Phonational gaps in the developing male adolescent voice

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Background in music performance and pedagogy. Prediction of voice change as a basis for voice-maturation management for adolescent males has assessed changes of vocal fold length and structure, hormonal changes assessed through genital development and blood analysis, and association of these with Tanner's five stages of pubertal development. Because of the invasive nature of these techniques, they are not readily available to music practitioners. Acoustic changes that accompany these physiological changes offer a possible alternative for accurately assessing young males' stages of vocal development and change.

Background in music acoustics. Fuchs et al. have acoustically identified vocal features of male changing voice, including noise component, jitter, shimmer, mean waveform correlation coefficients and fundamental frequency using spoken voice analysis features of the Goettingen Hoarseness Diagram (GHD). They reported significant acoustic features indicating restriction of vocal function seven and five months prior to onset of voice mutation. While most researchers agree that the voice-range lowers as a result of change, there is disagreement with respect to whether the lowering process is gradual or rapid, what other vocal changes occur during this process and consequently different recommendations for vocal management arise.

Aims. The aims of this study were to:

(1) assess the pattern and pace of vocal change in adolescent males,

(2) identify and acoustically analyze the phonational gaps, defined as a range of missing fundamental frequencies within the maximal phonational frequency range,

(3) identify any relationship between the appearance of phonational gaps and weight gain.

(4) develop a coherent model linking changes in vocal range and appearance of phonational gaps with changes in speaking fundamental frequency, tessitura and physical maturation as indicated by weight gain.

The development of an evidence-based pedagogy for adolescent male changing voice has been inhibited by lack of understanding about the processes involved in change. Tanner (1975) used an index (G1 to G5) to identify physiological changes occurring at puberty based on changes in height and genital development that resulted from hormonal changes. The impact of these changes on the voice were codified by Cooksey (1977a,1977b,1977c, 1978, 1992, 2000) who observed an invariant sequence of six stages in adolescent male voice change. Harries et al (1997) compared Cooksey's voice change stages (C1 to C6) with Tanner's index and found that speaking fundamental frequency (SFo) and singing frequencies showed a significant change between Tanner stages G3 and G4, and a more gradual change over Cooksey's C3, C4 and C5. In assessing vocal development against pubertal development rather than chronological age, Harries et al. showed that maximum vocal development (which he identified as 'voice breaking') occurred late in pubertal development. Harries et al considered that the sudden drop in frequencies was not a result of additional vocal fold length, but of maturation of the vocal fold layering. Swanson (1973), Groom (1984) and Cooksey (2000) noted that 'voice-breaking' involved the development of a 'Blank Spot' in the voice range. Cooksey identified a mid-range phonational gap in the region of 262-349 Hz [c4-f4] that was an indicator of 'Newvoice' in his vocal classification system. The 'Blank Spot' and 'voice-breaking' are influenced by rapid weight change and lowering SFo, two factors of particular interest in this study, as they create non-phonating frequencies (or phonational gaps) within the boundaries of the maximal phonational frequency range (MPFR).

The aim of this study, therefore, was to investigate the relationship between weight-gain, lowering SFo pitch, and the development of phonational gaps in the adolescent male changing voice.

Method

Ethics approval was obtained from the Human Research Ethics Committee of the University of Sydney, Australia, from the New South Wales Department of Education, from school principals of participating schools, and from the boys and their parents. The study used a prospective longitudinal design. Physical and acoustical measures were taken five times over a 12 month period. Twenty boys participated in data collection at time 1, 13 boys four months later at time 2, 12 boys 2 ½ months later at time 3, 13 boys three months later at time 4, and 18 boys 2 1/2 months later at time 5. Twelve boys were recorded five times. At each data collection time, boys completed physical, self-report and vocal assessments. Measures collected included age, weight, and height as indicators of general maturational development. Subjective responses of students were collected. These included completion of a visual analogue scale (VAS) indicating their responses to their changing singing and speaking voices. Vocal tasks included reading a passage (Arthur the Rat) to assess SFo, and the use of glides across their vocal range to assess maximal phonational frequency range (MPFR), and the presence, location and extent of phonational gaps in the range. Boys were instructed to use the vowel /ah/ to glide three times from 'as high as possible to as low as possible' for descending glides, and three times 'from as low as possible to as high as possible' for ascending glides. The recorded data were digitized over the range 0-16 kHz, then analyzed using *Phog Interactive Phonetography System*. Analysis of the Fo was undertaken using *Soundswell* program (Hitech, Sweden) on an *IBM Thinkpad A30*.

Results

Participants

The average age of the boys at time 1 was 12.11 years (range:12-13.7years); mean weight was 46.8 ks (range, 27.8-67.7kg) and mean height 159.6 cm (range, 139.5-171.5 cm). By time 5, average mean weight was 52.03 kg (range, 32.9-73.2 kg) and average mean height 164.16 cm (range, 147.5-175 cm). Reflecting Australia's multicultural society, the study participants were ethnically diverse, with 55% speaking Chinese (Mandarin, Cantonese) in the home, 11% Tamil, 11% Hindi, 11% English and 5% Vietnamese. At time 1, 55% of the boys were either involved in a choir or had private vocal training. Mean weight of those in training was 42.39 kg at time 1. Mean weight of those not in training was 50.73 Kg, indicating that those not in training were more physically mature and so at a later stage of change.

Phonational gaps and speaking fundamental frequency (SFo)

Figure 1 shows the phonational gap data arranged in order of descending SFo. This shows that over 61% of all glides recorded had phonational gaps with these gaps appearing over the same frequencies in all six glides, both descending and ascending. Unchanged voices had fewer phonational gaps, but small gaps were evident in some boys below the SFo or very high in the range, at between 818-1134 Hz g#5-c#6. This occurred when the SFo was in the range 205.1-267.9 Hz [g#3-c4], and may be associated with changes in noise component, jitter and shimmer (Fuchs et al, 2006). When the SFo was around 200 Hz [g3], it was difficult to ascertain the appropriate range to use in the glides with some boys not going into falsetto, and others not taking the glide into their developing lower range. The highest glide notes were recorded at this time – around 1495 Hz [g#6]. Pitches of the lowest note of the glide and the SFo were close. As the SFo dropped to the range 151-196.3 Hz [d#3-g3], the lowest note of the glide lowered in pitch away from the SFo, and phonational gaps developed mid-range (mean = 302.67-398.21 Hz [d#4-g#4] range = 180-767 Hz [f#3-gflat 5]. At around 145 Hz [d3], the lowest note of the glide and the SFo were again close in pitch, and for some boys, no phonational gaps were present. When the SFo was below 144 Hz [d3], the lowest note of the glide moved away from the SFo, and midrange phonational gaps became firmly established (mean, 269.32-431.33 Hz [c4-a4] range, 207.8-847 Hz [g#3-g#5]). The lowest SFo was 99.48Hz [g2], and the lowest glide note was 84 Hz [f2].

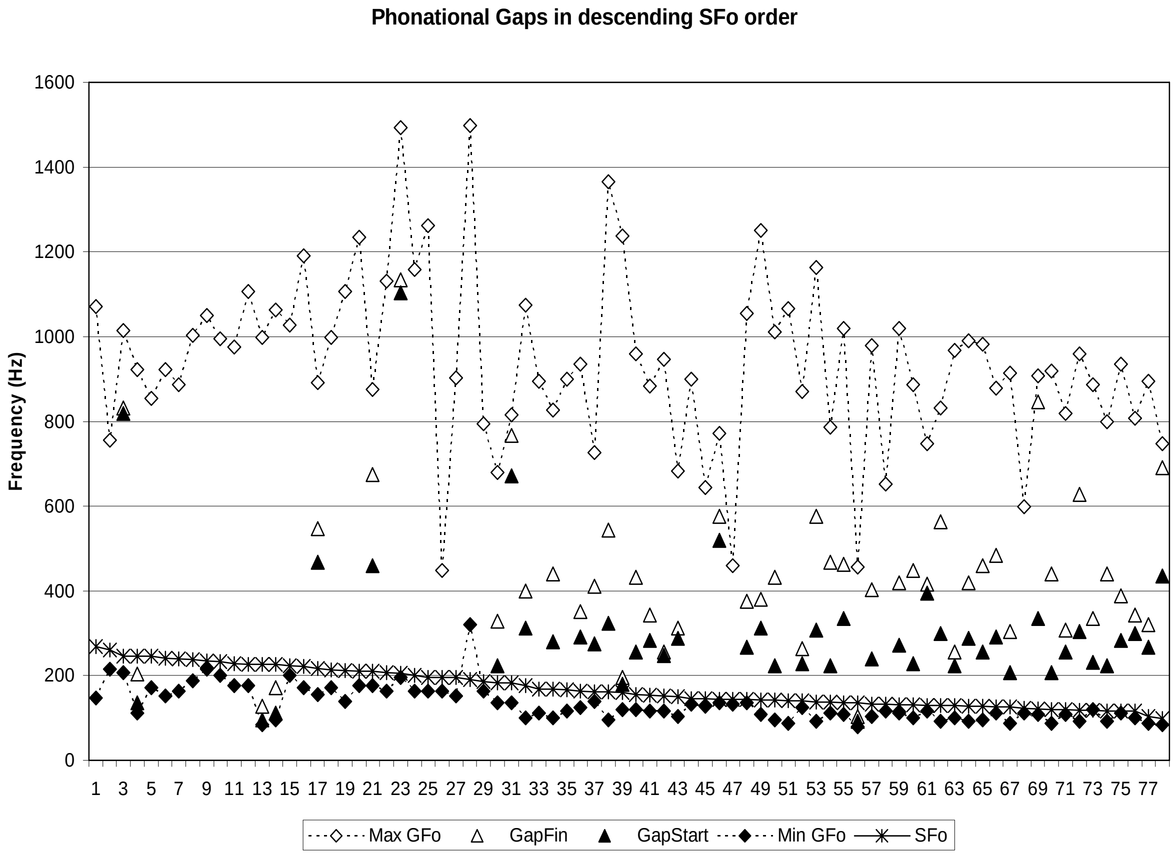

Figure 1. Minimum and maximum glide frequency and phonational gap data arranged in descending SFo order.

Phonational gaps and weight

This study confirms that there is a strong association between rapid weight-gain and the development of phonational gaps. Phonational gaps lower than the SFo were present in boys at 31.6 Kg, and for some boys who weighed between 38-42 kg. Low-range, midrange or high-range gaps were present in all boys who weighed between 42.2kg-44.3kg. Thirty-nine percent (38.5%) of the boys weighing between 44.3-49.9 kg had phonational gaps, compared with 90% of boys heavier than 50.7 kgs.

Longitudinal data on individual subjects indicated that phonational gaps develop in a predictable sequence. A low gap is followed by a high gap before a mid-range gap develops. After each phonational gap development, there was a time of consolidation during which the phonational gap would either narrow or in some cases disappear, before further weight-gain would prelude more phonational gap development. Subject 20, for example, gained 2.6 kg from time 1 (39.1kg) to time 3 (41.7kg) when a gap lower than his SFo developed (SFo at time 1 – 235 Hz [about b flat3]; at time 3 245 Hz.) In this case, the appearance of a low-range gap (136-204 Hz) pushed the SFo higher than at time 2 (238.3 Hz) and by time 4, his weight had stabilized (41.8Kg) and there were no phonational gaps. At time 5 he had again gained weight (42.7kg), and a higher range phonational gap had also developed (467.4-547.33 Hz [a#4-c#5]. For subject 37, rapid weight-gain from time 1 (38.9 kg) to time 3 (42.2 Kg) preceded the development of a midrange gap – 275.7Hz-411.5 Hz [c#4-g#4].

At time, he did not use falsetto range during the glides, so that the upper range note was only 447 Hz [a4].

Once the phonational gap appeared at time 3 the falsetto range was again used, with a maximum glide note of 727 Hz [f#5].

Weight increase from time 3, to time 4, to time 5 was steady (42.2-44.3kg) and the phonational gap remained. For a heavier student such as subject 27, rapid weight-gain from time 1 (51.2 kg) to time 2 (52.6kg) was accompanied by an increase in the phonational gap range – from 335.6-846.9 Hz [e4-a flat5]). As his weight stabilized, the phonational gap decreased at time 3 to a gap ranging 291.69-483.4 Hz [d4-a flat4]. At time 4 his weight was 54 kg, and the gap had increased again from 303.6-627.2 Hz [d#4-d#5]. By time 5, although his weight had increased to 55.7 kg, the phonational gap was much smaller (a gap from 267.7-319.6 Hz [c4-e flat4].

Conclusion

The variability of phonational gap ranges has pedagogical implications for working with boys of this age-group. While Cooksey gives the 'Blank Spot' range as 262-349 Hz [c4-f4], this study shows that phonational gaps are highly variable in pace of development and range. When working with groups of boys, vocal tessitura will vary depending on their stage of development, and positioning of phonational gaps.

Our primary recommendation is to work from falsetto to modal range, except in cases where boys cannot access their falsetto range. Boys need to be assessed individually and frequently to ensure positive outcomes from their voice-change experience.

References

Cooksey, J.M. (1977a). The development of a contemporary, eclectic theory for the training and cultivation of the junior high school male changing voice: Part 1, existing theories. *The Choral Journal,* 18 (2), 5-14.

Cooksey, J.M. (1977b). The development of a contemporary, eclectic theory for the training and cultivation of the junior high school male changing voice: Part II, scientific and empirical findings: Some tentative solutions. *The Choral Journal*, 18(3), 5-16.

Cooksey, J.M. (1977c). The development of a contemporary, eclectic theory for the training and cultivation of the junior high school male changing voice: Part III, developing an integrated approach to the care and training of the junior high school male changing voice. *The Choral Journal,* 18(4), 5-15.

Cooksey, J.M.(1978). The development of a contemporary, eclectic theory for the training and cultivation of the junior high school male changing voice: Pt IV, selecting music for the junior high school male changing voice. *The Choral Journal*, 18(5), 5-18.

Cooksey, J.M. (1992). *Working with the adolescent voice* (pp. 55-64). St Louis, MO: Concordia Publishing House.

Cooksey, J.M. (2000). Voice transformation in male adolescents. In L. Thurman & G. Welch (Eds.), *Bodymind and voice - Foundations of voice education* (pp.718-738, 821-841). USA: The VoiceCare Network.

Cooksey JM., Beckett RL, & Wiseman R. (2000). A longitudinal investigation of selected vocal, physiological, and acoustical factors associated with voice maturation in the junior high school male adolescent. In: L. Thurman & G. Welch (Eds.), *Bodymind and voice – Foundations of voice education* (pp.731-733). USA: The VoiceCare Network.

Fuchs, M., Frohlich, M., Hentschel, B., Stuermer, I.W., Kruse, E., Knauft, D. (2006). Predicting mutational change in the speaking voice of boys. *Journal of Voice.*

Groom, M.D. (1984). A descriptive analysis of development in adolescent male voices during the summer time period. In E.M. Runfola (Ed.), *Proceedings: Research*

Symposium on the Male Adolescent Voice (pp.80-85). Buffalo, NY: State University of New York at Buffalo Press.

Harries, M.L., Walker, J.M., Hawkins, S., Williams, D.M., Hughes, I.A. (1997). Changes in the male voice at puberty. *Archives of Disease in Childhood.* 77: 445-447.

Swanson, F.J. (1973). *Music teaching in the junior high and middle school.* Englewood Cliffs, New Jersey: Prentice-Hall.

Tanner J.M. (1975). Growth and endocrinology of the adolescent. In: I.L. Gardner (Ed.), *Endocrine and genetic diseases of childhood and adolescence* (pp. 14-64). Philadelphia, PA: W.B. Saunders.