THE COMPLEX INTER-RELATIONSHIPS BETWEEN VITAL CAPACITY, MAXIMUM PHONATION TIME, AND PHONATION QUOTIENT

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PREFACE

Normal values of maximum phonation time, vital capacity, and phonation quotient were obtained for college students. Relationships between these various measures were examined. A moderate relationship between vital capacity and maximum phonation time was established. Vital capacity was chosen as the factor to represent respiratory abilities, because this measure can be easily obtained with a compact spirometer. It is possible that another respiratory measure, such as phonation volume, may be more indicative of respiratory abilities as related to phonation. It was determined that ranges of maximum phonation time and phonation quotient could not be established for vital capacity groups.

I wish to express my sincere gratitude to all the people who assisted me in this study. I extend special thanks to my thesis adviser, Dr. Arthur Pentz, for his advice and assistance. I would also like to thank the other committee members, Dr. Nancy Monroe, and Dr. John Panagos, for their advise during the course of this project.

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CHAPTER I

INTRODUCTION

The communication process involves numerous components which must function efficiently and in precise synchrony if the oral signal is to convey the intended meaning to the listener. Typically the speech-language pathologist will attempt to assess the integrity of each of these processes by employing controlled observations of the various dimensions of each of several components.

For instance, the nature of phonological disorder might be better understood if a phonological process analysis is made. A language deficit might be better delineated by assessing the length and complexity of utterances. Vocal quality might be described by using a perceptual rating system like the Wilson Voice Profile (1972) or the Buffalo Voice Profile (1982). Unfortunately, such vocal assessment instruments have the problem of low reliability and validity associated with most subjectively oriented measures. Vocal functional efficiency lends itself to more empirical measures of its dimensions than some other aspects of the communication process. Many of those empirical measures of phonational function have been made possible through the use of such technologically sophisticated devices like pneumotachograph networks, magnetometers, laryngographs, and spirometers. Unfortunately, the use of such devices, by virtue of size and complexity, has been confined primarily to the laboratory environment.

An alternative would be to use similar measures which require less expensive and more portable instrumentation. Many sophisticated devices have been reduced in size, cost, and complexity of operation to the point where direct and accurate measures of phonatory function are possible for speech-language clinicians outside the research setting and in the regular clinical environment.

Maximum Phonation Time

One measure that provides objective data and is easy to obtain is maximum phonation time, or the length of time an individual can sustain a vowel sound after taking a deep breath. The clinician instructs the individual to take a deep breath and produce the vowel /a/ for as long as possible on one breath. A stopwatch is the only instrument required to make this measurement. Numerous investigators have recommended the use of maximum phonation time in voice evaluations (Arnold, 1964; Van Riper, 1954; Emerick & Hatten, 1974). Hirano, et al. (1968) also recommended using maximum phonation time to measure vocal progress, because they found this measure to be an indicator of change in vocal function.

Variability

Numerous researchers have reported data for maximum phonation time. (See Appendix A.) Results of those studies indicated that males have longer phonation times than females and that there is a great deal of variability within subjects and between subjects. Yanagihara, Koike, and von Leden (1966) stated maximum phonation times for adults should be between 20 and 30 seconds, but Hirano (1981) suggested that males should have maximum phonation times between 25 to 35 seconds and females should have times between 15 and 25 seconds.

Other studies have been conducted to determine the maximum phonation times typical for children. Westlake (1952) stated that children should be able to sustain a sound for at least 10 seconds in order to produce continuous speech, and Launer (1971) and Platt, Harris, Burk, Perez, and Grizzel (1975) found that seven- and nine-year-old children have maximum phonation times that are approximately half of reported adult times.

Inconsistencies in Procedures

The apparent variability in the results of maximum phonation time studies severely limits the inferential value of the findings in describing phonational efficiency. Numerous deviations in procedures appear to contribute to the variability of the results. Shanks and Mast (1977) noted the inconsistencies of procedures among various studies. They noted that Hirano, et al. (1968) did not specify the directions given or whether rest periods were given. In addition, Van Riper and Irwin (1958), Darley (1975), Brodnitz (1965), and Moore (1971) all failed to specify a set number of trials. Shanks and Mast (1977) noted that the lack of accepted techniques limits the use of reported measurements and conducted a study to establish a standard method of obtaining phonation time measurements. Based on their results, the investigators recommended having the subject sustain the vowel /a/ at a comfortable pitch and intensity level for four trials with one-minute rest periods between each trial. Shanks and Mast (1977) also suggested excluding the first trial from the analysis and interpretation of the remaining trial data.

Intensity and Pitch

A majority of investigators, including Iwata and von Leden (1970) and Hirano (1981), have recommended the use of comfortable pitch and intensity levels when determining maximum phonation time. Although Rau and Beckett (1984) also recommended using a comfortable pitch and intensity level, they suggested the use of comfortable levels predetermined from a counting task.

Ptacek and Sander (1963) stated that "maximum vowel duration appeared to be a function of both vocal pitch and intensity," and these investigators conducted a study to examine the effects of manipulating intensity and/or fundamental frequency. Even though some subjects exhibited substantial increases or decreases in phonation times with changes of intensity, results of the study indicated no significant differences between the group means for phonation with intensity level controlled and for phonation without controlled intensity level. Males exhibited only slight decreases in phonation times with increases in intensity, however, females exhibited slight increases of phonation times. Increases in intensity were not characterized by significant decreases in phonation time which conflicts with various aerodynamic principles (Timcke, von Leden, and Moore, 1958). Ptacek and Sander, however, did report that rigid control over volume intake of air prior to phonation, mouth opening during phonation, and reserve air after phonation was not exercised. Results of the study also indicated that control of fundamental frequency did not significantly affect maximum phonation times.

The problem of variability for maximum phonation time because of the physical size of the speaker remains. This is indicated by the differences in phonation times of children, females, and males. It is important to note that maximum phonation time is not affected by phonational efficiency alone. Vital capacity is also an influencing factor.

Phonation Quotient

Another indirect, empirical measure of vocal efficiency is phonation quotient. This measure can serve to place a control over the effects of vital capacity on maximum phonation time. Phonation quotient, as defined by Hirano, et al. (1968), is the ratio of vital capacity to maximum phonation time, and it can be determined by using a stopwatch and a hand-held spirometer (Rau & Beckett, 1984). This measure has often been used to estimate air flow rate when more direct flow measures were not available. Numerous investigators have noted that air flow rate during phonation was also a useful indicator of laryngeal function (Luchsinger, 1951; Isshiki & von Leden, 1964; Yanagihara, et al., 1966; Yanagihara & von Leden, 1967; Yanagihara & Koike, 1967; Hirano, et al., 1968). Phonation quotient can provide important information regarding the efficiency of the vocal mechanism. Thus, it not only provides information about air flow rate but also indicates the phonational efficiency of a system while considering the effects of vital capacity.

Several investigators have reported values of phonation quotients for normal adult subjects. Hirano (1981) stated that the average phonation quotient for adults is between 120 and 190 ml/sec, and Hirano, et al. (1968) reported mean values of phonation quotients of 145 cc/sec for males and 137 cc/sec for females. Iwata and von Leden (1970) reported a range of phonation quotients for normal subjects. The range for males was 101 to 207 cc/sec and 105 to 176 cc/sec for females. Shigemori (1977) reported phonation quotient values for school children and noted a large amount of variation.

Tait, Michel, and Carpenter (1980) noted that an abnormally short maximum phonation time could indicate a problem at the laryngeal level but could also be a result of reduced vital capacity. Therefore, the relationship between respiratory function and aerodynamic and acoustic parameters is important for evaluating the implications of a given maximum phonation time. Thus, a measure such as phonation quotient that can place an additional control over the effects of vital capacity on maximum phonation time becomes vital in interpreting a given phonation time. Establishing normal maximum phonation time, vital capacity, and phonation quotient values by using standard procedures can provide information essential to analyzing the complex relationships between these three measures.

The purposes of the present study were to: (a) obtain data on maximum phonation time using standard procedures, (b) obtain data on vital capacity, (c) describe the relationship between maximum phonation time and vital capacity, (d) determine if ranges for maximum phonation time are consistent for various vital capacity groups for males and females, and (e) determine ranges for phonation quotient in various vital capacity groups for males and females.

CHAPTER II

METHODS

Subject Selection Criteria

Twenty females, aged 18-25 years, were included in this study. Each subject met the following selection criteria: normal hearing, no history of vocal pathology or voice disorder, no current prescription medication use, no presence of a foreign dialect, and absence of physical disability.

Procedures

Each subject completed a questionnaire designed to determine if subjects met the selection criteria. (See Appendix B for questionnaire.) Information obtained from the questionnaire included age, height, history of vocal pathology, and current health status. The experimenter weighed each subject, and the weight was recorded on the questionnaire. The experimenter then screened each subject's hearing at 15 dB for the following frequencies: 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz, and 8000Hz. Each subject was asked to rest quietly for five minutes and then performed two randomized tasks.

Vital Capacity

The experimenter read a standard set of instructions which requested that the subject take a deep breath and blow into the mouthpiece of a Propper compact spirometer as long as possible. (See Appendix C for vital capacity instructions.) The experimenter then demonstrated the appropriate procedure and asked the subjects to indicate if the directions were understood. If the subject expressed confusion regarding the procedures, the experimenter repeated the directions and demonstrated the task again. The subjects then stood and completed one practice trial. Following the practice trial, the directions were read again. The subjects stood again and performed the task three times with one-minute rest periods between each trial. Data from a trial was recorded before the subject proceeded to the next one.

Maximum Phonation Time Task

The maximum phonation time task was completed in an audiometric suite, and the trials were tape-recorded using a Nagra 4.2 reel-to-reel recorder. The experimenter read a standard set of directions which instructed the subjects to phonate the vowel /a/ as long as possible after taking a deep breath. (See Appendix D for maximum phonation time instructions.) The experimenter demonstrated the procedure and then asked if the subject understood the instructions. The directions and demonstration were repeated if the subject expressed confusion with the task. Subjects stood and completed an initial practice trial after which the directions were repeated once again. Three trials were then completed by the subjects while standing. The length of the phonations were later determined from the tape-recordings. The audio output of the recorded sample was directed to a Bruel-Kjaer graphic level recorder. The phonations were graphically recorded by the sound level recorder. The length of the phonations were measured in millimeters which were converted to seconds.

Both tasks were to be repeated during a second session within one week from the initial completion of the tasks. Unfortunately, only half of the subjects returned for a second visit, and a number of the returning subjects did not return within one week due to illness or other extraneous variables.

Analysis

Analysis-of-variance measures were used to establish any significant differences between trials and between visits for maximum phonation time, vital capacity, and phonation quotient for the group of subjects who completed two visits. Analysis-of-variance measures for maximum phonation time, vital capacity, and phonation quotient were also completed to determine if any between-trial differences had occurred for the subjects who participated in one set of trials.

To establish test-retest reliability, the data from the first session and second session for maximum phonation time, vital capacity, and phonation quotient were compared. The reliability of between-trial data was examined by establishing the Pearson Product-Moment Correlation Coefficient for the three measures. Height, weight, and vital capacity were correlated, and mean maximum phonation times were compared to mean vital capacities to describe the relationship between these two measures.

The means, standard deviations, and ranges were determined for the following variables: age, height, weight, maximum phonation time, vital capacity, and phonation quotient.

CHAPTER III

RESULTS

Difference Measures

The group of subjects which participated in two visits was subjected to a two-factor (trials x visit) mixed design analysis-of-variance for each task. (See Appendix E.) There were no significant differences between groups or between trials for any of the tasks. Unfortunately, the analyses are limited by the very small number of participants.

A group of twenty female subjects who participated in at least one set of trials was studied using a separate set of analyses. Data from this group were subjected to a repeated measures analysis-of-variance. Each set of trials for maximum phonation time, vital capacity, and phonation quotient was contrasted, and there were no significant differences across trials for this group. Results are summarized in Table 1.

Relationship Measures

The Pearson Product-Moment Correlation Coefficient was used to correlate first visit data with second visit data from the two-visit group for three factors: maximum phonation time, vital capacity, and phonation quotient. The correlation coefficient for maximum phonation time was .734. This correlation was significant at the .05 level. A significant correlation coefficient of .790 (p-.01) was obtained for vital capacity, and for phonation quotient the correlation coefficient was .444, which was not significant.

Table 1

Summary of Analyses-of-Variance for Repeated Trials Within Subjects for the Single-Visit Group

Source of Variance	dF	F	Probability
Maximum Phonation Time			
Within Subjects			
(Repeated Trials)	2	0.15	0.8485
Vital Capacity			
Within Subjects			
(Repeated Trials)	2	0.43	0.6516
Phonation Quotient			
Within Subjects			
(Repeated Trials)	2	0.97	0.3881

Trial one, trial two, and trial three measures for maximum phonation time, vital capacity, and phonation quotient from the single-visit group and the second session of the two-visit group were compared using the Pearson Product-Moment Correlation Coefficient (Appendix F). All the correlations were significant at the .01 level.

For the single-visit group, the height, weight, and mean vital capacities were correlated using the Pearson Product-Moment Correlation Coefficient. The correlation matrix is summarized below in Table 2.

Table 2

Product-Moment Coefficients of Correlation Between Height, Weight, and Vital Capacity (VC)

	MEAN VC	HEIGHT	WEIGHT
MEAN VC	-	.547	.335
HEIGHT	-	-	.613
WEIGHT	-	-	-

The mean maximum phonation times and the mean vital capacities of all subjects were compared in order to assess the relationship between those measures. A Pearson Product-Moment Correlation Coefficient of .582 was noted. This correlation was significant at the .05 level.

Descriptive Measures

The means, standard deviations, and ranges for age, height, and weight are summarized in Appendix G. Data from the single-visit group were used to determine the means, standard deviations, and range for maximum phonation time, vital capacity, and phonation quotient, and these values are summarized in Table 3.

Table 3

Means for Maximum Phonation Time, Vital Capacity, and Phonation Quotient

	MEAN	SD	RANGE
MAXIMUM PHONATION TIME	17.35	6.16	30.90
VITAL CAPACITY	2959	557	2900
PHONATION QUOTIENT	186	71	466

Establishing Ranges for Vital Capacity Groups

Ranges of expected maximum phonation times and phonation quotients for various vital capacity groups could not be established for several reasons. First, the correlation between maximum phonation time and vital capacity indicated there was not a strong relationship between these two variables. Thus, the feasibility of using one measure as a possible predictor of ranges for another is restricted. Also, the standard deviation for vital capacity was so large that vital capacity groups would have greatly overlapped, thereby limiting the usefulness of any ranges that could have been established.

CHAPTER IV

DISCUSSION

The ten female subjects in the two-visit group performed the maximum phonation time and vital capacity tasks on two different occasions. Statistical comparisons of these performances and the resulting phonation quotients indicated that there were no significant differences between the group's performances on different occasions. Apparently the performance of the subjects does not change markedly from one occasion of the task-performance to another similar one a week later.

A more accurate indicator of the efficiency of measures of assessment is the reliability with which the subjects perform these tasks. The results of the analyses-of-variance for maximum phonation time and vital capacity imply that the distributions achieved by subjects are similar. The degree of similarity is better defined by correlating the individual performances on the first and second occasions. The Pearson r, which resulted from contrasting the performances of the subjects on the first and second visits, indicated that the maximum phonation times achieved on the first visit correlated at a level of .734 with those of the second visit. This level of correlation would indicate that young adult, female subjects can be expected to demonstrate maximum phonation times on different occasions which are very similar. The maximum phonation times do not appear to be affected much by short intervals of time between performances.

The Pearson r which resulted from contrasting the vital capacities achieved by the subjects on the first and second set of performances was .79. This level of correlation seems to indicate that young adult, female subjects can also be expected to achieve similar vital capacity measures on repeated occasions. Thus, the vital capacities appear to be affected little by short intervals of time between performances.

The results of the comparisons for maximum phonation time, which revealed a significantly high correlation, appear to be consistent with those of Shanks and Mast (1977). While previous investigations revealed large intra-subject variabilities, the Shanks and Mast (1977) study and the present study did not indicate this problem. While the exact source of reduced variability is not known, both the latter and former used standardized instructions to explain the nature of the task to each subject. Such a technique has been instrumental in reducing subject variability in research projects. Thus, it would seem that explicit repetition of instructions is important in measuring maximum phonation time of speakers, if that measure is to be most reliable.

The computed phonation quotients for each individual subject's performances of maximum phonation time and vital capacity on two different occasions were also compared. The Pearson r resulting from that correlation was .44, which was insignificant and low. The reasons for the difference between this correlation and those for maximum phonation times and vital capacities is not clear. The phonation quotient may not be as stable a measure over time as the other two. It would appear that the predictability of young adult females' computed phonation quotients is not very strong. Phonation quotient may be of questionable reliability and, therefore, be an inefficient measure of phonational function on repeated occasions.

Each single-visit subject met all the criteria described in the Methods section, and each performed all the tasks after careful instructions were provided. As with other subjects, each participant was asked to perform the maximum phonation time and vital capacity tasks three times.

The performances of all subjects on each of the trials were statistically compared using an analysis-of-variance, and there were no significant differences among the three measures for either task. Also, the computed phonation quotients for each of the three trials were compared. There was no significant difference among those measures. The performances of subjects on each series of trials were also contrasted using a Pearson r correlation. All correlations were significant at the .01 level. (See Appendix F.)

The subjects seemed to be reasonably consistent in their first, second, and third performances of the tasks on the same occasion. It appeared to matter little whether subjects were in their first, second, or third performance of a given task. Neither performance showed any significant difference over any other. Thus, it would seem that if a concise set of explicit instructions similar to the ones in the present study is provided to a subject that perhaps numerous repeated performances may not be as critical as when less direct instructions are presented.

The subjects' heights, weights, and vital capacities were contrasted using a Pearson r correlation. Height and body weight correlated at the highest level. Overall, physical height appears to relate better to body weight than it does to vital capacity. Generally as the height increases, the body weight tends to increase.

Speakers who are, on the whole, taller and heavier have larger respiratory systems and larger vital capacities. These speakers are physically capable of longer maximum phonation times than speakers who are shorter and lighter and have smaller vital capacities.

The mean vital capacities correlated least strongly with the measures of weight. Obviously body weight can vary widely within persons of the same or similar height. Also, the respiratory system size may or may not relate well to body weight because of differences in the amount of adipose tissue in the torso which contributes to a given person's weight.

The mean vital capacities correlated more strongly with height than weight. This would seem to indicate that taller people, but not necessarily heavier people, have larger vital capacities than shorter ones. It would seem to follow that males and females of a similar height should have very highly correlated vital capacities. However, this study failed to address that question.

The mean vital capacities, maximum phonation times, and phonation quotients are contained in Table 3. The maximum phonation times obtained in the present study appear to be consistent with those of other investigators (Ptacek and Sander, 1963; Sawashima, 1966; Yanagihara, et al., 1966; Isshiki, et al., 1967; Hirano, et al., 1968; Shanks and Mast, 1977). (See Appendix A.)

The mean vital capacities obtained in the present investigation appear to be consistent with those of Rau and Beckett (1984). In addition, the mean phonation quotients in the present study appear to be consistent with those of Hirano, et al. (1968) and Rau and Beckett (1984). It also appeared that the standard deviations of the three measures seemed larger than those reported in previous studies.

One of the original purposes of the present investigation was to not only establish a methodology for obtaining maximum phonation times, vital capacities, and phonation quotients reliably, but also to further delimit maximum phonation time and phonation quotient according to vital capacity groups. Thus, people within a certain vital capacity range could be compared to other speakers with similar vital capacities. Several factors precluded the fulfillment of this purpose.

First, the correlation between vital capacity and maximum phonation time was significant but not large enough to make accurate predictions. Second, the relationships or interactions between height, weight, and vital capacity must be considered when establishing vital capacity groups. Finally, the sample obtained in this investigation was too limited for the purpose of contrasting vital capacity groups. Thus, the very large variances and ranges would indicate that distinctions among subcategories would be vague. Even if there were a sufficient number of subjects and a variety of vital capacity subgroups could be adequately established, there would be large, unwieldy amounts of overlap across the categories. Thus, any vital capacity group comparisons would be virtually meaningless.

CHAPTER V

SUMMARY

A group of ten female, college students between the ages of 18 and 25 years was asked to perform certain speech-related tasks repeatedly on two different occasions. The results of these efforts would appear to indicate that uniformly-instructed speakers can be expected to perform vital capacity and maximum phonation time tasks similarly on repeated occasions about a week apart. Those subjects also demonstrated a large amount of inter-subject variability and a small amount of intra-subject variability.

A similar group ot twenty volunteers was asked to perform a similar set of tasks on one occasion. There was little difference in their performances for the repeated tasks of vital capacity and measures of maximum phonation time. When the performances were compared, there was a strong correlation among trials on maximum phonation time. Likewise, there was a strong correlation among repeated measures of vital capacity. There was a much more modest correlation among the phonation quotients computed for each set of trials.

Finally, large inter-subject variability appeared to make meaningful sets of maximum phonation time and phonation quotient data based on vital capacity groups virtually unobtainable. Maximum phonation times and phonation quotients for vital capacity groups could not be clearly delineated.

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APPENDIX A

Normal Maximum Phonation Time Values (in seconds) in Adults

Authors	Mean Males	Mean Females
Ptacek & Sander (1963)	25	17
Sawashima (1966)	29.7	20.3
Yanagihara, et al. (1966)	30.2	22.5
Isshiki, et al. (1967)	31	17
Hirano, et al. (1968)	34.6	25.7
Shanks & Mast (1977)	23.4	18.4

APPENDIX B

Subject Questionnaire

OKLAHOMA STATE UNIVERSITY

DEPARTMENT OF SPEECH-LANGUAGE-PATHOLOGY AND AUDIOLOGY

DATE________________________ SUBJECT NUMBER________________

S-NAME________________________ DATE OF BIRTH________________

AGE__________ SEX____________ HEIGHT________FT__________IN

Please answer the following questions to the best of your ability and recollection. All information will be held in the strictest confidence.

	YES	NO
1. Have you ever had to see an ear, nose, and throat doctor for problems with your voice or throat?	_____	_____
2. Have you ever been diagnosed as having a voice problem?	_____	_____
3. Have you had laryngitis in the past three months?	_____	_____
4. Do you presently have a cold, allergies, or upper respiratory infection?	_____	_____
5. Do you currently take any prescribed or		

non-prescribed medications? _____ _____

6. Do you smoke? _____ _____

WEIGHT ______________lbs

APPENDIX C

Vital Capacity Directions

This task is similar to blowing up a balloon. Take as deep a breath as possible. Then blow as long as you can into the cardboard mouthpiece of this device. Do NOT stop until you are completely out of breath. I will now demonstrate the task for you.

APPENDIX D

Maximum Phonation Time Directions

Take as deep a breath as you can and say the vowel /a/ as long as you can at a comfortable level of loudness. Continue to say the sound until you are completely out of breath. I will now demonstrate the task for you.

APPENDIX E

Summary of Analyses-of-Variance for Repeated Trials Within Subjects for the Two-Visit Group

Source of Variance	dF	F	Probability
Maximum Phonation Time			
Within Subjects			
(Repeated Trials)	2	0.57	0.5774
Vital Capacity			
Within Subjects			
(Repeated Trials)	2	2.50	0.8464
Phonation Quotient			
Within Subjects			
(Repeated Trials)	2	0.92	0.4194

APPENDIX F

Correlations Between Trials

Product-Moment Coefficients of Correlation Between Three Trials of Maximum Phonation Time Measures

	Trial 1	Trial 2	Trial 3
Trial 1	-	.883	.782
Trial 2	-	-	.803
Trial 3	-	-	-

Product-Moment Coefficients of Correlation Between Three Trials of Vital Capacity Measures

	Trial 1	Trial 2	Trial 3
Trial 1	-	.894	.942
Trial 2	-	-	.950
Trial 3	-	-	-

Product-Moment Coefficients of Correlation Between Three Trials of Phonation Quotient Measures

	Trial 1	Trial 2	Trial 3
Trial 1	-	.730	.823
Trial 2	-	-	.735
Trial 3	-	-	-

APPENDIX G

Mean Age, Height, and Weight

	Mean	SD	Range
Age (yrs)	20.7	1.9	7.0
Height (in)	65.6	2.8	11.0
Weight (lbs)	131	19.3	64.0

VITA

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