cycle of opening and closing, or vibration, to produce phonation. The vocal folds continue to vibrate due to their elasticity, top-down air pressure, and the Bernoulli Effect (Thomsom, Mongeau, & Frankel, 2005). As the air leaves the level of the vocal folds, it ascends and resonates through the supraglottic vocal tract, and the articulators (tongue, teeth, lips) work to form desired sounds for speech.

Prevalence of Voice Disorders

Prevalence is the number of individuals with a certain characteristic/disorder divided by the total population (Carding, Roulstone, Northstone, & Avon Longitudinal Study of Parents and Children (ALSPAC), 2006). According to a 2008 American Speech-Language-Hearing Association (ASHA) report, voice disorders are prevalent in approximately 28 million adult workers in the United States. It has been estimated that voice disorders affect about 3% to 7% of the general population, with the prevalence rising to 10% for those who have occupational voice demands (ASHA & American Academy of Otolaryngology-Head and Neck Surgery, 2005; Boone et al., 2010; Stemple et al., 2000). In 2004, Roy, Merrill, Thibeault, Parsa, Gray, and Smith conducted a large epidemiologic study to determine the prevalence of voice disorders in the adult population. After interviewing 2,531 adults, their results indicated that 43% of the participants reported they had a voice disorder at some point in their life.

Data on prevalence of childhood voice disorders has been limited due to both lack of research and validity of research (Carding et al., 2006). For instance, surveys given to determine prevalence of childhood voice disorders were not always controlled in terms of the population sample (i.e., ages, socioeconomic status, ethnicity), and who responded to the surveys (i.e.,
parents/caregivers, clinicians). From previous research, the prevalence of childhood dysphonia has been said to be between 6% and 38% (Carding et al.). The National Institute on Deafness and Other Communication Disorders (NIDCD) estimated that more than 7.5 million children in America have difficulty using their voice (Boone et al., 2010; NIDCD, 2007). Oates (2004) reported that between 5% and 9% of school-age children have voice disorders. Due to the limited data of prevalence of pediatric voice disorders, Carding, Roulstone, Northstone, & the ALSPAC Study Team (2006) conducted a study to determine the prevalence of voice disorders among 8-year-old children. For this study, pregnant women were recruited from an area of approximately 500 miles. When the children reached 8 years of age, they were asked to complete a formal assessment of their speech, language, and voice function. Out of 7,275 subjects, 445 (6%) were determined to have dysphonia per speech-language pathologist rating. Results indicated that more boys were identified with dysphonia, and subjects who had an older sibling appeared to have a greater occurrence of dysphonia. These results were deemed to be indicative of loud vocal use in boys, as well as increased vocal demand with older sibling(s), respectively.

Although there are reports of voice disorders in school-aged children, such as the study described above, there is limited literature on the prevalence of voice disorders in preschool-aged children. To determine the prevalence of voice disorders in preschool children, as well as the differences in prevalence between European American and African American children, Duff (2004) completed a study of 2,445 preschool children between the ages of 2 and 6 years. Although children had various voice disorder symptoms (i.e., breathiness, tension), Duff specifically looked at those children who experienced hoarseness in their voices. To establish data, teachers were asked to identify which children they suspected to have communication disorders (voice included). After the children were identified, speech-language pathologists both observed and interacted with the children to determine if a voice disorder was present. Inter-rater reliability was established as speech-language pathologists also served as judges for each other, determining if indeed the child presented with a voice disorder. Finally, parents and/or guardians were asked to complete a survey about their child’s speech. The results of this study indicated that the prevalence rate of voice disorders that contribute to hoarseness in preschool-aged children is 3.9%. There was no statistical significance between gender and race.
Evaluation of Voice Disorders

The evaluation of voice disorders is essential for determining the existence of a voice disorder, its etiology, and an appropriate treatment plan. The diagnostic voice evaluation, completed by speech-language pathologists and otolaryngologists, includes a medical examination, patient/caregiver interview, perceptual voice evaluation, acoustic and aerodynamic measures of voice, and evaluation of vocal fold movement (Colton et al., 2006; Stemple et al., 2000; Hirano, 1981). The evaluation process is not solely completed by the speech-language pathologist and otolaryngologist, but rather a team of professionals. Teams will vary according to the needs of particular patients, and may include pediatricians, audiologists, psychiatrists, psychologists, vocal coaches, neurologists, social workers, and school personnel (Stemple et al.; Wilson, 1979).

Medical Examination

The medical examination, completed by an otolaryngologist, is an essential part of the patient’s care. In order to determine the cause of the voice disorder and the appropriate plan of treatment, the otolaryngologist gathers the patient’s case history, examines the patient’s head and neck, and views the larynx via indirect, fiberoptic, or direct laryngoscopy (Stemple et al., 2000). From the results, the otolaryngologist gives a diagnosis and recommendations for treatment. Before the speech-language pathologist can begin a voice treatment program with a patient, a diagnosis and referral for therapy is needed from the otolaryngologist.

Patient/Caregiver Interview

Perhaps the most important part of the voice evaluation, the patient/caregiver interview allows the speech-language pathologist to glean information regarding the patient’s perception of his/her disorder, the impact the disorder has on the patient’s everyday life, and the patient’s vocal habits (i.e., abuse, poor vocal hygiene). The interview also establishes rapport between the patient, his/her caregiver (if present), and the speech-language pathologist (Boone et al., 2010; Colton et al., 2006; Stemple et al., 2000). As rapport becomes established, the patient recognizes the knowledge of the speech-language pathologist, feels comfortable asking questions, and trusts the speech-language pathologist with their vocal care. Informal interviews are completed, as well as more systematic procedures, during which patients analyze their own voice disorder. One example of a more formal self-analysis is the Voice Handicap Index (VHI; Jacobson et al.,
The VHI allows patients to rate their voice disorder by how it affects them functionally, physically, and emotionally.

An understanding of a patient’s medical and social history is imperative for providing appropriate care. Since voice disorders can be caused by various medical conditions (i.e., cerebral palsy, cleft palate, laryngomalacia) and vocal abuse/misuse in various social activities (i.e., screaming, throat clearing, coughing, exposure to cigarette smoke), it is important to learn the medical history and social habits of the patient in order to determine treatment goals that will modify these behaviors (Boone et. al., 2010).

An oral-peripheral examination is also important to complete during the initial assessment. Oral-peripheral examinations look at the overall shape and function of the structures in the mouth and throat. Abnormalities with the oral, pharyngeal, and laryngeal structures may indicate a voice and/or swallowing disorder.

**Perceptual Voice Evaluation**

Perceptually, the voice is measured by its overall quality. Terms such as hoarseness, roughness, breathiness, persistent glottal fry, and strained, are often used to describe abnormal vocal quality. To evaluate vocal quality, a common tool is the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V; Kempster, Gerratt, Abbott, Barkmeier-Kraemer, & Hillman, 2009). This scale ranks a patient’s overall voice quality severity in terms of roughness, breathiness, strain, pitch, and loudness, as determined perceptually by the speech-language pathologist.

**Acoustic and Aerodynamic Measures of Voice**

Instrumental measures of voice can help detect and determine the severity and cause of an abnormality of the voice, as well as assist the speech-language pathologist by being an effective biofeedback and patient education tool (Stemple et al., 2000). Such instrumental measurements include laryngeal stroboscopy, electroglottography, electromyography, and acoustic and aerodynamic measurements (Baken & Orlikoff, 2000; Hirano, 1981; Stemple et al.).

**Acoustic measures.** Acoustic measurements are non-invasive, objective means to determine if the voice is functioning normally (Stemple et al., 2000). Fundamental frequency, vocal intensity, spectral harmonics and noise, and perturbation are all measures that can be obtained through acoustic measurements of voice (Hirano, 1981; Stemple et al.). Although
acoustic measurements are unable to give a diagnosis of voice disorders, they are useful clinical tools to show vocal changes throughout treatment (Stemple et al.).

**Aerodynamic measures.** Like acoustic measurements, aerodynamic measures are also non-invasive, indirect, and objective (Boone et al., 2010; Stemple et al., 2000). Aerodynamic measurements can be used clinically for differentiating whether a voice is functioning normally or has a pathology, how severe the pathology or disorder is, and what may be the etiology of the disorder (Stemple et al.) These measurements are also useful biofeedback tools in therapy sessions (Boone et al.; Stemple et al.). The most current pneumotachograph system used to collect acoustic and aerodynamic measurements is the Phonatory Aerodynamic System (PAS; KayPENTAX, 2006), which gathers measures such as, but not limited to, fundamental frequency, estimated subglottal pressure, average airflow rate, and vital capacity (Boone et al.).

Aerodynamic measurements include subglottic pressure, supraglottic pressure, airflow rate, phonation threshold pressure, and glottal impedance (Hirano, 1981; Jiang & Tao, 2007). Subglottal pressure is the amount of pressure that builds beneath the vocal folds while they are adducted (closed). During speech, this pressure is applied to the vocal folds as they open. Subglottal pressure is measured in cmH\(_2\)O, and can be measured both invasively (i.e., tracheal puncture) and noninvasively (i.e., face mask). Non invasive measurements can be done in the clinical setting and are obtained by estimating the pressure within the oral cavity, which is created when the lips are sealed and the vocal folds are abducted (i.e., producing /p/; Weinrich et al., 2005). This intraoral pressure is then determined to be an estimate of subglottal pressure. Average subglottal pressure is approximately 3.2 to 8.7 cmH\(_2\)O for healthy adults, according to Kent and Ball (2000). A study by McAllister (1998) resulted in subglottal pressures for conversational speech ranging from 3 to 7 cmH\(_2\)O in children, ages 8.5 to 11.5 years.

Airflow rate is how quickly the air moves through the vocal folds as they are vibrating for speech. Airflow rate can be measured using a spirometer, a pneumotachograph, a manometer, or a hot-wire anemometer (Boone et al., 2010; Hirano, 1981). The pneumotachograph is commonly used for this measure, coupled with an airtight facemask (Kent & Ball, 2000; Stemple et al., 2000). The average airflow rate for normal voicing is approximately 70 to 200 mL/sec (Baken & Orlikoff, 2000; Hirano).

**Normative measures.** There is not a set of normative aerodynamic measures that are accepted universally (Kent & Ball, 2000). Normative data on aerodynamic measurements in
young children are sparse in the literature. The following study resulted in normative measures for children. More research is needed to determine normative data with the younger population.

Smith, Guyette, Patil, and Brannan (2003) gathered normative data of children and adolescent oral-nasal pressures, velopharyngeal orifice areas, and nasal airflow rates of nasal sounds. There were 56 participants in the study with an equal amount of girls and boys representing ages 5 through 18 years. The participants were deemed to not have any speech, language, hearing, or voice deficits. While the participants read a speech sample consisting of CV syllables /mi/ and /ma/ and the word “hamper,” a pneumotachometer–pressure transducer and a differential pressure transducer were used to measure the volume rate of airflow and velopharyngeal orifice area pressure drop, respectively. The nasal airflow rate results were as follows: 91.45 cc/s for /ma/ and 118.0 cc/s for “hamper” for the 5 to 9-year old group; 130.69 cc/s for /ma/ and 164.11 cc/s for “hamper” for the 10 to 13-year old group; and 121.70 cc/s for /ma/ and 167.53 cc/s for “hamper” for the 14 to 18-year old group. Results indicated no significant pressure differences between type of utterance, ages, or gender. When compared to adult normative data, the 5 to 9-year old children had less oral nasal pressure, less nasal airflow, and smaller velopharyngeal orifice areas when producing /ma/; and, slightly greater oral nasal pressure, less nasal airflow, and smaller velopharyngeal orifice areas when producing “hamper.” The 10 to 13-year olds had less oral nasal pressure for /ma/, less nasal airflow and velopharyngeal orifice area for both /ma/ and “hamper,” and higher oral nasal pressure for “hamper” than adults. The 14 to 18-group had less oral nasal pressure, less nasal airflow, and larger velopharyngeal orifice areas than the adults for /ma/, and almost equivalent oral nasal pressure, less nasal airflow, and less velopharyngeal orifice areas than adults when producing “hamper.” The consistency of the children and adolescents having less oral nasal pressure than adults was attributed to smaller nasal airways in children and adolescents compared to adults.

Evaluation of Vocal Fold Movement

Although the otolaryngologist completes a medical examination of the larynx, the procedures typically used during this examination (indirect, fiberoptic, and direct laryngoscopy) do not show the movement of the vibrating vocal folds. In order to observe and assess the vocal fold vibration, a method called videostroboscopy is needed. With videostroboscopy, the vocal folds and the surrounding tissue are viewed by a camera via either a flexible or rigid endoscope. A stroboscopy light pulses as a microphone is placed on the patient’s neck to track the
fundamental frequency of the voice (Colton et al., 2006; Stemple et al., 2000). As the stroboscopy light flashes at different points of the vibratory cycle, an image of the vibrating vocal folds is formed (Stemple et al.). By watching the image of the vibrating vocal folds, the speech-language pathologist or otolaryngologist can observe the wave periodicity, symmetry of vocal fold movement, glottal closure, movement of mucosal wave, degree of amplitude, and whether there is a portion of the vocal fold(s) that is not vibrating (Hirano, 1981). These observations assist the otolaryngologist in determining whether an individual’s dysphonia is a result of structural or functional deficits (Colton et al.).

**Repeatability of Measures**

Since limited normative data has been gathered with young children, there are many unknowns regarding normative data and the ability to repeat measures with young children. Stathopoulos and Sapienza (1997) reported difficulty in obtaining accurate measures from young children. When conducting an investigation comparing aerodynamic, acoustic, and respiratory measures between children and adults, Stathopoulos and Sapienza noted procedural differences that occurred with the 4 and 6-year old age groups. First, when producing syllable trains, the 4 and 6-year old age groups produced four syllables per breath, whereas the other participants (ages 8 to 30-years) produced an average of seven syllables. The researchers also allowed the 4 and 6-year old children to say the syllables at a faster rate, instead of following the rate of a metronome that was used to encourage a rate of 1.5 seconds per syllable. They did note, however, that the younger age group was required to produce the following: velopharyngeal closure, stable airflow while producing vowel, syllable trains on one breath, and stop closure. In addition, most of the participants in the 4 and 6-year old age groups did not undergo calibration respiratory maneuvers to determine vital capacity, rib cage capacity, and abdominal capacity due to decreased reliability. Considering the difficulty Stathopolous and Sapienza experienced with gathering data with this young age group, it is questionable whether repeated measures would be consistent.

**Statement of Problem**

Although there is literature regarding repeatability of acoustic and aerodynamic measurements in adults, there are minimal data in the literature about the consistency of repeated aerodynamic measurements in young children. Obtaining data in this area would assist the speech-language pathologist’s confidence that he/she is getting true measures of the child’s
abilities. Asking children to produce syllables and sustain the vowel /a/ at a comfortable loudness level can certainly be done, but the question remains as to how representative the individual’s data truly are.

Statement of Purpose

The purpose of this study is to acquire data regarding the consistency of repeated aerodynamic measures in young children. Specifically, average airflow will be addressed in this study. With very limited data in the literature about this area, this study will provide information that will be useful for clinicians and other researchers. More research is needed in this area, and the information gleaned from this study could serve as a foundation for future research.

Research Questions

1. For children, ages 4.0 to 5.11 years, are average airflow rate measurements repeatable with a brief time period between 2 trials?
2. For children, ages 4.0 to 5.11 years, are mean fundamental frequency measures repeatable during an average airflow task with a brief time period between 2 trials?
3. For children, ages 4.0 to 5.11 years, are mean intensity measures repeatable during an average airflow task with a brief time period between 2 trials?

Null Hypotheses

1. It is hypothesized that for children, ages 4.0 to 5.11 years, average airflow rate measurements will not differ significantly between 2 trials over a brief period of time.
2. It is hypothesized that for children, ages 4.0 to 5.11 years, mean fundamental frequency measures obtained during an average airflow task will not differ significantly between 2 trials over a brief period of time.
3. It is hypothesized that for children, ages 4.0 to 5.11 years, mean intensity measures obtained during an average airflow task will not differ significantly between 2 trials over a brief period of time.
CHAPTER II
Methods

Participants

Thirty male and female participants between 4.1 and 5.11 years of age were recruited from the southwestern Ohio area for this study. There were 16 participants (8 males; 8 females), ages 4.1 to 4.11 years (M = 4.4 years), and 14 participants (8 males; 6 females), ages 5.0 to 5.11 years (M = 5.3 years). There was an attrition of 1 participant (a 4 year old male), which reduced the study population from 30 to 29, due to inadequate sample size for data analysis. Participants were recruited from Mini University, the Miami University Speech and Hearing Clinic, and local preschools through flyers and parent letters (Appendices A and B). The research took place in the Clinical Voice Laboratory at the Miami University Speech and Hearing Clinic in Bachelor Hall. Before participation in the study, parental consent and child assent forms (Appendices C and D) were obtained, following an explanation of the research procedure. All participation in this study was voluntary. This study was approved by the Institutional Review Board at Miami University.

Procedure

After an explanation of the study, the legal guardian was asked to read and sign the parental consent form as the research investigator read the child assent form to the participant. Prior to enrollment in the study, a hearing screening and perceptual voice screening were administered to determine eligibility. If the participant did not pass the hearing screening and/or was determined to have a voice disorder, he/she was excluded from the study. Each testing session lasted approximately 30 minutes.

Hearing Screening

Each participant’s hearing was measured bilaterally using a portable audiometer (MAICO MA 25). The participants were asked to raise their hand when they heard a tone. The pure tones were presented bilaterally at 25 dB at 500, 1000, and 2000 Hz.

Perceptual Voice Screening

Following the hearing screening, a perceptual voice screening was completed. Participants were asked to repeat sentences from the Consensus Auditory Perceptual Evaluation-Voice (CAPE-V). Participants suspected to have voice disorders were not included in the study and referred to a speech-language pathologist for further evaluation and treatment.
Aerodynamic Measurement

Equipment. The average airflow measurements were obtained using the Phonatory Aerodynamic System (PAS; KayPENTAX, 2006). A face mask that covered the mouth and nose was placed on the participant, creating a tight (but comfortable) seal. The mask was connected to a filter, which was connected to the pneumotach via a tube. The PAS was connected to a computer, where the PAS software gathered the data and allowed for data analysis. The device was calibrated each day of use, every 4 hours.

Protocol. The research investigator asked the participant to count to 3 in order to match the participant’s comfortable pitch and provide a model for the task. Following the Voicing Efficiency protocol, participants were instructed to sustain /a/ at a comfortable pitch and loudness 3 times for 5 seconds each. Each participant practiced the task before beginning Trial 1. Verbal and tactile cues (i.e., sustaining /a/ with the participant, tracing the length of the participant’s arm to demonstrate length of utterance, using fingers to count to 5 to demonstrate length of utterance) were provided to encourage participation. After a brief time period (approximately 10 minutes), participants repeated the average airflow measures for Trial 2, following the same Voicing Efficiency protocol. All aerodynamic measurements were recorded into the PAS computer software, which calculated the data.

Data Measurement

Measurement of average airflow data was obtained using the middle two seconds of the sustained /a/. For each participant, three samples from both trials were measured. Averages were calculated for both Trial 1 and Trial 2 data. Fundamental frequency and intensity measures were recorded for each measured segment of the /a/ production.

Analysis of Data

Paired t-tests were used to analyze the data from this study. Trial 1 and Trial 2 average airflow means were compared for each participant. In addition, fundamental frequency and intensity means for each participant were compared to determine repeatability, due to their potential effect on average airflow measures. The analyses were completed using Predictive Analytics Software 17 (PASW Statistics 17) for Windows.
CHAPTER III
Results

The purpose of this study was to determine the short-term repeatability of average airflow measures. In addition to analyzing the repeatability of average airflow measures, fundamental frequency and intensity data were analyzed to determine their repeatability, due to potential interaction with airflow measures. These interactions would most likely occur between the airflow and intensity measures, as intensity has been shown to have a greater effect on airflow than frequency (i.e., as intensity increases, airflow increases; Holmberg, Hillman, & Perkell, 1989; Stathopoulos, 1985).

Analysis of Data by Research Question

Research Question 1

For children, ages 4.0 to 5.11 years, are average airflow rate measurements repeatable with a brief time period between 2 trials?

A paired t-test was used to analyze the average airflow measurements. Results from the paired t-test indicated that there was not a significant difference in average airflow measures between the two trials ($t = -0.166$, df = 28, $p = .869$). The mean airflow results are shown in Table 1 and Figure 1. Mean airflow results displayed by gender and age are depicted in Tables 2 and 3 and Figures 2 and 3, respectively.

Table 1

<table>
<thead>
<tr>
<th>Trials</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
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<tbody>
<tr>
<td>Mean</td>
<td>74.43</td>
<td>75.17</td>
</tr>
<tr>
<td>SD</td>
<td>21.55</td>
<td>28.90</td>
</tr>
</tbody>
</table>
Figure 1. Mean airflow (mL/sec) during average airflow trials.
Table 2

*Mean Airflow (mL/sec) and Standard Deviation by Gender*

<table>
<thead>
<tr>
<th>Trials</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
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</tbody>
</table>

*Figure 2.* Mean airflow (mL/sec) by gender.
Table 3

*Mean Airflow (mL/sec) and Standard Deviation by Age*

<table>
<thead>
<tr>
<th>Trials</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-year olds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>79.33</td>
<td>69.11</td>
</tr>
<tr>
<td>SD</td>
<td>20.29</td>
<td>23.01</td>
</tr>
<tr>
<td>5-year olds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>69.17</td>
<td>81.67</td>
</tr>
<tr>
<td>SD</td>
<td>22.34</td>
<td>33.79</td>
</tr>
</tbody>
</table>

*Figure 3. Mean airflow (mL/sec) by age.*
Research Question 2

For children, ages 4.0 to 5.11 years, are mean fundamental frequency measures repeatable during an average airflow task with a brief time period between 2 trials?

A paired t-test indicated there was no significance of mean fundamental frequency between the two trials ($t = -0.821$, df = 28, $p = .419$). The overall mean fundamental frequency and standard deviation for both trials are listed in Table 4, and the mean fundamental frequency measures for both trials are depicted in Figure 4. Tables 5 and 6 and Figures 5 and 6 display fundamental frequency results by gender and age.

Table 4

<table>
<thead>
<tr>
<th>Trials</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>218.49</td>
<td>222.91</td>
</tr>
<tr>
<td>SD</td>
<td>35.70</td>
<td>38.00</td>
</tr>
</tbody>
</table>

Figure 4. Mean fundamental frequency (Hz) during average airflow trials.
Table 5
*Mean Fundamental Frequency (Hz) and Standard Deviation by Gender*

<table>
<thead>
<tr>
<th>Trials</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>208.07</td>
<td>215.65</td>
</tr>
<tr>
<td>SD</td>
<td>34.00</td>
<td>36.97</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>229.65</td>
<td>230.68</td>
</tr>
<tr>
<td>SD</td>
<td>35.22</td>
<td>38.89</td>
</tr>
</tbody>
</table>

Figure 5. Mean fundamental frequency (Hz) by gender.
### Table 6

*Mean Fundamental Frequency (Hz) and Standard Deviation by Age*

<table>
<thead>
<tr>
<th>Trials</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-year olds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>201.86</td>
<td>210.56</td>
</tr>
<tr>
<td>SD</td>
<td>34.05</td>
<td>40.11</td>
</tr>
<tr>
<td>5-year olds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>236.31</td>
<td>236.14</td>
</tr>
<tr>
<td>SD</td>
<td>28.91</td>
<td>31.84</td>
</tr>
</tbody>
</table>

*Figure 6.* Mean fundamental frequency (Hz) by age.
Research Question 3

For children, ages 4.0 to 5.11 years, are mean intensity measures repeatable during an average airflow task with a brief time period between 2 trials?

A paired t-test indicated there was a significant difference between mean intensity measures from both trials ($t = -3.552$, df = 28, $p = 0.001$). Table 7 and Figure 7 display the mean intensity results for both trials. These results are also shown by gender and age in Tables 8 and 9 and Figures 8 and 9, respectively.

Table 7

<table>
<thead>
<tr>
<th>Trials</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>74.58</td>
<td>76.85</td>
</tr>
<tr>
<td>SD</td>
<td>4.05</td>
<td>4.59</td>
</tr>
</tbody>
</table>

Figure 7. Mean intensity (dB) and standard deviation during average airflow trials.
Table 8

*Mean Intensity (dB) and Standard Deviation by Gender*

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>76.03</td>
<td>77.79</td>
</tr>
<tr>
<td>SD</td>
<td>3.52</td>
<td>3.44</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>73.03</td>
<td>75.86</td>
</tr>
<tr>
<td>SD</td>
<td>4.12</td>
<td>5.52</td>
</tr>
</tbody>
</table>

*Figure 8.* Mean intensity (dB) and standard deviation by gender.
Table 9

Mean Intensity (dB) and Standard Deviation by Age

<table>
<thead>
<tr>
<th>Trials</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-year olds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>75.78</td>
<td>78.41</td>
</tr>
<tr>
<td>SD</td>
<td>3.75</td>
<td>5.26</td>
</tr>
<tr>
<td>5-year olds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>73.30</td>
<td>75.19</td>
</tr>
<tr>
<td>SD</td>
<td>4.10</td>
<td>3.11</td>
</tr>
</tbody>
</table>

*Figure 9. Mean intensity (dB) and standard deviation by age.*
CHAPTER IV

Discussion

Interpretation of the Results by Research Question

Research Question 1

For children, ages 4.0 to 5.11 years, are average airflow rate measurements repeatable with a brief time period between 2 trials?

The results of the paired t-tests showed there were no significant differences for average airflow measures between the two trials, indicating that for this population, average airflow rate measures were consistent when repeated after a brief time period (see Table 1 and Figure 1). With the lack of literature available on repeatability of aerodynamic measures with this population, the results of this study can be used for further normative data. The results from the present study could guide future investigation.

Stathopoulos and Sapienza (1997) reported difficulty with obtaining reliable measures with a younger population in a research setting. There are many factors to consider when working with this population, especially with the issue of compliance. In order to promote compliance during this study, it was helpful to have the parents of the participants in the room. This lessened possible anxiety, as the parents provided encouragement and reassurance for the participants. In addition, a variety of models and cues were useful in facilitating the participants’ understanding and proper completion of the tasks. Verbal models and verbal, visual, and tactile cues were utilized during the testing sessions to promote participation and 5-second sustained utterances. There were some participants who did not produce 5-second samples, in which samples greater than or equal to 3 seconds were accepted. The attrition of one participant was due to repeated sample lengths less than 3 seconds.

Gender group differences. Comparison of mean airflow results between male and female participants revealed a 3.87 mL/sec difference during Trial 1 and a 4.47 mL/sec difference during Trial 2. The females had greater airflow results during Trial 1, and the males had greater airflow results during Trial 2 (see Table 2 and Figure 2). These differences were slight (as listed above), indicating these differences may not be directly associated with gender.

Age group differences. When comparing the mean airflow results between the 4- and 5-year old age groups, there was a 10.16 mL/sec difference during Trial 1 and a 12.56 mL/sec difference during Trial 2. An interesting point is that the 4-year olds demonstrated greater
airflow values during Trial 1, and the 5-year olds demonstrated greater airflow values during Trial 2 (see Table 3 and Figure 3). However, the age group differences were minor, which would be anticipated for 4- and 5-year olds.

Research Question 2

For children, ages 4.0 to 5.11 years, are mean fundamental frequency measures repeatable during an average airflow task with a brief time period between 2 trials?

Mean fundamental frequency measures for both trials did not reveal significant differences. These results (see Table 4) indicated that fundamental frequency values were consistent with a brief time period between trials for the 4- and 5-year old population. The difference between Trials 1 and 2 was 4.42 Hz.

Gender group differences. Separating the fundamental frequency measures by gender, the female participants had less difference between the two trials than the males (1.03 Hz compared to 7.58 Hz), but neither difference would be perceptually noticeable. Female fundamental frequency measures were greater than the male measures on both trials, with a difference of 21.58 Hz for Trial 1 and 15.03 Hz for Trial 2 (see Table 5 and Figure 5). These results are consistent with the fact that female children have slightly higher fundamental frequency than males.

Age group differences. The 4-year olds demonstrated greater difference between trials than the 5-year olds (8.7 Hz compared to 0.17 Hz). These differences may be attributed to maturity and cooperation. The 5-year olds had higher fundamental frequencies than the 4-year olds, with 34.45 Hz and 25.58 Hz differences for Trials 1 and 2, respectively. Results grouped by age are shown in Table 6 and Figure 6.

Research Question 3

For children, ages 4.0 to 5.11 years, are mean intensity measures repeatable during an average airflow task with a brief time period between 2 trials?

The mean intensity measures between both trials were deemed to be significant by a paired t-test. Since it has been shown that airflow measures are related to intensity (Holmberg et al., 1989), a significant difference between mean intensity values could indicate significant mean airflow results; however, the mean airflow results were not significant in this study. Closer inspection of the mean intensity results revealed only a slight difference between trials (2.27 dB) as well as low standard deviations (see Table 7). These standard deviations proved to be
exceptionally low, when compared to those of mean airflow and mean fundamental frequency (see Tables 1 and 4). The low standard deviations are indicative of close individual intensity values. Due to the narrow range of these values, a small difference (2.27 dB) may be reported as being statistically significant, even though it perceptually would not be noticeable.

**Gender group differences.** When grouped by gender, the male participants had slightly higher intensity values than the females (see Table 8 and Figure 8). When compared, the female participants showed greater difference between trials than the males (2.83 dB compared to 1.76 dB). Both groups of participants had increased intensity during Trial 2. This increased intensity evident in both gender groups could be attributed to increased familiarity and comfort with the task.

**Age group differences.** Comparison of intensity results by age revealed a greater difference between trials with the 4-year olds versus 5-year olds (2.63 dB compared to 1.89 dB). These differences were considered negligible. Both age groups had greater intensity during Trial 2 (see Table 9 and Figure 9).

**Relationship of Average Airflow Rates and Fundamental Frequency/Intensity**

Garrison (2009) researched the repeatability of average airflow and estimated subglottal pressure with adult females, ages 18 to 24 years, over three testing sessions. The PAS Voicing Efficiency protocol was followed for all testing sessions, in which participants sustained the vowel /a/ at their comfortable pitch and intensity for three consecutive trials. The protocol was repeated after a 10-minute break, and again after a week break. A tuner and sound level meter were used to control and match the fundamental frequency and intensity for all sessions.

Results of the study showed no significant difference between mean airflow measures for the three sessions. In addition, there was no significant difference between mean fundamental frequency measures. The mean intensity measures, however, were determined to be statistically significant, but not perceptually significant, as there was a difference of 2 db SPL. This difference was attributed to the range of accepted intensity values (+/- 5 dB). It is interesting to note that the same results (i.e., no significance with fundamental frequency and no perceptual significance with intensity) occurred for the present study, in which fundamental frequency and intensity were not controlled. This presents the question as to whether it is necessary to monitor and control for frequency and intensity measures with any population.
Clinical Implications

Since there are limited data available on the repeatability of average airflow measures, continued normative data collection and future research in this area are needed, especially with younger populations. This study contributed to the data and literature. The results of this study indicated that repeated aerodynamic measurements over a short period of time can be reliable with the 4- and 5-year old population. This information helps to advocate the reliability of aerodynamic measures with a young population for diagnostic and clinical use. In addition, the study showed that fundamental frequency and intensity are also repeatable with this population over a brief time period, even when not controlled with instrumentation.

It is important to note that these results were obtained following a brief time period (approximately 10 minutes). The consistency of these measures may be different with increased time periods between trials. When using this information clinically, it is important to remember that average airflow, fundamental frequency, and intensity may change due to the treatment. When assessing progress from pre-treatment to post-treatment, using instrumentation to control for frequency and intensity measures would be necessary.

Limitations

This study was part of a larger study, in which acoustic measures were also obtained during testing sessions. Considering the age of the children who participated as well as the time required for testing sessions, estimated subglottal pressure measures were not a part of this study. Obtaining normative data for these pressure measures with this population, determining the repeatability of those measures, and comparing those results with the average airflow results would have provided more insight into the consistency of obtaining aerodynamic measures with this young population.

Implications for Future Research

Information gathered from continued research with this young population would be beneficial in order to develop more confidence in the data measures. Since it has been estimated that more than 7.5 million children in America demonstrate some kind of dysphonia (Boone et al., 2010; NIDCD, 2007), obtaining accurate and representative data is important for diagnostic and treatment purposes.

Further investigation could vary the amount of time between trials. This study focused on a short-term time period between trials, but it would be interesting to obtain data with different
increments of time between trials (i.e., 30 minutes, 1 day, 1 week) to determine repeatability for longer periods of time. Also, further research could be performed to determine the cause of the difference between 4- and 5-year old mean airflow data. Such investigation might focus on fatigue, familiarity, and comfort level. In addition, evaluating the repeatability of estimated subglottal pressure measures over various periods of time would be another area to investigate.
References


Attention Parents!

Children ages 4 and 5 years old needed at Miami University’s Speech and Hearing Clinic for a research study

Your child will...

- receive a hearing and voice screening.
- be asked to complete several speech tasks such as counting and telling a story.
- receive a small toy for their participation.

This study will take approximately 30 minutes and parents will receive a Kroger gift card in the amount of $15.

If interested, please contact Dana Sprouse or Shelley May at 513-529-7181 or email at sprousdc@muohio.edu or maysk2@muohio.edu

This study has been approved by the Miami University Institutional Review Board.

Protocol # 09-187
Dear Parent,

We are graduate students in the Speech Pathology and Audiology Department at Miami University, and in the upcoming months, we will be conducting a research study at Miami University Speech and Hearing Clinic in Oxford, Ohio. The research study will collect information about your child’s voice. The purpose of this study is to determine if having children perform different types of tasks makes their pitch change. We also hope to determine if airflow rate is repeatable. Airflow rate is the rate at which air flows through the vocal cords. A voice and hearing screening will be completed to ensure that your child does not have a voice disorder or hearing loss. Your child will first be asked to wear a mask that covers the mouth and nose while producing “ah” multiple times. This mask in no way obstructs breathing. This will provide us with measurements of your child’s airflow rate. Your child will complete this task at the beginning and then again at the end of the testing session to determine if airflow rate measurements remain consistent. Next, your child will be asked to do various tasks including sustaining an “ah,” counting from 1 to 10, and describing 4 picture cards. Your child will speak into a microphone for these 3 tasks that will be connected to a computer. Fundamental pitch values will be obtained from these tasks. Attached you will find a copy of the “Informed Consent” form. If you would like your child to participate please contact Miami University’s Clinical Voice Lab at 513-529-7181 or email Dana Sprouse at sprousdc@muohio.edu or Shelley May at maysk2@muohio.edu to set up a time for your child to participate in the study. The testing session will take place at Miami University’s Clinical Voice Lab located in Bachelor Hall, Room 49 in Oxford, Ohio. The testing session will last only 30 minutes. At the completion of the testing session your child will receive a small toy as well as a $15 Kroger card. Thank you for taking the time to consider your child’s participation in this research study.

Sincerely,

Dana Sprouse and Shelley May
Graduate Students
Department of Speech Pathology
Miami University

Dr. Brehm and Dr. Weinrich
Faculty
Department of Speech Pathology
Miami University
Appendix C

Informed Consent

The effect of task type on acoustic measures and repeatability of aerodynamic measures in children ages 4.0-5.11 years

Description of the Research

A primary component of a voice disorder evaluation is to collect measures of voice production, and measures related to the respiration required to support speech. Average airflow is one measurement that will be collected from your child. Average airflow is the rate of airflow through the vocal folds during speech. The purpose of this study is to investigate how repeatable average airflow is. In addition, fundamental pitch, which is an acoustic measurement, will be collected using various task types. Your child is being asked to participate in this study because he/she does not have any problems with his/her voice, but the results of this study will be beneficial in developing assessment protocols to use with children who have voice disorders.

Research Procedures

Testing Session

Prior to collecting the measurements of your child’s voice, your child will be required to pass a basic hearing and voice screening. The hearing screening will involve listening to a tone presented at four frequencies in each ear. Your child will have to raise his/her hand to indicate hearing each tone. The voice screening will involve the examiners listening to your child’s voice while repeating short sentences. Your child will be seated in a quiet room (Room 49 Bachelor Hall) and instructed to follow directions provided by the investigators.

Your child will wear a face mask that goes over his/her nose and mouth. This mask will not obstruct breathing. First, your child will be asked to sustain “ah” at a comfortable pitch and volume for 3 trials. Then your child will be asked to choose a card from a stack of cards sitting on the table. Each card represents a specific task that your child will complete. The tasks include sustaining a vowel; counting from 1 to 10, and telling a story using 4 picture cards. Your child will speak into a microphone for these three tasks. The microphone will be connected to a computer that will record all of your child’s speech productions.

The first set of tasks, during which your child wore the face mask and spoke several “ahs,” will be repeated again to examine the consistency of the measurements for this age group. The entire testing session will take approximately 30 minutes.

When these tasks are completed your child will be given a small toy. You will be given a $15 Kroger card for allowing your child to participate in this study.
Time Required for Participation

Your child’s participation will take approximately 30 minutes.

Risks

There are no known risks associated with this study and we do not foresee any potential for discomfort. If your child does not want to complete a certain task, the study will cease.

Benefits

This study has the potential to improve assessment protocols for patients with voice disorders.

Alternative Treatments

There are no alternative treatments in this study.

Confidentiality

The information obtained about your child in this study will be kept confidential. This information will be kept in a locked file cabinet in the primary investigator’s office. Information saved electronically will be on a password protected computer that does not have public access. Your child’s information will be assigned a code number, and the key for this code will be stored separately from your information. Once your child’s participation in this study is completed, all identifying information that could link your child’s information will be destroyed and your child’s data will be kept in a locked file cabinet as anonymous data.

Voluntary Participation

Your child’s participation in this study is voluntary. Your child has the right to refuse to participate with no penalty or loss of benefits to which they would otherwise be entitled. Your child may discontinue his/her participation in this study at any time and may refuse to answer specific questions without penalty or loss of benefits to which he/she would otherwise be entitled.

Questions About the Study

You may ask questions regarding the study and the study procedure at any time. You can reach the primary investigator for this study, Susan Brehm, Ph.D. at (513) 529-2553 or bakerse1@muohio.edu. You may also contact Barbara Weinrich, Ph.D. at (513) 529-2548 or weinribd@muohio.edu with any questions regarding your rights as a participant in this study.
Questions About Rights of Participants

You may contact the Office for the Advancement of Research and Scholarship at (513) 529-3734 or at humansubjects@muohio.edu with any questions regarding your rights as a participant in this study.

In signing this document I acknowledge that I am the legal guardian of this participant. I have been informed about this study’s purpose, procedures, possible benefits, risks, and how my privacy will be protected. I will receive a copy of this form. I have been given the opportunity to ask questions and told that I can ask questions at any time. I voluntarily agree to allow my child to participate in this study. By signing this form, I am not waiving any legal rights.

_______________________________________  ______________
Signature of Person Consenting          Date

_______________________________________  ______________
Witness                                Date
Appendix D

Child Assent

Hello! Our names are Dana and Shelley. What is your name? We are going to play some games and we would like you to play with us. At any time you can choose not to do something. The first thing we will do is see how your ears are hearing. Let’s see those ears of yours! We are going to pretend that you are an airplane pilot and put these earphones over your ears. We will have you listen closely for beeps and tell us when you hear them. The next thing we will do is have you repeat some sentences. Then we will have you put on this mask (show mask). This mask will not hurt you at all. You will be able to breathe just as you are right now. When you are wearing the mask we will ask you to say some funny sounds. After that, we will start a different game. We have cards on the table, and you can pick whatever card you want. This will tell us what game we are going to play! We will play each game three times. You will get to say “ah”, count from 1 to 10, and make up a story from pictures! After all those games, you will get to put the mask back on and say some more sounds before you leave. Do you have any questions about the games we are going to play? Remember, if you do not want to play a game, it is OK to tell us! Let’s start!