VOICE ACOUSTIC ANALYSIS OF TAIWANESE ADULTS WITH DYSARTHRIA FOLLOWING STROKE

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1. INTRODUCTION

Stroke is probably the most common cause of motor speech disorders, especially dysarthrias (Duffy, 2005). Although perceptual voice analysis for speakers with stroke-related dysarthria is still the most commonly used method in clinical settings, physiologic or acoustic voice analysis can provide a complementary objective evaluation of voice dysfunction in these speakers. Among the acoustic voice analysis tools, the Multi-Dimensional Voice Program (MDVP) (Kay, 1993) is commercially available and very easy-to-use. MDVP was reported to have fairly good suitability and reliability for the analysis of voice dysfunction in dysarthria (Biddle, Watson, & Hooper, 2002; Kent, Vorperian, & Duffy, 1999). However, as Kent et al. (1999) indicated 'Single trials may not be sufficient for the identification of voice dysfunction, and it appears that at least two trials are needed (p. 135)'. Moreover, the number of trials of vowel prolongation required to yield a reliable MDVP analysis for healthy speakers and speakers with dysarthria has not been determined. Investigating the discrepancy of MDVP values across trials for different populations could provide insight into this issue. Studies related to voice dysfunction in speakers with stroke-related dysarthria are still limited. It seems that objective acoustic analysis could detect voice abnormalities in dysarthrias following stroke and that group comparisons could delineate the voice profile in speakers with stroke-related dysarthria.

In order to obtain reliable acoustic measures to reach valid conclusions on the effects of stroke on voice function, it is legitimate to examine discrepancies between trials and make group comparisons based on at least two trials of vowel phonation for healthy speakers and speakers with stroke-related dysarthria. The purposes of the current study were: (1) to examine the trial-to-trial discrepancy between healthy speakers and speakers with stroke-related dysarthria; and (2) to investigate the effects of stroke on voice dysfunction in Taiwanese adults during a task of vowel phonation based on the acoustic voice parameters extracted by the MDVP.

2. METHOD

Ten Taiwanese male adults with mild to moderate stroke-related dysarthria (age 48.6 ± 13.0, ranging from 26 to 70 years) recruited from Taipei Veterans General Hospital, Taiwan. Ten neurological healthy age-and-gender matched participants were served as the controls. All participants wore an Audio-Technica PRO 8 head-mounted hypercardioid microphone connected to a digital audio tape recorder (TASCAM DA-P1). The microphone-to-mouth distance was 8 to 10 cm at an angle of about 45 degrees. They were instructed to "take a deep breath and say 'ah' for as long and as steadily as you can, until you run out of air" after the examiner's demonstration. Two trials of prolongation of the vowel /a/ for each participant were recorded on digital audio tapes (DAT R-94) at a sampling rate of 44.1 kHz and 16-bit quantization in a quiet room.

As Kent et al. (2003) suggested, the first 25 ms and the terminal phase of phonation in each trial were discarded. An interval of the most stable 3 s in the middle portion of the phonation of trial 1 and trial 2 were selected and analyzed with the Computer Speech Lab (CSL) and MDVP. The MDVP outputs of the two trials were then used to calculate the absolute mean difference (AMD-trial), standard deviation across trial (SD-trial). Finally, the means of the two outputs for each parameter were used to perform group comparisons. Based on a review of the literature that used MDVP for voice analysis, 17 out of the 33 acoustic voice parameters extracted by the MDVP were selected for this study, as shown in Table 1.

Due to the small number of subjects, limited knowledge about the nature of the data distribution, and the potential problem of non-independent relationship among acoustic measures in the current study, nonparametric statistic method (Mann-Whitney U test) was used to perform the designated group comparisons at a significance level of 0.05. Furthermore, the Bonferroni correction was applied to each group of MDVP-derived parameters to maintain the familywise error rate, i.e., 0.017 for fundamental frequency information measurements, 0.008 for short and long-term frequency perturbation measurements, 0.01 for short and long-term amplitude perturbation measurements, and 0.017 for noise related measurements.

3. RESULTS

As shown in Table 1, compared to the results of Kent et al. (1999), ten out of the 17 parameters were larger than previous reported data. The stroke group exhibited significantly larger discrepancies in fundamental frequency and its standard deviation (f_0 and STD), very long-term f_0 variation (vf_0), very short-term variability of the peak-to-peak amplitude (ShdB and Shim), and noise-to-harmonic ratio (NHR) than the control group.

Table 1. Means and standard deviations of the absolute differences between trial 1 and trial 2 (AMD-trial and SD-trial) for the 17 selected acoustic voice parameters extracted by the MDVP and statistical results of the group comparisons.

Parameter	Kent	Controls		Men with stroke		Z	p
		AMD-trial	SD-trial	AMD-trial	SD-trial		
f_0 (Hz)	8.62	2.58	2.69	**8.76**	10.54	**2.570**	0.010
STD(Hz)	3.69	0.35	0.24	**10.26**	25.17	**2.948**	0.003
PFR(semitone)	2.69	0.40	0.52	**4.40**	7.29	1.476	0.140
Jita(μs)	51.39	22.11	15.98	46.34	60.60	1.890	0.059
Jitt(%)	0.73	0.30	0.18	0.60	0.84	1.021	0.307
RAP(%)	0.41	0.18	0.11	0.34	0.50	0.492	0.623
PPQ(%)	0.48	0.18	0.12	0.38	0.70	0.076	0.940
sPPQ(%)	1.35	0.15	0.07	**1.78**	3.84	0.454	0.650
vF_0(%)	2.40	0.24	0.14	**5.80**	13.69	**3.326**	0.001
ShdB(dB)	0.18	0.06	0.05	**0.29**	0.26	**2.721**	0.007
Shim(%)	1.98	0.72	0.57	**3.05**	2.48	**2.721**	0.007
APQ(%)	1.43	0.56	0.38	**2.11**	2.05	1.739	0.082
sAPQ(%)	2.34	0.81	0.78	**2.60**	2.55	**1.965**	0.049
vAm(%)	7.28	3.82	6.79	5.97	6.02	1.739	0.082
NHR	0.04	0.01	0.01	**0.06**	0.06	**3.029**	0.002
VTI	0.03	0.01	0.01	0.02	0.03	1.102	0.270
SPI	4.30	2.80	2.10	2.23	2.41	0.907	0.364

As shown in Table 2, all mean MDVP values of the men with stroke-related dysarthria exceeded the threshold values, except for VTI, which is equal. Moreover, all mean MDVP outputs of the men with stroke exceeded those of the healthy controls. The stroke group exhibited significantly larger standard deviation and range of f_0 (STD and PFR), very long-term f_0 variation (vf_0), and long-term peak-to-peak amplitude variation (APQ and sAPQ) than the control group.

Table 2. Mean and standard deviation data for the 17 selected acoustic voice parameters extracted by the MDVP and statistical results of the group comparisons.

Parameter	Threshold	Controls		Men with stroke		Z	p
		M	SD	M	SD		
f_0 (Hz)	N/A	135	30	134	28	0.000	1.000
STD (Hz)	N/A	1.432	0.778	10.274	16.963	**2.570**	0.010
PFR (semitones)	N/A	2.100	0.459	7.300	8.782	**2.580**	0.010
Jita (us)	83.20	63.373	14.926	**122.473**	82.891	1.512	0.131
Jitt (%)	1.04	0.866	0.330	**1.670**	1.289	1.436	0.151
RAP (%)	0.68	0.515	0.202	**0.980**	0.757	1.209	0.226
PPQ (%)	0.84	0.497	0.186	**1.061**	0.916	1.209	0.226
sPPQ (%)	1.02	0.689	0.170	**2.626**	3.690	**1.965**	0.049
vf_0 (%)	1.10	1.029	0.349	**6.485**	9.842	**3.099**	0.002
ShdB (dB)	0.35	0.325	0.118	**0.675**	0.436	**2.570**	0.010
Shim (%)	3.81	3.677	1.189	**7.356**	4.233	**2.495**	0.013
APQ (%)	3.07	2.717	0.776	**5.668**	3.257	**3.024**	0.002
sAPQ (%)	4.23	4.155	1.021	**8.457**	5.107	**3.402**	0.001
vAm (%)	8.20	**13.692**	18.686	**17.897**	8.701	**2.495**	0.013
NHR	0.19	0.137	0.021	**0.195**	0.086	1.814	0.070
VTI	0.06	0.049	0.015	0.060	0.024	0.950	0.342
SPI	14.12	**14.160**	5.327	**14.424**	5.785	0.000	1.000

4. DISCUSSION

The current study indicates that, compared to the control group, (1) the stroke group exhibited significantly larger discrepancies in certain MDVP-derived acoustic parameters, such as fundamental frequency and its standard deviation (f_0 and STD), very long-term f_0 variation (vf_0), very short-term variability of the peak-to-peak amplitude (ShdB and Shim), and noise-to-harmonic ratio (NHR); and (2) stroke effects on acoustic voice parameters are mainly on the standard deviation and range of f_0 (STD and PFR), very long-term f_0 variation (vf_0), and long-term peak-to-peak amplitude variation (APQ and sAPQ).

The discrepancy across trials for the speakers with stroke in the current study is comparable to that in previous study (Kent et al., 1999), but the current study reports the degree of the discrepancy for the commonly used parameters in the literature and indicates that the values of certain parameters were more inconsistent between trials, and perhaps more than two trials for these parameters are needed to yield reliable measures to establish stable voice profile for speakers with stroke-related dysarthria. That is, less stable voice needs a greater number of trials to obtain representativeness.

Based on the average of two trials, the results of the current study roughly corresponds to previous studies (Kent et al., 1999; Kent et al., 2003), although some inconsistency exists among these studies. It is possible that the measurement discrepancy contributes to the inconsistency among studies. However, it is also possible that the differences in age, gender, lesion size and location, dysarthria severity, or other factors account for the corresponding voice stability and the resulting inconsistency among different studies.

The current study indicates changes in acoustic voice measures in stroke-related dysarthria. Discrepancies across trials of certain MDVP parameters for speakers with stroke-related dysarthria are significantly larger than those of healthy speakers. These parameters are relatively unstable and require more trials to obtain reliable measurements. Stroke effects on acoustic voice parameters are mainly on the standard deviation and range of f_0, very long-term f_0 variation, and long-term peak-to-peak amplitude variation. The results of the current study could form the basis of a larger investigation.

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ACKNOWLEDGEMENTS

This work was supported in part by Research Grant number NSC 95-2314-B-010-095 from the National Science Council, Taiwan.