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Vocal tract dimensional characteristics of professional male singers with different singing voice types

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ABSTRACT

Background

Traditionally, professional singing voices are categorized by experienced vocal pedagogues into at least three main singing types: bass, baritone, and tenor for male singers, and alto, mezzo-soprano, and soprano for female singers (Titze, 1994). Classification of singingvoices is important for professional singers in order to make the best use of their voices. If a singer sings out of his/her capability, i.e., singing at a voice type beyond his/her voice range, his/her vocal folds would be placed under extra stress and, if prolonged, could be harmed (Sell, 2005). In addition, singing at an inappropriate voice range might not have an immediate hazard and could help develop unhealthy or even harmful singing habits over time (McKinney, 1994). Traditionally, singing teachers refer to singing apprentices' voice range, tessitura (the area in one'svoice which sounds and performs the best and is most comfortable), size of voice, timbre characteristics to classify theminto different voice types according to their experience (Sell, 2005; Smith &Sataloff, 1999). However, this method of classification is highly subjective.This way of classifying singing singers is apparently in lack of scientific basis and can be unreliable and inefficient. An objective means to classify singing types is necessary in order to avoid the adverse consequence of misclassification of singers.

Previous studies suggested various objective measures for voice classification, including singing fundamental frequency(F0) range (Titze, 1994), vocal fold length (Roers, Murbe, &Sundberg, 2009b), vocal fold width (Larsson &Hertegård, 2008), singing formant frequency (Dmitriev& Kislev, 1979), frequency at which register changes (Callaghan, 2000), and timbre transformation (Erikson, Perry,& Handel, 2001; Erickson, 2003).It is known that classification of singing voices depends on:(1) F0, which is determined by vocal fold vibration, and (2) formant frequencies, which are affected by the vocal tract. However, the relationship between formant frequencies and vocal tract, and their interaction with singing voice classification still remains uncertain.

A review of the literature indicates that only a handful of studies on singing vocal tract have been reported (Dmitriev& Kislev, 1979;Roers, Mürbe,& Sundberg, 2009a). Dmitriev and Kislev (1979) foundthat voice classification was correlated with singers' vocal tract lengthand the acoustic characteristics (low and high singing formants) of their productions. Yet, all studies used x-ray technology and only two-dimensional vocal tract images could be obtained, with a lack of vocal tract volume measurement.It is not known whether vocal tract volume also plays a role in determining voice timbre of different singing voices and classification of singing voices. Apparently, the x-ray can be hazardous to subjects due to its radioactive nature. In the present study, an acoustic pharyngometer, a non-invasive device that allows 3-dimensionalmeasurement of the vocal tract, was used to detect vocal tract dimensions. The acoustic pharyngometer makes use of Acoustic Reflection Technology (ART) and can directly measure the vocal tract dimensions.Its functions like a sonar; sound wave is firstly generated and transmitted along the tube into the airway. A portion of the acoustic wave is reflected back at each point of the discontinuity in the upper airway and is recorded by a microphone attached to the mouthpiece (Kamal, 2003). The other end of the transmitting tube is connected with the computer processor that transforms the wave signal into dimensional values shown on the monitor. The changes in cross-sectional area of the oral cavity can be calculated by comparing the amplitude and temporal changes of the reflected acoustic pulse and the incident pulse. Vocal tract length and volume information can be directly obtained.

Aims

The present study attempted to investigate the relationship between male singing voice classifications and their vocal tract length and volume, and formant frequencies using acoustic reflection technologies -acoustic pharyngometer.

Method

Participants

A total of 29professional singerswere recruited from the Xinghai Conservatory of Music in China, including 19tenors, 10 baritones. All singers were classified into different singing voice types usingthe same criteria. Their singing quality was consistently confirmed by experienced pedagogues. All singers were of ages ranged from 19 to 27 years, with duration of singing training ranged from 2 to 9 years. They were able to control their voice production so as to produce different registers voluntarily. All singers had no reported history of any craniofacial abnormalities, and no upper respiratory tract diseases at the time of data collection.

Procedure

During data collection, each participant was seated upright on a straight-backed chair facing forward. Each participant was instructed to mentally produce the vowel /a/ and breathe out air from his/her mouth to the wave tube of the pharyngometer through the mouthpiece. The corresponding area-distance curve that showed the cross-sectional area of the vocal tract as a function of the distance from the lips to the glottis was subsequently obtained and shown on a computer monitor. This procedure was repeated for three times. In addition, to obtain the reference, the similar procedure was repeated once with nose breathing. Upon completion of data collection, a total of four area-distance curves that showed the vocal tract dimension of each participant (thrice with mouth breathing and once with nose breathing) were obtained.

Data analysis

Comparison was made betweenthe cross-sectional area versus distance graphs obtained from mouth- and nose-breathing to locate the oral pharyngeal junction (OPJ) as described by Kamal (2003), and Xue, Hao, and Mayo (2006).Using the location of OPJ, the selected cross-sectional area-distancecurve was then divided into the oral and pharyngeal regions. The oral cavity was defined as the area from the incisors to the OPJ;whilethe pharyngeal cavity was defined as the area from OPJ to the opening of the vocal folds (Hood Laboratories, USA.). Based on this definition,six vocal tract dimension parameters including the oral length (OL), pharyngeal length (PL), total length (TL), oral volume (OV), pharyngeal volume (PV), total volume (TV) were identified.

Results

The mean and standard deviation values of the six vocal tract dimensions of male singers are summarized in Table 1.

Independent-samples t-tests were carried out to compare the six vocal tract dimensions of different voice types. There were no significant differences between baritones and tenors in all the six vocal tract dimensions: oral length (t = -.545, p = .590), pharyngeal length (t = .212, p = .834), vocal tract length (t = -.290, p = .774), oral volume (t = -.099, p = .922), pharyngeal volume (t = .422, p = .676), and vocal tract volume (t = .064, p = .949).

Table 1. Mean (and standard deviation) values of male singers of different singing voice types.

	Vocal tract dimensions					
Voice types	OL (cm)	PL (cm)	TL (cm)	OV (mL)	PV (mL)	TV (mL)
Baritones	9.66 (0.68)	8.79 (0.81)	18.45 (0.99)	60.81 (11.77)	26.50 (3.82)	87.30 (13.08)
Tenors	9.82 (0.84)	8.73 (0.83)	18.55 (0.81)	61.20 (10.57)	25.78 (5.04)	86.99 (13.80)

*Note:*OL = Oral length; PL = Pharyngeal length; TL = Total vocal tract length; OV = Oral volume;PV = Pharyngeal volume; TV = Total vocal tract volume.

Conclusions

Thepresent results show that voice types (baritones, tenors) did not have significant effect on oral length, pharyngeal length, total vocal tract length, oral volume, pharyngeal volume, and total vocal tract volume.They appear to be consistent with the study reported by Roers, et al. (2009a), in which no significant difference in vocal tract length between tenors and baritones based on x-ray images. However, the present findings fail to agree with Dmitriev and Kislev (1979). They reported a close correlation between vocal tract lengthand singing voice type; higher voice types (e.g., tenor) had shorter vocal tract length than lower voice types (e.g., baritones and basses). The discrepancy may be related to the small sample size and the overlap range of vocal tract length on tenors and baritones in these studies. It follows that, even equipped with similar vocal tract configuration; two singers could be classified into different singing voices. The present results failed to demonstrate any vocal tract measure that was specific to a particular voice classification.This appears to suggest that, in addition to vocal tract length, other factors such as vocal fold length and width may also affect singer types and the characteristic voice timbre of a professional singer (Larsson& Hertegård, 2008; Roers, Murbe, & Sundberg,2009b). Future research perhaps should be carried out to investigate additional factors that may contribute to voice classification.

Keywords

Vocal tract, Singing voices type, Acoustic reflection technology.

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