Measurement Reliability of Phonation Quotient Derived From Three Aerodynamic Instruments

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Summary: Objective. The purpose of this study was to examine parallel forms reliability between two hand-held spirometers and a pneumotachograph-based system for vital capacity and derived phonation quotient measurements.
Study design. This is a prospective, repeated measures design.
Methods. A total of 20 adult males were tested using three aerodynamic instruments—Baseline windmill-type spirometer, Contec SP10 digital spirometer and the Pentax Medical Phonatory Aerodynamic System (PAS), Model 6600 for measures of vital capacity. Phonation quotient was calculated using vital capacity from each instrument along with maximum phonation time. Repeated measures analyses of covariance (ANCOVAs) were performed to test for main effects of the instruments on vital capacity and phonation quotient, with age as a covariate. Pearson Product Moment correlation was performed to assess measurement reliability between the instruments.
Results. Statistically significant differences on ANCOVA were seen in vital capacity measures for the digital spirometer compared with the windmill spirometer and PAS. No differences were found between any of the instruments for phonation quotient. Large and positive correlations were present between all three instruments for both vital capacity and phonation quotient measurements.
Conclusions. Strong parallel forms reliability in measures of vital capacity and derived phonation quotient was seen among the three instrument systems, although measurement precision was different when comparing the digital spirometer to two other instrument types.
Key Words: Measurement reliability–Spirometer–Aerodynamics–Vital capacity–Phonation quotient.

INTRODUCTION

Phonation is the result of aerodynamic and muscular activity acting on vocal-fold tissue to generate audible acoustic energy called "voice."[1] Changes in aerodynamic pressure and flow typically follow laryngeal pathology and/or physiological imbalances in the subsystems responsible for voice production.[1–3] The measurement of these aerodynamic influences provides valuable clinical evidence to the speech-language pathologist for the purposes of impairment detection, characterization, and differential diagnosis. It is thus not surprising that the clinical measurement of laryngeal aerodynamics underlying phonation is considered a standard modality in the evaluation of voice impairments.[4,5] In theory, quantifying measures of flow and/or pressure will provide the clinician with information that can improve diagnostic precision, inform treatment planning, provide a means of biofeedback during treatment, and enable objective measurement of clinical benefit.[4]

Aerodynamic assessments, often conducted as part of the clinical procedure "Laryngeal Function Studies" (current procedural terminology code 92520) in the United States, can measure parameters of volume, flow, pressure, and vocal efficiency.[6] Applied clinically, volume has been measured using calculations of vital capacity (VC), phonation volume, and forced expiratory volume, while airflow has been measured as average and peak flow rates, among other measurements.[4,7–10] Clinical measurement of vocal efficiency has included maximum phonation time (MPT), s/z ratios, aerodynamic efficiency, and the ratio of VC to MPT, called phonation quotient (PQ).[3,7–11] PQ, measured in milliliters per second (mL/s), has been used as an indicator of the efficiency of the valving function of the vocal folds for phonatory airflow. As a measure of vocal efficiency, PQ has been used to differentiate normal from impaired phonation and as a means to document treatment outcome.[4,12–15] The calculations of PQ require a measurement of VC derived from a spirometry system, and measurement of MPT, typically derived by measuring audible vocalizations with a timing device such as a stopwatch. Previous studies have found that PQ is sensitive to changes and imbalances in the subsystems of voice due to aging, pathology, or the impact of voice rehabilitation.[8,9,12,13,15,16]

Hirano et al[7] coined the term phonation quotient as a measure of air consumption during phonation and examined its reliability in the absence of expensive equipment such as a pneumotachograph. Because the total volume of air used during MPT (used to calculate mean flow rate when using a pneumotachograph) is less than VC, PQ is usually higher than mean flow rate (MFR).[13,17,18] Although measurement precision of airflow and volume is likely greater when using a pneumotachograph-based instrument, Hirano et al[7] found a high correlation between their measures of MFR and PQ both for males and for females, indicating that PQ can substitute MFR as a parameter of aerodynamic evaluation in the absence of pneumotachograph-derived airflow measurements. Rau and Beckett[9] measured PQ across three different spirometers, including low-cost hand-held devices, in healthy adults to assess feasibility of the equipment. Their data were consistent with the Hirano et al[7] study, with higher PQ values obtained for males than for females as a result of the comparable difference in VC between genders.

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During normal development and with aging, lower MFR, MPT, and VC values have been reported in children and older adults (>65 years) compared with young adults (18–40 years).[19,20] However, a significant difference in PQ was not observed in a study by Awan[12] among 50 women divided into 5 age groups between 18 and 79 years, even though significant differences were found for VC and MPT. A strong correlation was found between VC and MPT which might explain the consistent ratio, ie, PQ, across age groups. Morsomme et al[21] saw similar results in their examination of PQ in 30 women with the age of 70–90 years. There was no significant difference in PQ means for these women when compared with young adult females. On the other hand, in their comparison of 10 older men with young adult men, they found 25% lower values in older men as compared with the young adult men. Morsomme et al[21] used normative data for young adults from previous studies performed by different researchers using different test procedures. The logistical variations make the comparison in PQ values for men and women more difficult. The difference in sample size between elderly men (n = 10) and women (n = 30) could also attribute to the discrepancy in the resultant data. A greater standard deviation from the mean was seen for women (mean = 154 mL/s, SD = 87) than men (mean = 153 ml/s, SD = 48) with similar means. The large variability in the older women data could have washed out some of the differences between age groups.

The early studies that looked at PQ in persons with laryngeal pathologies were performed by Hirano et al[7] in 1968 and, Iwata and von Leden in 1970.[8] Both studies measured PQ using a pneumotachograph in patients with vocal-fold inflammation, benign and malignant tumors, and unilateral and bilateral vocal-fold paralysis. The Hirano et al[7] study also tested patients with spasmodic dysphonia and functional voice disorders. PQ values were significantly greater than normative values in both studies, and Hirano et al. concluded that PQ was sensitive enough to identify laryngeal dysfunction but not for differential diagnosis between laryngeal pathologies. In a study on patients with unilateral vocal-fold paralysis undergoing treatment with hyaluronic acid injections, Wang et al[16] used PQ as a parameter to track progress at 1 week, 3 months, and 6 months postinjection. PQ values showed significant change at each time point, consistent with results on MPT, MFR, perceptual, and patient self-rating measures. Over the years, there have been other studies that have used PQ to measure change with treatment in patients with vocal-fold paralysis,[22–24] Parkinson disease,[25] and early glottic cancer.[26,27] Variations in PQ for spoken and sung tones in asymptomatic singers have also been reported.[28]

Although PQ has been used as a measure of vocal efficiency in the research literature and in clinical practice for many decades, spirometric equipment used in the acquisition of this measurement has been variable. Additionally, the use of pneumotachograph-based systems for measurement of aerodynamics remains somewhat prohibitive in many speech and voice clinics due to their high cost (eg, well above $1000). Although high-cost and low-cost options have been utilized in the literature and are currently available for measuring VC, PQ, and other quantitative measures of voicing efficiency, there is a paucity of data reporting the clinical reliability of measurements between different aerodynamic instrumental options. Clinicians who acquire these measures during the process of Laryngeal Function Studies must have evidence for the measurement reliability of instrumental choices for their valid application to the processes of impairment detection, characterization, and differential diagnosis.

Parallel forms or alternative forms reliability is the measurement of the same variable using different forms or versions of an instrument.[29] Its purpose is to determine if two instruments produce equivalent results when measuring the same variable or construct under identical measurement conditions. When measurements are very similar, parallel forms reliability is interpreted as being strong and suggests that either instrument is reliably capable of measuring the variable of interest. The purpose of this study was to investigate the parallel forms measurement reliability between three commercially available instrument systems. We used a pneumotachograph-based instrument and two hand-held spirometers for measuring VC, from which subsequent measurements of PQ were derived. If strong parallel forms measurement reliability is found, the results of this study might inform clinical practice by providing evidence for instrument choices used in the acquisition of certain aerodynamic measurements.

METHODS

Participants

A total of 20 adult men between the ages of 25–69 years were recruited in this study. We chose to control for sex as this factor influences measurements of VC and derived measurements of PQ.[9,30] All participants were self-reported nonsmokers with no history of hearing impairment, pulmonary, neurological, and previous or current voice disorder. The study was approved by the Committee for Protection of Human Subjects at the University of Houston.

Instruments

Three instruments were used to compare VC and derived PQ values. Two of the three instruments were low-cost (eg <$300) hand-held spirometers—an analog windmill type (Baseline Measurement Instruments, Fabrication Enterprises, Inc., White Plains, NY) (Figure 1) and a digital spirometer (SP10, Contec Medical, China) (Figure 2). The Phonatory Aerodynamic System (PAS) Model 6600 (KayPENTAX Corp, Lincoln Park, NJ) (Figure 3) was used as the pneumotachograph-based system and was also considered a high-cost (eg >$1000) comparative. Windmill spirometer consists of a lightweight hand-held plastic body with an internal resistance screen. Airflow through a mouthpiece moves an analog dial around a measurement window on the face piece of the spirometer. The digital spirometer consists of a hand-held frame with internal metal blades, which provide resistance to airflow. A small internal circuit board provides analog-to-digital conversion of the airflow signal and displays digital measurements on the LCD screen of the device. The PAS consists of a pneumotachograph with line input to a desktop personal computer. Custom software is used to digitize and process the aerodynamic signal for recording, playback, and analysis.