Science for Singers

A SERIES OF VOICE RESEARCH COLUMNS BY INGO R. TITZE, PHD

Critical Periods of Vocal Change: Early Childhood

This is a three-part series of comments dealing with vocal growth and maturation. Although voices change continuously over a life span, there are some critical periods of rapid change, such as early childhood, puberty, and advanced age that are particularly interesting and important to singing teachers. We begin with early childhood, the years 2-6.

An important aspect of early vocal development is the changing structure of vocal fold tissues. The vocal ligament and the thyroarytenoid muscle begin to take shape. Prior to years 2-3, the vocal folds are made up primarily of mucosal tissue. Such tissue can vibrate easily, but the vibration is difficult to control in terms of frequency and regularity of movement. The ligament and the muscle help to stabilize the vibration patterns.

Increase in vocal fold length is also a key factor of early development. Figure 1 shows some measurements of vocal fold length as a function of age taken from cadavers (Kahane, 1978; Hirano, 1980). L_m is the membranous length (the portion that vibrates) and L_c is the cartilagenous length. At infancy the membranous length is approximately 2 mm. The growth rate is 0.4 mm per year for females and 0.7 mm per year for males, leading to a maximum adult length of around 16 mm for males and 10 mm for females. Note that the cartilaginous length L_c does not display as large a gender difference as L_m.

Figure 2 shows how long-term average speaking fundamental frequency (F_o) changes with membranous length. This figure is derived as a composite of data given by Kent (1976) and Hirano (1980). Age is indicated as a parameter at some of the data points. Also shown is a solid curve ($F_o = 1700/L_m$) that serves as a model of an inverse F_o-length relationship. This model predicts that fundamental frequency drops steadily as membranous length increases.

The major deviations from the model occur at ages three to ten. It is not entirely clear why F_o drops less in this age range. Length appears to increase in a rather constant manner, as Figure 1 shows. There may be compensating dimensional changes in the vocal fold tissue layers, or there may be changes in tissue elasticity. As stated above, the development of the vocal ligament and the thyroarytenoid muscle, which continues through early childhood (Hirano, 1980), may be responsible for this.

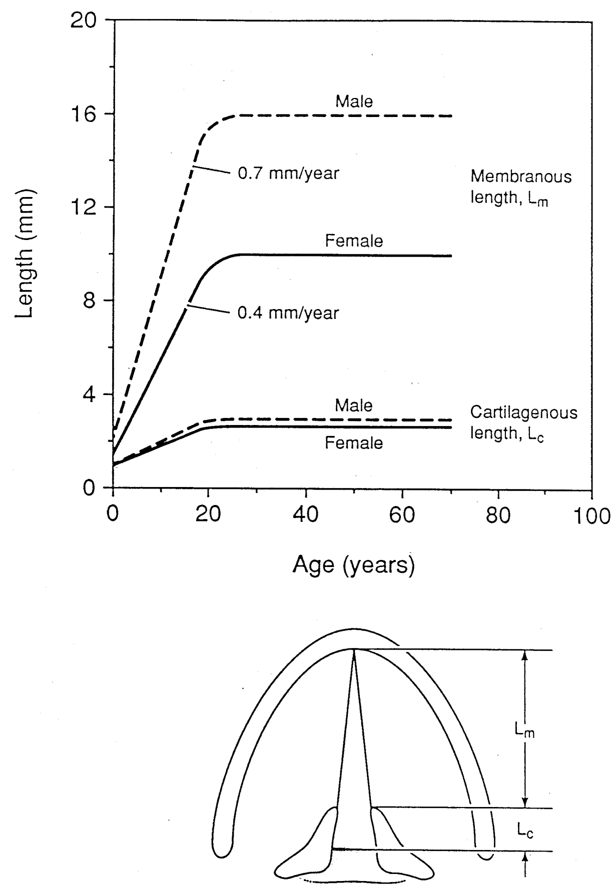

Figure 1. The membranous length of the vocal fold as a function of age for 48 males in the cadaveric state.

The new tissue layers could well stiffen the fold, thereby slowing down the rate of decline of F_o. By analogy, if a vibrating string were to be tensed while it was being lengthened, the pitch may not change much.

It is also possible, though less likely, that children maintain a hypertense musculature in the larynx while producing speaking fundamental frequencies during those childhood years. More data, under controlled conditions and increased number of subjects, are needed to shed light on this topic.

An interesting question is: how are children with much smaller vocal folds (and smaller lungs) able to produce sounds as loud as adults? One answer is that higher F_o guarantees higher intensity. Vocal intensity increases about 8-9 db per octave increase in F_o (Titze & Sundberg, 1992). At 300 Hz, a child's speaking F_o is about twice that of an average adult F_o of 150 Hz. This means that the child's intensity is 8-9 dB higher, all else being equal.

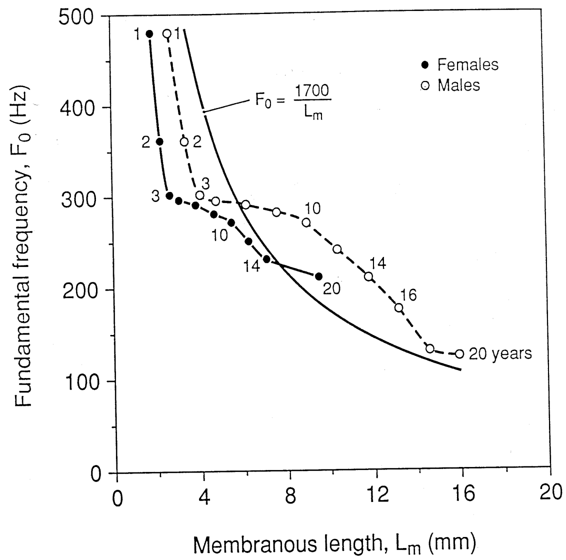

Figure 2. Fundamental frequency as a function of membranous length of the vocal fold.

But all else is not equal. Physiologically, children's vocalizations are not simply scaled-down versions of adult vocalizations. Consider the aerodynamic (pressure-flow) events, for example. According to Stathopoulos and Sapienza (1991), children of ages 4-8 years produce time-varying (oscillatory) airflows similar to adults when asked to phonate either soft, comfortable, or loud. With membranous vocal fold lengths less than half of the adult value, this is possible only if either the lung pressure or the amplitude of vibration is significantly greater in children. Stathopoulos and Sapienza measured this lung pressure and indeed found a 50-60% greater value for children than for adults. Along with that, lung volume excursion relative to vital capacity was greater in children than adults.

Basically, then, children attempt to match the vocal loudness of adults by working harder. They compromise the length of their vocal utterances to achieve this equality. It is well-known that children take more frequent breaths during speech and singing. Making them sing adult-length phrases would be a disservice to their developing respiratory system.

If amplitude of vocal fold vibration is indeed disproportionately large in children (which has yet to be proven), then it would also be understandable why children have a difficult time making pitch and loudness independent. The amplitude-to-length ratio determines the amount of pitch increase that can be expected with rising lung pressure. Children would find it difficult to sing a crescendo at constant pitch. They would have a tendency to sing sharp when lung pressure is increased, a phenomena that has been observed (informally) by this author.

In summary, early childhood is an important period of vocal development. If singing is structured, care must be taken not to interfere with the rapid growth changes. In the next issue we will discuss equally important changes related to puberty.

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