Effect of Age, Gender, and Repeated Measures on Intraoral Air Pressure in Normal Adults

Susan G. Hiss, Kathleen Treole, and Andrew Stuart

East Carolina University

Address all correspondence to Susan G. Hiss, MS, Department of Communication Sciences and Disorders, East Carolina University, Belk Annex, Greenville, NC 27858-4353. Telephone calls may be made to (252) 353 - 8552. Electronic mail may be sent via Internet to smh0704@mail.ecu.edu.

Abstract

The effect of age, gender, and repeated measures on intraoral air pressure (P_0) was examined. Sixty adults comprised of ten males and ten females in each of three age groups (i.e., 20 to 39, 40 to 59, and 60 to 83 years) participated. P_0 was assessed during voiceless stop plosive /p/ productions in repeated vowel/consonant syllables. The three medial plosives of a seven syllable train were averaged to comprise a token. Five tokens were obtained and averaged for each of three trials. Thus each participant contributed 105 syllables and a subsequent three P_0s for analyses. There was no statistically significant difference in P_0 as a function of age or gender (p>.05). These findings support the conception that P_0 remains stable throughout adulthood and is not dependent on gender. Differences in repeated measures of P_0 attained statistical significance ($p = .03$), however the mean differences between trials (.23 cm H_20) were negligible and deemed to be clinically insignificant. Thus, across a short sampling session, P_0 is a relatively stable measurement and does not change as a function of age or gender. **Key words:** Intraoral air pressure-Aerodynamic measurement-Age-Gender-Repeated measures.

Effect of Age, Gender, and Repeated Measures on Intraoral Air Pressure in Normal Adults

Intraoral air pressure (P_0) has been investigated extensively in order to determine how it is affected as a function of dynamic physiologic changes that occur during speech. Specifically, P_0 has been reported to vary as a function of vocal intensity.[1-6] That is, P_0 increases with increases in vocal intensity. In addition to intensity, P_0 varies as a function of presence or absence of voicing. P_0 is greater for voiceless than voiced cognate pairs.[3,5,7-13] The degree of P_0 produced in the oral cavity is also dependent on the consonant itself. For example, Arkebauer, Hixon, and Hardy[7] and Malecot[14] found that peak pressures are greater for a voiceless plosive when compared to its fricative cognate. Peak pressure, on the other hand, is greater for a voiced fricative relative to its plosive counterpart. Black[15] also reported that pressures generated during fricatives surpassed those of plosives, yet this finding was based on pooling voiced and voiceless cognates together. Outside of the voicing environment, vowel context also affects P_0. Karnell and Willis[16] substantiated previous reports of Brown[2] that greater P_0 is produced with /u/ as compared to /a/. Arkebauer, and colleagues[7] reported that P_0 increased with increased syllable rate; whereas Brown and McGlone[17] reported P_0 did not significantly increase with increases in syllable rate.

With respect to the effects of gender on P_0, the findings are equivocal. For example, Holmberg and colleagues[4] reported data acquired during a syllable sequence task with young to middle-aged adult males (*n* = 25) and females (*n* = 20). They found no differences in P_0 measures between the genders (cf. 5.91 and 6.09 cm H_20 for males and females under normal speaking voice condition, respectively). However, Bernthall and Beukelman[18] compared the P_0 values of six men and six females (*M* = 30 years) and found that females contributed a slightly greater P_0 than males but these values did not reach statistical significance. Subtelny, Worth, and Sakuda[6] also reported that females had higher P_0s than males. In contrast, Stathopoulos[5] reported that of the ten males and ten females (range = 22 to 33 years), males tended to generate a higher P_0 than women but again those values did not reach statistical significance. Thus, further studies investigating P_0 as a function of gender are warranted considering the equivocal findings of the limited available data with small sample sizes.

Studies of age effects on P_0 have been limited. Melcon, Hoit, and Hixon[19] reported P_0s of 60 healthy men encompassing six decades from 20 to 70 years. Mean P_0s ranged from 5.8 to 6.4 cm H_20 across the six age groups. As these differences were not statistically significant, Melcon and colleagues concluded, "driving pressure does not differ as a function of age"(p. 285).[19] No female P_0s were examined in this study. However, Morris and Brown[20] did specifically investigate P_0 of 25 young (i.e., 20 to 35 years) versus 25 elderly (i.e., over 75 years) women and found no significant differences between the mean P_0s of the two groups. However, when the P_0s of elderly denture wearing women were compared to the P_0s of young and dentate elderly women, denture wearing elderly women demonstrated significantly greater peak P_0 on voiceless consonants. Significantly greater P_0 has been reported in children as compared to adults,[5,18] yet when Stathopoulos[5] held intensity level constant there was no difference in P_0 across the age groups. That is, it appears children simply use a louder normal speaking volume than adults explaining the difference in P_0 between the groups. Brown and McGlone[17] investigated whether oral cavity and vocal tract size correlated with differences in P_0s of 15 young adult males. If a correlation existed, then a plausible explanation of the previous P_0 gender difference trends could be made. That is, females tend to have smaller vocal tracts than males and would subsequently exhibit inversely higher P_0s. However, no relation between oral cavity size and peak P_0 was found. Thus anatomical size differences alone would not predict P_0 differences across genders or age. P_0 variations as a function of age have not been supported. However, Higgins and Saxman[21] reported data acquired during a syllable repetition task from young (*n* = 20) and elderly (*n* = 21) male and female adults. They found P_0 changes with age as a function of gender. An age effect was present for male P_0 but not for females. They reported means of 5.81 cm H_20 for young males (*M* = 24.1 years), 7.99 cm H_20 for elderly males (*M* = 75.3 years), 6.51 cm H_20 for young females (*M* = 26.6 years), and 6.35 cm H_20 for elderly females (*M* = 74.6 years). Thus, the findings of age effects on P_0 are equivocal. "There is an urgent need for more replications in the field of speech-language pathology and audiology"(p. 929)[22] and specifically P_0. Replication of findings as to the role of age on P_0 would hence improve accuracy in generalization.

A normative database that obtains P_0 in a normal speaking voice from a large number of participants is needed. In addition, the data should be comprised of P_0 obtained from a wide range of ages and across both genders. Some of the above studies that have reported mean P_0s across age groups were conducted holding vocal intensity constant. Subglottal air pressure which is often derived from P_0 in a voiceless stop environment is a primary variable in controlling vocal intensity.[23-25] If P_0 is obtained at a prescribed vocal intensity, then the respiratory effort used may not be indicative of that used in normal speech for a given individual. In many voice disorders, an inappropriate intensity is actually a finding of the voice disorder itself[26] and "asking such patients to alter their loudness may obscure or alter aspects of the vocal behavior one wants to study"(p. 485).[8] Thus, not only is a comprehensive database across age groups and genders needed to substantiate the presence or absence of an age and/or gender effect on P_0, it is also needed where sound pressure level is not a controlled variable.

P_0 has also been investigated with respect to its variability across repeated measures. Brown and McGlone[17] reported that very little within subject variation was found in repetitions of /tʌ/ produced by ten young females and ten young males. Brown and Shearer[27] found no significance for within subject variance of P_0 and reported "speakers appear to have a high degree of control over their articulation (p. 54)." However, Morris and Brown[28] investigated P_0 variability in a population other than young adults and reported that increased P_0 variability is found in older women (i.e., over 75 years) as compared to young women (i.e., 20 to 35 years). Males were not included in the study. Thus, the current literature presents P_0 as a stable measurement in young adults but suggests trends of variability in aging, and the anatomic changes that occur in aging could result in physiologic changes in the consistent production of P_0. Therefore, more investigation is needed to support if in fact P_0 variability increases with age for females as well as for males. The purpose of this study was, therefore, to establish group P_0 data and to determine the effect of age, gender, and repeated measures on P_0 measurements among young, middle-aged, and elderly adults during the production of a stop plosive in a vowel/consonant syllable repetition task.

Method

Participants

Sixty adults served as participants. Twenty individuals comprised each of three age groups: 20 to 39 years (*M* = 27.6 years, *SD* =5.7), 40 to 59 years (*M* = 49.5 years, *SD* = 6.0), and 60 to 83 years (*M* = 69.2 years, *SD* = 7.5). Ten males and ten females were represented in each group. Participants were volunteers and reported no history of smoking, pulmonary disease, neurological disease, structural disorders, language disorders, speech disorders, and/or voice problems. All participants were monolingual, English speaking Caucasians.

Apparatus

A Kay Elemetrics Aerophone II System (Kay Elemetrics, Lincoln Park, NJ) was utilized to obtain peak P_0. Measures of P_0 were obtained via a 7 cm patent polyethylene tube with an internal diameter of approximately 3 mm. The first cm of the proximal end of the tube was occluded while the second cm had four perforations offset by 90 degrees as a result of two drill cuts. The tube was threaded through a small opening in a facemask. The facemask was utilized for acquisition of other aerodynamic measures. The distal end of the tube was coupled to an analog to digital air pressure transducer (Eurosensor Model 1210A002DM) and interfaced with a personal computer (IBM Model PS/2 or Toshiba Model 325 CDS). The transducer was factory calibrated. Digital eight-bit samples were obtained with a sampling frequency of 1000 Hz. The system software generated air pressure measures as a function of time. Peak pressure values (i.e., maximum displacement of cm H_20) associated with the production of /p/ were extracted from the pressure waveforms off-line.

Procedure

Participants repeated the voiced vowel /i/ and the voiceless stop-plosive /p/ seven times in vowel/consonant format. The peak oral pressures of the third, fourth, and fifth productions of /p/ in a seven syllable train were averaged and comprised one token. Five tokens were then obtained and averaged to comprise one trial. Three trials were obtained with an inter-trial interval of two minutes. Thus, each participant contributed three peak P_0 measurements to the data analyses. Participants were instructed to take a deep breath before beginning the syllable train and to produce each syllable train on a continuous expiration at normal loudness and pitch.[29] The investigator determined that each participant was producing the syllable trains consistent with loudness and pitch of previous conversational speech and trial syllable train productions. Participants were also instructed to place equal stress on each syllable.[30] To assure equal rhythm, participants matched their utterance rate to a 1.5 syllables/s metronome audible click.

Participants were seated upright with the facemask placed over their nose and mouth creating a comfortable airtight seal. The proximal end of the intraoral tube was positioned approximately one to two cm past the central incisors. Participants were trained in the utterance task until they produced the syllable train at the appropriate pace and were speaking at their comfortable loudness level.

Results

Mean P_0 as a function of age, gender, and trial are presented in Table 1. A three-factor mixed analysis was performed to investigate P_0 as a function of age, gender, and trial. This was performed with general linear model repeated measures ANOVA utilizing SPSS 8.0 statistical software (SPSS Inc., 1999). The results of the analysis are presented in Table 2. Relative treatment effect sizes (i.e., proportion of variance accounted for) and statistical power are indexed by omega squared [ω^2][31] and phi [ϕ],[32] respectively. The analysis revealed a significant main effect of trial. The main effect of age and gender and all interactions were not significant. Table 3 depicts mean P_0 as a function of trial collapsed across age and gender.

Post hoc analyses in the form of single-*df* comparisons[31,33] were undertaken to assess the main effect of trial (see Table 3). It was found that the mean P_0 in trial one was significantly different from trial three [F (1,108) =7.24, Geisser-Greenhouse p = .0093]. Mean P_0 in trial two was not significantly different from either trial one [F (1,108)= 1.94, Geisser-Greenhouse p = .17] or three [F (1,108)=1.69, Geisser-Greenhouse p = .20]. In other words, P_0 increased significantly from trial one to three.

Discussion

This study revealed that significant differences did not exist in P_0s between young, middle-aged, and elderly adults or between genders as assessed during voiceless stop plosive /p/

productions in repeated syllable trains. That is, P_0 does not significantly change throughout adulthood and is not dependent on gender. Significant differences existed, however, in repeated measures of P_0 across trials in a relatively short sampling session. That is, P_0 s increased across the three successive trials. Although these differences in repeated measures of P_0 attained statistical significance, their relative treatment magnitude sizes (see Table 2) were small.[33] In addition the mean differences between trials (.23 cm H_20) were negligible and thus deemed to be clinically insignificant.

The P_0 means reported here are comparable to those previously reported in the literature. Group means as a function of age, gender, and trial for this study's sixty participants range from 5.55 to 6.79 cm H_20 (see Table 1). Holmberg and colleagues[4] reported P_0 mean values of 5.91 and 6.09 cm H_20, for young males and females, respectively. Mean P_0 values of 5.81, 6.51, 7.99, and 6.35 cm H_20 for young males and females and elderly males and females, respectively, were reported by Higgins and Saxman.[21] Thus, these group means, as acquired with commercially available aerodynamics instrumentation, fall well within previously reported normative P_0 values.

Concerning the conflicting P_0 findings regarding age and gender, this study found no age or gender effect on P_0. Statistically significantly higher P_0 values for elderly males over young males,[21] trends of higher P_0 s in females over males,[6,18] and higher P_0 s in males over females[5] were not substantiated by this study. However, Melcon and colleagues[19] reported no statistically significant age effect for P_0 in males, Morris and Brown[20] reported no statistically significant age effect for P_0 in dentate females, and Holmberg and colleagues[4] reported no gender effect, all of which are consistent with the findings of this study. Thus, this study which incorporated an equal representation of gender and three age groups provides much needed replication of previous P_0

reports and substantiates that P_0 is a consistent measurement across adulthood regardless of gender.

The statistically significant finding of a trial effect would at first seem to be in contrast with conclusions drawn by Brown and McGlone[17] and Brown and Shearer[27] in that P_0 is a relatively stable measurement. However, the mean differences across trials were less than .23 cm H_20 that though statistically significant lacks any clinical significance due to the meagerness of the difference. However, Morris and Brown[28] had reported increased variability in P_0 in elderly females when compared to young females. This study does not support those findings. A significant group by trial interaction would have been present which was not the case here. In other words, all age groups in this study exhibited the same degree of P_0 variability across trials. The post-hoc analysis did reveal that P_0 increased from trial one to trial three. Thus, a practice effect was probably present. That is, participants became more comfortable with the task and subsequently increased their speaking loudness level. An increase in speaking loudness level was not perceptually detected by the examiner, and the increase in loudness levels were most likely minimal at most as the P_0 only increased by .23 cm H_20 across trials. The vocal intensity levels were specifically not instrumentally monitored, as a goal of this study was to acquire P_0 at a comfortable loudness level for future comparison to pathologic voices. By simply viewing Table 1, one can determine that even though a slight increase in P_0 exists from trial one to trial three, the values across age groups, gender, and trial were stable.

Conclusions

This study provides adult normative P_0 data from a sample representative of both genders and an age range spanning from young adulthood to the elderly. These findings offer clarification to existing equivocal literature and support that P_0 does in fact not change as a function of age or gender. Thus, clinically a diagnostician may consult a normative P_0 database for comparison to pathologic P_0s without regard to specific age or gender provided the acquisition of data is equivalent to that described herein. In addition, despite statistical significance of trial, trial mean differences, or lack thereof, support that P_0 is a stable measurement within a relatively short sampling session.

References

1. Arkebauer HJ. A study of intraoral air pressures associated with production of selected consonants. Doctoral thesis State University of Iowa. 1964.
2. Brown WS Jr. An investigation of intraoral pressures during production of selected consonants. Doctoral thesis State University of New York at Buffalo. 1969.
3. Brown WS Jr., McGlone, RE, Proffit MR. Relationship of lingual and intraoral air pressures during syllable production. *J Speech and Hear Res*. 1973;16:141-151.
4. Holmberg EB, Hillman RE, Perkell JS. Glottal airflow and transglottal air pressure measurements for male and female speakers in soft, normal, and loud voice. *J Acoust Soc Am*. 1988;84:511-529.
5. Stathopoulos ET. Relationship between intraoral air pressure and vocal intensity in children and adults. *J Speech Hear Res.*1986;29:71-74.
6. Subtelny JF, Worth JH, Sakuda M. Intraoral pressure and rate of flow during speech. *J Speech Hear Res.* 1966;29:498-518.
7. Arkebauer HJ, Hixon TJ, Hardy JC. Peak intraoral air pressures during speech. *J Speech Hear Res.*1967;10:196-208.
8. Holmberg EB, Hillman RE, Perkell JS, Gress C.. Relationships between intra-speaker variation in aerodynamic measures of voice production and variation in SPL across repeated recordings. *J Speech Hear Res.*1994;37:484-495.
9. Kent RD, Moll KL. Vocal tract characteristics of the stop cognates. *J Acoust Soc Am.* 1969;*46*:1549-1555.
10. Klich RJ, Sabo WJ. Intraoral pressure differences in various degrees of breathiness. *Folia Phoniatr*. 1988;*40*:265-269.

11. Murray T, Brown WS, Jr. Intraoral air pressure in whispered stop consonants. *J Phonet*. 1976;4:183-187.

12. Netsell R. Subglottal and intraoral air pressures during the intervocalic contrast of /t/ and /d/. *Phonetica*. 1969;20:68-73.

13. Warren DW, Hall DJ. Glottal activity and intraoral pressures during stop consonant productions. *Folia Phoniatr*. 1973; 2:121-129.

14. Malecott A. An experimental study of force of articulation. *Studia Lingua.* 1955;*9*:35-45.

15. Black JW. The pressure component in the production of consonants. *J Speech Hear Dis.* 1950;15:207-210.

16. Karnell MP, Willis CR. The effect of vowel context on consonantal intraoral air pressure. *Folia Phoniatr.* 1982;34:1-8.

17. Brown WS Jr., McGlone RE. Constancy of intraoral air pressure. *Folia Phoniat*. 1969;21:332-339.

18. Bernthal JE, Beukelman DR. Intraoral air pressure during the production of /p/ and /b/ by children, youths, and adults. *JSHR*. 1978;21:361-371.

19. Melcon MC, Hoit JD, Hixon TJ. Age and laryngeal airway resistance during vowel production. *J Speech Hear Dis.* 1989;*54*:282-286.

20. Morris RJ, Brown WS Jr. Age-related voice measures among adult women. *J Voice.* 1987;1:38-43.

21. Higgins MB, Saxman JH. A comparison of selected phonatory behaviors of healthy aged and young adults. *J Speech Hear Res.* 1991;34:1000-1010.

22. Muma JR. The need for replication. *J Speech Hear Res.* 1993;36:927-930.

23. Stevens KN. Physics of laryngeal behavior and larynx modes. *Phonetica*. 1977;34:264-279.

24. Fant G. Glottal source and excitation analysis. *Quarterly Report, 1*, Speech Transmission laboratory and Music Acoustics, The Royal Institute of Technology, Stockholm, Sweden. 1977:85-107.

25. Fant G. Preliminaries to analysis of the human voice source. *Quarterly Report, 4*, Speech Transmission Laboratory and Music Acoustics, The Royal Institute of Technology, Stockholm, Sweden, 1982:1-27.

26. Hillman RE, Holmberg, EB, Perkell JS, Walsh M, Vaughan, C. Phonatory function associated with hyperfunctionally related vocal fold lesions. *J Voice*. 1990;4:52-63.

27. Brown WS Jr., Shearer WM. Constancy of intraoral air pressure related to integrated pressure-time measures. *Folia Phoniatr.*1970;22:49-57.

28. Morris RJ, Brown WS Jr. Age-related differences in speech variability among women. *J Comm Dis.* 1994; 27:49-64.

29. Smitheran JR, Hixon TJ. Clinical method for estimating laryngeal airway resistance during vowel production. *J Speech Hear Dis*. 1981;46:138-146.

30. Hertegard S, Gauffin J, Lindestad P. A comparison of subglottal and intraoral pressure measurements during phonation. *J Voice.* 1995;9:149-155.

31. Keppel G. *Design and analysis: A researcher's handbook* (3rd ed.). Upper Saddle River: Prentice Hall, Inc. 1991.

32. Cohen J. *Statistical power analysis for the behavioral sciences* (2cd ed.). Hillsdale: Lawrence Erlbaum Associates, Inc. 1988.

33. Keppel G, Zedeck S. *Data analysis for research designs.* New York: W. H. Freeman and Company. 1989.

Table 1

Mean Intraoral Air Pressure (cm $H_2 0$) as a Function of Age, Gender, and Trial.

	Trial		
Group	One	Two	Three
Young Female	6.35 (0.46)	6.50 (0.46)	6.34 (0.50)
Young Male	6.31 (0.46)	6.25 (0.45)	6.31 (0.50)
Middle-aged Female	5.84 (0.46)	6.25 (0.45)	6.23 (0.50)
Middle-aged Male	5.96 (0.46)	5.99 (0.45)	6.37 (0.50)
Elderly Female	5.85 (0.46)	5.81 (0.45)	5.97 (0.50)
Elderly Male	6.19 (0.46)	6.42 (0.45)	6.60 (0.50)

Note. Standard errors of the mean are presented in parentheses.

Table II.

Summary Table for the Three-Factor Mixed Analysis of Variance Investigating Intraoral Air Pressure as a Function of Age, Gender, and Trial.

Source	*df*	*F*	*p*	ω^2	ϕ
Group	2	0.15	.86	.01	.07
Gender	1	0.13	.72	.00	.07
Trial	2	3.62	.03*	.06	.67
Group X Gender	2	0.29	.75	.01	.09
Trial X Group	4	1.19	.32	.04	.37
Trial X Gender	2	0.66	.51	.01	.16
Trial X Group X Gender	4	0.67	.62	.02	.21

Note. *p* values following Geisser-Greenhouse correction, * considered significant at $\alpha = .05$.

Table III.

Mean Intraoral Air Pressure (cm H_20) as a Function of Trial Collapsed across Age and Gender.

	Trial		
	One	Two	Three
Mean	6.08	6.20	6.32
	(0.09)	(0.08)	(0.09)

Note. Standard errors of the mean are presented in parentheses.