

Relationship of the Cricothyroid Space with Vocal Range in Female Singers

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Summary: Objectives. This study aims to investigate the relationship between the anterior cricothyroid (CT) space at rest with vocal range in female singers. Potential associations with and between voice categories, age, ethnicity, anthropometric indices, neck dimensions, laryngeal dimensions, vocal data along with habitual speaking fundamental frequency were also explored.

Study Design. This is a cohort study.

Methods. Laryngeal dimensions anterior CT space and heights of the thyroid and cricoid cartilages were measured using ultrasound in 43 healthy, classically trained, female singers during quiet respiration. Voice categories (soprano and mezzo-soprano), age, ethnicity, weight, height, body mass index, neck circumference and length, anterior thyroid and cricoid cartilage heights, practice and performance vocal range, lowest and highest practice and performance notes along with habitual speaking fundamental frequency were collected.

Results. The main finding was that mezzo-sopranos have a significantly wider resting CT space than sopranos (11.6 mm versus 10.4 mm; $P = 0.007$). Mezzo-sopranos also had significantly lower “lowest and highest” performance notes than sopranos. There was no significant correlation between the magnitudes of the anterior CT space with vocal range. The participants with the narrowest and widest anterior CT space had similar vocal ranges.

Conclusions. These results suggest that the CT space is not the major determinant of performance vocal range.

Key Words: Cricothyroid space—Vocal range—Female singers—Ultrasound—Larynx.

INTRODUCTION

There is growing evidence that the cricothyroid (CT) space is important in determining vocal pitch. The CT space decreases when singing higher pitches. Indeed, CT approximation surgery, a procedure where the CT space is deliberately made smaller, is used to elevate the speaking voice of male to female transgender subjects.¹⁻⁴ An article by Ingo Titze⁵ entitled “Five ingredients of a physiologically gifted voice” suggested that the CT space was one of the most important anatomical dimensions of the larynx in determining vocal range. In the early 1900s, several studies investigated the relationship between the CT space and fundamental frequency (F_0). Using radiography, it was shown that the CT space is in a partly open neutral position during quiet respiration⁶⁻⁹ and the CT space became narrower with rising pitch^{8,10} and wider with decreasing pitch.⁸ Laukkanen et al¹¹ used ultrasound to show that when singers sang rising intervals of perfect fifths throughout their range, the CT space decreased. Gugatschka et al¹² confirmed these findings. Vilkmann et al¹³ used ultrasound to measure the CT space in participants speaking three- and five-word sentences. They demonstrated that the CT space widened with decreasing speech as a function of speech declination. These findings confirm that changes in the anterior CT space dimensions reflect alterations in F_0 . In a study carried out on excised larynges from human cadavers, Kitajima et al¹⁴ showed that the relationship between CT space and vocal pitch, expressed in semitones, was almost linear.

As noted above, previous studies have shown that ultrasonography is a reliable technique for measuring the anterior CT

space, despite some recognized limitations.¹¹⁻¹³ However, most of these ultrasound studies of the CT space have focused on pitch synchronous changes,^{11,12} have been performed on only small numbers¹³ or untrained singers,¹² and have not explored the relationship with overall vocal range. Furthermore, it also appears that no study has previously been performed on healthy, trained female singers. Thus, the suggestion by Titze⁵ that a large CT space is important for a wide vocal range appears not to have been systematically investigated.

Statement of purpose

The purpose of this research was twofold. The primary goal was to determine whether the dimensions of the resting CT interval correlate with vocal range in female singers. The second aim was to investigate potential associations between voice categories (soprano and mezzo-soprano), age, laryngeal dimensions (thyroid and cricoid cartilage heights), neck dimensions (circumference and length), anthropometric indices (weight, height, body mass index), and habitual speaking fundamental frequency (SFF).

MATERIALS AND METHODS

Subjects and the task

The study procedures complied with the University of Waikato's ethics policy (approval number FS2010-33). Following written informed consent, data were collected from 43 healthy, classically trained, female singers aged between 18 and 65 years at a minimum vocal performance level of second-year university. Voice had to be in a comfortable Fach—no history of voice disorder; no active upper respiratory tract infection or allergy; and be symptom free on the day of testing. Laryngeal dimensions (anterior CT space and heights of the thyroid and cricoid cartilages) were measured using ultrasound during quiet respiration. Further data such as age, ethnicity, anthropometric indices (height,

Accepted for publication November 5, 2015.

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Journal of Voice, Vol. 31, No. 1, pp. 125.e17-125.e23

0892-1997

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<http://dx.doi.org/10.1016/j.jvoice.2015.11.026>



FIGURE 1. Illustrates the examination procedure (Source: Author).

weight, and body mass index), neck dimensions (circumference and length), usual SFF, vocal data (practice and performance vocal range, and lowest and highest practice and performance notes) were also collected.

Ultrasonography

The ultrasound machine used was a Siemens ACUSON Sequoia 512 (Mountainview, CA) with an 8–15 MHz multifrequency linear-array transducer (15L8w). Standard calibrated electronic calipers were used to make distance measurements. Ultrasound images were recorded on a DICOM data DVD (NEMA, Rosslyn, VA), and numeric data were entered into a *Microsoft Excel 2010* spreadsheet (Microsoft Corporation, product version 14.0.6029.1000).

Participants were seated, and the transducer was placed on the skin anteriorly over the larynx in the mid-sagittal plane (Figure 1). Each ultrasound investigation was carried out by the same experienced sonographer. Recorded measurements were height (mm) of the cricoid and thyroid cartilages in the midline and CT space (mm), measured in the midline. The linear echogenic band between the anteroinferior border of the thyroid cartilage and the anterosuperior edge of the cricoid cartilage was used to define the CT space¹⁵ (Figure 2).

Vocal data

To ascertain the two vocal ranges, each participant was asked to state their practice (total vocal range irrespective of vocal

quality) and performance (lowest to highest notes they would sing publicly) ranges. Counting in semitones, each participant's practice and performance range was then calculated, assigning C⁴ as middle C.

Statistical analysis

Statistical analysis of laryngeal dimensions, anthropometric data, and vocal data were performed using analysis of variance (*Minitab version 16.2.2* [2010] statistical software, State College, PA). The Student's two sample *t* test was used to compare the means of the two normally distributed continuous variables (soprano and mezzo-soprano) from separate samples (age, ethnicity, anthropometric indices, neck dimensions, and vocal data). Whereas, the paired Student's *t* test was used to assess differences between intra-rater measurements. Continuous variables were analyzed with Pearson product-moment correlation co-efficient (*P* value).¹⁶ All tests were performed as two-sided analyses, taking *P* < 0.05 as statistically significant. The relationships between variables were analyzed using linear regression, with categorical predictors being included where it was useful to test whether relationships depended on category.

RESULTS

The study group comprised 43 women: 33 sopranos and 11 mezzo-sopranos. A summary of all measurements including general anthropometric indices, laryngeal cartilage dimensions, and acoustic measurements are shown in Table 1.

CT space

The mean CT space was measured at 10.7 ± 1.4 mm ranging from 7.3–14.0 mm. When the CT space was divided into voice types, this showed a statistically significant difference between the two groups (*P* = 0.007) (Figure 3). Mezzo-sopranos had a larger CT space than sopranos.

The sopranos CT space measurement ranged from 7.3 mm to 12.4 mm, whereas the mezzo-sopranos range was from 10.5 mm to 14.0 mm. Figure 4 shows that all singers with a resting CT space of less than 10.4 mm were sopranos (comprising 15 out of the 32 sopranos), whereas all singers with a resting CT space of greater than 13.0 mm were mezzo-sopranos. Individuals with

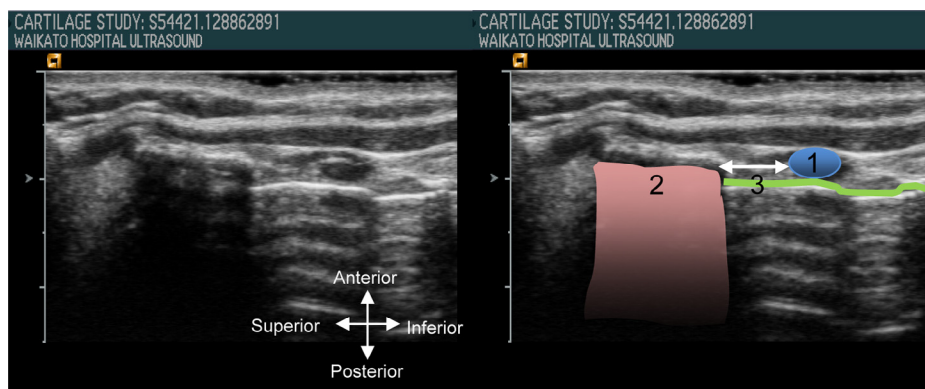


FIGURE 2. Ultrasound image showing cartilaginous structures of the larynx on longitudinal sagittal view. The image on the right is a numbered version of the left to highlight anatomical structures. (1) Cricoid cartilage, (2) lower edge thyroid cartilage, (3) tracheal lumen (line). Arrow: anterior cricothyroid space. There is a centimeter scale bar on the left of each image (Source: Author).

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