

Temporal Characteristics of Aerodynamic Segments in the Speech of Children and Adults

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Objectives: The primary purpose of this study was to determine the temporal characteristics of aerodynamic segments in the normal speech of children and adults without cleft palate. A secondary objective was to determine the within-speaker variability of the segments.

Method: Speakers consisted of 46 children aged 6 to 8 years, 41 older children aged 11 to 12 years, and 41 adults aged 18 to 37 years (total $n = 128$) who repeated the word "hamper" during continuous utterances. The pressure-flow method was used to determine the duration of six segments of the oral air pressure and nasal airflow pulses associated with the /mp/ sequence. Descriptive statistics, including coefficients of variation (COV), were computed for each segment as a function of age and sex of the speakers. Analysis of variance (ANOVA) procedures were used to determine the effects of age, sex, or both on the temporal variables.

Results: ANOVAs indicated statistically significant main effects ($p < .008$) for age on five of the six temporal measures and for sex on three of the six measures. Five of the six COVs were also statistically significant for age. There were no statistically significant interactions between speaker age and sex for any measure.

Conclusions: The results indicate distinct patterns of timing for aerodynamic segments of speech produced by children and adults. Overall, adults exhibited less temporal variability than children. The generally longer and more variable segments produced by children suggest diagnostic and treatment implications relative to speakers with velopharyngeal dysfunction.

KEY WORDS: *pressure-flow method, speech aerodynamics, speech development, speech timing, velopharyngeal function*

The pressure-flow technique, originally described by Warren and DuBois (1964), is an objective method for the evaluation of velopharyngeal (VP) function during speech production. The original technique provided information on differential oral-nasal air pressure levels, rates of nasal airflow, and estimates of VP orifice size. Warren et al. (1985) described a modification of the technique that enabled the temporal assessment of certain aspects of VP function. Essentially, the modification involved measurement of the separate oral air pressure pulse associated with specific phonetic contexts. During production of the /mp/ sequence in the word "hamper," for example, the duration from the start of nasal airflow (/m/) to peak oral pressure (/p/) can be inferred as the time required to achieve VP closure for this segment.

Warren and colleagues have reported various findings re-

sulting from the use of the modified pressure-flow technique. Warren et al. (1985), for example, reported that certain timing parameters associated with the /mp/ sequence distinguished speakers with cleft palate who exhibited inadequate VP function from those with adequate VP function. In addition, the authors reported preliminary timing data for 10 adult speakers without cleft palate who had normal speech. Warren et al. (1989) reported that the duration of the nasal airflow pulse in "hamper" differentiated groups of patients with various degrees of VP inadequacy. There was a progressive increase in the duration of the nasal airflow pulse as VP inadequacy increased. The authors suggested that this phenomenon reflected a compensatory response involving the respiratory system. Warren et al. (1993) further reported that hypernasal patients with adequate VP function produced certain aerodynamic segments that were significantly longer than those produced by patients with cleft palate with normal resonance and adequate VP function and noncleft controls. The segments that differentiated the speakers included: (1) the duration of the nasal airflow pulse, (2) the time from the beginning of nasal airflow to the peak of oral pressure, (3) the time from the beginning of nasal airflow to the end of oral pressure, and (4) the time

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from the beginning of oral pressure to peak pressure. Based on the findings, Warren et al. (1993) suggested that "a delay of about 50 ms in achieving closure" was associated with hypernasality in the patients (p. 150).

Given that the above findings suggest important clinical implications for the assessment of VP timing patterns, it is surprising that relatively few studies have investigated speakers without cleft palate. VP timing data are especially lacking relative to age and sex considerations. Zajac and Mayo (1996), for example, reported timing measures based on nasal airflow and oral air pressure for 42 normal-speaking adults without cleft palate. They reported timing values that were generally consistent with preliminary data reported by Warren et al. (1985) for normal-speaking adults without cleft palate. Leeper et al. (1998) investigated temporal characteristics of VP function in 24 normal-speaking children without cleft palate ranging in age from approximately 3 to 12 years. The children were divided into four age groups, with three boys and three girls per group. The authors measured eight timing variables associated with differential oral-nasal air pressure and nasal airflow obtained from the word "hamper." Although Leeper et al. (1998) reported a numerical trend toward shorter duration of segments with increasing age, they further stated that "normal children . . . performed similarly to the normal adults studied by Warren et al. (1985)," (p. 219). It must be noted, however, that a limitation of the study was the small number of children ($n = 6$) per age group.

Based on evidence from several areas of investigation, we suspect that children and adults may indeed differ relative to the temporal aspects of VP aerodynamics during speech. It has been reported, for example, that anticipatory nasal airflow (Thompson and Hixon, 1979), peak oral air pressure (Netsell et al., 1994; Zajac, 2000), and peak nasal airflow (Zajac, 2000) differ between children and adults. In addition, a growing body of evidence from acoustic studies has indicated differences in the duration of speech segments and syllables between children and adults (see Smith et al., 1996, for a review). Smith et al. (1996) longitudinally studied 12 children between the ages of 7 and 11 years at two different time periods separated by approximately 1½ years. They reported an overall decrease in speech segment and syllable duration of approximately 10%. They also reported a decrease in the within-speaker variability of the segments of approximately 35%. The authors noted that not all children demonstrated a decrease in speech segment duration as a function of time.

The primary purpose of the present study was to determine temporal characteristics of aerodynamic segments in the normal speech of children and adults without cleft palate. It was hypothesized that both the overall duration of speech segments and the within speaker variability of the segments would decrease as a function of increasing age.

METHOD

Participants

Participants consisted of 128 speakers divided into three arbitrary age groups. There were 46 children (25 girls, 21 boys)

between the ages of 6 and 8 years, 41 older children (17 girls, 24 boys) between the ages of 11 and 12 years, and 41 adults (21 women, 20 men) between the ages of 18 and 37 years. All speakers previously participated in a larger study of speech aerodynamics described by Zajac (2000). In addition, the adult speakers were previously studied by Zajac and Mayo (1996). All speakers reported English as a first language. Except for seven of the older children, all speakers lived in the Pittsburgh, Pennsylvania, area. The overall racial composition of the speakers was approximately 83% Caucasian, 15% African American, and 2% Asian American. Additional details regarding the speakers, including information that shows no racial differences relative to aerodynamic measures, are described by Zajac (2000).

Speakers were excluded from the study if they reported a history of cleft palate, hearing loss, tonsillectomy or adenoidectomy within a year of the study, or upper respiratory infections at the time of the study. In addition, all of the children underwent a visual examination of the oral cavity performed by either the investigator or a trained graduate student in communication disorders. The oral examinations revealed no evidence of undetected submucous cleft palate (i.e., bifid uvula or midline palatal translucence) in any of the children included in the study. Although formal assessments of voice, resonance, and articulation were not performed, all speakers were judged to exhibit age-appropriate perceptual characteristics at the time of testing. Finally, informed parental and adult written consents were obtained for all participants.

Speech Sample

The speakers repeated the word "hamper" approximately five times using self-determined rate, pitch, and loudness levels during a single-breath group. The five-repetition utterance was produced up to a total of three times. The word "hamper" was selected because the /mp/ sequence requires dynamic adjustment of the VP mechanism from an open to a closed position during the sequence.

Procedures

The pressure-flow method as described by Warren et al. (1985) was used to acquire simultaneous oral air pressure, nasal air pressure, and nasal airflow data during production of the speech sample. Nasal air pressure was obtained to estimate VP orifice area as part of the larger study. The timing measures reported below, however, were based on nasal airflow and oral air pressure as described by Warren et al. (1985, 1993). Details regarding the present procedures and instrumentation are described by Zajac (2000). Briefly, calibration of all pressure-flow instrumentation was performed on a daily basis. The pressure-flow signals were low-pass filtered at a cutoff of 15 Hz and digitized to a computer at a rate of 200 samples per second with 12-bit resolution for 5 seconds using PERCI-PSCOPE software, version 1.1 (Microtronics, Inc., Chapel Hill, NC).

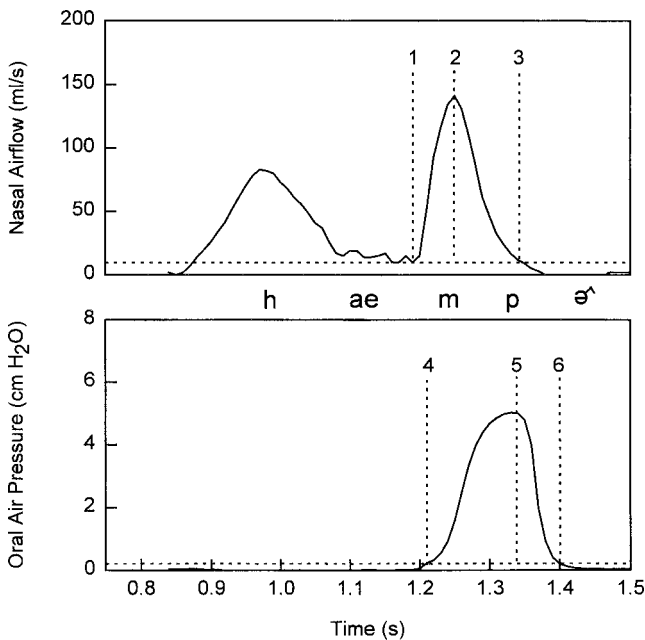


FIGURE 1 Example of nasal airflow (top) and oral air pressure (bottom) data from an adult speaker during production of “hamper.” Numbered vertical lines indicate the beginning and end points of the timing measures for the /mp/ sequence. Horizontal lines indicate the airflow and pressure thresholds for measurements. 1 = begin airflow; 2 = peak airflow; 3 = end airflow; 4 = begin pressure; 5 = peak pressure; 6 = end pressure.

Data Analysis

Figure 1 presents typical pressure-flow data associated with a single production of the word “hamper” from an adult speaker. The figure illustrates six points associated with the /mp/ sequence. These points were used to derive the duration of the following six segments evaluated in the present study: (1) 1 through 3 (the beginning of nasal airflow to the end of nasal airflow), (2) 1 through 5 (the beginning of nasal airflow to the peak of oral pressure), (3) 1 through 6 (the beginning of nasal airflow to the end of oral pressure), (4) 2 through 5 (peak nasal airflow to peak oral pressure), (5) 4 through 5 (the beginning of oral pressure to peak oral pressure), and (6) 4 through 6 (the beginning of oral pressure to the end of oral pressure). Although Warren et al. (1993) described 15 possible timing measures associated with the /mp/ sequence, the present study focused on only six of the measures. Four of the measures were selected because Warren et al. reported that these measures identified patients with hypernasality who exhibited adequate VP function (i.e., segments 1-3, 1-5, 1-6, and 4-5). Segment 2-5, a measure of the overlap of the airflow and pressure pulses, was selected because Warren et al. (1985) reported that it discriminated patients with adequate, borderline, and inadequate VP function. Segment 4-6, a measure of the duration of the pressure pulse, was selected because of its potential for diagnostic use as discussed below.

As shown in Figure 1, nasal airflow typically preceded the beginning of the /mp/ sequence. This anticipatory nasal airflow

was produced consistently by most of the speakers. Although anticipatory nasal airflow may be expected during the vowel segment, one may question its occurrence during the /h/ segment. We must emphasize, however, that previous studies have confirmed this phenomenon (e.g., Zajac, 1997). In addition, as reported by Zajac (2000), this phenomenon may not be the sole result of regional dialect. Zajac (2000) reported that speakers from both Pennsylvania and North Carolina tended to exhibit anticipatory nasal airflow, as illustrated in Figure 1.

For most speakers, the six timing measures were based on means derived from nine productions of “hamper” (i.e., the middle three productions of each five-repetition utterance times three utterances). In some cases, a speaker did not produce three utterances of the speech sample. This resulted in means being based on three to six productions of “hamper.” The second author manually determined the timing measures using PERCI-SARS software (version 3.0, Microtronics Inc.). As illustrated in Figure 1, an arbitrary threshold of 0.2 cm H₂O was used to determine the onset (point 4) and offset (point 6) of oral air pressure associated with the /mp/ sequence. This threshold was selected to negate the effects of small shifts in baseline pressure. A threshold of 10 mL/second was used to determine the onset (point 1) and offset (point 3) of nasal airflow associated with the sequence. This threshold was selected because Hoit et al. (1994) suggested that nasal airflow up to 10 mL/second may occur as artifact even in the presence of airtight VP closure. In some cases, the level of anticipatory nasal airflow during the vowel segment exceeded the 10 mL/second threshold value. When this occurred, the beginning of nasal airflow for the /mp/ sequence was determined at the point at which airflow exceeded the lowest level of the vowel by 10 mL/second.

The reliability of the second author’s measurements was estimated by randomly selecting three speakers and repeating the measurements for segment 1-6. A total of 24 measurements was repeated. The correlation coefficient between the two sets of measurements was 0.988 ($p < .001$). The mean duration for the first set of measurements was .195 seconds (SD = .029); the mean duration for the second set of measurements was .194 seconds (SD = .027). The difference was not significant ($t[23] = 1.57, p = .129$).

Statistical Analysis

Descriptive statistics, including group means (M), standard deviations, and coefficients of variation (COVs) were computed for the six timing measures. COVs were computed as the SD divided by the M for each speaker and variable. Analysis of variance (ANOVA) procedures were used to determine possible age (three levels) and sex (two levels) effects on the mean data for each of the six timing variables. Alpha levels were set at .008 (.05 divided by 6 to adjust for multiple ANOVAs). Post hoc differences among age groups were determined using Bonferroni tests with alpha levels set at .017 (.05 divided by 3). As a secondary analysis, the COV data were

TABLE 1 Group Means (M) and Standard Deviations (SD) of the Timing Variables (in Seconds) as a Function of Age and Sex of the Speakers

Variable	6-8			Age Group (y) 11-12			18-37		
	Male (n = 21)	Female (n = 25)	Group (n = 46)	Male (n = 24)	Female (n = 17)	Group (n = 41)	Male (n = 20)	Female (n = 21)	Group (n = 41)
1-3									
M	.082	.084	.083	.084	.096	.089	.087	.092	.090
SD	.024	.023	.023	.021	.029	.025	.026	.020	.023
1-5			●	●	●	●	●	●	●
M	.123	.136	.130	.113	.123	.117	.100	.120	.110*†
SD	.020	.027	.025	.022	.021	.022	.018	.018	.020
1-6			●	●	●	●	●	●	●
M	.226	.231	.229	.203	.204	.204	.174	.190	.182*
SD	.026	.037	.032	.026	.021	.023	.019	.019	.020
2-5			●	●	●	●	●	●	●
M	.085	.092	.089	.076	.077	.076	.070	.079	.074*
SD	.014	.028	.023	.016	.014	.015	.027	.015	.022
4-5			●	●	●	●	●	●	●
M	.117	.132	.125	.106	.124	.114	.092	.116	.104*†
SD	.022	.028	.026	.018	.028	.024	.016	.013	.018
4-6			●	●	●	●	●	●	●
M	.211	.227	.220	.197	.199	.198	.166	.186	.176*†
SD	.024	.036	.032	.021	.024	.022	.019	.017	.020

* Significant post hoc differences among age groups as indicated by brackets.

† Significant sex differences (see text).

analyzed by both parametric and nonparametric procedures as described below.

RESULTS

Descriptive measures of skewness indicated that all six of the timing variables were normally distributed. Table 1 presents group M and SD of the timing variables as a function of age and sex of the speakers. The 2 × 3 ANOVAs indicated significant main effects of age for five of the six timing variables (segments 1-5, 1-6, 2-5, 4-5, 4-6) and significant main effects of sex for three of the six variables (segments 1-5, 4-

5, 4-6). There were no significant interactions involving age and sex for any of the variables. Table 2 presents the results of the ANOVAs for each main effect and variable.

Post hoc testing indicated the following significant group differences relative to age and sex of the speakers: (1) 1-5, significant differences between the younger and older children and the younger children and adults; girls and women significantly greater than boys and men; (2) 1-6, significant differences among all three age groups; no significant sex difference; (3) 2-5, significant differences between the younger and older children and the younger children and adults; no significant sex difference; (4) 4-5, significant difference between the younger children and adults; girls and women significantly greater than boys and men; and (5) 4-6, significant differences among all three age groups; girls and women significantly greater than boys and men.

Descriptive measures of skewness indicated that two of the six COVs were positively skewed (segments 1-6 and 2-5). Because of this, these two variables were analyzed by nonparametric statistics as described below. Table 3 presents the COVs of the six timing variables as a function of age and sex of the speakers. The values in Table 3 are group means that reflect individual COVs computed as the SD divided by the M for each speaker. Because COVs are standardized by the means, these measures control for variability that is associated with differences in duration of the aerodynamic segments. The COVs, therefore, reflect relative within speaker variability that is unaffected by segment duration. As shown in Table 3, the COVs generally decreased in magnitude as a function of increasing age for each variable. On average, all segments

TABLE 2 ANOVA Results for the Main Effects of Age and Sex for the Six Timing Variables

Main Effect/ Timing Variable	df	F Value	p Level
Age effect			
1-3	2	1.18	.311
1-5	2	9.24	<.001*
1-6	2	35.04	<.001*
2-5	2	6.33	.002*
4-5	2	9.49	<.001*
4-6	2	32.95	<.001*
Sex effect			
1-3	1	2.52	.115
1-5	1	13.94	<.001*
1-6	1	2.57	.111
2-5	1	2.58	.111
4-5	1	22.97	<.001*
4-6	1	8.28	.005*

* Significance at p < .008. No age-by-sex interactions were significant.

TABLE 3 Coefficients of Variation (COVs) of the Timing Variables as a Function of Age and Sex of the Speakers

Variable	Age Group (y)								
	6–8			11–12			18–37		
	Male (n = 21)	Female (n = 25)	Group (n = 46)	Male (n = 24)	Female (n = 17)	Group (n = 41)	Male (n = 20)	Female (n = 21)	Group (n = 41)
1–3	.27	.33	.30	.21	.20	.21	.17	.15	.16*
1–5	.17	.21	.19	.14	.18	.16	.15	.11	.13
1–6	.12	.16	.14	.14	.11	.13	.08	.07	.07*
2–5	.18	.26	.22	.22	.19	.21	.14	.14	.14*
4–5	.17	.20	.19	.14	.17	.15	.10	.10	.10*
4–6	.12	.13	.12	.10	.10	.10	.06	.08	.07*

* Significant post hoc differences among age groups (see text). COVs are group means that reflect individual COVs (SD divided by the mean) for each speaker.

showed a reduction in variability from the younger children to the adults of 42%. The 2×3 ANOVAs indicated significant main effects ($p < .008$) of age for segments 1-3, 4-5, and 4-6. There were no significant main effects of sex and no significant interactions involving age and sex. Post hoc testing indicated the following significant age group differences: (1) 1-3, significant differences between the younger and older children and the younger children and adults; (2) 4-5, significant differences between the younger children and adults and the older children and adults; and (3) 4-6, significant differences between the younger children and adults and the older children and adults. Krushal-Wallis ANOVAs indicated significant main effects ($p < .008$) of age for the two segments that were positively skewed. Post hoc testing using Mann-Whitney U tests indicated the following significant age group differences: (1) 1-6, significant differences between the younger children and adults and the older children and adults; and (2) 2-5, significant difference between the younger children and adults. There were no significant sex differences for either COV.

DISCUSSION

The primary purpose of this study was to determine the temporal characteristics of aerodynamic segments in the normal speech of children and adults. As hypothesized, five of the six segments decreased in duration as a function of increasing age. Three of the segments also were associated with significant sex differences; female speakers exhibited longer segments than males. A secondary objective was to determine the within-speaker variability of the segments. Five of six COV measures decreased in magnitude as a function of increasing age. These findings are consistent with previous acoustic studies that have indicated reduced speech segment duration and variability as a function of age (e.g., Kent and Forner, 1980; Smith et al., 1996). Kent and Forner (1980) reported that 4-year-old children had longer speech segment durations and greater variability of segment durations than adults and older children aged 6 and 12 years. Similarly, Smith et al. (1996) reported that 7- to 12-year-old children exhibited reduced speech segment duration and variability when studied over time.

The findings of the present study have clear diagnostic implications relative to speakers with VP dysfunction. Because

there appear to be distinct differences between children and adults, the results of pressure-flow tests involving most timing parameters need to be interpreted relative to the age of the speaker and secondarily to sex for some parameters. As an example, we recently evaluated an 8½-year-old girl who presented with a repaired submucous cleft palate, hypernasal speech, and dysarthria. Based on the clinical evaluation, we suspected that her hypernasality was due primarily to dysarthria. Because this condition is characterized by reduced speed and range of motion of the articulators, we were especially interested in the assessment of her VP timing parameters. Pressure-flow testing revealed longer duration of segment 1-3 (295 milliseconds), 1-5 (203 milliseconds), and 4-6 (283 milliseconds) as compared with values for 8-year-old children (see Table 1). Segment 1-3 was greater than 3 SDs above the expected mean, and segments 1-5 and 4-6 were approximately 2 SDs above the expected sex means. The diagnostic significance of these timing measures is further highlighted by the fact that the girl exhibited adequate VP closure during production of “hamper” as indicated by estimated orifice areas that were less than 5 mm² at peak pressure (Warren et al., 1989). Because a neuromotor timing problem was clearly implicated, prosthetic and behavioral management was recommended rather than secondary palatal surgery. Possible behavioral strategies that may address VP timing problems are discussed below.

The findings of the study also may have practical implications relative to management decisions involving children with normal neuromotor function, repaired cleft palate, and marginal VP dysfunction. Such children present the cleft palate team with difficult decisions because they typically exhibit perceptual speech symptoms consisting of mild to moderate nasal air emission and hypernasality but no gross compensatory articulation errors. As indicated by Warren et al. (1993), some of these speakers may exhibit “adequate” VP closure during pressure-flow testing. In these cases, treatment recommendations may range from secondary surgical management to behavioral speech therapy to a wait-and-see strategy. The last option is especially likely to be recommended for young children who may not be ready for speech therapy or have other conditions that contraindicate secondary surgical management (e.g., Pierre Robin sequence and possible airway compromise). The results of the present study provide some support for this

option. Because young children exhibit longer speech segment duration, the perceptual consequences of nasal air escape or hypernasality may be more salient than in older children and adults. The younger children in the present study, for example, produced oral air pressure pulses (segment 4-6) that were approximately 45 milliseconds longer on average than those produced by adults. In addition, Zajac (2000) has reported that peak oral air pressures of these children were approximately 2 cm H₂O higher than in adults. Clearly, the use of a higher driving pressure in combination with a longer segment duration may result in more severe perceptions of audible nasal air emission in younger children. Similar physiologic factors (i.e., relatively increased subglottal pressure and longer vowel duration) may also exacerbate the perception of hypernasality in younger children. The results of the present study, therefore, suggest that a reduction in the perceptual severity of some speech symptoms may occur because of shorter speech segments and reduced segment variability as a function of age. If reductions in the severity of speech symptoms for children with marginal VP dysfunction were to occur over time, then management recommendations may also change.

Based on the above findings, we believe that useful pressure-flow criteria may be developed to guide treatment decisions for young children with repaired cleft palate who exhibit marginal VP dysfunction. (1) If VP closure is adequate (i.e., < 5 mm²) and timing parameters are within age limits, then a wait-and-see strategy may be appropriate. This recommendation is based on the assumption that primary surgery has optimized VP movement capabilities and normal developmental aspects of segment control are primarily responsible for perceptual symptoms. (2) If VP closure is adequate and timing parameters exceed age limits, then behavioral management options may be appropriate. This recommendation is based on the assumption that primary surgery has not fully optimized VP movement capabilities as reflected by timing parameters. (3) If VP closure is borderline (i.e., 5 to 10 mm²) and timing parameters exceed age limits, then either behavioral management or surgical options may be appropriate, depending on the severity of the perceptual symptoms. This recommendation is also based on the assumption that primary surgery has not fully optimized VP movement capabilities as reflected by both VP orifice size and timing parameters. At our center, the team typically recommends trial speech therapy if symptoms are relatively mild and therapy has not been previously attempted. If previous therapy has been unsuccessful or symptoms are moderate, then surgical options are recommended. Finally, we need to note that based on previous findings (Warren et al., 1989) and our clinical observations, we do not believe that normal timing patterns would be found when speakers exhibit borderline VP closure.

The second and third recommendations above assume that VP timing may be improved by behavioral therapy techniques. Although it is not our intent to evaluate or recommend specific techniques, we do believe that at least two strategies exist that may benefit some children who exhibit VP timing problems. These strategies include the application of continuous positive

airway pressure to the nasal passage as described by Kuehn (1991) and the use of increased vocal effort as described by McHenry (1997). In theory, both strategies may promote increased displacement and velocity of articulators. Although McHenry (1997) reported improved VP closure in speakers with dysarthria, she did not report measures of VP timing. Obviously, the effectiveness of these and other behavioral techniques must be evaluated by clinical research studies.

We must emphasize that the pressure-flow criteria for treatment decisions that we recommend are tentative and also need to be evaluated by appropriate research. We should note, however, that several previous investigations have provided some support for the notion that perceptual speech characteristics may be influenced by the duration of the word or segment. Jones et al. (1990) reported that 4 of 10 children with cleft palate who exhibited inconsistent nasalization during connected speech were perceived as less nasal when word production time was experimentally decreased. Similarly, Dotevall et al. (2001) recently reported that children with cleft palate who were judged high on clinical ratings of hypernasality and audible nasal escape tended to have longer durations of nasal airflow during the VP closing phase of nasal-plosive segments than children who were judged low on the ratings. This duration corresponds to segment 2-3 as illustrated in Figure 1 of the present study.

Finally, we need to note that the overall validity of the VP timing measures obtained in the present study is supported by other research. Kuehn (1976), for example, reported that cine-radiographic determination of velar movement duration approximated 109 milliseconds by a normal adult male speaker and 124 milliseconds by a normal adult female speaker. These values are quite similar to the mean duration of segment 1-5 reported in Table 1 for adult male (100 milliseconds) and female (120 milliseconds) speakers, respectively. Also, Dalston and Keefe (1988) determined VP reaction times during speech to an auditory stimulus using a photodetector system. They reported mean reaction times of approximately 206 milliseconds for 10 normal speakers (separate sex values not reported). Dalston and Keefe indicated that the VP reaction time included a latency of at least 75 milliseconds required for auditory processing of the stimulus. Given this auditory latency, the VP reaction times were similar to the duration of segment 1-5 reported in this study.

SUMMARY

The primary purpose of this study was to determine the temporal characteristics of aerodynamic segments in the normal speech of children and adults. Results indicated clear age-related differences in the duration of five of six segments associated with the nasal-plosive sequence in the word "hamper." The results suggest that age-specific criteria must be used to interpret VP timing patterns in clinical populations. The results further suggest that the perceptual severity of speech characteristics in some young children with marginal VP dysfunction may lessen as a function of developmental changes

in sound segment duration. Specific pressure-flow criteria based on the findings were suggested to guide treatment decisions and future research.

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