# chapter 4

# voice transformation in male adolescents

**John Cooksey**

*Editors' Note: The landmark California Longitudinal Study of male adolescent voice transformation, by Cooksey, Beckett, and Wiseman (1985) was never published in its entirety (see Editor's Note at the beginning of Book V, Chapter 8). This chapter, in the 1997 edition of* Bodymind and Voice, *was the first published summary of its findings. Some of this chapter was originally printed in* Voice, *the Journal of the British Voice Association, Volume 2, Number 1, 1993, pages 15-39.* Voice *has been merged into a new European journal,* Logopedics Phoniatrics Vocology. *Material from* Voice *is used by permission.*

*Two additional notes: (1) Data for the Cooksey-Beckett-Wiseman study were gathered about 20 years ago. The study was written in the terminologies that were current about 15 years ago. Much voice science data and findings have accumulated over the intervening time span. Theoretical formulations and terminologies also have evolved. As a result, the scientific terminologies of the Cooksey male adolescent voice classification guidelines have required periodic updating. (2) This chapter's description of Dr. Cooksey's studies have attempted to incorporate vocal terminologies that are used in Book II. The classification labels of New Baritone and Settling Baritone, however, have been retained in this chapter. In Chapter 8 of Book V, they have been changed to Dr. Cooksey's new labels--*Newvoice *and* Emerging Adult Voice, *respectively.*

## Introduction

For many years, music educators, choral conductors, voice scientists, laryngologists, speech pathologists, and others have been concerned about how to help male adolescents to optimize their voices for speaking and singing during puberty. The anatomic, biochemical, and physiological complexity of pubertal processes have generated many controversial points of view about its effects on voice function and voice health. Unfortunately, most of the points of view are based on personal interpretations of personal experiences, because there has been a relative paucity of scientific research that helps clarify the controversies. The following questions, among others, have been raised.

1. Do the vocal growth processes of adolescent males proceed as a sequential continuum?

2. Do these growth processes occur at a *steady* spatio-temporal rate or do they occur in sequential spurts or stage categories?

3. If they occur in stages, can the stages be identified and described?

4. Can criteria be developed for:

a. methods of voice classification?

b. the assignment of vocal parts in choirs or singing classes? and

c. appropriate pitch ranges that can be used by composers and arrangers of vocal music that is to be sung by boys whose voices are transforming?

5. Does prolonged singing in the falsetto register affect vocal development, and if so, how?

6. Do singing and speaking functions interrelate during voice transformation, and if so, how?

7. Can effective methods of voice education be applied to the spoken and sung self-expression of early-adolescent males?

8. Does singing during voice transformation present a risk to short-term or long-term vocal health, and if so, can it be managed so that singing is safe?

## Historical Perspective

In the latter part of the 19th century, Manuel Garcia, an Italian singing teacher, and Sir Morell McKenzie, a well-known English laryngologist, argued over whether or not the pubescent voice should be exercised (Weiss, 1950). Garcia proposed that the voice should be rested during its time of change, and that no further training be given. All singing activity should cease. He thus initiated the traditional voice-break theory, which influenced many choirmasters throughout Europe, and is still prominent today (Greene & Mathieson, 1989). Sir Morell McKenzie, on the other hand, saw no difficulty in continuing singing activities. He viewed the 'break' as a normal developmental process; thus the changing voice could, and should, be exercised during its transformation.

In the 1930s these issues again arose. Dr. Cyril Winn, Her Majesty's Staff Inspector of Music for the public schools of Great Britain, began to promote a view that music publishers should write music to fit the limits of the male changing voice (McKenzie, 1956). He spoke strongly against those proponents of the voice-break theory who, because of practical considerations, did not want to deal with the problem. Many choirmasters preferred to keep boy sopranos on the top part as long as possible, then bring in replacements upon the advent of the 'break'. In an interesting description, the London County Council Schools (1933) issued a statement opposing the traditional attitudes associated with the 'voice-break' phenomenon:

> The "broken voice" is the outstanding problem of the boys' secondary school. But it will be less difficult to deal with the problem if two simple truths are understood and acted on: (a) A boy's voice never breaks. Physiologically the vocal cords lengthen at an age that varies with individuals. Nothing in the vocal apparatus breaks or does anything that could reasonably be described by that word. (b) Singing and speaking are essentially the same process. During the changing period it is essential that voices not be strained; which means that talking and singing (within a restricted force and compass) are both definitely desirable activities. (cited in McKenzie, 1956, p. 11)

In the mid-1930s, W. Norman Mellalieu (1947) reported the results of his 7-year study of the adolescent changing voice. He concluded that the male voice could be exercised during the change, and that ways of managing the voice change should be devised. Dr. Herbert Wiseman, Director of Music in the Edinburgh public schools during the 1930s, added his support for Mellalieu's approach (McKenzie, 1956). Much later, in the 1950s, he reported that the scene in Great Britain had changed, at least in the secondary schools. There seemed to be wider acceptance of the idea that boys should sing through adolescence, and that voice change followed a gradual, somewhat predictable pattern.

Probably as a result of the more progressive developments in British education, such as the increase in mixed voice and male voice choirs and the publication of some limited range choral literature, Duncan McKenzie, a Professor from Edinburgh, and an authority on youth choirs, was encouraged to pursue research in America. After extensive observation of the American system, McKenzie introduced his **alto-tenor plan**--a new theory for developing and training the male adolescent voice during puberty (McKenzie. 1956). This approach set forth specific criteria for recognizing stages of voice transformation, and clearly described new techniques for exercising the voice during its most active phases of change.

In the United States, the problems associated with the male changing voice came into focus when the junior high school came into existence during the early 1900s (Cooksey, 1988). The question was not whether the young adolescent should sing during puberty, but rather how voices should be classified and trained during that time. W.L. Tomkins (1914) and Hollis Dann (1936) introduced music for changing voices. In the 1930s and 1940s, Mae Nightingale (1939) and Genevieve Rorke (1947) recognized some of the problems associated with changing voices such as its breaks and limited range. They attempted to write music to meet the unique vocal capabilities of adolescent males.

In the 1950s and 1960s, Swanson (1959) and Cooper & Kuersteiner (1965) developed integrated theories and methodologies for classifying changing male voices. Cooper advocated a **cambiata plan** which took into account range, tessitura, and shifting tonal qualities. His approach pinpointed vocal problems in the male of junior high school age (ages 13 through 15 years). He evolved a method for composing and arranging choral music for this age group that is distinguishable from the standard SATB voicing (soprano, alto, tenor, bass) and TTBB voicing (two tenor parts, two bass parts). A cambiata or 'C' vocal part was substituted for the traditional tenor part, so that arrangements and compositions which use his method are written for SACB and CCBB voices.

*[Editors' Note: In this chapter, tessitura always refers to a range of vocal fundamental frequencies, produced at a moderate intensity, which are subjectively judged to be produced with the greatest physical and acoustic efficiency. Judgments are made by the subject, based on physical sensations of relative effort; and by an expert observer based on auditory perception of voice quality and visual evaluation of the degree of neck-throat effort.]*

Swanson, on the other hand, opposed most of Cooper's ideas, and proposed that during mutation, voices change "fast," develop first in the lower part of the bass clef, and often have a "blank spot" between $C_4$ and $F_4$ where no notes can be produced. He believed that vocalizing a young man's falsetto register downward could help "bridge" this gap and enable these singers to regain the "lost" notes. Swanson stated that boys learn more quickly and are less self conscious when they sing only with other boys and no girls are present. He further advocated arranging music for a contra-bass classification. Finally, Swanson pressed for acceptance of the idea that there should be a separate voice part appropriate for each stage of voice transformation.

In summary, the voice-break traditionalists, mainly concentrated in the British and American church music area, and progressive public school educators who advocated some approach for managing voice transformation, created a conflicting and ever changing body of knowledge. Because the differences were based on anecdotal and empirical evidence, controversial issues continued to exist.

## Unresolved Questions

A renewed interest in the changing male voice phenomenon occurred in Europe and the United States during the late 1970s and the 1980s. The empirically-based debates generated by the voice-break traditionalists and their progressive counterparts led to the identification of some specific questions.

- What are the stages of voice maturation? How can they be described?
- Is there a predictable pattern to the rate, scope, and sequence of voice maturation?
- Is the rate of voice maturation erratic and fast, or slow and gradual?
- What are the ranges and tessiturae of adolescent male voices as they progress through maturational stages?
- How does one classify a voice during maturation? What criteria should be used?
- Does training affect the outcome of voice classification?
- Should one use the falsetto register during maturation? If so, how? Can techniques for range extension that use this register adversely affect voice health?
- Does a "blank spot" occur in the pitch range of male adolescents as they initiate their voice maturation?
- Do male adolescent voices "break"? Can that terminology suggest a "self-fulfilling prophecy" into existence? Can other terms and approaches to voice education reduce the probability of abrupt register transitions in speaking and singing?
- Can pitch and quality characteristics of voices during speech be used as a valid means of assessing voice maturation? Does the production of adult-like voice qualities during voice transformation reflect the normative dimensions of laryngeal and vocal tract anatomy?
- Given the fact that male voices are in various stages of change within any grade level during the junior high school years, is unison singing possible or advisable?

Laryngologists, speech pathologists, and speech-voice scientists also became interested in such questions as:

- Can vocal dysphonia occur during male adolescent voice transformation that is related *only* to anatomical growth effects?

- Is the vocal anatomy of pubertal males especially vulnerable to voice-use pathology during voice transformation?
- If so, how might voice-use pathologies be prevented during voice mutation?
- How do singing and speaking correlate and what is their impact upon the biomechanics of voice production during puberty?
- How do singing skills develop during male voice change, taking into account scientific measurement of anatomic, physiologic, and acoustic factors?
- How should voice education for speaking and singing be addressed during puberty from a biomedical (health) perspective?

Informed music and choral educators recognized that interdisciplinary cooperation was needed in order to gain information and find answers to the above questions. Anecdotal and empirical data and existing physiological, anatomical, and acoustical data were needed to present hypotheses that could be tested with the greater precision of the scientific method. There also was a need to find a closer correlation between various experimental findings so that more refined theoretical models for voice classification during mutation could be developed.

## Early Scientific Research

In a search for answers to these issues, Cooksey (1977a,b,c; 1978) consolidated the findings of empirical and scientific research in Europe and the United States. Naidr, Zboril and Sevcik (1965) investigated the onset and rate of pubertal changes in 100 boys, all of whom were students at a boarding school. Their 5-year longitudinal study reported that maturation occurs in three easily definable stages, with the maximum number of changes falling during the ages of 13, 14, and 15 years. Primary voice maturation began at age 13 in most cases, lasted an average of 13 months, reached a high point or *crux* of maturation at age 14, then tapered considerably by age 15. The principal mutational changes occurred in the first half of pubertal growth, paralleling the most significant increases in body height. These changes occurred somewhat in advance of the increase in size of the larynx. Voice changes first became evident by a lowering of the upper limit of singing pitch range. Subsequently, a narrowing of the pitch range occurred during the most active phase of maturation. A renewed extension of pitch range occurred after the most active period. Changes in the singing and speaking ways of using voice were correlated with development of the primary and secondary sexual characteristics and concomitant developments in the larynx, body height, and weight.

Frank and Sparber (1970a,b) conducted a 10-year study to determine the changes in singing pitch ranges of 5000 children, aged 7 through 14 years. They found three stages of voice development that overlapped and extended the stages identified by Naidr and colleagues. These were identified as premutational, mutational, and postmutational. Frank and Sparber also used sonographic analysis to identify vocal registers (modal, falsetto, and whistle) in changing voices.

## Theoretical Framework for Relating Voice Mutation Stages and Voice Classification Guidelines

Using the then current research data, the empirical observations of his professors, and his own years of practical experience, Cooksey (1977b) devised male adolescent voice classification guidelines for adolescent singers (see Figure IV-4-1). His guidelines were consistent with the anatomical and physiological maturation stages that had been articulated by Frank and Sparber (see Table IV-4-1). In accordance with the findings of these and other researchers, Cooksey's classification guidelines were based on the premise that voice maturation stages follow each other in predictable patterns.

Table IV-4-1.
Stages of Voice Maturation and Cooksey's (1977b) Proposed Voice Classification Labels.

| Voice Maturation Stage | Voice Classification |
|---|---|
| Premutational | Unchanged |
| Stage I: Early Mutation | Midvoice I (beginning of change) |
| Stage II: High Mutation | Midvoice II (middle of change) |
| Stage III: Mutation Climax | Midvoice IIA (climax of change) |
| Stage IV: Post-mutation Stabilization | New Baritone (tapering period) |
| Stage V: Post-mutation Settling and Development | Settling Baritone (expansion/development) |

Maturational stages and voice classification guidelines were identified and defined using the following criteria:

1. total pitch range;
2. tessitura (most 'comfortable' singing pitch range);
3. voice quality (degree of constriction, breathiness, and spectral configuration);
4. register development; and
5. average fundamental frequency of speech samples.

A detailed statement of tenets was also developed regarding the debated issues associated with the male changing voice (Cooksey, 1977b). These tenets have provided the foundation and impetus for several subsequent research studies, and include the following.

1. Recognizing the individuality and uniqueness of people and their voices is the foundation of voice education with young males who are experiencing voice transformation. Healthy concepts about singing arise from a young man's experience with, and increased understanding of, his vocal capabilities and limitations. When he is fully informed about the physical aspects of voice transformation and its concomitant effects on pitch range, tessitura, and voice quality, then voice change can be a true adventure--not a fearful nightmare.

2. Voice transformation can be that adventure if young men come to admire the context of their skeletal and muscular growth and the transformational changes that are taking place in their breathing, sound-making, and sound-shaping anatomy.

3. The pubertal stages of sexual development closely parallel the stages of voice mutation. The most extensive limitations to singing capability occur at the climax of puberty.

4. Voice mutation proceeds at various rates through a predictable, sequential pattern of stages, and they affect singing capability differently in each stage. The onset of voice transformation is variable and is presumed to be genetically triggered.

5. For most boys, mutation begins at 12-13 years of age, reaches its most active phase between 13 and 14, then tapers off between 15 and 17-or-18 years of age. The newly changed voice usually appears between 14 and 15, but "settles" and develops for one or two years afterward.

6. Triggered by hormone secretions, the first stage of voice mutation occurs at different times in different individuals. Detecting the onset of the first stage is challenging at first. Typically, the timbre of the upper register changes slightly (there is an increase in breathiness and strain), as the upper range limit is descending.

7. There tends to be more stability and less individual variation in the lower register and lower range limits throughout the different stages of voice mutation. In the upper register and range limits, there is great variation throughout the first three stages, but this stabilizes noticeably in the New Baritone classification (maturational stage III).

8. The most noticeable voice changes occur in the Midvoice I, Midvoice II, and Midvoice IIA classifications (maturational stages I and II). Their combined time-length averages about 14 months.

9. Register definitions (modal, falsetto, whistle) become clear during the high mutation period (Midvoice II classification, maturational stage II).

10. Age and grade level are not reliable criteria for voice classification.

11. The average speaking fundamental frequency lies near the bottom of the voice pitch range. The Harries, et al., study (1996) recently supported the Cooksey, et al., findings (1984, 1985) regarding the relationship between (1) singing pitch range during the most active phases of voice trans-

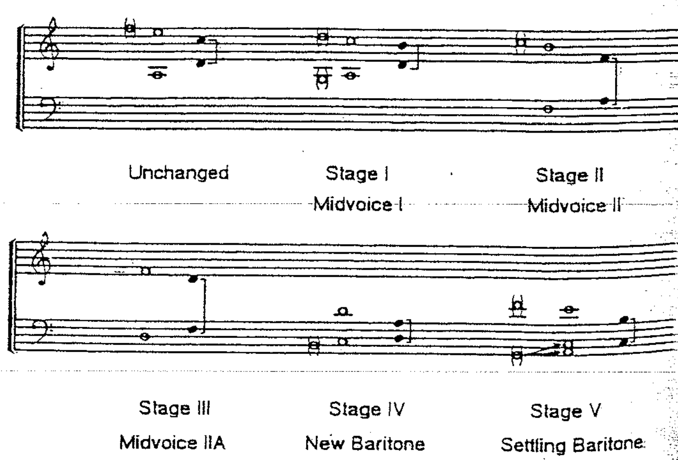



Figure IV-4-1: Index of voice classification in junior high school male adolescents, as formulated by Cooksey, 1977b. [Notes in parentheses indicate exceptional range boundaries, whereas notes in brackets show the limits of the tessitura ranges. In the Settling Baritone classification, the typical variation in low terminal pitches is shown.]

formation, and (2) habitual average speaking fundamental frequency (ASFF). More research is needed to determine if the habitual ASFF findings are consistent with physically and acoustically efficient speaking.

### Research Evaluations of the Preliminary Classification Guidelines

The proposed maturational stages and classification guidelines were investigated by several researchers. Groom (1984) conducted an investigation to document the physical and vocal development that occurred in a group of adolescent boys during the summer months. Variables observed and recorded, with or without controls, were: age, height, weight, average speaking fundamental frequency, singing pitch range, tessitura, vocal flexibility, rhythmic agility, and vocal maturity. Groom also completed a thorough survey of research literature related to the male changing voice. She applied the Cooksey classification guidelines in her study. She stated some significant conclusions.

1. During the time of puberty in boys, the voice pitch range (speaking and singing) lowers gradually.
2. There are varied high treble pitches for an indefinite time period after the new lower tones are attained.
3. There is some loss of vocal agility during vocal mutation.
4. The Cooksey ranges and tessiturae for the changing male voice are reinforced as being the most appropriate for the classifications suggested and adopted.
5. Boys from 12 to 15 years of age exhibit different stages of vocal growth. The mean age of boys experiencing voice change in 1939 was 14.25 years (Sturdy, 1939). In 1972 it was 13.8 years (Friesen, 1972), and in 1978 (Groom, unpublished data) it was 13.5 years.
6. Age is not a reliable indicator for voice classification. The most reliable indicators appear to be singing pitch range and vocal timbre.

In a 3-year longitudinal study, Rutkowski (1984) investigated the validity of the guidelines for training adolescent voices. She found that not only could the classifications be confirmed, but also the sequence of growth. She noted that most subjects entered the various stages earlier than previously reported.

Barresi and Bless (1984) studied the relationship of selected variables to the perception of tessitura pitches in adolescent changing voices. In addition to confirming the voice maturation stages, average speaking fundamental frequency (ASFF) was found to be a significant criterion for voice change. They found that the ASFF was three to four semitones above the lowest pitch of the singing range for each voice change classification. In the area of tessiturae identification, the opinions of experts were matched with certain acoustic and aerodynamic measurements. Barresi and Bless concluded that the perception of tessiturae may be enhanced by measuring such parameters as glottal resistance, air flow control, and sound pressure level.

## The California Longitudinal Study of Male Adolescent Voice Maturation: The Cooksey, Beckett, and Wiseman Investigation (1977-1980)

John Cooksey, Ralph Beckett, and Richard Wiseman, then professors at California State University at Fullerton, conducted a comprehensive 3-year longitudinal study to investigate "...selected vocal, physiological, and acoustic factors associated with voice maturation in the male adolescent attending junior high school" (partial publication, 1984; complete unpublished manuscript, 1985). The study used many of Cooksey's Statement of Tenets (Cooksey, 1977b,c) as hypotheses to be tested by the scientific method, including his proposed voice classification guidelines. Instruments were used that were capable of objectively recording and categorizing the vocal, physiological, and acoustic data for subsequent statistical analysis. The following major questions were addressed.

1. What are the most reliable and valid vocal criteria for identifying and defining different stages of voice maturation?
2. Is there a predictable pattern to the sequence, distribution, and rate of change for the voice maturation stages?
3. Can voice maturation stages be identified and defined according to selected physiological and acoustic factors?
4. How can sonographic analysis contribute to increased knowledge about voice maturation and vocal dysphonias in boys of this age?

The research project was begun in October 1977, and completed in June 1980. With the cooperation of the Orange Unified School District, Orange County, California, 86 seventh grade boys, aged 12-13 years, from two junior high schools were chosen to participate. Forty-one of the sample were enrolled in a choir, while 45 of the subjects had no singing experience or training. A research team, consisting of specialists in vocal-choral music and speech communication and speech pathology, visited each school once each month, from October to June in each of the three years. During each visit, twenty-two predetermined items of data were recorded and analyzed. The data items that were gathered from each of the 86 subjects were:

1. singing $F_0$ range;
2. frequency range of singing tessitura;
3. voice quality (breathiness as indicated by harmonics-to-noise measures and constriction ratings);
4. register development (degrees of tonal continuity and intensity level when producing lower, upper, and falsetto register pitches);
5. average speaking fundamental frequency;
6. intensity ranges (gross and singing);
7. a sustained lower register tone;
8. a sustained upper register tone;
9. a sustained falsetto register tone;
10. noise components in lower range partials ($F_0$ to 4100-Hz);
11. noise components in upper range partials (4100-Hz to 8,000-Hz);
12. formant frequency regions;
13. number of formants;
14. frequency spread between the first two formant frequencies $F_1$ and $F_2$;
15. vital capacity;
16. phonation time;
17. sitting height;
18. standing height;
19. gross body weight;
20. chest size;
21. waist size;
22. total body fat;
23. percentage of body fat.

During the course of the 3-year study, some 6,500 sonograms were made from audio recordings that had been made at the subjects' schools. **Low terminal pitches** (LTPs) in the lower register and **high terminal pitches** (HTPs) in the upper register were recorded in order to determine the singing $F_0$ range data. Frequency ranges of singing tessiturae were assessed by analyzing patterns of intensity change within the $F_0$ ranges displayed in the sonograms. These two data items were to be used as baseline information for construction of an index of voice classification--one that was based on hard data gathered during in the study. The criterion of frequency range of singing tessitura was included at first, but the tessitura data displayed such high variance that it was discarded as analysis proceeded.

One aim of the classification index was to determine the extent to which the index data correlated with the maturational stage indices of Frank and Sparber (1970a, b) and Naidr, et al., (1965), and the hypothesized voice classification guidelines that were published by Cooksey (1977b). Although the subjects' LTPs and HTPs displayed variability, the variability was comparatively limited as the subjects progressed through the maturational stages. Because of its relative stability, singing $F_0$ range was used as the sole criterion for creating the study's index of voice classification. The $F_0$ ranges of the index (see Figure IV-4-3) were determined by calculating the mean of all subjects' HTPs and LTPs as they proceeded through their maturational stages. The index was formulated only after careful consideration of exceptional individual cases and overlapping pitch ranges in the raw data (see Figure IV-4-2A).

Exceptional cases were examined from the standpoint of the degree to which they varied from the most frequent HTPs or LTPs. Although subject HTPs exhibited significant variability, they never exceeded a general upper boundary frequency range within the Unchanged and Midvoice I and II classifications. There were no exceptional HTP cases in the New Baritone and Settling Baritone classifications. Much less variability occurred among the LTPs. The most frequent LTP exceptional cases were $Db_3$ for Midvoice IIA and $C_3$ for the New Baritone classifications.

More HTP and LTP exceptions occurred in the Midvoice II and Midvoice IIA classifications than in any other classification. The fewest exceptions occurred in the New Baritone and Settling Baritone classifications. This result was not unexpected, as the most active phase of mutation was completed after the Midvoice IIA classification.

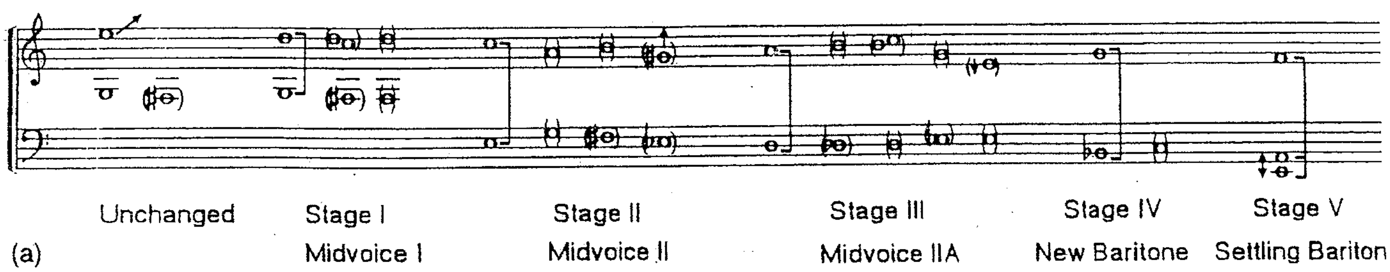
Some of the $F_0$ range raw data (see Figure IV-4-2A) shows that range boundaries for each of the classifications were fairly wide, but when the six range categories were compared, the upper and lower limits did not overlap. When overlap occurred in the LTP, the HTP compensated by being higher. For example, when a subject was in the Midvoice IIA classification, and the HTP was $A_4$ (the same as the HTP for Midvoice II), then the LTP was likely to be $E_3$.

Once all of the $F_0$ range raw data was analyzed, means were calculated for each voice classification category, and the study's voice classification index was determined (see Table IV-4-3). All subjects were then classified using the new index. A one-way analysis of variance using the voice maturation stages and the low terminal pitches (LTPs) and high terminal pitches (HTPs) of the new index was then completed. The multiple comparisons test (least significant difference--LSD) showed that the voice maturation stages and the singing $F_0$ ranges were differentiated to statistically significantly degrees. The five-stage sequence of voice maturation in the male adolescent was confirmed.

## Summaries of the Study's Data Items

Singing $F_0$ range and frequency range of tessiturae. A common pattern was observed as the subjects proceeded through their maturational stages. The subjects remained in one classification until the upper $F_0$ border became unstable (generally increased phonational effort such as increased laryngeal constriction and increased use of external laryngeal muscles). After the appearance of upper $F_0$ range instability, the lower $F_0$ border would descend. This predictable growth pattern proceeds at a somewhat unpredictable rate, but is reliably sequential. This pattern became less extensive, however, during the New Baritone classification. $F_0$ range increase (considering both LTPs and HTPs) for nearly all of the subjects occurred only during the final stage of maturation (Settling Baritone classification). Means, standard deviations, and medians for HTPs and LTPs ($F_0$ range), tessiturae, and register transition points were computed in the study.

Figure IV-4-3 shows the revised index of *mean* $F_0$ ranges and tessiturae for the voice change classifications. This index closely matches the proposed Cooksey model of 1977 (shown in Figure IV-4-2B). As shown in the study's raw data Figure IV-4-2A), there was much more instability and individual variation for HTPs than for LTPs. The lower border of the singing $F_0$ range descends in ever increasing



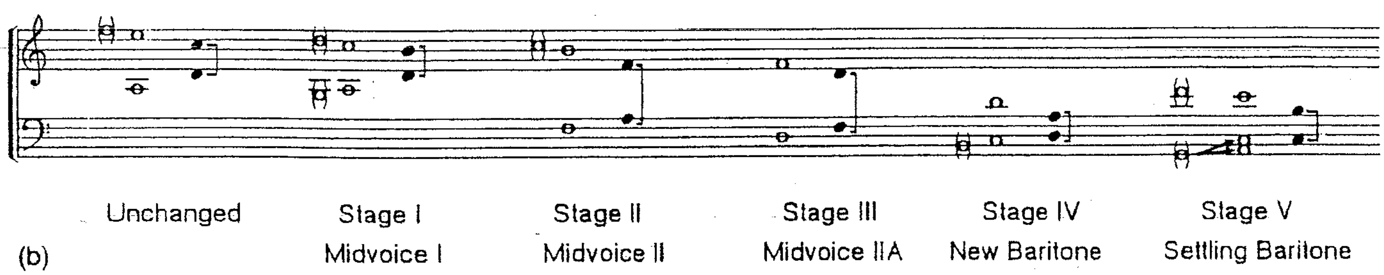




Figure IV-4-2: (A-top) is a presentation of raw data from voice classification procedures used with junior high school male adolescent subjects. The bracketed notes represent the most frequent pitch range boundaries, whereas notes in parentheses represent notable exceptions. In the New Baritone classification, the typical variation in low terminal pitches is shown. (B-bottom) is the original, hypothesized index for voice classification as published in Cooksey, 1977b.

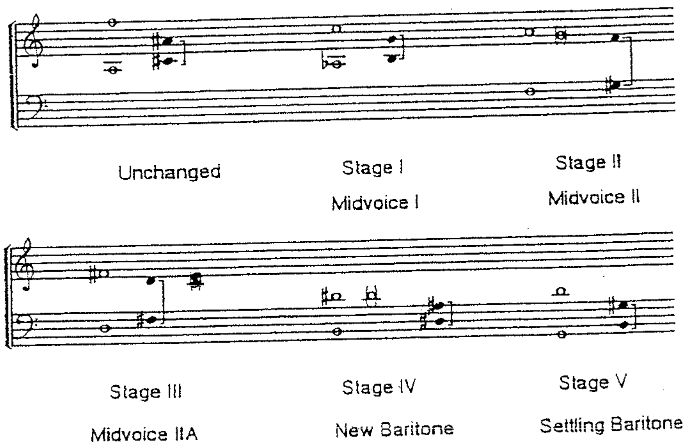



Figure IV-4-3: The revised index of male adolescent voice classification for singing showing the *mean* $F_0$ ranges and tessiturae ranges for the voice change classifications. Bracketed notes represent tessitura pitch boundaries, whereas notes in parentheses represent significantly frequent exceptions to the norm.

intervals, while the lowering of the upper border occurs with more variability and inconsistency. This pattern is not so obvious in the study's voice classification index (Figure IV-4-3) because the HTPs are derived from means of the raw data. Also in all the voice classifications, the variance in the tessiturae HTPs (the highest tone in the clearest, most comfortable $F_0$ region) is also more extensive than for the tessiturae LTPs.

Table IV-4-2.
Average Number of Semitones (st) in the $F_0$ Range and the Frequency Range of Tessiturae

| Classification | Semitones in $F_0$ Range |
|---|---|
| Unchanged | 20.6 |
| Midvoice I | 16.6 |
| Midvoice II | 15.5 |
| Midvoice IIA | 15.5 |
| New Baritone | 15.5 |
| Settling Baritone | 19.2 |

In subjects whose voices had not yet begun adolescent transformation--unchanged voices--the average $F_0$ range was about 20 to 21 semitones (half-steps on the piano keyboard). In voice maturation stage I (early mutation, or voice classification Midvoice I), the $F_0$ range decreased by about 4 to 5 semitones. That pitch range compass continued throughout the transformation process until maturational stage V (postmutational development, the Settling Baritone classification). When that stage was reached, the $F_0$ range compass re-expanded to an average of 19.2 semitones (see Table IV-4-2). Frequency range compass of tessiturae were essentially unaffected.

In summary, much instability was observed in the upper $F_0$ range borders of subjects during the most active phases of adolescent voice transformation. By comparison, their lower $F_0$ borders were more stable. Changes in $F_0$ range followed a predictable pattern within the voice maturation stages, and the frequency range of singing tessiturae seemed to remain in a relatively consistent position within each maturational stage. Finally, once the maturation process began, the $F_0$ range decreased or became slightly diminished (by about four semitones), but remained stable across the various voice maturation stages. This seems to contradict some of the reports by Weiss (1950) and others who claimed that the changing voice has a *very* diminished pitch range during maturation.

**Vocal registers.** Although the register variable was not used as a criterion in the development of the study's index of voice classification, it was a very important aspect of the voice maturation process. Register transitions were observed only for the upper register transition to falsetto register, which first emerged in the Midvoice II classification. The crossover frequencies between these two registers also can be used as an indication of changes in voice maturation and voice classification. Crossover frequency areas were highly variable within and across individuals, indicating instability in neuromuscular coordinations of larynx muscles as well as vocal fold mucosal waving. Figure IV-4-5, A through F, shows examples of sonographic spectra from sustained upper register $F_0$s from the unchanged, Midvoice I, Midvoice II, Midvoice IIA, New Baritone, and Settling Baritone voice classifications.

Sonographic patterns also show the emergence of a falsetto register *and* a distinct whistle register during the Midvoice II classification. Figure IV-4-5, G and H, shows sonographic examples of a sustained $F_0$s in Midvoice IIA falsetto register and Midvoice II whistle register, respectively. Most upper register to falsetto register transitions occurred for Midvoice II between $G_4$ and $D_5$. For almost half the sample, however, the crossover frequency was $A_4$. This is lower than previous research findings on falsetto emergence in adolescent males. In the Midvoice IIA classification, most boys (74.6%) showed upper-to-falsetto register transitions between $E_4$ and $B_4$, but half changed to falsetto on $G_4$. No whistle register was detected during this classification. In the New Baritone classification, there was considerably less variability in the upper-to-falsetto crossover frequencies. Over half of the subjects transitioned to falsetto register at $E_4$ and $F_4$. There seemed to be a slightly wider distribution of crossover frequencies during the New Baritone classification, indicating a slight extension upward in its pitch range. Figure IV-4-4 shows the modal (upper and lower registers together), falsetto, and whistle registers for the Midvoice II classification.

**Voice quality**. Sonographic evidence was used to assess one aspect of voice quality, that is, degrees of air-turbulence noise compared to the presence of harmonics (overtones) when subjects were sustaining a lower register tone and an upper register tone. Harmonics were measured in two ranges:

1. from the $F_0$ to 4100-Hz (lower range harmonics); and
2. from 4100-Hz to 8000-Hz (upper range harmonics).

In addition, perceptual rating scales of degrees of breathiness and laryngeal constriction were completed by trained judges. The sonographic evidence revealed that unchanged voices produced noticeably clear harmonics with normally small amounts of air-turbulence noise, even when they were sustaining upper range $F_0$s (above $C_5$). With the onset of voice transformation, however (Midvoice I), the sonograms of $F_0$s at $C_5$ and above showed high ratios of air-turbulence noise, and the judges perceived the tone qualities as effortful, strained, and breathy. Significant amounts of noise were detected in both the lower and upper register tones that were sampled.

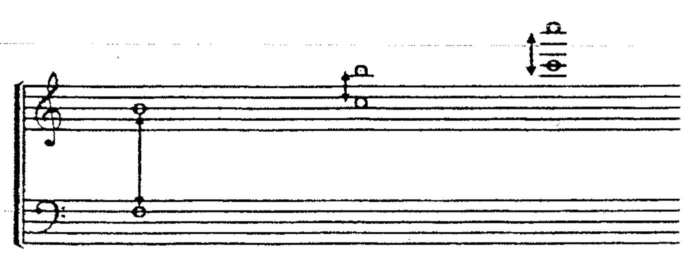


Figure IV-4-4: Typical ranges of registers in the Midvoice II classification.

As voice maturation progressed, the sonograms revealed an obvious and very strong trend toward an increase of noise components within the $F_0$-to-4100-Hz range of harmonics, even through the completion of the Settling Baritone classification. Increased breathiness and constriction were perceived in all voice change classifications, compared to trained adult norms of tonal clarity (see Figure IV-4-5, A through F). The noise levels in the lower and upper register tones increased significantly from the unchanged to Midvoice II classifications, and almost doubled in the lower register tones from the Midvoice II to Settling Baritone classifications.

In comparing the noise components in the upper and lower harmonic ranges, as produced in the lower and upper register sustained tones, the upper register tones generally showed more noise components and the lower register tones generally showed less noise. Sonographic analysis revealed that the upper harmonics (the 4100-8000-Hz range) are greatly affected by maturation. Vocal instability first appeared in this range of harmonics after male voices began their transformation. Noise components in both the lower harmonic range and the higher harmonic range were greater in the lower register tones than in the upper register tones. Greater constriction of the intrinsic muscles of the larynx was observed during the production of lower $F_0$s than for higher $F_0$s. Finally, the falsetto register sustained tones had a lower ratio of noise components than both the lower and upper register sustained tones.

**Formant frequency regions, number of formants, and frequency spread between the first two formants** ($F_1$ and $F_2$). When subjects were singing lower register sustained tones, spectrographic analysis revealed that the unchanged voices produced the greatest number and the most intense harmonics. As maturation progressed, the number of upper harmonics decreased and perceived vocal richness diminished, although the differences were not drastic. The fewest harmonics were produced during the Midvoice IIA classification, and the intensity level of all harmonics was least. This characteristic of the Midvoice IIA classification indicated that it occurred during the maturational stage of greatest vocal instability. Voice quality was perceived as being the least clear.

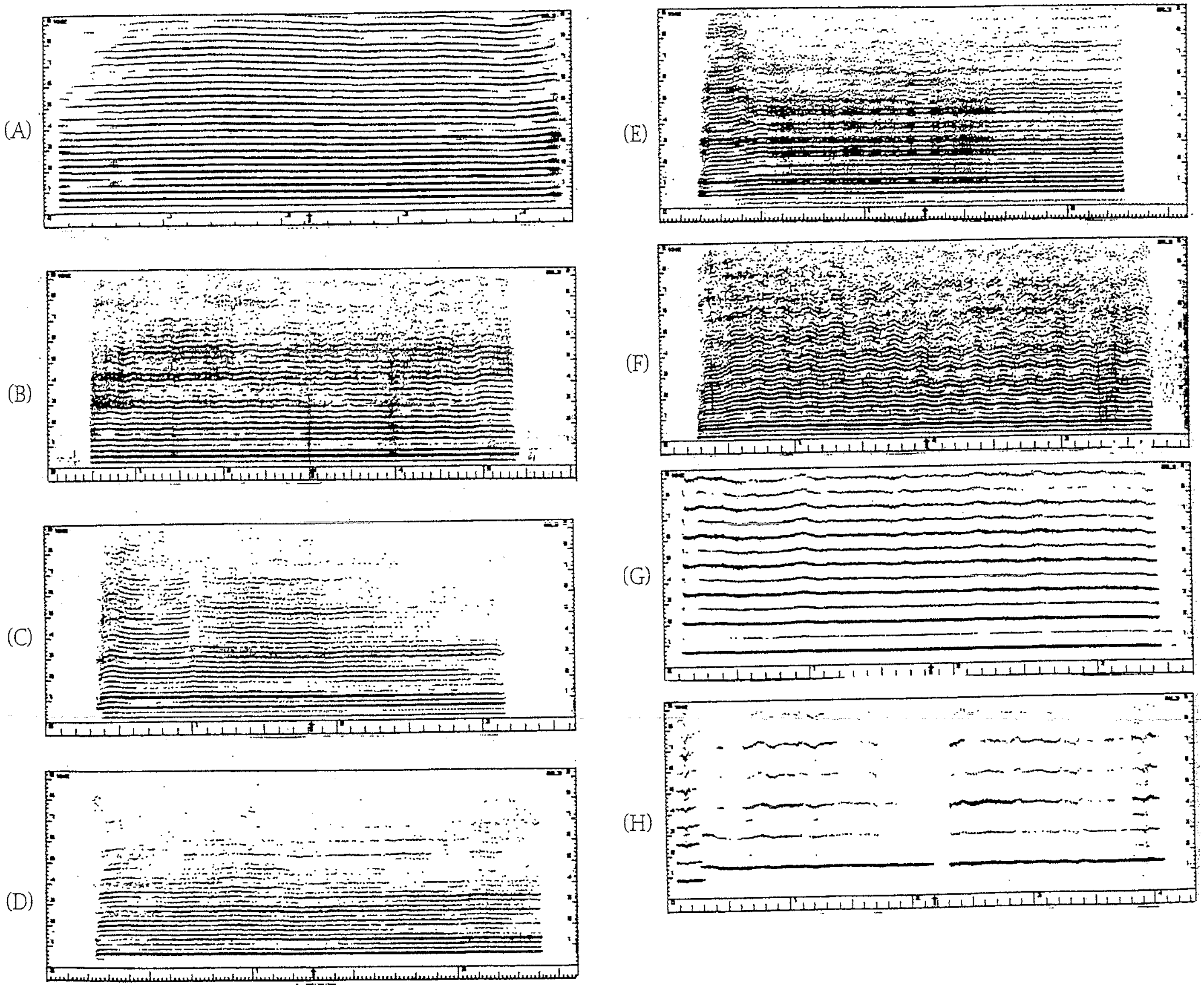



Figure IV-4-5: Narrow band spectrographic samples. (A) Unchanged voice, (B) Midvoice I, (C) Midvoice II, (D) Midvoice IIA, (E) New Baritone, (F) Settling Baritone, (G) Midvoice IIA falsetto register, (H) Midvoice II whistle register. The vowel /ah/ is sung for all examples.

Adult-like quality is not present in any stage of male adolescent voice transformation. During mutation, neither the amount nor the distribution of formant intensity above 4100-Hz was adult-like in nature. When the adult $F_0$ range was approximated during the Settling Baritone classification, the number and intensity of harmonics did not approximate adult characteristics. The $F_1 - F_2$ statistics also supported this conclusion. In the /ah/ vowel used by the Settling Baritone subjects, the spread between $F_1$ and $F_2$ ranged from about 550-Hz to about 500-Hz (about 220-Hz to 170-Hz above adult norms). All measurements were moving *toward* normal adult data, yet were still not close. Male adolescent voices cannot be expected to produce a voice quality that is comparable to an adult baritone, bass, or tenor, unless they produce vocal sound with exaggerated, inefficient laryngeal and vocal tract coordinations.

**Average speaking fundamental frequency**. There was a very close relationship between changes in average speaking fundamental frequency (ASFF) and the lowest singing $F_0$ produced by the research subjects (see Table IV-4-3 and Figure IV-4-6). Beginning with Midvoice II, the frequency interval difference between the lowest singing $F_0$ and the ASFF remained stable across the voice change classifica-

Table IV-4-3.

Comparison of Low Terminal Pitch (LTP) With Average Speaking Fundamental Frequency (ASFF) During Premutation and the Five Mutational Stages

[Voice classification designations are in parentheses.]

| Mutational Stage and Classification | LTP | ASFF |
|---|---|---|
| Premutation (Unchanged) | 218-Hz/$A_3$ | 259-Hz/$C_4$ |
| Early Mutation (Midvoice I) | 206-Hz/$Ab_3$ | 226-Hz/$Bb_3$ |
| High Mutation (Midvoice II) | 174-Hz/$F_3$ | 210-Hz/$Ab_3$ |
| Mutation Climax (Midvoice IIA) | 148-Hz/$D_3$ | 186-Hz/$F\#_3$ |
| Postmutation Stabilization (New Baritone) | 125-Hz/$B_2$ | 151-Hz/$D_3$ |
| Postmutation Development (Settling Baritone) | 95-Hz/$G_2$ | 120-Hz/$B_2$ |

tions. As voice transformation proceeded through the remaining maturational stages, both the lowest sung $F_0$ and the ASFF descended in frequency. Confirming the findings of Groom, (1984), Frank and Sparber (1970a, b), Naidr, et al. (1965), Hollien and Malcik (1967), and van Oordt and Drost (1963), the ASFF, during and after the most active stages of voice change, remained at about three to four semitones above the LTP of the singing range (musical intervals of the major and minor third).

Other Physical Findings. Confirming the findings of Weiss (1950), Tanner (1972), and Smart, Smart, and Smart (1978), chronological age was not a valid or reliable criterion for predicting a specific vocal-physiological stage of maturation. In general terms, however, the most extensive changes in vocal maturation took place between 12.5 and 14 years of age. This correlates highly with the growth patterns that have been described by pubertal growth authorities. According to Tanner (1972), the growth process proceeds in phases. These conclusions are supported by the findings of this study. The growth spurts were revealed in the measures of the various physiological factors. Each factor seemed to have its own growth rate velocity, but all measures increased over time (decreases in body fat measures excepted).

1. Increases in weight and in sitting and standing height closely paralleled normative charts for chronological age.

2. Increases in weight and in sitting and standing height during the most active voice change stages closely matched statistics given by other researchers.

3. Sitting and standing height, weight, chest size, waist size, phonation time, and vital capacity all showed progressive increases across the voice change stages.

4. Subcutaneous body fat measurements yielded inconsistent results; the overall pattern of change indicated a general loss of "baby fat" and increased muscular development in the chest and arm region.

5. Maximum phonation times (how long the subject could sing a sustained tone on one breathstream) were above established norms for adolescents and approached adult levels.

6. There was decreased glottal efficiency in the last two stages of voice maturation.

7. Within each of the voice change stages, steady increases of vital capacity seemed to be the most consistent measure of all the physiological variables tested.

The 1977-1980 study addressed the effect of voice skill training on developing vocal anatomy, and the relationship between (1) laryngeal growth spurts and (2) the incidence of true vocal dysphonias. Some choral educators and singing teachers have wondered if choral singing during voice change might affect vocal anatomy and physiology beneficially or adversely. The study's findings were inconclusive. Measures of gross vocal and singing intensities, ASFF, singing $F_0$ range, and tessitura limits during the most active phases of voice change showed no particular benefit. Cooksey, et al., concluded that whatever vocal training the subjects received might have had some positive effect in extending their upper range and tessitura limits

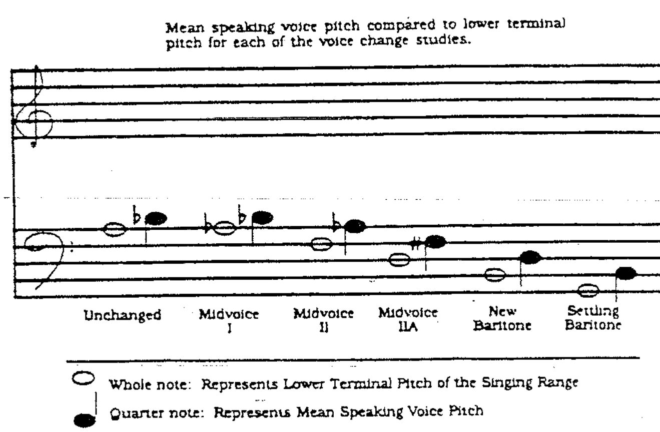



Figure IV-4-6: Average speaking pitch compared to low terminal pitch for each of the voice transformation classifications.

during the most active phases of voice change. No evidence was found to indicate that their training affected the rate of change or actual classification category. This question needs further study, but more stringent research methodologies are needed.

The cautionary concerns of the voice-break traditionalists, otolaryngologists, and speech pathologists regarding the relationship of vocal dysphonia and voice change was not substantiated. The voices in this study did not evidence a normal adult vocal quality and lacked perceived adult richness even during the Settling Baritone classification. Trained adult vocal production norms include such characteristics as little or no breathiness and optimal laryngeal constriction. Variance from *those* norms in changing voices were sometimes statistically significant, but the degrees of variation across measurements never proved to be *clinically* significant. A process of anatomical maturation was significantly underway, but did not appear to impact either the voice or the vocalist adversely. This finding implies that, while vocal pathologies do not normally exist during adolescent voice transformation, singing and speaking activities and training can be continued as long as efficient voice use and healthy management occur.

### Distribution of Subjects Across Voice Classifications, School Grade Level, and Voice Transformation Velocity Rates

The following assumptions appeared to be confirmed.

1. Many voices began the diminishing of $F_0$ range associated with puberty before the seventh grade (12-13 year olds).

2. All voice classifications in this study were present in the eighth grade (13-14 year olds).

3. There was more shifting between Midvoice II to Settling Baritone during the summer months between the seventh and eighth grades (13-14 year olds), than for the same period between the eighth and ninth grades (14-15 year olds).

4. The Midvoice II classification remained strongly present throughout the seventh and eighth grades (12-14 year olds).

5. Very few boys in the eighth grade (13-14 year olds) were at the Unchanged and Midvoice I classifications

6. There was a strong upsurge of New Baritones and Settling Baritones during the spring months of the eighth grade.

7. Individual growth rates within and across the voice change classifications were very different, but the average time spent in the most active phases of mutation closely approximated the same measures reported by Naidr, Zboril and Sevcik (1965).

8. Individuals tended to stay in the Midvoice II classification more than twice as long as any other classification (excluding the unchanged and Settling Baritone categories).

9. Finally, because of the wide and skewed dispersions, a truly accurate and precise measure of the velocity of growth rate could not be ascertained. Individual variability existed throughout the voice transformation period. Predictions of how long individuals will remain in each of the voice change classifications were not possible.

## Two Follow-Up Predictive Validity Studies (1983)

Utilizing the descriptive physiological and acoustical data from the original California Longitudinal Study (1984, 1985), Wiseman, Cooksey, and Beckett (1983a,b) conducted two predictive validity studies. The purpose of the first study was to determine if any of the eight physiological variables that were measured in the original study could be highly correlated with the voice change stages. Any variables with high correlation to the stages might be used to predict which change stage the boys were in with relatively high validity.

The eight physiological variables were: (1) standing height, (2) sitting height, (3) chest size, (4) waist size, (5) percentage of body fat, (6) total fat, (7) phonation time, and (8) vital air capacity. Measurements of the variables were taken monthly during the school year. Both linear and quadratic discriminant statistical analyses were applied to the original study's data. Using only the physiological variables as criteria, only 35.9% of the study's subjects were accurately placed into their voice change stages and classifications. The best predictor of voice change, however, was standing height, followed by the square of standing height. Basically, extensive but rapid increases in standing height appeared to be negatively correlated with voice change. This seems contradictory, but during the Midvoice II stage (lengthiest stage), the most extensive growth spurt took place among most of the boys; in other stages, height increases were not so extreme. The third best predictor of voice change was the interaction between standing height and weight. This was followed by the single variable of weight. When physiological measures are considered independently of each other, they generally appear not to be powerful predictors of voice change stages. Changes in the physiological measures vary across voice change stages. The growth rates of different maturational processes vary across time.

The purpose of the second study was to determine if any of the nine acoustical/vocal variables that were measured in the original study could be highly correlated with the voice change stages. The nine acoustical/vocal variables included: (1) dynamic singing range, (2) breathiness of the voice, (3) constriction of the voice, (4) degree of low frequency noise (i.e., less than 4,000-Hz or 4-kiloHertz), (5) degree of upper frequency noise (i.e., greater than 4-kHz), (6) number of formants, (7) the average center of the upper formants, (8) location of the first formant, and (9) location of the second formant. In addition, Two other variables that are closely related to the vocal/acoustical phenomena were studied, that is, phonation time and vital air capacity.

By applying quadratic discriminant statistical analysis, 41.1% of the cases could be accurately classified--a result significantly better than chance alone. Four variables were significant predictors of voice change. The most potent predictor of voice change was vital air capacity--a physiological variable that correlated significantly with certain acoustic variables. The interaction between vital air capacity and perceived breathiness was the next best predictor, while the statistical interaction between the first and second formants was third best. The fact that the spread between $F_1$ and $F_2$ remained constant, supported the perceptual stability of the phoneme utilized. Low frequency noise in the voiced signal also showed significance as a predictor, and increases in the level of noise were also associated with changes in voice stages.

## Studies Since Cooksey-Beckett-Wiseman

### Vocal-Acoustical Measures of Prototypical Patterns Related to Male Adolescent Voice Transformation

In an effort to test the validity of the Cooksey voice classification guidelines and to compare other acoustic information, a prototype investigation was undertaken, using more precise acoustic measures (Cooksey, 1985). Dr. Joel Kahane, Professor of Audiology and Speech Pathology at Memphis State University (Memphis, Tennessee, USA) assisted in the planning and implementation of the project. The primary purpose was to test the singing $F_0$ ranges and ASFFs of subjects who could serve as prototypes for the various voice classifications represented in the revised index. Three Memphis city schools were chosen for the initial testing of 50 subjects. Using the piano and pitch pipe as frequency references, 15 boys who best represented prototypical pitch range patterns were further tested at the Memphis State University Speech and Hearing Center.

Each subject was tested in a soundproof room, and measurements were taken through a one-inch condenser microphone and ReVox A77 Tape Recorder. Through a series of readings and vocalizations on prescribed pitch patterns (including the vowels /ah/, /eh/, /ee/, /oh/, and /oo/), results were examined using Kay Elemetrics Visi-pitch equipment (Model 6087). A continuously variable electronic cursor was used to measure the trace patterns appearing on the oscilloscopic screen. Stored recorded traces of the singing and speaking $F_0$ patterns produced by readings and sung passages were measured by digital readouts. Frequency bands (A,B,C,D) were selected depending upon the subject's $F_0$ range, and settings at 1, 2, 4 or 8 second intervals were employed in an effort to obtain the optimum tracing patterns on the screen.

The schematic representation in Figure IV-4-7 shows how the singing HTP and LTP frequencies were determined. The shape of the tracing patterns show distinctive features.

1. Each sung pitch was represented by a plateau between consecutive transition areas.

2. Transition areas were shown by increases or decreases in frequency (sloped areas) between two adjacent pitches.

3. The beginning boundaries of each pitch were selected after the transition increases or decreases were completed.

These individual pitches represented the component parts of each scale pattern. The digital frequency readout for each pitch was determined by a cursor-measuring unit which was moved horizontally and positioned over the mid-point of each pitch produced. In the case of determining the ASFFs, approximately 70 equidistant digital readings were made across the various syllables of the recorded passage. A follow-up cursor measure of peaks, low areas, and plateau regions also was completed.

Results indicated that the prototype voices clearly matched the maturation criteria that were described in the Cooksey, Beckett, and Wiseman study (1984, 1985). Initial on-site voice testing procedures were also found to be valid; that is, assignments to the voice classifications were accurate, and accurate vocal $F_0$ ranges were ascertained. Furthermore, the mean $F_0$ ranges (averaged HTPs and LTPs) of the 86 subjects in the Cookman-Beckett-Wiseman study were established as valid reference points for voice classification. The prototype voices, when analyzed acoustically, did not differ significantly from the Cooksey, et al., measures. Figure IV-4-8 shows a comparison of the mean singing ranges and the ASFFs of the two sample populations. There are small pitch differences from the original mean figures of the Cooksey, et al., study, but all fell well within the $F_0$ range boundaries established by the study's voice classification index. The prototype subjects' ASFFs were somewhat lower than those of the Cooksey, et al., study.

Whereas in the Cooksey, et al., study, the ASFFs remained in a relatively consistent position above the LTPs for each of the voice classifications, the prototype sample showed a different trend. The pitch intervals above the LTPs (beginning with Midvoice I) became wider for successive voice classifications, possibly indicating more rapid growth patterns. Further research is needed to determine the validity of this finding.

The results of the prototype study were consistent with the sequential continuum in the growth processes associated with male adolescent voice transformation. Certain vocal and acoustic factors followed a sequential pattern of development, and were measured accurately and precisely. Based upon the criteria of singing range, register develop-

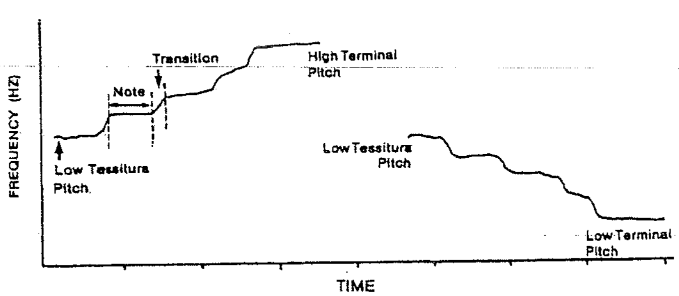



Figure IV-4-7: Schematic representation of the oscillographic tracing of recorded sounds from prototypical grade school and junior high school subjects. Displayed on the left is a subject singing a series of ascending pitches to determine high terminal pitch. Displayed on the right is a subject singing a series of descending pitches to determine low terminal pitch.

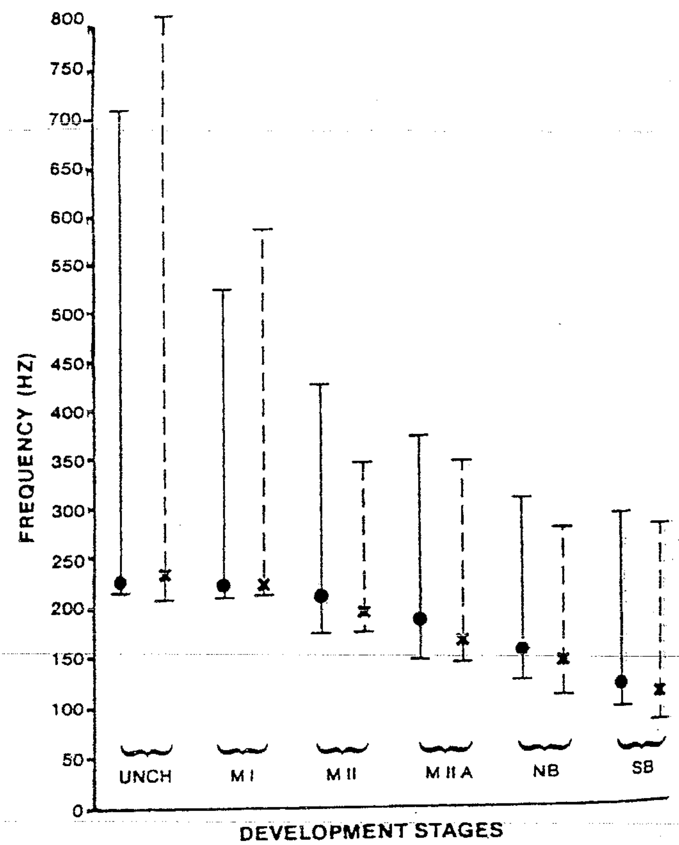



Figure IV-4-8: Frequency ranges of singing and speaking at different stages of voice maturation. *Range frequency*: continuous line = original sample; broken line = new experimental sample. *fundamental frequency*: (•) = average speaking fundamental frequency pitch pipe analysis; (X) = Visi-pitch analysis of average speaking fundamental frequency. UNCH = unchanged voice; M I = Midvoice I; M II = Midvoice II; M IIA = Midvoice IIA; NB = New Baritone; SB = Settling Baritone.

ment, and average speaking fundamental frequency, the following conclusions were drawn.

1. There were distinct stages of voice mutation, which can be defined operationally and tested scientifically.

2. The Cooksey, et al., revised voice classification index was a useful measure in determining specific voice classification assignments.

3. On-site voice assessment procedures were reliable in determining voice classifications. The acoustic measures supported the preliminary judgments that were based upon the range and register criteria. The piano and pitch pipe were useful referents in this process.

4. There were varying degrees of vocal stability, depending upon the particular voice change classification; for example, Midvoice IIA had the most erratic tracer configurations.

5. There was a monotonic shift in singing and speaking pitch ranges as the climax of mutation was approached. The New Baritone and Settling Baritone classifications represented a more stable, tapering period.

6. There were sometimes double- and triple-banded frequency areas for the falsetto and whistle registers (Midvoice II and IIA) indicating some pitch instability. This phenomenon did not occur, however, during the New and Settling Baritone classifications.

7. The average speaking fundamental frequency occurred close to the lowest terminal pitch of the singing pitch range. Pitch intervals above the lower borders, however, became slightly higher with successive voice change classifications.

### The London Oratory School Study: Cross-Cultural Perspectives (1992-1994)

Approximately sixty male pupils, aged between seven and eighteen years, from the London Oratory School and the London Oratory Primary School, were subjects in a study of various aspects of male voice development (Cooksey & Welch, 1997). These students sing daily and receive voice training. Data were gathered from each boy once per month over one academic year (1992-1993). A variety of selected singing and speech activities were recorded for subsequent musical, acoustic, and laryngographic analysis (Book II, Chapter 7 describes the latter as electroglottographic analysis).

A follow-up comparative assessment was completed in June, 1994. The data were compared to the Index of Voice Change that was validated in the Cooksey, et.al., 1984 study. That study's subjects were predominantly inexperienced and untrained in singing. The data examined related to how voices developed as determined by their acoustic signals (vocal fold patterning, relative energy levels across frequencies of vowel production, closed quotient analysis) and their vocal output (vocal ranges, tessiturae, and registers).

The London boys followed the same general sequence of voice transformation stages that had been established in the Cooksey, et al., study, and pitch ranges and tessiturae were remarkably similar. Falsetto register characteristics remained the same for stages III-V, but the whistle register was found in a number of unchanged voices, providing an exception to the findings in the California study.

Several interesting cases appeared which illustrate the diversity and complexity (and challenge) of adolescent voice development. For example, pupils A and B were close to the same age, 12 years, but pupil A progressed through three stages of voice change between November, 1992, and June, 1993. Stage I lasted two months, stage II, three months, and stage III, three months. So, pupil A was in stage IV (New Baritone) one year later. During this twelve-month period of rapid change, vocal coordinations were difficult, and voice quality was inconsistent. Nevertheless, many of these problems did not appear when his voice was reassessed in 1994.

In contrast, pupil B's voice remained unchanged throughout the entire first year of testing. He was able to continue a vigorous solo treble schedule, and sang throughout his pitch range with comfort and ease of production. One year later, 1994, his voice was classified as being at stage II, a *much* slower progression than pupil A, and with vocal coordination remaining quite stable throughout his pitch range. In general, age continued to be a poor criterion for establishing voice change stages, and a variety of stages could be found at any point within the 12-14 year age span of the London sample. This finding is quite similar to previous studies. Analysis of the study's data continues.

### The Cambridge Study (UK)

Harries, et al., (1996), conducted a one-year longitudinal study of 26 boys, ages 13 and 14 years, who resided in Cambridge, United Kingdom. Data were gathered once every three months for a total of five data collection periods over the year. In the data gathering sessions, the boys underwent a physical examination by physician researchers, and various vocal tasks were performed, observed, and recorded.

During the physical exam, various aspects of the physical growth and development of the boys were observed and described. They were then classified according to specific characteristics of five physical growth stages during puberty that were designated by Tanner (1984) as G1, G2, G3, G4, and G5.

The boys were asked to speak their name, read two well known speech passages, sustain a comfortable pitch in lower register and then create pitched scales from that pitch (no fry or falsetto allowed), and sing the song "Happy Birthday" in a self-chosen comfortable key. Voice data were recorded by various instruments for subsequent analysis, including a laryngograph and a tape recorder. Average speaking fundamental frequency and singing pitch range (within lower and upper registers only) were two prominent measures of the study.

The study's findings were correlated with data from the California Longitudinal Study (Cooksey, et al., 1984, 1985). Tanner's five physical growth stages correlated highly with the five stages of voice transformation from the California study. The data on speaking and singing pitch range also correlated highly.

## Summary and Conclusions

European and American research findings reported in this chapter have provided music and choral educators, laryngologists, speech pathologists, voice scientists, and others in the medical professions with important information about the vocal, acoustic, and physiological characteristics associated with male adolescent voice transformation.

These studies showed that:

1. Voice maturation, as revealed in measures of singing capabilities, proceeds at various rates of velocity through a predictable, sequential pattern of stages. Individual growth rates and distribution of voice "types" are highly variable, however.

2. Total pitch range compass is the most important vocal criterion in determining a particular voice maturation stage. HTPs and LTPs are variable within and across individuals (depending on nervousness and other factors), nevertheless, this criterion is very reliable.

3. Other important criteria for male changing voice classification include tessitura, voice quality, register development, and average speaking fundamental frequency.

4. One can expect voices representing all stages of maturation during the seventh grade school year (12-13 year olds), especially at mid-year.

5. For most boys, adolescent voice mutation begins at 12-13 years of age, reaches its most active phase between 13 and 14 years, then tapers off between 15 and 18 years. Voices continue to mature and expand their pitch ranges during the latter age range.

6. There tends to be more stability and less individual variation in the lower pitch range limits throughout the different stages of voice maturation than in the upper pitch range limits. There are great variations in the upper range areas, but stability comes with the New Baritone classification, after the high point of voice maturation is passed.

7. Triggered by hormone secretions, the first stage of voice maturation occurs at different times in different individuals. It is challenging to detect. At first, the upper pitch range becomes unstable and more effortful and voice quality becomes slightly breathy and constricted.

8. The pubertal stages of sexual development closely parallel the stages of voice maturation. The most noticeable changes in singing capability occur at the climax of puberty, when secondary sex characteristics are fully developed and reproductive capability begins.

9. On average, the most active period of voice change occurs over about a 13 month period.

10. Adult voice quality should not be expected from the early adolescent male voice, even after the Settling Baritone classification has been reached.

11. The width of the comfortable singing pitch range (tessitura) remains fairly stable throughout the stages of voice change, but there is high individual variability.

12. The physiological variables of sitting and standing height, weight, chest size, waist size, phonation time, and vital capacity show a steady increase across the voice maturation stages. Height seems to be closely related to the most extensive voice maturation stages, whereas weight increases occur more extensively during the Settling Baritone classification.

13. Falsetto register first appears during the most active stage of voice maturation (Midvoice II) and shows consistent levels of noise in succeeding stages.

14. Average speaking fundamental frequency occurs close to the lower end of the singing pitch range through all of the voice maturation stages, although this finding does not necessarily reflect efficient voice use.

15. Acoustic data reveal increased breathiness and constriction during the most active stages of voice maturation (particularly Midvoice IIA), but voice-use pathologies are not commonly present.

More precise knowledge is being gathered about how the maturational stages affect both singing and speaking functions (Harries, et al., 1996). Rather than seeing the act of singing as detrimental to the healthy development of early-adolescent voices, voice medicine scientists are seeing the singing milieu as an important avenue to gaining new insights into (1) voice mutation processes, (2) dysphonic function that may occur only because of mutation processes, and (3) the incidence and treatment of voice-use disorders in pubertal children.

The transformation of the male adolescent voice is a complex phenomenon. With the information at hand, interested voice educators, voice scientists, speech-language pathologists, and laryngologists can develop guidelines for the careful management of singing and speaking functions during the time of mutation and for the treatment of any voice disorders that may occur. If singing activities were continued, and music, choral, and voice educators used science-based criteria for voice classification, music selection, and vocal part assignment, then perhaps male adolescent boys would be more likely to continue expressive singing and speaking activities over their entire lifespan.

## Implications for Further Research

The Cooksey, et al., study established a strong theoretical and scientifically tested conceptual framework for understanding the processes of male adolescent voice transformation as they affect singing and--to some extent--speaking. It showed that the interrelationships between all the vocal-acoustic-physiological processes are highly complex, and that developing research methodologies for teasing them out is challenging. For instance, there is strong evidence to show that some variables such as ASFF, height and weight, vocal quality, and register development are closely associated with changes in the singing pitch range. All of these changes occur as a part of the pubertal growth process. Predictive validity and correlation studies might be useful in giving additional information, and creating areas for further research.

As a result of this scientific framework, much progress has been made in developing practical approaches to adolescent voice education and health care. Significant questions remain, however. Of primary importance is continued development of methods for teaching efficient voice skills, optimum vocal conditioning, and voice health protection. For instance, would vocalises, solo song, and choral literature--carefully composed to fit the Cooksey voice classification guidelines--produce more skilled, stronger, and healthier adolescent voices? Would these male singers maintain a greater degree of pitch perception and accuracy both during and after voice change? Can frequent "top-down" vocalization be used to strengthen the falsetto and upper registers, to achieve blended register transitions and efficiently produce "seamless" voice quality families (see Book II, Chapters 10 and 11)? Can the same process be used to extend the upper pitch range? Scientific instruments, such as electroglottographic and spectrographic analysis, can measure the effects of such voice education methods.

Measures of vocal function such as singing range, tessitura, register development, and voice quality can give scientists and medical personnel information on whether or not the vocal mechanism is intact as it develops during adolescence. Variable stability in vocal functions appears to occur during the different stages of vocal maturation, particularly in mucosal waving. Such information could provide cooperative voice treatment teams with additional important information from which new therapeutic methodologies and treatments of functional disorders may be devised.

Finally, the vocal-acoustic-physiological factors of voice transformation need to be studied in relation to selective neuropsychobiological and cultural factors. How might development of singing skills during adolescent voice transformation affect myelinization patterns and cognitive growth patterns in males (see Fischer & Rose, 1992; Thatcher, 1992)? Can an understanding and effective practice of healthy voice management during voice change better enable young men to withstand negative peer pressure regarding participation in singing activities? If success and stronger self-identity occur as a result of expressive vocal experiences, will the adolescent male be more likely to take part in singing and music activities later on in life? It is generally accepted that adult male participation in choirs and other singing activities is at best minimal in most parts of the Western world. Perhaps if adolescent voices were cultivated, using methodologies based upon scientific findings, more young men would be encouraged to continue their participation in singing activities.

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