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Intensive Voice Treatment for Cantonese-speaking Patients with Parkinson's Disease: Effects on Intonation and Lexical Tone Production

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ABSTRACT

The aim of this pilot study was to investigate the effects of intensive voice treatment on Cantonese-speaking patients with Parkinson's disease. All four patients participating in the study demonstrated an increase in vocal loudness after 16 individual therapy sessions scheduled in one month. Pre- and post-treatment voice recordings of the patients were analyzed for changes in intonation during connected speech and lexical tone production of single words embedded in carrier phrases. Results from both perceptual and acoustic measures indicated a generalization of treatment effect to improve intonation but not lexical tone production, which support a possible dissociation between the fundamental frequency control for intonation and for lexical tone production.

KEY WORDS: Parkinson's disease, LSVT, voice treatment, intonation, lexical tone.

INTRODUCTION

Parkinson's disease (PD) is a progressive neurological condition caused by a deficiency of dopamine in the part of the basal ganglia referred to as the substantia nigra (Hornykiewiex & Kish, 1986). Impairment of basal ganglia function is manifested in movement deficits. Primary symptoms include rigidity, tremor, and bradykinesia. Patients with PD may experience limitation in rate and range of movement, difficulties in the initiation of movement, and problem with balancing (Gentil & Pollak, 1995) Apart from motor signs, speech and voice abnormalities are frequently reported in this population (Logemann, Fisher, Boshes, & Blonsky, 1978). Speech abnormalities are characterized by reduced loudness, monoloudness, disordered voice quality, disordered pitch, reduced pitch variability, problems with prosody, and changes in intelligibility (Ramig, 1992). These may have adverse effects not only on communication, but also on the social, economic, and psychological well-being of affected individuals (Baumgartner, Sapir, & Ramig, 2001).

Traditional speech therapy, focusing on improving articulatory skills and speaking rate, is generally regarded as ineffective in this population (Green & Mathieson, 2001). Improvement in speech is often noted during therapy, but generalization and maintenance of treatment effect are reportedly low (Sarno, 1968).

In 1987, Ramig and colleagues developed an intensive treatment program for patients with PD, known as the Lee Silverman Voice Treatment (LSVT®) (Ramig, Pawlas, & Countryman, 1995). Based on the hypothesized underlying pathologies, which included vocal fold hypoadduction, rigidity and hypokinesia in laryngeal musculature, and reduced respiratory support, the LSVT® program aims at maximizing overall speech intelligibility by focusing on improving true vocal fold adduction, and the coordination between respiratory and laryngeal system. According to Ramig et al. (1995), there are five essential concepts of the LSVT® program:

(a) *Voice Focus*: focus exclusively on increasing vocal loudness, even if the patient has evidence of disordered rate or articulation. The simple focus of increasing loudness is particularly suitable for PD patients who often have difficulty with complex tasks and simultaneous execution of different movements. Instead of remembering many instructions for speaking, all the patients have to remember is to speak with increased vocal loudness.

(b) *High Effort*: stimulate productions using high phonatory effort with multiple repetitions. Increased phonatory effort helps the patients to achieve better vocal fold adduction and override the rigidity in the laryngeal and respiratory muscles.

(c) *Intensive Treatment*: four individual sessions a week for four weeks, with 16 sessions completed within one month. An intensive schedule of treatment is more likely to facilitate habituation and carryover of the loud voice and increased phonatory effort into daily communication.

(d) *Calibration*: enhance sensory awareness of the phonatory effort needed to produce a loudness level within normal limits. As patients with PD may have difficulty scaling their motor output amplitude, they frequently report feeling they are "talking too loud" when they increase their loudness level. Therefore, it is essential for the patients to realize that they are now producing a voice with normal loudness level.

(e) *Quantification*: objective measurement of behaviors. Objective data provide evidence of patients' daily improvement, which help motivate and reinforce the patients, as well as allowing documentation of treatment efficacy.

Favourable outcomes of LSVT® treatment have been widely reported in a number of studies using perceptual, acoustic, aerodynamic, videostroboscopic, and electroglottographic outcome measures (see Fox, Morrison, Ramig, & Sapir, 2002 for review). Patients with PD who received LSVT® demonstrated increased vocal loudness across a variety of speech tasks, as measured by both sound pressure level and listener's perception (Ramig, Bonitati, Lemke, & Horii, 1994; Ramig, Countryman, O'Brien, Hoehn, & Thompson, 1996; Sapir, Ramig, Hoyt, Countryman, O'Brien, & Hoehn, 2002). Increase in subglottal air pressure, improvement in vocal fold adduction, and significant reductions in the impact of PD on oral communication, as perceived by both patients and family members, have been noted (Dromey, Ramig, & Johnson, 1995; Ramig, Countryman, Thompson, & Horii, 1995; Ramig & Dromey, 1996; Smith, Ramig, Dromey, Perez, & Samandari, 1995). Maintenance of improvement has been reported six months, one year and two years post-treatment (Ramig et al., 1996; Ramig, Sapir, Countryman, Pawlas, O'Brien, Hoehn, & Thompson, 2001).

While the program focuses exclusively on increasing vocal intensity, improvement in intonation, articulation, voice quality, and swallowing have been documented as positive side effects (Baumgartner et al., 2001; Countryman, Hicks, Ramig, & Smith, 1997; Countryman, Ramig, & Pawlas, 1994; Dromey et al., 1995; El Sharkawi, Ramig, Logemann, Pauloski, Rademaker, Smith, Pawlas, Baum, & Werner, 2002; Ramig et al., 1994). However, all of the aforementioned studies were done on English-speaking patients with PD, while no known study has been done regarding the efficacy of intensive voice therapy for Cantonese-speaking Parkinson's patients.

One of the major differences between English and Cantonese phonology is that Cantonese is a tonal language. In addition to consonants and vowels, Cantonese speakers use distinctive and indispensable differences in pitch, which are called "lexical tones", to contrast one word from another (Bauer & Benedict, 1997). There are six contrastive tones in Cantonese, with each tone characterized by its level and contour. In this study, the six tones are described using the numerical system developed by Chao (1947). Although the system was developed based on perceptual judgments, the categorization has been generally supported by subsequent studies on Cantonese tone using acoustic analysis (Bauer & Benedict, 1997). The six lexical tones in Cantonese are: 55 (high level), 35 (high rising), 33 (mid level), 21 (low falling), 23 (low rising), and 22 (low level). The first number represents the starting level of tone, while the second number represents the finishing level. Three additional entering tones (2, 3, and 5) are produced with the same pitch level as tones 55, 33, and 22 but of shorter duration (Fok Chan, 1974). Occurring only with final stops /-p/, /-t/, /-k/, these three entering tones are considered not contrastive and were not included in the current study.

As both tonal contrast and intonation depend on laryngeal maneuvering and control of fundamental frequency (f_0), impairments in intonation and lexical tone production might be associated (Ciocca, Whitehill, & Ng, 2002). In the few studies that investigated the speech of Cantonese-speaking patients with congenital dysarthria, abnormal intonation pattern and errors in the production of lexical tone have been noted (Ciocca et al., 2002; Whitehill, Ciocca, & Chow, 2000; Whitehill, Ciocca, & Lam, 2001). Abnormal intonation and lexical tone errors have also been noted in Cantonese speakers with Parkinson's disease. Wong (1999) found that speech production of Cantonese-speaking patients with PD had reduced variability in pitch range, which correlated to the perception of monotone. Their lexical tones were more difficult to identify when compared with normal speakers.

According to Fok (1974) and Vance (1976), there is a constant relationship between the relative distances among different tones. Violation of this constant relationship will result in confusion in perception. Although it was suggested that there are ranges of acceptable variation in tone f_0 for their correct identification (Vance, 1977), disturbance in the relative distances between f_0, the relative f_0 level or the f_0 contour to outside the acceptable range would influence perception and result in misidentification. Identification accuracy and intelligibility of Cantonese-speaking patients with PD may be affected as the compression of pitch and changes in pitch contour are likely to cause a reduction in contrastiveness among lexical tones.

The current study served as a pilot study for the effects of intensive voice treatment on Cantonese-speaking patients with PD. The focus was on the generalization of treatment effects to Cantonese-speaking patients with PD. Cantonese, as a lexical tonal language, offers the opportunity for investigating possible generalization effect to improvement in lexical tone production. It was hypothesized that through intensive, focused, and high effort training, patients with PD would be able to override the rigidity or hypokinesia of the laryngeal musculature. With the improved range of motion in the cricothyroid, the patients could have better control over pitch variability and thus improve intonation. Increased pitch variability and improved control over pitch change might also lead to improvement in lexical tone production.

However, it was also hypothesized that there might be differential control over intonation and lexical tone production (Vance, 1976). For example, in Cantonese, there is sentence-final lowering in intonation without neutralization of tonal distinctions (Vance, 1976). If the underlying mechanisms for the control of intonation and lexical tone production are indeed different, it might be possible to have improved intonation but no effect on the accuracy of lexical tone production. Therefore, investigation of pre- and post-treatment changes in intonation and lexical tone production might provide further insights on the relationship between the control of pitch and pitch variation in connected speech (intonation) and control of lexical tone production.

METHOD

Subjects

Four Cantonese-speaking patients (three female, one male) with idiopathic Parkinson's disease participated in the study. Their ages ranged from 45 to 59 years. Three of the subjects were native Cantonese speakers while the remaining one (YYP) had Mandarin as her first language, but had been using Cantonese as the primary language in daily communication for over 35 years. All subjects were receiving regular medication for Parkinson's disease.

All subjects passed a pure-tone audiological screening test conducted at 30 dB HL at 500, 1000, 2000, and 4000 Hz for the better ear. They had no structural abnormalities as determined by an oromotor examination carried out by the investigator. In order to obtain a connected speech sample, the patients had to be literate and be able to read a standard passage spontaneously. The subjects' initial speech and voice deficits were determined through clinical observation by the investigator during conversation in the screening session. Patient characteristics, speech and voice deficits, and anti-Parkinson medications are summarized in Table 1. The subjects did not change medications during the course of the treatment.

Table 1. Patient characteristics

Subjects	Sex	Age	Years;Months post-diagnosis	Speech/Voice deficits	Anti-Parkinson medications
Patient 1 CSK	M	59	1;6	Increased rate, Repetition, Reduced loudness	Sinemat, Benzhexol
Patient 2 NKL	F	45	3;9	Hoarse voice, Hypernasality, Reduced loudness	Sinemat, Madopar, Benzhexol, Bromocriptine mesylate, Piracetam, Amantadine
Patient 3 WSY	F	51	6;3	Reduced loudness, Monotone	Sinemat, Artan, Bromocriptine mesylate
Patient 4 YYP	F	59	1;8	Reduced loudness, Hoarse voice	Sinemat

Treatment program

The treatment program was implemented based on the principles of the LSVT® (Ramig, Pawlas, & Countryman, 1995; Ramig, Countryman, Thompson, & Horii, 1995). Two final-year students in the Division of Speech and Hearing Sciences delivered the treatment under the supervision of a clinical supervisor. Neither the supervisor nor the clinicians were certified in LSVT®, but had read available literature, manuals and observed training videotapes. Subjects were randomly assigned to the two clinicians. The clinicians worked closely together through observation and discussion to ensure consistency in treatment delivery. A typical treatment session consisted of two parts. The first half included: (a) drills on maximum sustained phonation; (b) generation of the highest and lowest fundamental frequencies; (c) repeated productions of the patient's commonly used phrases/sentences using a loud voice.

Visual feedback regarding intensity and fundamental frequency range were provided with a sound level meter and Visipitch respectively. The sound level meter provided objective feedback regarding vocal intensity in terms of decibel level. The subjects were encouraged to monitor and gradually increase the decibel level of their productions. The Visipitch provided instantaneous visual feedback regarding fundamental frequency of the subject's voice in the form of traces displayed on the computer. The subjects were encouraged to produce voice with higher and higher traces during generation of the highest fundamental frequencies, and lower and lower traces during generation of the lowest fundamental frequencies.

In the second half of the session, the subjects were stimulated to maintain high phonatory effort and use increased vocal intensity in a hierarchy of speech tasks, which moved through short phrases, sentences, paragraph reading, to conversation. The hierarchical speech loudness drills allowed the subjects to progress systematically from using a loud voice in short phrases in week one to using the loud voice in paragraph reading or conversation in week four. Examples of speech stimuli used are included in Appendix A.

The subjects were required to complete homework practice on a daily basis, which aimed at establishing a practice schedule and facilitating maintenance of the loud voice and increased phonatory effort outside the treatment room. Carryover exercises, which facilitated generation of loud voice into functional communication, were assigned at the end of each session. Simple carryover exercises (eg. greeting another subject in the waiting room) were assigned initially, while more difficult exercises (eg. asking for directions on the street) were assigned as the treatment went on.

Data collection

Pretreatment experimental data were collected three to four days before initiation of treatment, while post-treatment data were collected six days after treatment termination. Additional post-treatment data collection sessions were planned one month and six months after the therapy program in order to investigate maintenance and long-term treatment effects. However, these long-term efficacy data are not included in the current study. All data collection sessions were to be completed by the same experimenter and were scheduled at approximately the same time of the day for each subject in order to minimize the possible effects of drug cycle.

Recordings were made in a sound-treated room with noise level below 40dBA as measured by a Bruel & Kjaer Precision Sound Level Meter Type 2235. Speech data were recorded on Sony Digital Audio Tapes (DAT) using a Sony PCM-R300 DAT recorder and a Bruel & Kjaer (4003) low-noise unidirectional microphone. A mouth-to-microphone distance of 10cm was maintained during the recording. Recordings were digitized at a sampling rate of 44.1 kHz and stored as sound files using a Digidesign Audiomedia II DSP card and an Apple PowerMacintosh 7100.

The following speech tasks were carried out in each of the data collection sessions: (1) maximum sustained vowel phonation, (2) maximum fundamental frequency range, (3) reading of a standard passage, (4) conversational monologue, (5) a list of lexical tone stimuli, each embedded in the medial position of a carrier phrase. Apart from the speech tasks, a visual analog scale (adopted from Ramig, Pawlas, & Countryman, 1995) was used to obtain subject self-ratings as well as family member ratings of the subject's voice. Each subject also completed a Voice Activity and Participation Profile (Ma & Yiu, 2001) at the end of each recording session. The order of the tasks was kept constant across data collection sessions in order to minimize fluctuation in pre- and post-treatment performance for each task due to task ordering.

As the focus of the current study was to investigate the effects of intensive voice treatment on intonation and lexical tone production among Cantonese-speaking patients with PD, only the standard passage reading and the list of lexical tone stimuli were analyzed. Details of the two tasks and the rationale for their choice were as follows:

<u>Standard passage reading.</u> The subjects were asked to read aloud a standard passage (Yiu, 1991) (see Appendix B). No specific information regarding target intensity level was given. Although intonation during oral reading may not be equivalent to that during spontaneous speech (Bunton, Kent, & Kent, 2000), standard passage reading maintains constant language content across speakers and provides more uniform samples of connected speech, which allows for comparison within and across speakers (Sapir et al., 2002). The second sentence from the standard passage was extracted for analysis so as to avoid initiation and fatigue effects.

Lexical tone. The subjects were asked to read aloud a list of lexical tone stimuli, each embedded in the medial position of the carrier phrase "ŋɔ23 sœŋ35 tok22 ___ pei35 nei23 tʰɛŋ55" (I want to read ___ for you to listen). The list consisted of 18 single words, representing each of the six lexical tones of the CV syllables /sɛ/, /fu/ and /ji/. Each word was repeated 3 times, which made up a total of 54 carrier phrases. The list was randomized for each patient before each recording session.

Since individual speakers have different frequency ranges, perceptual judgment of lexical tone presumably involves a process of normalization according to the inferred speaker (Leather, 1983; Wong, 1998). A carrier phrase with the target words embedded, which enables normalization of the speaker's voice, was thus chosen as the speech task for tone identification. In order to avoid the effect of sentence-final tone lowering which might negatively affect intelligibility (Vance, 1976), the target words were embedded in the medial position of the carrier phrase.

Data Analysis

Both perceptual and acoustic variables were used to investigate differences in pre- and post-treatment intonation and lexical tone production. As speech is ultimately defined by listener perception, perceptually based investigations of speech production are considered "more clinically motivated" (Penner et al., 2001, p.552). However, concerns regarding reliability and sensitivity have been raised for the sole reliance on perceptual judgment of speech (Kearns & Simmons, 1988; Kent, 1996). Therefore, in addition to perceptual analysis, acoustic analysis was used to obtain objective information, which served as a referent and complement for perceptual judgment (Ludlow & Bassich, 1984; Kent, Kent, Duffy, & Weismer, 1998).

Acoustic analysis of intonation. Mean fundamental frequency (f_0), which is the primary correlate of pitch level, and standard deviation of fundamental frequency (SDf_0), which is frequently used to quantify degree of monotonicity (eg. Schlenck, Bettrich, & Willmes, 1993; Whitehill, Ciocca, & Lam, 2001), were computed for the second sentence of the standard paragraph using an autocorrelation method by Soundscope, version 1.2 (1993, G.W. Instruments).

All speech samples were reanalyzed by the same investigator. Intrajudge reliabilities using Pearson's product-moment correlation were 0.999 (2-tailed $p < 0.01$) for both measures.

Perceptual analysis of intonation. Intonation during standard passage reading was perceptually rated by a panel of six listeners, who were all final-year students in the Division of Speech and Hearing Sciences. None of the listeners had previous interaction with the patients in the present study. In order to offset the possible influence of loudness on the perceptual rating of intonation, all the speech samples were normalized using Sound Designer II.

The listeners rated individually free-field in a sound-attenuated room. Two perceptual tasks, a visual analog scale and a pairwise comparison method, were used to investigate the change in pre- and post-treatment intonation of the subjects. The two tasks were carried out in the same session, with the order kept constant (visual analog proceeding pairwise comparison).

Before conducting the perceptual ratings on intonation, the listeners were asked to judge the pitch level of the pre- and post-treatment samples of each subject. The samples were presented once each in random order, with the age and gender of the speaker provided. The listeners were required to indicate whether the pitch level of the samples were considered 'Within normal limits', 'Abnormally low', or 'Abnormally high' for the age and gender of the speaker. Pre- and post-treatment averaged ranks were computed for each subject by assigning 'Abnormally low' as 1; 'Within normal limits' as 2; and 'Abnormally high' as 3. For example, if pre-treatment pitch level of patient A was rated as 'Abnormally low' by one listener; 'Within normal limits' by three listeners; and 'Abnormally high' by two listeners, the averaged rank computed would be

$(1 \times 1 + 2 \times 3 + 3 \times 2) / 6 = 2.17$.

Task 1: A visual analog scaling procedure was used. Visual analog scale has been reported to have greater measurement sensitivity and produce more reliable results for voice evaluation when compared to an equal-appearing interval scale (Schieffman, Reynolds, & Young 1981; Krieman, Gerratt, Kempster, Erman, & Berke, 1993). Each sample was presented five times to each listener using Cool Edit 2000, with the order of presentation randomized. The listener was asked to rate the degree of monotonicity of each sample, and mark accordingly on a 100 mm undifferentiated line, with 'normal intonation' and 'severely monotone' labeled at the left and right ends respectively. No specific definition of monotonicity was provided. For each rating, a score, corrected to the nearest millimeter, was calculated by measuring the length between the starting point of the scale and the point at which the scale line was marked. Pre- and post-treatment scores were obtained for each subject by taking the average of the five ratings across listeners.

Interlistener reliability and intralistener reliability were calculated using Cronbach's coefficient alpha. Interlistener reliability was 0.75 while intralistener reliabilities were 0.92, 0.82, 0.71, 0.63, 0.61, and 0.60 for individual listener, with a mean reliability of 0.71.

In view of the relatively low intra-listener reliability and the fact that the pre-treatment samples were not rated as very monotone (over 80% of the ratings were marked on the 0-50mm portion of the visual analog scale), a second task was employed, which used pairwise comparison. This procedure was expected to yield more reliable results for relatively small differences between the pairs.

Task 2: Pre- and post-treatment speech samples from each subject were presented in pairs to the listeners in random order. Listeners were asked to compare the intonation of the pair and indicate the one with 'better intonation'. Listeners could indicate 'no difference' if they did not hear a difference between the samples. Each pair of speech samples was presented five times, with the order randomized for individual listeners.

A percentage score was computed for each of the three response types for each listener. For example, if a listener identified the pre-treatment sample as having better intonation in two presentations, post-treatment sample in another two presentations, and indicated 'no difference' in the remaining one, a 40%, 40%, 20% distribution score was entered to the corresponding response types. A final score was calculated for each sample by taking the average percentage score across six listeners.

Intra-listener reliability was calculated by finding the average number of agreement among sample pairs, which were 100%, 90%, 90%, 90%, 85% and 85% for individual listeners.

Acoustic analysis of lexical tone. Lexical tone stimuli were analyzed using Praat version 4.0.41 (Boersma & Weenink, 1992-2003). The voiced portion of each target stimuli was identified by inspecting the waveform, listening to the sound, and inspecting the wide-band spectrogram. The segment from the third cycle to the third-to-last cycle of the voiced portion was selected for analysis. Fundamental frequency (f_0) was measured at the 0%, 25%, 50%, 75%, and 100% time points of the selected segment. The lexical tone configuration for each patient was determined by taking the average of the nine tokens (three repetitions of three CV syllables) representing each lexical tone.

Acoustic analysis was repeated for 10% of the stimuli by the investigator and another examiner. Reliability was computed using Pearson's product-moment correlation. Pearson's correlation coefficients were $r = 0.999$ (2-tailed $p < 0.01$) for intrajudge reliability and $r = 0.955$ (2-tailed $p < 0.01$) for interjudge reliability.

Perceptual analysis of lexical tone. The lexical tones of the target stimuli were phonetically transcribed by two final-year students in the Division of Speech and Hearing Sciences, who had no previous exposure to the subjects' speech. Transcription was done individually in a quiet room. The speech stimuli were presented to the listeners via Sennheiser HD250 headphones connected to a Pentinum III computer. The transcribers were allowed to listen to the stimuli as many times as necessary.

Transcription was repeated for 10% of the stimuli in order to investigate intra-transcriber reliability. Intra-transcriber reliability was 89.6% for both transcribers. Reliability between the two transcribers for lexical tone transcription was 83.1%. The transcription of the first transcriber was chosen for error analysis in order to avoid "canceling out" of error patterns due to combined results from different judges.

Due to the small number of subjects involved, inferential statistics were not used (McReynolds & Kearns, 1983). Pre- and post-treatment baseline data were analyzed using descriptive statistics to analyze differences in perceptual rating of intonation, differences in SDf_0, and in number and pattern of tonal errors. The results from acoustic analysis of lexical tone produced by the subjects were compared with those of normal speakers for investigation of abnormal patterns. Normative data were adopted from the studies of Whitehill, Ciocca, & Chow (2000) and Whitehill, Ciocca, & Lam (2001). As the normative data were taken from a relatively young population, with age ranged from 14 to 39 years (mean age 20.6 years), a difference in fundamental frequency between the normative data and the subjects in the current study was expected as an effect of aging (Linville, 2001). Therefore, the comparison focused on the identification of abnormal patterns in tone contours rather than any difference in fundamental frequency.

RESULTS

Loudness

All four subjects received 16 individual therapy sessions within four weeks. All of them demonstrated an increase in loudness level during maximum sustained vowel phonation and production of functional phrases. An increase in maximum fundamental frequency range was noted for all subjects. Two of the subjects (WSY & YYP) progressed to "conversation" level in the hierarchical speech loudness drills, while the other two (CSK & NKL) were at the level of "paragraph reading" by the end of the treatment program. Details of loudness progress across sessions are included in Appendix C.

Intonation

Acoustic analysis. Pre- and post-treatment measures of f_0 and SDf_0 during standard passage reading are summarized in Table 2. Increases in both f_0 and SDf_0 were noted in all four subjects. The increase in f_0 ranged from 25.110Hz to 71.710Hz, and the increase in SDf_0 ranged from

3.195Hz to 18.228Hz.

Table 2. Pre- and Post-treatment f_0 (Hz) and SDf_0 (Hz) (in brackets) during standard passage reading

Subjects	Pre-treatment	Post-treatment	Difference
CSK	112.130(16.423)	149.692(20.263)	+37.562(+3.840)
NKL	172.941(30.673)	220.261(38.688)	+47.320(+8.015)
WSY	157.926(25.712)	183.036(28.907)	+25.110(+3.195)
YYP	154.942(23.249)	226.662(41.477)	+71.710(+18.228)

Pitch level. Pre- and post-treatment pitch level as perceived by six listeners with reference to the speaker's age and gender are summarized in Table 3. An averaged rank of 2 indicates pitch level perceived to be within normal limits, while an averaged rank of 1 and 3 indicates that the pitch level was perceived as abnormally low and abnormally high respectively by all six listeners. The results were generally consistent with those from the acoustic measurement of f_0, showing an increase in perceived pitch level for each subject. While the post-treatment pitch level of three of the subjects (CSK, NKL, WSY) were considered to be within normal limits by the majority of listeners, it should be noted that the pitch level of YYP was considered abnormally high for her age.

Table 3. Pitch level of pre- and post-treatment standard passage reading

Subjects	Pre-treatment	Post-treatment
CSK	1.67	2.33
NKL	1.17	2
WSY	1.5	1.83
YYP	1.83	3

Rating of monotonicity using visual analog scale. Pre- and post-treatment ratings of monotonicity are summarized in Table 4. A score of 0 represents 'normal intonation' while a score of 10 represents 'severely monotonous'. A decrease in perceived monotonicity was noted for all four subjects; the subjects were rated as less monotone post-treatment.

Table 4. Degree of monotonicity in pre- and post-treatment standard passage reading

Subjects	Pre-treatment	Post-treatment	Difference
CSK	3.6	2.4	-1.2
NKL	3.4	2.9	-0.5
WSY	3.2	1.7	-1.5
YYP	3.1	1.8	-1.3

Rating of monotonicity using pairwise comparison. The average percentage score for each response type is summarized in Table 5. When presented as a pair, the post-treatment sample was identified as having better intonation over 80% of the time for each subject, which was consistent with, and provided strong support for, the results from the perceptual task using visual analog scaling procedure.

Table 5. Percentage of listeners for each category of judgment in pairwise comparison of intonation between pre- and post-treatment standard passage reading.

Category of judgment	CSK	NKL	WSY	YYP
Pre-treatment sample identified as having better intonation	3.33%	3.33%	0%	6.67%
Post-treatment sample identified as having better intonation	93.33%	93.33%	83.33%	86.67%
No difference in terms of intonation between the pair	3.33%	3.33%	16.67%	6.67%

Consistent findings were obtained from the acoustic and perceptual analysis of pre- and post-treatment changes in intonation during standard passage reading. An increase in pitch level and improvement in intonation were noted in all four subjects after intensive voice therapy.

Lexical tone

Phonetic transcription. Table 6 shows the pre- and post-treatment performance in lexical tone production for individual subjects, in terms of overall percentage accuracy and most commonly confused contrasts (MCCC). MCCCs for each subject were identified as those in which more than 20% of the stimuli (out of 18 stimuli per minimal contrast pair) were confused. For example, if Tone A was identified as Tone B in three trials while Tone B was identified as

Tone A in two trials for an individual subject, the total percentage of confusion for the contrast was 27.78% and Tone A vs Tone B was considered one MCCC for that subject. Confusion matrices for individual subjects were included in Appendix D.

Table 6: Pre- and post-treatment performance in lexical tone production

Subjects	Total percentage accuracy		MCCC	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
CSK	51.85%	55.56%	Tone 35 vs Tone 23	Tone 35 vs Tone 23
			Tone 21 vs Tone 22	Tone 21 vs Tone 22
			Tone 33 vs Tone 22	Tone 33 vs Tone 22
NKL	81.46%	81.46%	Tone 35 vs Tone 23	Tone 35 vs Tone 23
WSY	88.89%	85.19%	None	None
YYP	62.96%	57.41%	Tone 35 vs Tone 23	Tone 35 vs Tone 23
			Tone 21 vs Tone 22	Tone 21 vs Tone 22
			Tone 33 vs Tone 23	Tone 33 vs Tone 22

None of the subjects showed obvious changes in the accuracy of lexical tone production. Pre- and post-treatment differences in overall percentage of correct identification out of 54 stimuli were 3.7% (CSK), 0% (NKL), -3.7% (WSY) and -5.6% (YYP). The most commonly confused contrasts were consistent for individual subject before and after treatment. As a group, the three most commonly confused contrasts were Tone 35 vs Tone 23, Tone 21 vs Tone 22, and Tone 33 vs Tone 22.

Results from perceptual analysis through phonetic transcription suggested no improvement in the production of lexical tone. Pre- and post treatment data on lexical tone were further analyzed using acoustic analysis for any subtle changes in tone contour that were perceptually unidentifiable.

Acoustic analysis. Figures 1 to 4 show the f_0 pattern of the six lexical tones produced by each of the subjects before and after treatment. As a group, all four subjects' productions of level tones (Tones 55, 33, and 22) resembled the normal pattern. There was some difference in f_0 height, as suggested earlier, but the normal contour of level tones was generally maintained, for all four

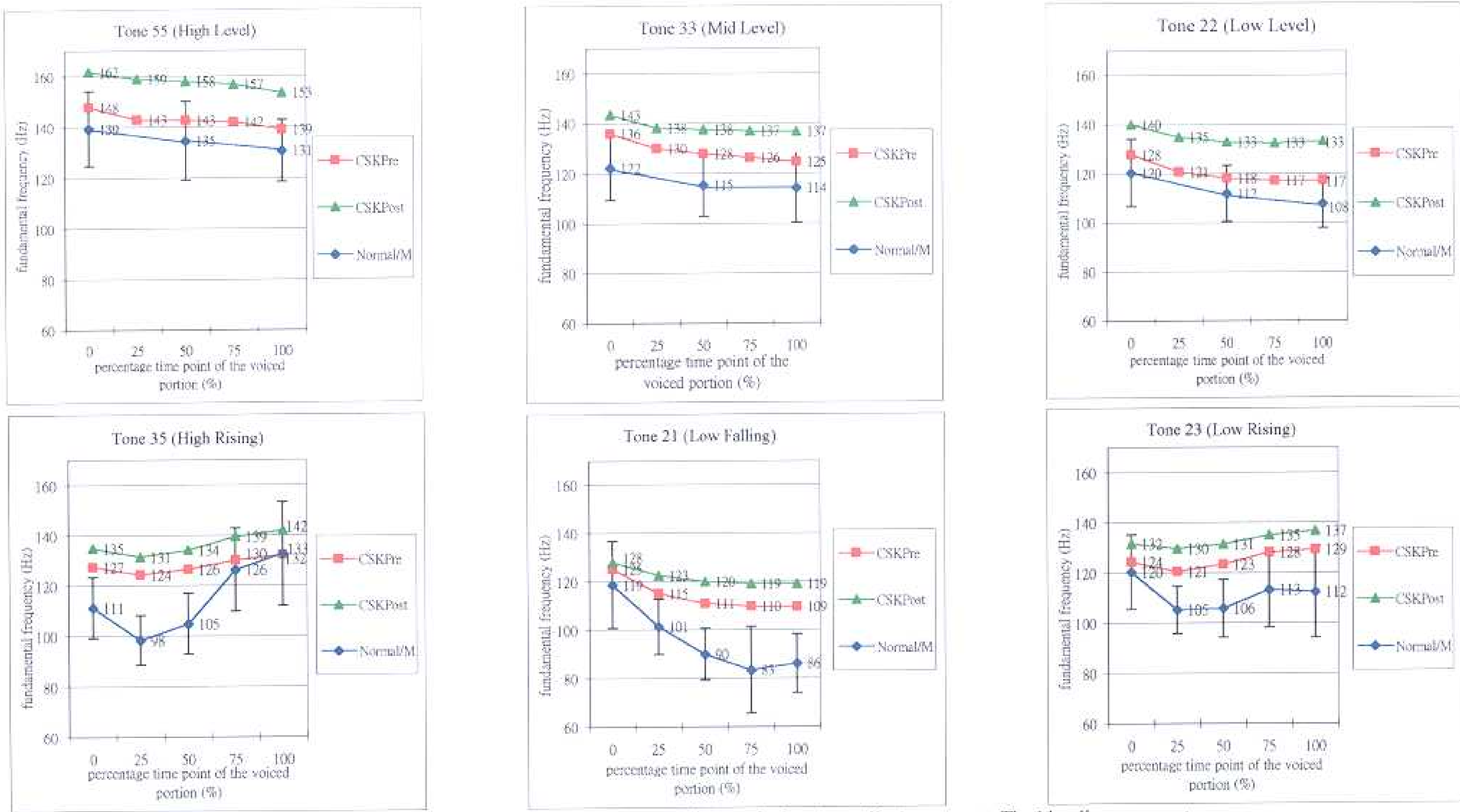

Figure 1. F0 pattern of the six lexical tones produced by CSK (59/M) before (red line) and after (green line) treatment. The blue line represents normative male data, with the error bars showing one standard error above and below mean (Whitehill et al., 2000; Whitehill et al., 2001.)

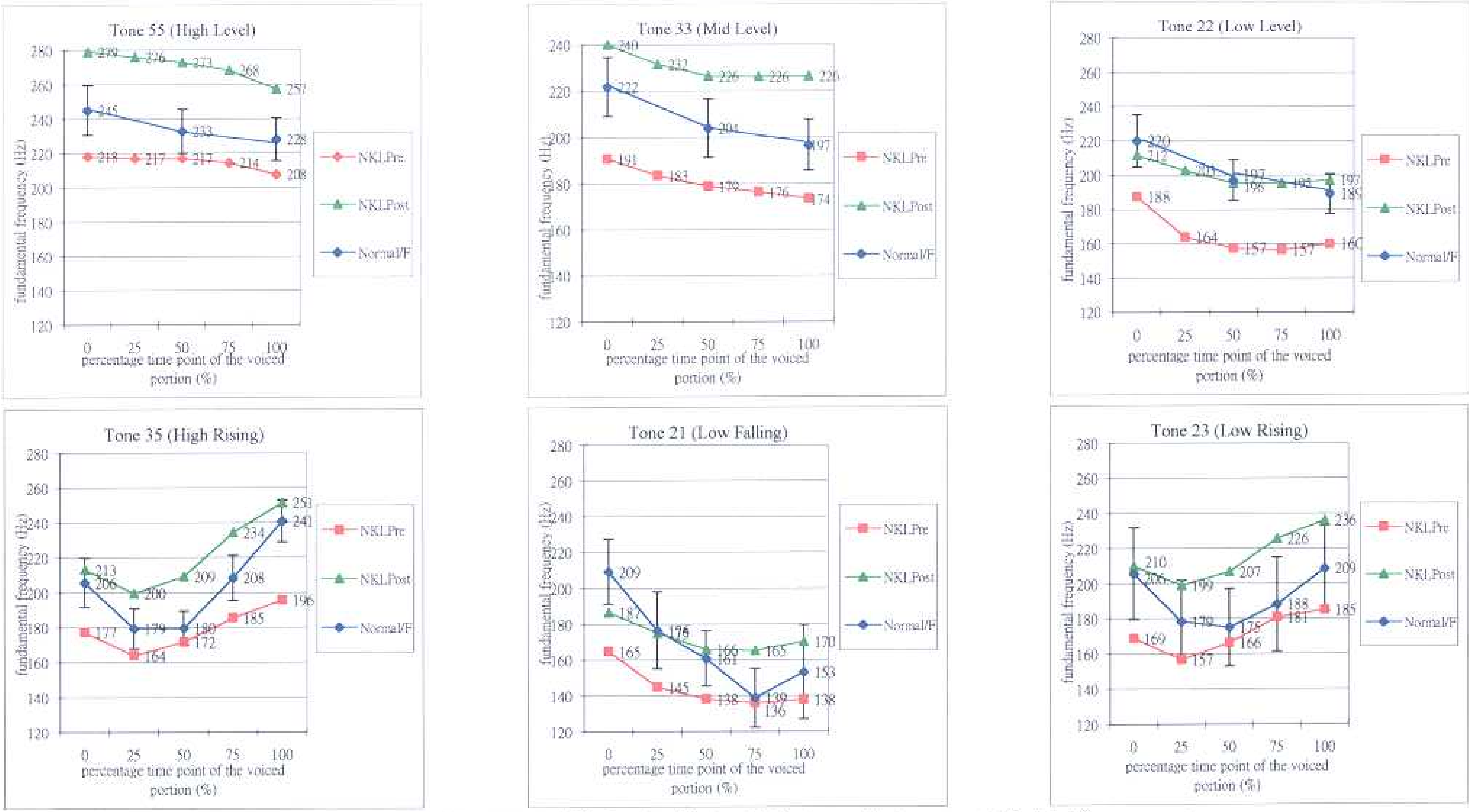

Figure 2. F0 pattern of the six lexical tones produced by NKL (45/F) before (red line) and after (green line) treatment. The blue line represents normative female data, with the error bars showing one standard error above and below mean (Whitehill et al., 2000; Whitehill et al., 2001.)

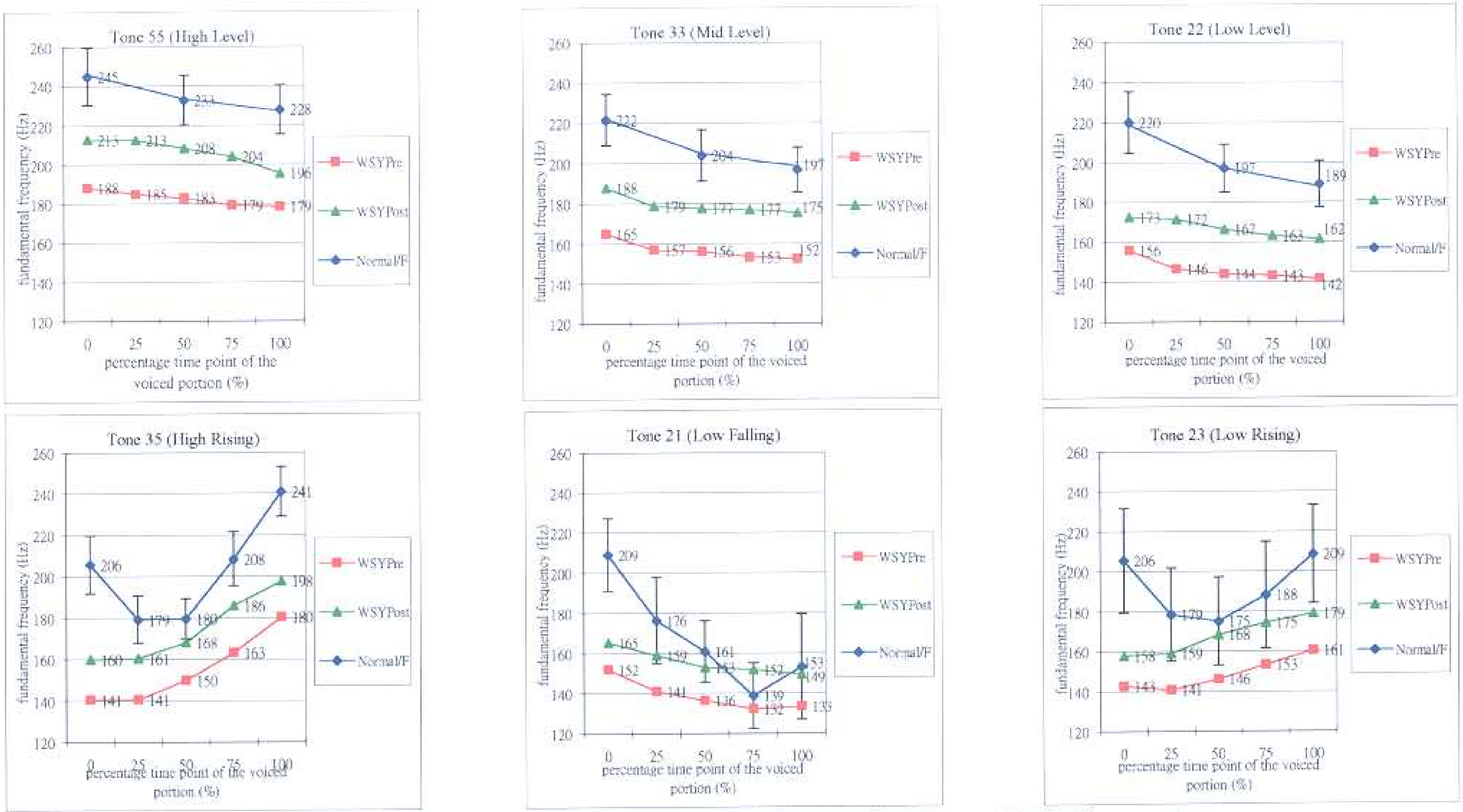

Figure 3. F0 pattern of the six lexical tones produced by WSY (53/F) before (red line) and after (green line) treatment. The blue line represents normative female data, with the error bars showing one standard error above and below mean (Whitehill et al., 2000; Whitehill et al., 2001.)

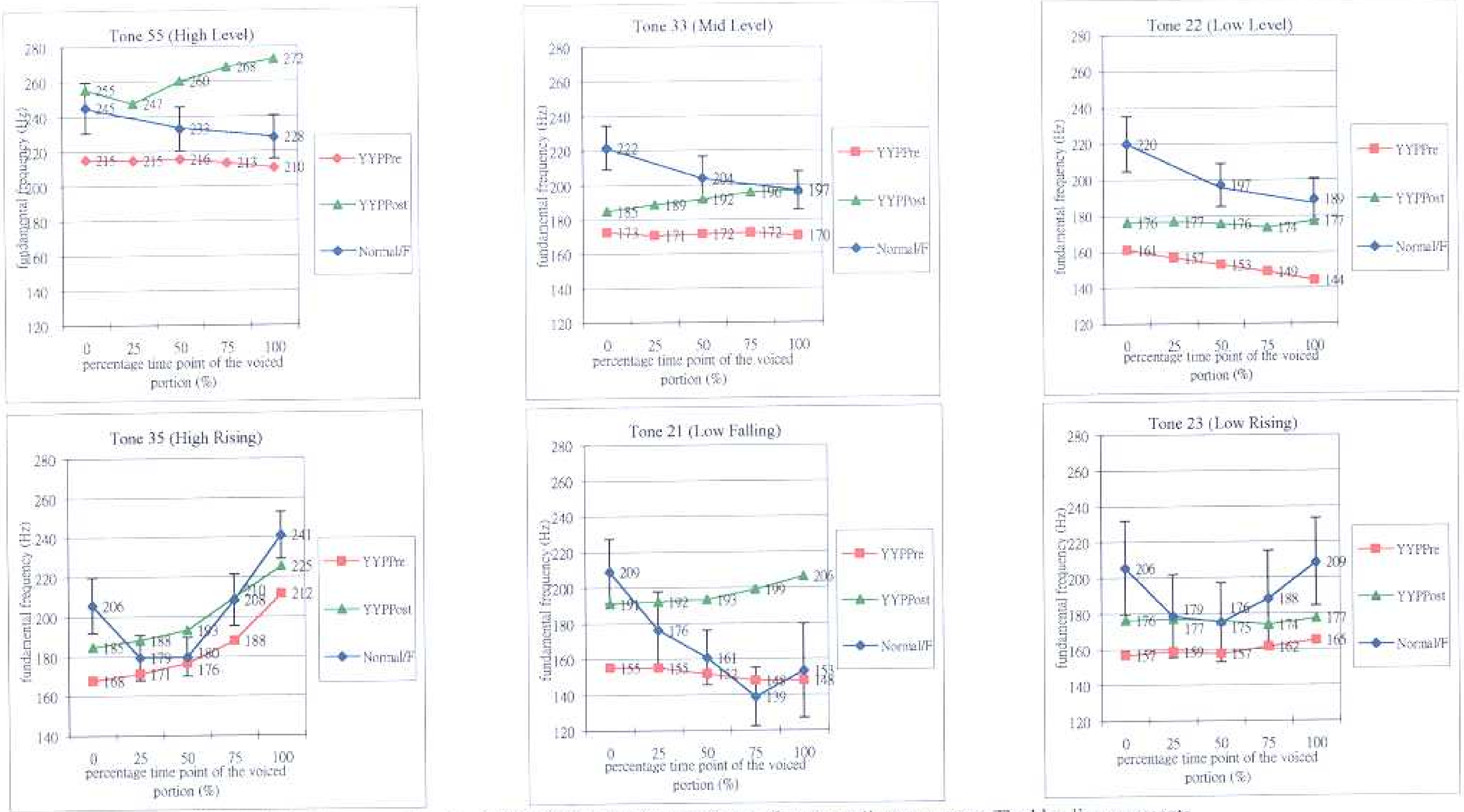

Figure 4. F0 pattern of the six lexical tones produced by YYP (59/F) before (red line) and after (green line) treatment. The blue line represents normative female data, with the error bars showing one standard error above and below mean (Whitehill et al., 2000; Whitehill et al., 2001.)

subjects. However, a flattening of contour tones (Tones 35, 21, and 23) when compared with the normative data was noted for all subjects. After treatment, an upward shift was noted in the f_0 patterns, which indicated an increase in mean fundamental frequency. However, no significant changes in the pattern of tone contour were noted (except for certain tones produced by YYP, which will be discussed later in the section). In other words, post-treatment patterns of contour tones were still considered flattened when compared with normative data.

The results from the acoustic analysis were largely consistent with the results from phonetic transcription. Flattening of contour tones reduced the contrastiveness between the two rising tones (Tones 35 and 23), thus making it a common error pair among all subjects.

Another commonly confused pair was Tone 21 vs Tone 22, which could be attributed to the flattening of the Tone 21. The normative data show that there is a lowering of tone contour towards the end of the level tones. Tone 21 might be distinguished from Tone 22 as the former has a more dramatic lowering of tone contour. A reduced extent of lowering in Tone 21 might make it resemble the pattern of Tone 22 and render discrimination between the pair difficult.

Confusion between Tone 33 and Tone 22 were noted in the transcription task in three of the subjects (CSK, WSY, & YYP). Although it was noted that the patterns of their level tones resembled normative data, the contrasts between the heights of the two level tones might be reduced in these subjects. However, it was noted that the difference was also small among normal subjects (Whitehill et al., 2000; Whitehill et al., 2001). Vance (1977) hypothesized that differentiation of Tone 22 from the other tones involves something besides f_0. The essential characteristics of Tone 22 are yet to be determined.

Post-treatment changes in tone pattern of YYP

Instead of a lowering towards the end of the level tones, YYP produced level tones with a rising contour (Appendix E). A rising contour was also noted in Tone 21, which should in fact be a falling tone. As noted earlier, YYP had Mandarin as her mother tongue. The unusual pattern might be associated with her Mandarin accent, although the actual pattern cannot be easily explained by Mandarin tones. It should also be noted that pre-treatment level tone and falling tone pattern of YYP resembled normal pattern. The unusual post-treatment pattern might also be associated with her raise in f_0, which was greatest among the four subjects.

DISCUSSION

The data reported in this study support the effectiveness of intensive voice treatment for the improvement of vocal loudness and intonation in a group of Cantonese-speaking patients with Parkinson's disease. However, no generalization to improved accuracy of lexical tone production was noted.

The finding of improvement in intonation during connected speech, as shown in both acoustic and perceptual measures, was consistent with previous studies on English-speaking patients with PD. Before treatment, the subjects might have experienced rigidity which affected their ability to maneuver their laryngeal and respiratory muscles. The limited range of motion and reduced coordination had detrimental effects on the prosodic aspect of speech.

Increased variability of f_0 noted post-treatment might be related to the increased range of motion of the cricothyroid and thyroarytenoid muscles, which could be a generalization effect of improved maximum f_0 range (Ramig et al., 1994). Improvement in intonation might suggest that after intensive voice treatment, the subjects were able to generate the necessary variation in their speech as they could exert better control over the laryngeal muscles, and had improved coordination in the laryngeal, sub- and supraglottal events (Ramig, 1992). Another possible explanation was that, with a stronger voice, the subjects experienced more effective oral communication, which had positive effects on their attitude and emotion (Dromey et al., 1995). The improved affection might be reflected as improved intonation of their speech. It was noted that speech with higher f_0 and increased f_0 variability was perceived to be happier, more joyful, and more confident (Schere, London, & Wolf, 1973).

The apparent lack of generalization effect to the production of lexical tone might provide evidence of a dissociation between fundamental frequency control for intonation and for lexical tone production. In order to produce intonation successfully, the speakers have to control timing over sentence- or phrase-sized units. On the other hand, accurate production of lexical tone requires control over a much smaller temporal domain – syllable-sized units (Gandour, Petty, & Dardarananda, 1988). A dissociation between lexical tone and intonation has been reported in previous study on Cantonese-speaking patients with hypokinetic dysarthria; Whitehill, Ma, & Lee (in press) found that intonation was relatively severely affected, while lexical tone was found to be one of the most robust speech dimensions.

Vance (1976) proposed that there might be differential control for lexical tone and intonation. Vance hypothesized that intonation was produced by changes in subglottal pressure while lexical tones were produced by laryngeal maneuvering. There has been no direct physiological evidence to support or disprove this hypothesis. The results of the current study support a possible dissociation between intonation and lexical tone production. However, both increases in subglottal pressure and improvement in laryngeal control have been reported in previous studies of LSVT® on patients with PD (Dromey et al., 1995; Ramig & Dromey, 1996). This issue warrants further study.

It should also be noted that the subjects in this study had relatively intact lexical tone production pre-treatment. Results on pre- and post-treatment changes in lexical tone production might be affected, as possible improvement might be masked by the relatively high pre-treatment accuracy. Further study including more subjects with tone errors is suggested.

Apart from the increase in vocal loudness and improvement in intonation, all four subjects involved in the study demonstrated a noticeable increase in speaking f_0, which was also noted in previous studies on English-speaking patients with PD (Countryman et al., 1997; Ramig et al., 1994; Ramig et al., 1995). F_0 raising was found to be a strategy for increasing vocal intensity (Alku, Vintturi, & Vilkman, 2002). For patients who were perceived to have abnormally low pitch level before treatment (NKL & WSY in the current study), an increase in f_0 would result in a post-treatment pitch level that was perceived to be within normal limits. However, for YYP who had relatively normal pitch level before treatment, a remarkably raised f_0 resulted in a pitch level regarded as abnormally high for her age and gender post-treatment. An increase in speaking f_0 might increase laryngeal tension and result in a high-pitched, strained, or pressed sound. This may have an adverse effect on the patient's voice and may even be socially embarrassing.

Recently, a modified treatment program, known as the Pitch Limiting Voice Treatment (PLVT) was developed (De Swart, Willemse, Maassen, Horstink, 2003). With the new method of instruction "speak loud and low", the PLVT is comparable with the LSVT® but from the very outset prevents an increase of pitch level and thereby prevents the frequently-encountered adverse therapy effects seen with LSVT®. PLVT might be preferred in treating patients with PD, as it was found to produce comparable increase in loudness, but limited increase in vocal pitch when compared to LSVT®. However, long-term effects of PLVT still await further studies.

In order to assess the efficacy of a treatment program, it is essential to establish that any pre- and post-treatment difference noted is treatment-specific and not secondary to extraneous factors including placebo effect, Hawthorn effect, and improvement associated with repeated testing. One of the best ways to eliminate effects of these extraneous factors is to have a comparable group of subjects undertaking an alternative treatment method. The two methods should be nearly identical in terms of therapy schedule, structures, and intensity, but different in main focus. Efficacy studies comparing LSVT® to an alternative treatment method which emphasized high respiratory effort have been reported (Raming et al., 1996; Ramig et al., 1995; Ramig et al., 2001). The studies showed advantages of the LSVT® over the alternative treatment program. By comparing the performance of patients received LSVT® with untreated patients and normal age-matched controls, Ramig, Sapir, Fox, & Countryman (2001) further suggested that improvement noted among patients with PD after intensive voice treatment was treatment-specific and not related to extraneous factors such as repeated testing, familiarity with testing material, experimental setting, or the experimenter.

No control group was included in the current pilot study, which focused on investigating generalization effect of intensive voice treatment to intonation and lexical tone production. The absence of control group was also noted in a number of studies (Countryman et al., 1994; Dromey et al., 1995; El Sharkawi et al., 2002; Ramig et al., 1994) that investigate treatment efficacy of LSVT® for patients with Parkinson's disease, which is a degenerative condition from which no spontaneous recovery would be expected. The current pilot study to investigate the effects of intensive voice treatment on Cantonese-speaking patients with PD, served as a pathway for further studies with a larger treatment group and with the inclusion of a group of control subjects.

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Appendix A: Examples of speech stimuli used during treatment

i) Phrases

唔好	我係	多謝	等陣
邊個呀	呢度吖	飽未呀	起身啦
俾返你	熄燈呀	點解呀	慢慢行
好耐冇見	有冇人呀	你搵邊位	唔駛客氣
返屋企啦	走得未呀	一齊去呀	伙記埋單

ii) Sentences

今日好熱呀　唔該街口有落　我去買報紙　聽朝飲茶呀

啲菜幾錢斤呀?　你今晚幾點返呀?　我今晚唔返嚟食飯呀。

頭先陳生打過電話俾你。　你地呢度有冇廁所呀?

你哋聽朝幾點鐘開門呀?　請問呢架車經唔經皇后大道中架?

我下個星期二朝頭早要去醫院覆診。聽朝九點係中環地鐵站恒生銀行等呀。

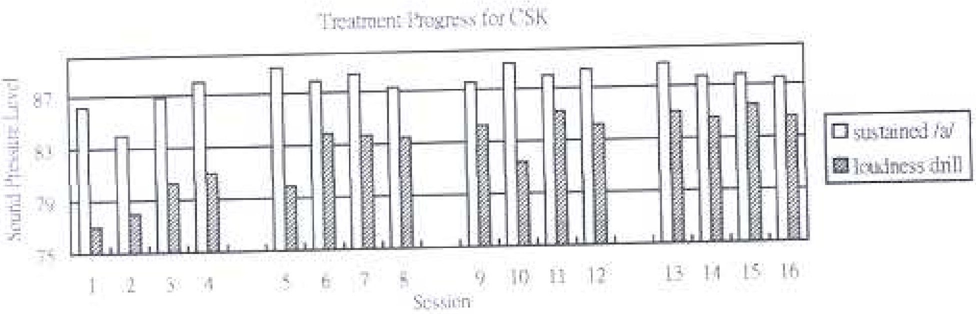
iii) Paragraph

香港是一個繁榮的都市，有接近六百萬人口，是國際重要的金融貿易中心。香港已有「東方之珠」的美譽，它的夜景是世界馳名的。每年從世界各地來港觀光的旅客，都讚歎香港的成就是個奇蹟。由百多年前的一個平淡的漁村，演變成爲今日著名的大都會，絶不是偶然或僥倖的。由於中國傳統的克苦耐勞及自強不息的精神；促使我們不斷的努力，才能爭取到今天的成就。

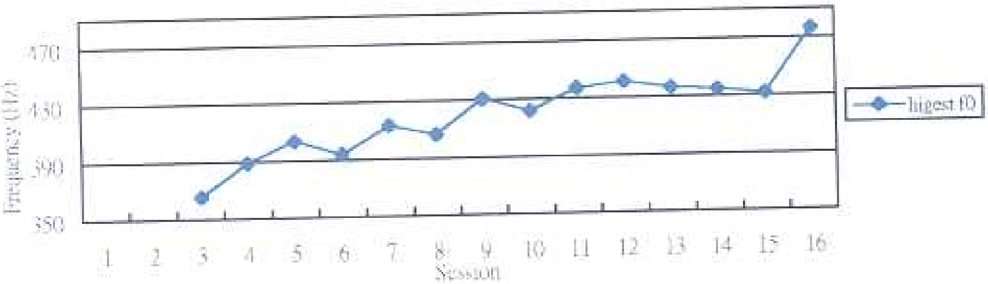
巴巴拉史翠珊是我很喜歡的一位美國女明星。她沒有如花的美貌，但她的演技在「俏郎君」一片中發揮得淋漓盡致，使這齣戲和它的主題曲都成爲傳頌一時的佳作。今天，銀圈的男女藝員都以色相自高，其實只有自我宣傳的鬼主意，頻頻「車大炮」、造新聞，盼能提高知名度。而演技高低，已與他們無關了。

Leung, M.T.'s passage modified by Yiu, E. (1991)

Appendix C: Treatment progress for individual subject across sessions

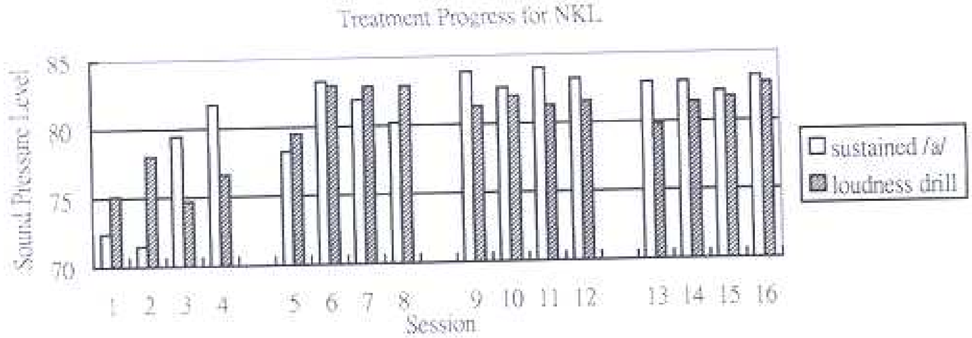


Appendix C1. Averaged sound pressure level during maximum sustained vowel phonation (sustained /a/) and maximum functional speech loudness drill (loudness drill) for CSK

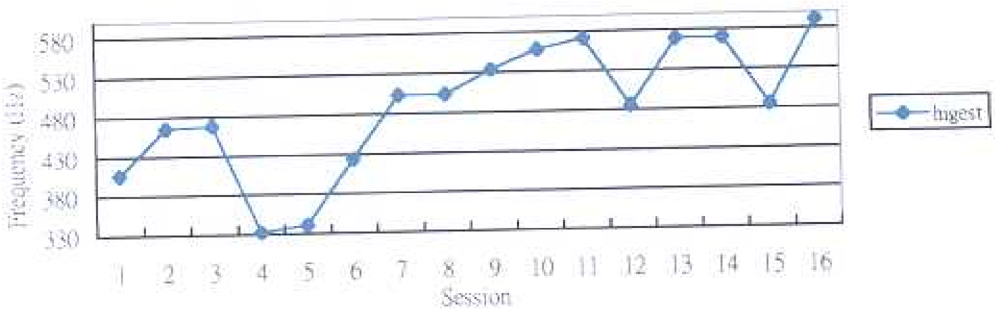


Appendix C2. Averaged highest fundamental frequency (f0) attained during generation of maximum frequency range for CSK

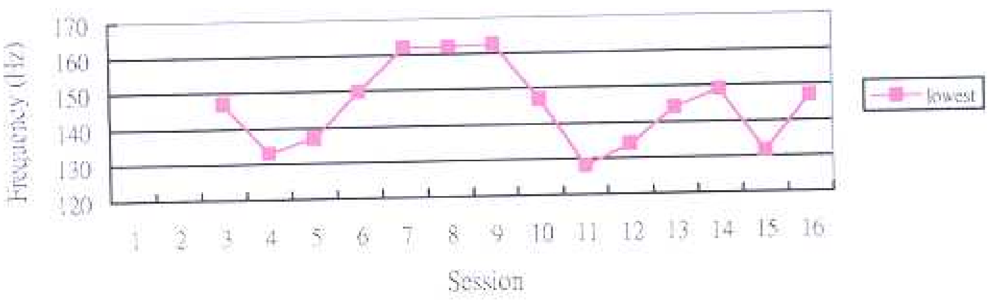
Appendix C3. Averaged lowest fundamental frequency (f0) attained during generation of maximum frequency range for CSK.



Appendix C4. Averaged sound pressure level during maximum sustained vowel phonation (sustained /a/) and maximum functional speech loudness drill (loudness drill) for NKL

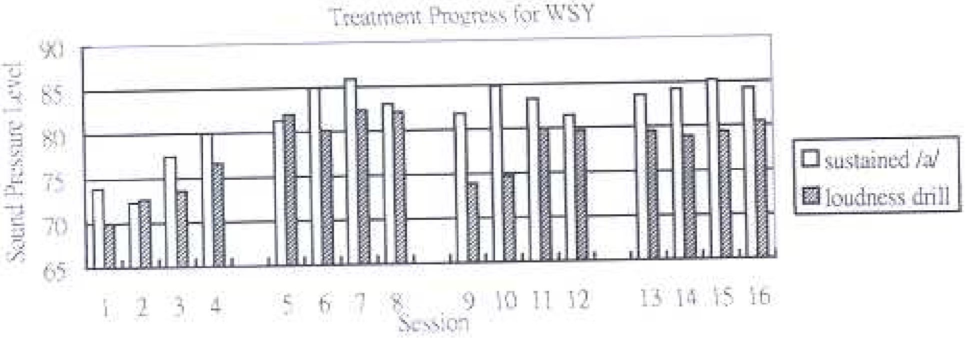


Appendix C5. Averaged highest fundamental frequency (f0) attained during generation of maximum frequency range for NKL

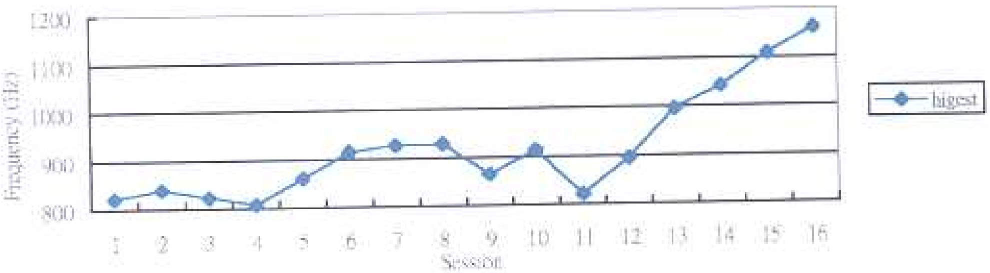


Appendix C6. Averaged lowest fundamental frequency (f0) attained during generation of maximum frequency range for NKL

Appendix C (con`t)

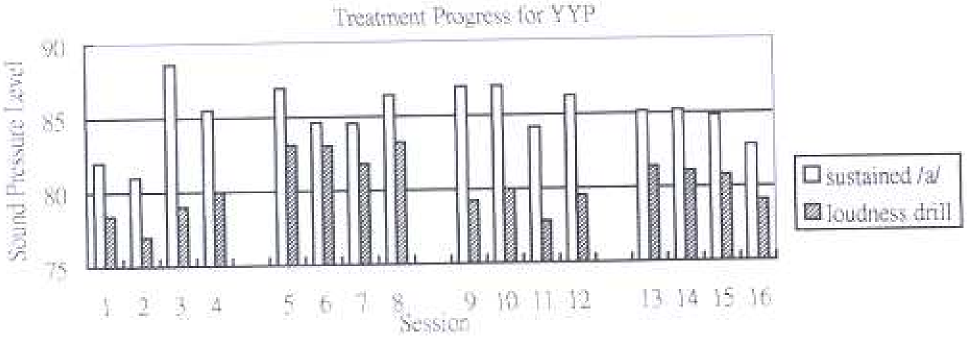


Appendix C7. Averaged sound pressure level during maximum sustained vowel phonation (sustained /a/) and maximum functional speech loudness drill (loudness drill) for WSY

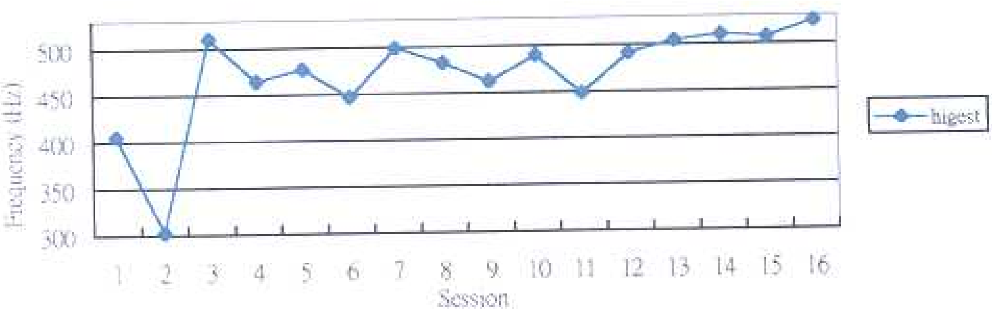


Appendix C8. Averaged highest fundamental frequency (f0) attained during generation of maximum frequency range for WSY

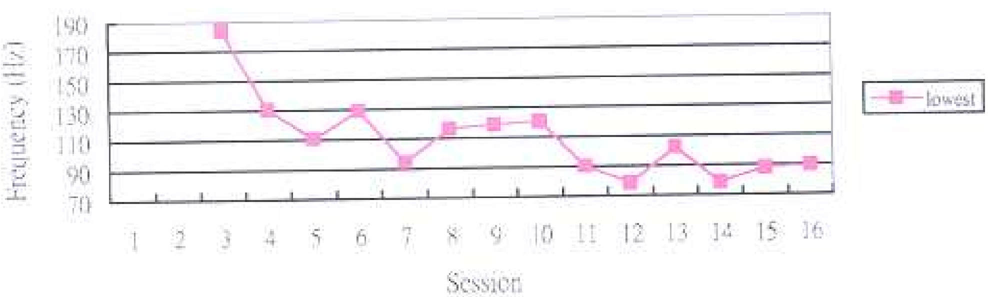
Appendix C9. Averaged lowest fundamental frequency (f0) attained during generation of maximum frequency range for WSY



Appendix C10. Averaged sound pressure level during maximum sustained vowel phonation (sustained /a/) and maximum functional speech loudness drill (loudness drill) for YYP



Appendix C11. Averaged highest fundamental frequency (f0) attained during generation of maximum frequency range for YYP



Appendix C12. Averaged lowest fundamental frequency (f0) attained during generation of maximum frequency range for YYP

Appendix D: Confusion matrices of the pre- & post-treatment lexical tone production

Appendix D1 to D4 show the confusion matrices of the pre- and post-treatment performance for each individual subject, in terms of percentage of response. Vertical axis shows the target tones, while the horizontal axis shows the perceived tones. Cell numbers represent percentage of response out of nine stimuli for each tone.

Appendix D1: Confusion matrixes for CSK

a) Pre-treatment

Target Perceived Tones

Tone	55	35	33	21	23	22
55	100.00					
35		88.89	11.11			
33	33.33		66.67			
21				11.11		88.89
23		100.00			0.00	
22			55.56			44.44
Overall correct identification: 51.85%						

b) Post-treatment

Target Perceived Tones

Tone	55	35	33	21	23	22
55	100.00					
35		88.89	11.11			
33	11.11	11.11	77.77			
21				44.44		55.56
23		88.89	11.11		0.00	
22			55.56			44
Overall correct identification: 59.26%						

Appendix D2: Confusion matrixes for NKL

a) Pre-treatment

Target Perceived Tones

Tone	55	35	33	21	23	22
55	100.00					
35		100.00				
33			100.00			
21				100.00		
23		88.89			11.11	
22				22.22		77.78
Overall correct identification: 81.48%						

b) Post-treatment

Target Perceived Tones

Tone	55	35	33	21	23	22
55	100.00					
35		77.78			22.22	
33		11.11	88.89			
21				100.00		
23		66.67			33.33	
22				11.11		88.89
Overall correct identification: 81.48%						

Appendix D3: Confusion matrixes for WSY

a) Pre-treatment

Target Perceived Tones

Tone	55	35	33	21	23	22
55	100.00					
35		100.00				
33			100.00			
21				100.00		
23		33.33			66.67	
22			22.22		11.11	66.67
Overall correct identification: 88.89%						

b) Post-treatment

Target Perceived Tones

Tone	55	35	33	21	23	22
55	100.00					
35		88.89			11.11	
33			100.00			
21				88.89		11.11
23		22.22	11.11		66.67	
22			22.22		11.11	66.67
Overall correct identification: 85.19%						

Appendix D4: Confusion matrixes for YYP

a) Pre-treatment

Target Perceived Tones

Tone	55	35	33	21	23	22
55	100.00					
35		88.89			11.11	
33			66.67		33.33	
21			11.11	33.33	11.11	44.44
23		55.56	22.22		11.11	11.11
22			11.11	11.11		77.78
Overall correct identification: 62.96%						

b) Post-treatment

Target Perceived Tones

Tone	55	35	33	21	23	22
55	88.89		11.11			
35		100.00				
33			100.00			
21		33.33	22.22	22.22		22.22
23		44.44	55.56		0.00	
22		11.11	33.33	22.22		33.33
Overall correct identification: 57.41%						