Phonation Quotient in Women: A Measure of Vocal Efficiency Using Three Aerodynamic Instruments

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Summary: Objective. The purpose of this study was to examine measures of vital capacity and phonation quotient across three age groups in women using three different aerodynamic instruments representing low-tech and high-tech options.
Study Design. This study has a prospective, repeated measures design.
Methods. Fifteen women in each age group of 25–39 years, 40–59 years, and 60–79 years were assessed using maximum phonation time and vital capacity obtained from three aerodynamic instruments: a handheld analog windmill type spirometer, a handheld digital spirometer, and the Phonatory Aerodynamic System (PAS), Model 6600. Phonation quotient was calculated using vital capacity from each instrument. Analyses of variance were performed to test for main effects of the instruments and age on vital capacity and derived phonation quotient. Pearson product moment correlation was performed to assess measurement reliability (parallel forms) between the instruments. Regression equations, scatterplots, and coefficients of determination were also calculated.
Results. Statistically significant differences were found in vital capacity measures for the digital spirometer compared with the windmill-type spirometer and PAS across age groups. Strong positive correlations were present between all three instruments for both vital capacity and derived phonation quotient measurements.
Conclusions. Measurement precision for the digital spirometer was lower than the windmill spirometer compared with the PAS. However, all three instruments had strong measurement reliability. Additionally, age did not have an effect on the measurement across instruments. These results are consistent with previous literature reporting data from male speakers and support the use of low-tech options for measurement of basic aerodynamic variables associated with voice production.
Key Words: vocal efficiency–spirometer–aerodynamics–vital capacity–phonation quotient.

INTRODUCTION

Aerodynamic assessment forms one of the main domains of voice evaluation. Assessment of airflow, air pressure, lung volume, phonation efficiency, and associated measurements has been recommended as part of a comprehensive voice evaluation by the Special Interest Group 3 of the American Speech-Language-Hearing Association in addition to the European Laryngological Society.[1,2] Subtle changes in the laryngeal anatomy and function can alter the balance between the respiratory and the phonatory systems and impair the process of voice production. Assessment of aerodynamics in disordered voice contributes to clinical understanding of the pathophysiology underlying a voice disorder, developing a treatment plan to rehabilitate vocal function, and obtaining baseline measurements to which change with treatment can be compared.[3] Among the aerodynamic measurements available to clinicians, vital capacity (VC) and transglottal airflow rate provide information about the volume of air available to power vocal fold vibration and how efficiently the vocal folds valve that air, respectively. Although acquisition of these measurements requires instrumentation, there is a wide range of instruments available for clinical application. Unfortunately, there is little research evidence available to inform our knowledge of measurement reliability between different instruments used for aerodynamic analyses.

For clinicians working in settings ranging from private practice, schools, hospitals, nursing homes, and home health, cost of the assessment tools plays a major role in deciding the assessment protocol. A complete aerodynamic assessment using a precision high-tech pneumotachograph-based system to obtain aerodynamic measurements may not be possible for a large number of clinicians who do not have the necessary resources, or cannot justify purchasing equipment costing thousands of dollars. In the absence of high-tech equipment, clinicians do have other viable options in the form of low-tech spirometers combined with physiological measurements such as maximum sustained phonation.[4,5] Although low-tech options do not allow for measurements of air pressure, spirometers can be used to measure VC and a stopwatch or timer can be used to measure maximum phonation time (MPT). These measurements provide important clinical information regarding lung capacity and phonation efficiency, respectively. Together they can be used to calculate an indirect estimate of transglottal airflow rate. The ratio of VC to MPT (VC/MPT) will provide the measurement of phonation quotient (PQ) in milliliters per second (mL/s), an indirect measure of airflow rate that can also be used to infer voicing efficiency. PQ has been used in comparative studies of normal aging and sex differences; disordered phonation secondary to neurologic, benign, and malignant lesions; and to document treatment outcomes.[3,5–11]

Hirano et al[12] in 1968 were the first to use and assess the reliability of PQ as a measure, without a pneumotachograph, to quantify air usage during phonation. Measurements of mean flow rate (MFR) obtained from pneumotachograph-based instruments tend to be lower than PQ derived from VC and MPT, because the latter are obtained from productions of maximum performance.[9,13,14] Although absolute values were different, Hirano et al[12] found a strong correlation between MFR obtained with

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a high-tech instrument and PQ obtained with low-tech instruments for both men and women, demonstrating the feasibility of using PQ in the absence of a pneumotachograph. PQ has been used in other diagnostic studies of disordered voice in patients with vocal fold inflammation, benign and malignant tumors, unilateral and bilateral vocal fold paralysis, spasmodic dysphonia, and functional voice disorders.[10–12] PQ values in disordered voices are typically higher[7] owing to reduced MPT in the context of VC remaining within normal limits. Although PQ does not distinguish between different pathologies, it does provide information specific to how pathology influences airflow through the glottis during phonation. As such, PQ has been used in treatment studies to monitor change in patients with vocal fold paralysis,[15–17] Parkinson disease,[18] and early glottic cancer.[19,20]

Rau and Beckett[5] used three different spirometers to measure PQ in healthy adults to assess feasibility of the equipment. They used data from a high-tech wet respirometer as a reference to compare the data they obtained with their handheld spirometers. The values obtained with the spirometers corroborated with those in the initial Hirano et al study,[12] leading them to the conclusion that low-tech handheld spirometers can be reliably used for aerodynamic assessment. In a recent study using two handheld spirometers (a digital spirometer and an analog spirometer) and a pneumotachograph in men, we found PQ values derived from all three instruments were consistent with the results found by Joshi and Watts[4] and Rau and Beckett.[5] More importantly, although there were strong correlations between the three instruments for VC and PQ, there was no statistically significant difference in the data obtained with the analog handheld spirometer and the pneumotachograph-based system.

Differences between male and female values on aerodynamic measures are well documented secondary to physiological differences in the respiratory and phonatory systems.[21,22] Adults in the age group of 18–40 years have been shown to have the highest values for MFR, MPT, and VC as compared with children and older adults (over 65 years).[23,24] However, Awan[6] did not find significant differences in PQ across age groups in women. This could be attributed to consistent changes in the components of the PQ measurement—MPT and VC—with age. The purpose of the present study was to extend our previous investigation by replicating the methodology in women. In addition, we recruited women representing three different age ranges to determine if VC and PQ obtained from low-tech and high-tech systems were affected by age. A major purpose of this line of investigation is to determine the extent of parallel forms reliability between low-tech, relatively inexpensive equipment and high-tech equipment used for aerodynamic analyses.[25] To accomplish this, a pneumotachograph-based system was used as the standard for comparison of VC and PQ measures with lower cost analog and digital spirometers.

METHODS

Participants

Forty-five nondysphonic women were recruited for this study. Participants were recruited into three different groups comprising 15 women each within the ages of 25–39 years, 40–59 years, and 60–79 years. All participants were self-reported nonsmokers with no complaints of hearing loss, pulmonary, neurological, previous, or current voice disorder. The study was approved by the Committee for Protection of Human Subjects at the authors' respective universities.

Instruments

VC and derived PQ values were obtained using three instruments (Figures 1–3). The two low-tech (cost < $300) handheld spirometers chosen were an analog windmill-type (Baseline Measurement Instruments, Fabrication Enterprises, Inc., White Plains, NY) and a digital spirometer (SP10, Contec Medical, China). Both were handheld devices placed by the participants to their mouth. Airflow through a mouthpiece on the windmill spirometer moves an analog dial around a measurement window on the face piece of the spirometer. The body of the spirometer is lightweight with an internal resistance screen. The digital spirometer converts the analog signal to a digital signal using an internal circuit board. This device also requires air to be blown through a mouthpiece against the resistance of internal metal blades. The

FIGURE 1. Baseline windmill-type spirometer. (Baseline Measurement Instruments, Fabrication Enterprises, Inc., White Plains, NY.)

FIGURE 2. SP10 Digital Spirometer. (Contec Medical, China.)