Speaking Fundamental Frequency (SFF) Changes Following Successful Management of Functional Dysphonia

Fréquence vocale fondamentale (FVF); changements consécutifs au traitement réussi de la dysphonie fonctionnelle

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Abstract

Speaking Fundamental Frequency (SFF) and its perceptual correlate "habitual pitch" have been considered important and controversial parameters in voice assessment and treatment. Eight female subjects with functional dysphonia were successfully treated with a manual laryngeal muscle tension reduction procedure. Pre- and post-treatment SFF measures were acoustically analyzed to assess changes following resolution of vocal symptoms. Results indicated that, as a group, no significant change in mean SFF or SFF variability was observed. Although no consistent directional pattern was identified, six of the eight subjects experienced pitch changes greater than one semitone, suggesting that voice improvement is often accompanied by a shift in SFF. Clinical implications of the data are discussed.

Abrégé

La fréquence vocale fondamentale (FVF) et la «hauteur tonale habituelle», son corrélat perceptuel, sont considérées comme des paramètres importants, mais controversés, de l'évaluation et du traitement de la voix. On a traité avec succès huit femmes atteintes de dysphonie fonctionnelle au moyen d'une intervention manuelle visant à diminuer la tension des muscles laryngés. L'analyse acoustique des mesures de la FVF effectuées avant et après le traitement a permis d'évaluer les changements après la résolution des symptômes vocaux. Globalement, les résultats n'indiquent aucune modification significative de la variabilité de la FVF ou de sa valeur moyenne. Bien qu'on ne décèle aucune tendance directionnelle constante, on note une variation de la hauteur tonale de plus d'un demi ton chez six des huit sujets, ce qui donne à penser que l'amélioration de la voix est souvent accompagnée d'un déplacement de la FVF. On discute de la portée clinique des résultats.

Speaking fundamental frequency (SFF) and its perceptual correlate "habitual pitch" have traditionally been considered important parameters in the assessment and treatment of voice disorders. The calculation of SFF and its relationship to diagnosis, voice classification, and treatment continues to interest researchers and clinicians alike. Without exception, contemporary voice texts stress the importance of obtaining habitual pitch measures for comparison with normative data, and cautiously propose methods to determine "optimal pitch."

Habitual pitch refers to the pitch level most used by the speaker during connected speech, (Boone & McFarlane, 1988) whereas optimal pitch describes the level at which an individual with a normal larynx can produce voice efficiently with economy of physical effort (Fairbanks, 1960). In clinical practice, the observed difference between habitual and derived optimal pitch has been a source of debate (Britto & Doyle, 1990). Confusion and disagreement abound regarding (a) the diagnostic and therapeutic significance of such a difference and, (b) the role of habitual pitch in the pathogenesis of voice disorders. Some authorities strongly believe that inappropriate vocal pitch contributes to the development and maintenance of certain voice disorders (Cooper, 1974; Koufman & Blalock, 1988). Van Riper and Irwin (1958) and Wilson (1962) have postulated that nodule formation was related to a vocal pitch that was too high. However, Cooper (1974) felt that too low a pitch was causally implicated in almost 90% of 2,000 cases involving a variety of functional and organic voice disorders. Others maintain that abnormal pitch is a product of an underlying primary problem, i.e., laryngeal hyperfunction (Aronson, 1990; Stemple, 1984). Aronson (1990) believes that "each person who has a nonorganic voice disorder has the inherent capacity to phonate at the proper pitch, but the muscular tensions underlying the disorder have pulled the larynx out of optimum position. When the musculature has returned to its normal state, the correct pitch usually follows (p.312)."

In voice therapy, direct isolated targeting of habitual pitch remains a controversial subject because of numerous conflicting assumptions regarding relationships between pitch and the presence of additive lesions and laryngeal hyperfunction. For example, it has been suggested that if vocal nodules are eliminated with treatment, pitch will increase because of a reduction in the mass loading effects on the vibratory characteristics of the vocal folds (Brodnitz, 1961; Mueller, 1975). Others believe that if laryngeal hyperfunction, which ostensibly results in stretched, thin folds is reduced, pitch will decrease. Other approaches seek to reduce laryngeal hyperfunction by directly manipulating habitual pitch to improve the vibratory efficiency of the vocal folds (Fisher & Logemann, 1970; Cooper, 1973). Still others strongly advise caution when employing pitch manipulation as a treatment for any voice disorder, unless it has been isolated as the primary etiological factor (Stemple, 1984).

In spite of these divergent opinions regarding the role of habitual pitch in the development, maintenance and treatment of disordered voices, relatively few studies have objectively evaluated SFF changes following voice improvement. In fact, the majority of the research presently available in this area fails to identify or substantiate any solid relationships. For instance, Murry (1978), after finding no difference in SFF between three experimental groups with various laryngeal pathologies and a normal control group, concluded that habitual pitch was not an etiologic factor. The literature comparing changes in SFF following treatment does not reveal any consistent directional or magnitude change in SFF after treatment. Laguaite and Waldrop (1964) found no relationship between fundamental frequency and voice quality before and following therapy with a group of patients with varied laryngeal pathology. Hufnagle and Hufnagle (1984) also found no significant change in SFF following treatment of patients with vocal nodules and therefore concluded that "therapy for dysphonia associated with nodules is best managed by procedures other than those manipulating pitch and thus changing SFF" (p.99). Unfortunately, both of these studies examined patients in whom perceptually normal voice quality was not necessarily achieved following treatment, and significant disagreement existed among listeners regarding the degree of voice improvement observed. Cooper (1974) concluded that elevating habitual pitch was responsible for voice improvement observed in a large heterogeneous group of patients with organic and non-organic voice disorders. However, he neglected to provide any intra- or interjudge reliability measures for the perceptual judgements upon which his conclusions were based. In a study of functional dysphonics, Koufman and Blalock (1988) reported the results of treatment with a group of professional voice users for a voice disorder they labelled "Bogart-Bacall Syndrome." This voice condition is characterized by a low pitch speaking voice, increased laryngeal muscle tension, poor breath support and vocal fatigue. The authors report impressive results (i.e., resolution of symptoms in the majority of patients) following one treatment session employing techniques for pitch elevation, increased breath support and muscle relaxation. Koufman and Blalock concluded that inappropriate lowering of habitual pitch was a primary etiologic factor in this functional voice disorder. But, despite their conclusions regarding the importance of pitch elevation, they did not report any physical/acoustical data supporting post-treatment changes in SFF.

Because SFF has been established as a contentious issue in the assessment and treatment of voice disorders, it is necessary to evaluate objectively selected patient subgroups to determine whether predictable changes in SFF occur following improvement in vocal symptoms. The present retrospective investigation was therefore designed to answer the following experimental questions:

1. Does SFF change following marked resolution of vocal symptoms in a group of treated functional dysphonia patients?

2. Do consistent directional and magnitude changes in SFF occur following successful treatment?

3. Does SFF change following a treatment method that does not directly target pitch as a perceptual entity to be manipulated (Aronson, 1990)?

Method

Subjects

Eight (8) female subjects, ages 20 to 58 years (mean age of 39 years), participated in this study. All of the subjects presented varying degrees of dysphonia ranging in duration from four days to two years, with a mean duration of twenty weeks. The diagnostic label of "functional dysphonia" was made after a transoral videolaryngoendoscopic examination by one of three otolaryngologists revealed both (a) the absence of visible mucosal disease, and (b) normal vocal fold mobility on phonation. All patients were nonsmokers, with no co-existing upper respiratory infection symptoms and no previous laryngeal microsurgery.

Procedure

Each of the eight subjects underwent an assessment based on an interview technique, and a treatment protocol based on Aronson's manual laryngeal muscle tension reduction procedure. This technique does not directly attempt to find, establish or refer to a "correct" or "optimal" pitch level. The protocol, outlined in detail in Appendix A, was completed in one session that ranged in duration from 45 minutes to two hours. The effectiveness of this approach as a treatment for functional dysphonia has been reported in previous research (Roy & Leeper, 1993).

All subjects were recorded in a quiet setting on a research quality cassette tape recorder (Marantz model PMD201) while reading "The Rainbow Passage" (Fairbanks, 1960) prior to and immediately following the assessment and therapy session. The central portion of the reading passage ("these take the shape of a long round arch with its path high above and its two ends apparently beyond the horizon") was dubbed from the original pre- and post-therapy audio recordings onto a master tape for later use in the perceptual phase of this study. The signal level input was manually adjusted to prevent overload distortion. The connected speech samples for all subjects were randomized and a ten second inter-stimulus interval (rating period) was maintained between each sample to allow adequate time for listener judgments. To permit an estimate of the intra-judge reliability of the perceptual ratings, the first five samples on the experimental tape were repeated at the end of the rating session.

To obtain ratings of severity of dysphonia for the voice samples, four clinically certified speech-language pathologists with extensive experience in the assessment and treatment of voice disorders served as listeners. These judges were instructed to rate each voice sample on a seven point equal-appearing interval scale, where one indicated a normal voice and seven indicated a severe voice disorder. The listeners were also instructed that they might employ mid-point measures for this particular rating scale. Ten practice samples were presented to familiarize the listeners with a range of severity of vocal dysfunction. These voice samples were selected as representative of the experimental samples, but were not the same as those included in the experimental tape-recorded portion. The selection of the practice samples was predicated on the agreement of the investigators. Following each practice sample, the judges compared and discussed their ratings until agreement on all practice items was achieved.

Inter-observer and intra-observer reliability estimates were calculated for the perceptual ratings of severity. Inter- and intra-observer ratings were considered to be in agreement if they were within 1.0 scale point value of one another on the severity rating scale. An inter-observer concordance measure of 87.5 % was achieved with an intra-class correlation coefficient of $r = .98$. The intra-observer agreement level was 100% with an intra-judge correlation coefficient of $r = .99$. A signal processing package, CSPEECH (Milenkovic, 1987), was used to digitally analyze and measure vocal fundamental frequency of the same tape-recorded pre-/post-treatment connected speech samples employed in the perceptual ratings. The speech waveform was sampled at 22 kHz and filtered at 10 kHz. CSPEECH employs a pitch extraction method based on short-term autocorrelation function of the speech waveform to provide fine resolution of the pitch period. Using a CSPEECH subprogram to derive mean SFF, a frequency contour waveform of the same middle sentence was computed using a Fundamental Period (FPRD) algorithm. This pitch contour indicates a zero value for unvoiced intervals or for intervals where the FPRD algorithm does not detect a periodic signal. The first portion of periodic voicing was identified and the frequency contour was subsequently divided into consecutive 100 msec segments. The corresponding values in Hz were recorded and the mean and standard deviations of the SFF were calculated for each subject.

The identical middle portion of the pre- and post-treatment recordings of "The Rainbow Passage" (Fairbanks, 1960) was selected because (a) it has been shown to correlate highly with the entire first paragraph (Shipp, 1967), (b) it avoids any special effects associated with initial and final sentences and yields an estimate of acceptable accuracy (Horii, 1975), and (c) using the same sentence, rather than voice samples of the same duration without regard for content, significantly reduces the errors of SFF calculation (Horii, 1975).

Results

Table 1 summarizes the mean pre- and post-treatment listener ratings of the severity of dysphonic symptoms. A significant improvement in dysphonia following the management session was confirmed [$t(7)=6.27, p<.0004$]. All subjects demonstrated either normal voice or only the mildest dysphonic symptoms following treatment (i.e., subjects received mean post-treatment listener ratings of < or = 2 on the severity rating scale).

Table 1: Mean Pre- and Post-Treatment Listener Severity Ratings of Vocal Dysfunction for Individual Subjects.

SUBJECT NO.	PRE-TREATMENT	POST-TREATMENT
1	5.88	1.0
2	6.63	1.13
3	6.00	1.50
4	2.00	1.00
5	4.75	1.63
6	4.38	2.0
7	3.75	1.13
8	6.63	1.00
Mean	5.00	1.30*
S.D.	1.61	0.37

*The difference between the means is significant at the p<.0004 level.

Table 2 summarizes the SFF group data for these subjects. The results of the t-test for related measures did not reveal a statistically significant difference between pre- and post-treatment mean SFF measures. Also, SFF variability as measured by the standard deviation of the fundamental frequency, did not show significant change when comparing pre- and post-treatment measures [t(7) = 1. 96,p < .098].

Table 2: Pre- and Post-Treatment Group Mean and Standard Deviations of Frequency Dependent Measures.

	SFF (Hz)		SD OF SFF (Hz)	
	MEAN	(S.D.)	MEAN	(S.D.)
PRE-TREATMENT	195.04	(62.08)	34.69	(16.39)
POST-TREATMENT	198.39	(26.54)	25.40	(10.37)

Table 3 summarizes the change in SFF for individual subjects following voice improvement. Visual inspection of these data showed that six subjects experienced a change greater than one semitone in vocal pitch. Half of these subjects experienced a rise in vocal pitch and the other half witnessed a reduction.

Discussion

This investigation studied the changes in SFF following marked resolution of abnormal vocal characteristics in a group of treated functionally dysphonic subjects. From the results, it is apparent that, as a group, no consistent directional change in mean SFF or SFF variability occurred following significant improvement of vocal symptoms. However, when we reviewed changes in SFF for individual subjects, the results indicated that voice improvement was often accompanied by a discernible change in SFF. If we accept one semitone to represent a perceptually detectable shift in pitch, then for 75% of our subjects improvement in dysphonia was accompanied by a perceptible change in habitual pitch.

Although pitch was never directly manipulated during the course of therapy, the majority of subjects experienced a substantial shift in SFF. Because no reference was made during the course of the management session to directly or indirectly find or establish a "correct" or "optimal" pitch level, it seems reasonable to suggest that this observed shift therefore might be causally related to some treatment factor(s) other than direct pitch modification. These results with "nonorganic" voice disordered patients appear to bolster Aronson's contention that abnormal pitch may be a result of disordered extrinsic and intrinsic laryngeal muscle tension (i.e., laryngeal hyperfunction). Although the laryngeal muscle tension reduction procedure is purported to reduce excess musculoskeletal tension, we in no way objectively evaluated the presence, absence or reduction of such tension (i.e., electromyography). Therefore, we cannot directly substantiate Aronson's belief concerning the causative relationship between pitch normalization and the reduction of laryngeal musculoskeletal tension. Also, the absence of any control group leaves open the possibility that pitch changes may be related to some factor(s) other than voice improvement. More objective measures of the presence or absence of excess laryngeal musculosketal tension and its relationship to SFF and voice improvement should be explored.

Table 3: Pre- and Post-Treatment Comparison of SFF Changes for Individual Subjects.

SUBJECT NO.	PRE-TREATMENT		POST-TREATMENT		CHANGE (+/-Hz)	CHANGE (+/-semitones)
	Mean	(S.D.)	Mean	(S.D.)		
1	161.89	(44.23)	190.44	(38.22)	+28.55	+2.79
2	276.41	(65.55)	196.24	(19.32)	-80.17	-5.98
3	264.65	(41.20)	252.87	(20.36)	-11.78	-.797
4	177.75	(12.23)	174.39	(14.80)	-3.36	-.399
5	166.63	(35.74)	192.13	(39.87)	+25.50	+2.39
6	84.42	(19.83)	221.52	(34.87)	+137.1	+16.7
7	201.43	(29.45)	174.68	(18.63)	-26.75	-2.47
8	227.11	(28.51)	184.83	(17.13)	-42.28	-3.59

Clinical Implications

The finding of significant voice improvement without directly targeting pitch and thus SFF, raises many interesting questions regarding, (a) the need to search for an "optimal" pitch and, (b) the therapeutic value of direct pitch modification as a primary treatment approach. If a patient can achieve normal voice production within one session, without any mention of vocal pitch during treatment, then how important must direct isolated pitch modification techniques be to the eventual outcome? Targeting SFF as a primary treatment strategy may in fact be a simplistic view of the complex multidimensional aspects of voice/speech production and perception. As we did not attempt to manipulate pitch directly, the question remains, however, whether similar improvements could have been achieved simply by emphasizing habitual pitch modification. For example, subject six, whose SFF changed by approximately 1.5 octaves, may have achieved the same treatment result simply by elevating habitual pitch level. Consequently, there is a need to evaluate the short and long term effects of direct controlled pitch modification on perceived voice improvement.

Another question raised by these results involves the relationship between disordered habitual pitch and the development of vocal fold lesions. If we accept the supposition offered by some authorities that inappropriate pitch acts as a primary etiologic factor in the development of benign mucosal disease, we must ask the question: why did none of these patients have any evidence of laryngeal pathology in spite of speaking at a pitch that presumably was not "optimal"?

Admittedly, the current findings do not answer many of the questions concerning the implied causative relationships between SFF change and voice improvement. Because no predictable directional or magnitude change in SFF was identified, it is difficult to define the role of habitual pitch in the development, maintenance and eventual resolution of functional dysphonia. At a minimum, clinicians should be wary of generalizations regarding the direction of pitch change and employment of pitch-altering techniques as a primary treatment for functional dysphonia.

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APPENDIX A

TREATMENT PROTOCOL

(i) Review of the laryngologist's findings and reassurance that there was no evidence of lesions or disease.

(ii) Discussion and explanation of the patient's voice in relation to the effects of emotion on muscle tension and phonatory control.

(iii) Discussion of the therapy plans once the patient appeared to understand the mechanism of the voice disorder. The therapy approach was explained and the outlook for recovery was established.

(iv) The manual laryngeal musculoskeletal tension reduction technique was undertaken following the description of Aronson (1990). First, (a) the hyoid bone was encircled with the thumb and middle finger, working them posteriorly until the tips of the major horns were felt. (b) Light pressure was exerted with the fingers in a circular motion over the tips of the thyroid bone. (c) The procedure was repeated beginning from the thyroid notch and working posteriorly. (d) The posterior borders of the thyroid cartilage just medial to the sternocleidomastoid muscles were located and the procedure was repeated. (e) With the fingers over the superior borders of the thyroid cartilage, the larynx was worked gently downward, also moving it laterally at times. (f) The patient was asked to hum or prolong vowels during the above procedures, noting changes in vocal quality. Clearer voice quality and reduction in pain and laryngeal height suggested a relief of tension. Finally, the improved voice was progressively shaped from vowels and words (usually automatic/overlearned speech, i.e., counting, days of the week) to sentences and finally conversation.

(v) After completion of the procedure, the results of the therapy approach were discussed with the patient in terms of the unpleasant life situations contributing to the voice disorder and whether further psychological assessment or counselling was necessary.

(vi) All of the patients were encouraged to telephone a friend, relative, or spouse while in the office to stabilize the voice.

(vii) Each patient was instructed to contact the clinician by telephone in one week to insure maintenance of the improved vocal quality.