# Speech Disorders of Voice Quality, Maximum Sound Prolongation, and S/Z Ratio in Patients with Parkinson's Disease

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**ABSTRACT**

With populations aging all over the world, Parkinson's disease (PD) is expected to increase in the future. The goal of this present study is to assess speech deficits found in PD patients with dysarthria by focusing on three measures: (1) voice quality, (2) maximum sound prolongation (MSP), and (3) S/Z ratio. Sixteen male patients diagnosed with PD with Hoehn & Yahr Stage of 2 to 4, and sixteen controls participated in this study. The results showed that PD patients performed statistically poorer on maximum sound prolongation than controls. They were relatively unable to sustain certain sounds. However, no significant difference was found in voice quality and S/Z ratio between patients and controls. These findings will help us have a clearer understanding of the communication problems of PD patients.

Keywords: Parkinson's disease; voice quality; maximum sound prolongation; S/Z ratio

# 巴金森氏病患者在音質、最長發音時長、S/Z 比值之言語分析

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## 摘要

巴金森氏病隨著人口老化，可預期的是未來罹患巴金森氏病的人口將會持續增加。本研究旨在藉由三個檢測項目，分別為音質、最長發音時長以及 S/Z 比值，檢測巴金森氏病患者言語障礙。共有 16 位巴金森氏病男性患者參與研究，其嚴重程度為第二期至第四期，另外還有 16 位男性對照組也參與研究。本研究主要有以下發現：巴金森氏病患者最長發音時長與對照組在統計上有顯著性差異，患者持續把音拉長的能力比較差，但其音質跟 S/Z 比值與對照組在統計上並未達到顯著性差異。本研究結果可幫助我們更瞭解巴金森氏病患者言語溝通的問題，並期望本研究結果可以對身受言語溝通之苦的患者在其跟家人及照護者間的溝通有所助益。

關鍵字：巴金森氏病；音質；最長發音時長；S/Z 比值

## 1. INTRODUCTION

Due to more aging populations all over the world, the number of Parkinson's disease sufferers is expected to increase. Therefore, communication problem in PD patients is a serious issue that we should pay attention to. The present study concerns the differences in the speech performances between the PD group and a control group, and aims at speech deficits in PD patients with dysarthria compared with a control group, matched for age and sex. We investigate speech deficits in PD patients, the findings are expected to help us to have a clearer understanding of the communication problems in PD patients. It is hoped that this improved understanding will lead to more successful communication of PD sufferers with their family and caregivers.

### 1.1 Background

Many researchers have reported that Parkinson's disease (hereafter PD) is a progressive neurodegenerative disorder (Lang and Lozano; Li, Li, and Wang; Olanow, Stern, and Seth). Olanow, Stern, and Sethi suggest that PD seems to be associated with age. Accordingly, in aging populations all over the world, Olanow, Stern, and Sethi regard PD as a noticeable health problem and one that is expected to increase in the future.

PD mainly occurs as a result of a loss of dopaminergic neurons in substantia nigra pars compacta of the midbrain, resulting in neuron degeneration or apoptosis (Widnell; Li, Li, and Wang; Olanow, Stern, and Sethi; Patel et al.). Tremors, rigidity, bradykinesia (Lang and Lozano; Widnell; Li, Li, and Wang), impaired postural balance (Patel et al.), and dysarthria (Li, Li, and Wang) may occur when neurons degenerate to 50%. In addition to symptoms such as tremors, rigidity, and bradykinesia, an estimated 70% of PD patients have speech or voice problems, characterized as hypokinetic dysarthria (Hartelius and Svensson; Goberman, Coelho, and Robb). Metter and Hanson also report that hypokinetic dysarthria is usually considered to be monopitch and hypoprosody.

### 1.2 Voice Parameters

With the large disparity between subjective reports about voice problems and clinical examination, Chu et al. argue that acoustic analysis has become an indispensable tool for providing an objective evaluation. According to Chu et al., analyzing voice quality is a way to provide an objective examination of voice problems because a large disparity exists between subjective reporting of voice problems and reports resulting from clinical examination.

There are some common voice parameters listed in the literature that should be discussed. To begin with, according to Wang and Huang, fundamental frequency (hereafter F0) refers to the vibrating rate of the vocal folds, and can be measured either through sustained vowels or the reading of a passage. Canter finds a higher F0 in patients than the controls, as do Metter and Hanson's study; however, Zwirner, Murry, and Woodson explain that this is questionable, citing findings from Metter and Hanson showing that F0 tends to increase with more severe dysarthria and more severe clinical symptoms. Zwirner, Murry, and Woodson provide the possible reason for this discrepancy: no description of severity of disease progression in talkers with PD has been reported in previous studies. They suggest that F0 varies with the degree of severity of disease progression in talkers with PD. Wolfe and Martin also report low F0 in patients with dysphonic voice. F0 for /a/ is lower in healthy male subjects than in female ones (Chu et al.; Wang and Huang). Wang and Huang further state that F0, generally governed by the tension, length, and mass of the vocal folds, is found significantly more in women than men.

Jitter, another parameter related to frequency perturbations, is defined by Zwirner, Murry, and Woodson as "cycle-to-cycle variation in frequency" (291). Therefore, according to Chen and Lin, jitter is low if there is little variation in frequency. In Wolfe and Martin's study, they find that jitter is only correlated with strained voice, a conclusion not supported by Eskenazi, Childers, and Hicks who assert that jitter serve as a good parameter for detecting severity of hoarseness, and breathiness.

The next parameter associated with amplitude perturbations is shimmer. Zwirner, Murry, and Woodson refer to shimmer as the cycle-to-cycle variation in amplitude. According to Kitajima and Gould, shimmer might serve as a good indicator for differentiating a pathologic voice from a normal one, and might also be useful for evaluating hoarseness. When comparing the sustained phonation of 20 subjects with vocal cord polyps against 45 controls, Kitajima and Gould demonstrate that shimmer may be associated with laryngeal polyps. Lower shimmer was observed in male subjects than in female ones in the study of Wang and Huang. Xue and Deliyski also find significant difference in shimmer among different age groups in both sexes.

Noise to Harmonic Ratio (hereafter NHR) is a key parameter related to noise. Authors define NHR as "an average ratio of energy of the in-harmonic components in the range 1500-4500 Hz to the harmonic components energy in the range 70-4500 Hz" (Godino-Llorente et al. 467). As Bhuta, Patrick, and Garnett state, NHR, which examines aperiodic noise in the voice sample, is related to roughness. HNR, the reciprocal of the NHR, has been found to be a good indicator for discriminating roughness from breathiness in the study of de Krom and is low in talkers with vocal fold problems in the study of Chu et al. Nevertheless, Chen and Lin do not find significant difference in NHR between talkers with self-reported voice problem and controls. In the study of Eskenazi, Childers, and Hicks, NHR also fails to predict voice hoarseness.

Relative Average Perturbation (hereafter RAP), Pitch Perturbation Quotient (hereafter PPQ), Amplitude Perturbation Quotient (hereafter APQ) are also common voice parameters to examine voice quality. According to Xue and Deliyski, RAP refers to variability of the pitch period at smoothing factor three periods while PPQ is defined as variability of the pitch period at smoothing factor five periods. APQ, on the other hand, shows the variability of the peak-to-peak amplitude at smoothing factor eleven periods. As Godino-Llorente et al. stated, RAP, and PPQ are related to frequency perturbations; APQ is associated with amplitude perturbations. Xue and Deliyski investigated the voice quality of normal elderly subjects by examining their RAP, PPQ, and APQ. Chen and Lin also adopted RAP, PPQ, and APQ as some of voice parameters to compare voice quality of the teachers who have self-reported voice problems and that of their controls, though no significant difference was found between groups.

### 1.3 Tasks to Evaluate Speech Deficits in Motor Speech Disorders

Many previous studies have explored the speech deficits in motor speech disorders (Kent, Kent, and Rosenbek; Zwirner, Murry, and Woodson; Thoonen et al.; Thoonen et al.; Ziegler; Wang et al.). In order to evaluate the oral motor system of patients with motor speech disorders, a group of tasks have been employed. For example, maximum performance tasks, which can be further classified into tasks of maximum sound prolongation (hereafter MSP) and tasks of maximum repetition rate, are commonly used among patients with motor speech disorders (Kent, Kent, and Rosenbek; Thoonen et al.; Thoonen et al.; Ziegler; Wang et al.). Maximum performance tasks focus on examining respiration, phonation, as well as articulation as separate components of the speech mechanism, and are associated with phonation volume, especially vital capacity, and also air flow through the larynx (Kent, Kent, and Rosenbek; Thoonen et al.). Although Kent, Kent, and Rosenbek indicate that maximum performance tasks assess different speech capabilities from normal speech does, Thoonen et al. believe that it helps investigate the motor speech abilities in dysarthria or developmental apraxia of speech.

MSP, as one of the tasks in maximum performance tasks, examines the maximum duration for which one can sustain a sound in one ongoing breath (Kent, Kent, and Rosenbek; Colton, Casper, and Leonard) and uses this data to evaluate respiratory and phonatory capacity as shown in Thoonen et al.'s study. Since PD is one of motor speech disorders, many studies have examined it by using MSP (Zwirner, Murry, and Woodson; Jiménez-Jiménez et al.; Gamboa et al.). According to Kent, Kent, and Rosenbek, MSP is associated with phonation volume, especially vital capacity, and air flow through the larynx. Also, in the view of Colton, Casper, and Leonard, MSP can measure one's respiratory capacity and phonatory control.

S/Z ratio also serves as a measure to evaluate speech motor disorders. Gamboa et al., for example, investigate speech performance of subjects with Parkinson's disease by using S/Z ratio. Eckel and Boone argue that it can also detect dysphonic subjects with laryngeal impairments. The sustained fricative phonation can provide information about the articulatory and phonatory performance (Kent, Kent, and Rosenbek). According to Boone, S/Z ratio is obtained by which voiceless sustained fricative duration is divided by voiced sustained fricative duration. Eckel and Boone report that an S/Z ratio tends to be in excess of 1.4 in dysphonic subjects with laryngeal pathology while control subjects have about only 1.0 for S/Z ratio. Chu et al. also state that when the S/Z ratio is larger than 1.4, there might be laryngeal-related disorders. However, Gamboa et al. do not find significant difference in PD subjects, which may result from severity of laryngeal pathology in PD patients. Gamboa et al. do not provide information about severity of laryngeal impairments in the 41 PD patients; however, Hoehn & Yahr Scale evaluates motor impairments based on the level of clinical disability, not for speech performance specifically. It is possible that those PD patients show motor impairments rather than serious laryngeal problems.

Although some studies have investigated the speech performances of PD patients, many findings are inconsistent in different studies with different methodology. Take F0 for example, not only Canter but also Gamboa et al. observed higher F0 in male PD patients than controls, whereas Jiménez-Jiménez et al. found higher F0 in female PD patients without receiving dopaminergic drugs than controls. Metter and Hanson, and also Zwirner, Murry, and Woodson even explored that there was no significant difference found in F0 between PD patients and controls. Shimmer is another voice parameter with conflicting results. According to Jiménez-Jiménez et al., higher shimmer was observed in PD patients; nevertheless, Zwirner, Murry, and Woodson found no significant difference between PD patients and controls. As a consequence, the present study would like to clarity those inconsistent findings and investigate the speech deficits in PD patients with a more thorough way. The research question in the present study concerns the differences in the speech performances between the PD group and a control group. Speech deficits are investigated in PD patients with dysarthria compared with a control group, matched for age and sex. The present study investigates not only the voice quality of PD patients but also MSP, and S/Z ratio, as compared with a control group, in order to better understand the nature of their communication problems with family or caregivers. It is expected that PD patients would show speech impairments in dimensions of voice quality, MSP, and S/Z ratio. The findings will help us to have a clearer understanding of the communication problems in PD patients, and it is hoped that this improved understanding will lead to more successful communication of PD sufferers with their family and caregivers.

## 2. METHODS

### 2.1 Participants

The current study has been reviewed and approved by the Institutional Review Board of National Cheng Kung University Hospital. All the PD patients were referred by a neurologist from a single hospital in Southern Taiwan. There are sixteen male patients recruited in the present study. They should be diagnosed with Parkinson's disease by a neurologist, and no other neurological diseases. Patients should also be reported hypokinetic dysarthria, and no other hearing or speech disorders unassociated with Parkinsonism.

Table 1 shows the personal information for each of the PD patients. Their mean age is 68 ± 1.39 years old (range, 55−75). Their PD severity of Hoehn & Yahr Stage varies from Stage 2 to Stage 4. According to five stages in Hoehn & Yahr Scale reported in the study of Hoehn and Yahr, Stage 2 represents bilateral or midline involvement without balance problem; Stage 3 shows unsteadiness when patients are pushed from standing equilibrium. Patients in Stage 4 are severely disabled, but are able to walk and stand unassisted. Furthermore, in terms of disease duration, they had been diagnosed with PD from 3 to 24 years before the present study begun. All the PD patients in this study speak Taiwan Southern Min as their native language.

All sixteen controls from Southern Taiwan were recruited from the Community center. Their mean age is 66.06 ± 2.05 years old (range, 50−80). The controls are not diagnosed with PD, other neurological diseases, chronic diseases, and hearing/speech disorders. In order to ascertain the health of the participants in control group, a health evaluation form was used, as shown in Appendix. With chronic disease items following the medical records from one hospital in Southern Taiwan, it not only elicits their past history for chronic diseases and neurological diseases but also examines their limb movement. In addition, the three simple examinations for limb movement －tremor at rest, finger taps, and leg agility, given in Appendix, come from Unified Parkinson's Disease Rating Scale by Fahn, Elton, and Members of the UPDRS Development Committee.

Table 1. Demographic and clinical features in patients with Parkinson's disease

| PD patients | Sex | Age (years) | Education years | Hoehn & Yahr Stage | Levodopa equivalent daily dose (mg) | Disease duration (years) |
|---|---|---|---|---|---|---|
| P1 | M | 64 | 6 | 4 | 1285.7 | 18 |
| P2 | M | 62 | 16 | 2 | 562.5 | 5 |
| P3 | M | 75 | 9 | 3 | 487.5 | 6 |
| P4 | M | 63 | 18 | 2 | 600 | 4 |
| P5 | M | 75 | 6 | 2 | 337.5 | 4 |
| P6 | M | 67 | 16 | 2 | 375 | 7 |
| P7 | M | 65 | 12 | 3 | 450 | 5 |
| P8 | M | 64 | 0 | 3 | 660 | 4 |
| P9 | M | 55 | 14 | 3 | 750 | 6 |
| P10 | M | 70 | 6 | 3 | 1200 | 15 |
| P11 | M | 68 | 14 | 3 | 814.3 | 7 |
| P12 | M | 71 | 6 | 3 | 330 | 4 |
| P13 | M | 71 | 6 | 2 | 675 | 11 |
| P14 | M | 71 | 9 | 3 | 1087.5 | 7 |
| P15 | M | 74 | 12 | 2 | 680 | 3 |
| P16 | M | 73 | 18 | 2 | 150 | 24 |

**2.2 Protocol**

The present study collected data using only sound recording without video. The equipment which would use is a TASCAM DR-100 recorder, a R-09 recorder, a AKG behind-the-ear microphone, and a portable loudspeaker. The recording was conducted on the same day as the patients' regular visit to their neurologist in the morning before they took their noon medication, or just in the morning for the controls.

Recording was conducted in either a quiet and empty room in the hospital for PD patients or at the participants' own home for controls. All the participants were informed of the details of the project and what would be recorded. They were asked to sign two copies of the Informed Consent Form if they were willing to taking part in this project. Each recording session lasted around 40 minutes with all the instructions recorded in advance, and played through a portable loudspeaker, making sure that every participant received the same instructions. All the participants were recorded only once.

Before the recording was started, the experimenter had asked the subjects to fill in the personal information form, e.g., name, sex, birth date, education level. They were also asked the disease duration of PD, other diseases that require the taking of long-term medication, languages they use, occupation, family members whom they live together with, and the best way to reach them if later contact were required. All the participants are asked to produce utterances in normal pitch, and normal volume. By adapting maximum performance tasks, participants need to prolong a single phoneme (/a/, /f/, /s/, /z/) for as long as they can in one single breath by three times. They were also asked to produce monosyllable sounds (/pa/, /ta/, /ka/), and trisyllables /pataka/ as fast as possible in one single breath. This was also repeated three times.

**2.3 Analytical Framework**

**2.3.1 Voice Quality**

The Multi-Dimensional Voice Program (hereafter MDVP) Model 5105, developed by Kay Elemetrics, was used to perform a quantitative acoustic assessment of the voice quality in all participants. The voice sample was analyzed along several parameters and the results were graphically displayed with normative threshold values. When the range of values is within the normative threshold they are colored green, but are red if the values fall outside the normative threshold. Figure 1 is a sample of MDVP for one PD patient. Figure 1 shows that the values in most parameters for that patient are out of the range of the normative threshold except for VTI and NHR; the largest discrepancy is in F0.

The current study investigates voice quality by adapting the same acoustic parameters as Chen and Lin's study, which a single prolonged vocalized /a/ is analyzed based on seven main voice parameters out of 33, that is, Average Fundamental Frequency (hereafter F0), Jitter Percent (hereafter Jitt), Relative Average Perturbation (hereafter RAP), Pitch Perturbation Quotient (hereafter PPQ), Shimmer Percent (hereafter Shim), Amplitude Perturbation Quotient (hereafter APQ), and Noise to Harmonic Ratio (hereafter NHR). According to Godino-Llorente et al., F0, Jitt, RAP, and PPQ are related to frequency perturbations. Shim and APQ are then associated with amplitude perturbations. As for NHR, it reflects the noise in the voice. The three single prolonged vocalized /a/ sounds uttered by each participant were averaged in order to obtain a mean performance.

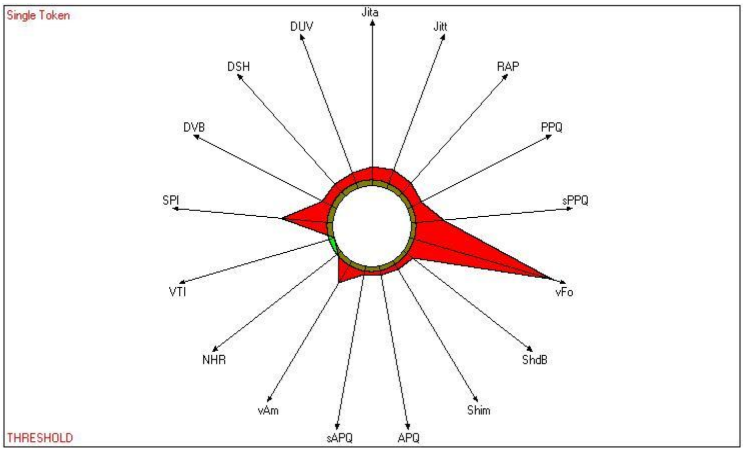


Figure 1. One sample of MDVP analysis of a single prolonged vocalization /a/

### 2.3.2 Maximum Sound Prolongation (MSP)

MSP refers to the maximum duration that an individual can sustain a sound in a single breath (Kent, Kent, and Rosenbek; Colton, Casper, and Leonard). MSP was assessed by examining the duration of /a/, /f/, /s/, /z/ in one single breath. As mentioned, the trial was performed three times for each phoneme. Praat software was used to examine the duration of each target sound, measured in seconds. In this manner the mean prolongation duration of each target sound was obtained.

### 2.3.3 S/Z Ratio

S/Z ratio was obtained by following the Boone's calculation, in which voiceless sustained fricative duration was divided by voiced sustained fricative duration. The voiceless sustained fricative /s/ and voiced sustained fricative /z/ was derived from the MSP which each participant produced in three trials. For example, if the participant had a mean four-second MSP for /s/ and a mean five-second MSP for /z/, then the S/Z ratio was derived from four divided by five, which equals 0.8. The mean S/Z ratio for each group was obtained to enable comparison between groups.

## 3. RESULTS

### 3.1 Voice Quality

Using a Multi-Dimensional Voice Program (MDVP) to obtain results regarding voice quality from both the PD group and controls, seven parameters were measured: Average Fundamental Frequency (F0), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Pitch Perturbation Quotient (PPQ), Shimmer Percent (Shim), Amplitude Perturbation Quotient (APQ), and Noise to Harmonic Ratio (NHR). The results are shown in Table 2 and Table 3.

In addition to the individual graphical results with normative threshold values by

MDVP, voice quality comparison based on seven parameters between PD group and control group are presented in Table 2. Table 2 displays a comparison of the results of the voice quality comparison of the PD and control groups based on seven parameters. The PD group has lower F0 value than control group, and the values of the other parameters, that is Jitt, RAP, PPQ, Shim, APQ, and NHR in PD group, are a little higher than control group.

An independent-samples t-test has been calculated to compare the mean F0, Jitt, RAP, PPQ, Shim, APQ, and NHR of PD group and control group. The results are shown in Table 3. No significant difference between the mean F0 of the two groups is observed. Neither are their differences in Jitt, RAP, PPQ, Shim, APQ, and NHR, as can be seen in Table 3. The means of all seven voice parameters for the PD group are not significantly different from the means of the control group.

Table 2. Mean value on seven voice parameters between PD group and control group

| Parameters | PD | Control |
| --- | --- | --- |
| **F0 (Hz)** | 149.73 ± 26.12 | 158.41 ± 34.20 |
| **Jitt (%)** | 1.88 ± 1.37 | 1.79 ± 1.30 |
| **RAP (%)** | 1.10 ± 0.80 | 1.08 ± 0.79 |
| **PPQ (%)** | 1.13 ± 0.95 | 1.05 ± 0.80 |
| **Shim (%)** | 5.43 ± 4.15 | 4.95 ± 2.25 |
| **APQ (%)** | 4.08 ± 3.10 | 3.80 ± 1.51 |
| **NHR** | 0.16 ± 0.07 | 0.16 ± 0.04 |

Note:
F0 = Average Fundamental Frequency
Jitt = Jitter Percent
RAP = Relative Average Perturbation
PPQ = Pitch Perturbation Quotient
Shim = Shimmer Percent
APQ = Amplitude Perturbation Quotient
NHR = Noise to Harmonic Ratio
In x ± y, x refers to the mean value while y refers to standard deviation.

Table 3. Independent-samples t-test results in comparing PD group and control group based on seven voice parameters

| **Parameters** | ***T* score** | ***P* value** |
|---|---|---|
| **F0 (Hz)** | -.806 | .426 |
| **Jitt (%)** | .206 | .838 |
| **RAP (%)** | .072 | .943 |
| **PPQ (%)** | .278 | .783 |
| **Shim (%)** | .407 | .687 |
| **APQ (%)** | .330 | .744 |
| **NHR** | .069 | .945 |

Note:
F0 = Average Fundamental Frequency
Jitt = Jitter Percent
RAP = Relative Average Perturbation
PPQ = Pitch Perturbation Quotient
Shim = Shimmer Percent
APQ = Amplitude Perturbation Quotient
NHR = Noise to Harmonic Ratio

### 3.2 Maximum Sound Prolongation (MSP)

In order to examine the capability of MSP in two groups, Table 4 displays the MSP for vowel /a/ and three fricatives. The results of Table 4 reveal that the control group can sustain an /a/ sound much longer than the PD group. An independent-samples t-test has been calculated to compare the mean /a/ MSP of the PD group and control group. There is a significant difference between the means of the two groups: $t$ (30) = -2.123, $p$ < .05. The mean /a/ MSP of the PD group is significantly lower than the mean of the control group.

Moreover, when we compare the MSP for the three fricative consonants, it is clear that the control group is capable of producing a longer phonation for all three fricatives which are much longer than the PD group, as can be seen in Table 4. In terms of the capability of voicing distinction in both groups, Table 4 shows that both groups can produce a longer MSP of /z/ than for /s/. An independent-samples t-test has been calculated to compare the mean MSP of /f/, /s/, and /z/ of the two groups, and it is observed that there is a significant difference for /f/, $t$ (30) = -2.348, $p$ < .05, a significant difference for /s/, $t$ (30) = -2.749, $p$ < .05, and a significant difference for /z/, $t$ (30) = -2.143, $p$ < .05, between the two groups. Therefore, it can be concluded that the mean MSP of /f/, /s/, and /z/ of the PD group is significantly lower than the mean of the control group.

In order to examine the capability of voicing distinction in both groups, a 2 x 2 mixed–design ANOVA has been calculated to examine the effects of the groups (PD group, control group) and voicing (voiceless /s/, voiced /z/) on their mean MSP, as

Table 5 shows. The main effect for voicing turns out to be significant, $F$ (1, 30) = 11.297, $p < .01$. The main effect for groups is also significant, $F$ (1, 30) = 8.201, $p < .01$, although the Voicing x Group interaction was found to have no significant difference, $F$ (1, 30) = 0.060, $p > .05$. This indicates that voiced consonant have a higher mean MSP than voiceless consonants in both groups.

Table 4. Mean maximum sound prolongation of vowel /a/ and three fricatives /f/, /s/, /z/ in both PD and control group

| **Tasks** | **PD** | **Control** | ***T* score** | ***P* value** |
|---|---|---|---|---|
| **/a/ duration (sec)** | 7.32 ± 4.08 | 11.31 ± 6.32 | -2.123 | .042* |
| **/f/ duration (sec)** | 3.50 ± 2.22 | 6.02 ± 3.69 | -2.348 | .026* |
| **/s/ duration (sec)** | 4.74 ± 1.82 | 8.90 ± 5.77 | -2.749 | .010* |
| **/z/ duration (sec)** | 7.89 ± 4.48 | 11.62 ± 5.32 | -2.143 | .040* |

Note:
* $p < .05$.
In x ± y, x refers to the mean value while y refers to standard deviation.

Table 5. A 2 x 2 mixed–design ANOVA for the effects of the groups (PD group, control group) and voicing (voiceless /s/, voiced /z/) on their mean MSP (sec)

| **Source** | ***F* ratio** | ***P* value** |
|---|---|---|
| **Group** | 8.201 | .008** |
| **Voicing** | 11.297 | .002** |
| **Group x Voicing** | 0.060 | .809 |

Note:
** $p < .01$.

### 3.3 S/Z Ratio

S/Z ratio is another measure for examining the individual's articulatory and phonatory capabilities of speakers. Table 6 reveals the S/Z ratio for both the PD group and control group. The results show that the mean S/Z ratio of the two groups is quite close. In order to find the statistical significance, a further independent-samples t-test has been calculated to compare the mean S/Z ratio of the PD and control groups. We can see that there is no significant difference between the mean S/Z ratio of the two groups: $t$ (30) = -0.397, $p > .05$. In other words, the S/Z ratio for the PD group cannot be distinguished from that for the control group.

Table 6. Mean S/Z ratio for PD and control group

| Task | PD | Control | *T* score | *P* value |
|---|---|---|---|---|
| **S/Z ratio** | 0.71 ± 0.23 | 0.76 ± 0.41 | -.397 | .694 |

Note:
In x ± y, x refers to the mean value while y refers to standard deviation.

# 4. DISCUSSION

## 4.1 Voice Quality

When comparing the voice quality in the PD group with that of the control group, no significant difference in F0 was found, a result consistent with the study of Zwirner, Murry, and Woodson. In spite of no significant difference in F0 between the PD and control groups, 3 out of the 16 patients in the present study have been observed to have particularly low F0 values, approximately 115 Hz, showing that these patients may not be capable of vibrating their vocal folds as fast as the controls do.

In terms of the results in NHR, no significant difference has been found between the PD and control groups. The results in NHR resemble the findings in the study of Chen and Lin, who find no significant difference in NHR between talkers with self-reported voice problem and controls. However, according to Chu et al., HNR, the reciprocal for NHR, will be small in talkers with vocal fold problems. That is to say, NHR should be larger if talkers have vocal fold problems.

The results in Jitt, RAP, PPQ, Shim, and APQ, however, are mostly inconsistent with the previous literature. Jitt, for example, is statistically higher in PD patients as reported in study of Gamboa et al. In addition, Colton, Casper, and Leonard demonstrate that higher values in PPQ and Shim are found in people with vocal problems. According to Kitajima and Gould, Shim can serve as a good indicator when differentiating a pathologic voice from a normal one. With regard to finings in the present research which are inconsistent findings in the previous literature, there may be two main reasons for the contradictory results. First, they may be due to the limited numbers of participants in the current study. Due to the small number of participants studied, it is uncertain to what extent the reported results are reliable. Additionally, although all the PD patients were diagnosed by neurologist and reported to have hypokinetic dysarthria, no further evaluation had been conducted on the severity of dysarthria by speech therapists. Assessment with Hoehn & Yahr Scale evaluates the overall body movements rather than just speech production itself.

The finding in terms of voice quality in the control group has also been compared with findings from previous literature, as Table 7 shows. Table 7 compares voice quality in male controls with normative threshold by Kay Elemetrics, and findings in study of Xue and Deliyski, as well as in study of Wang and Huang based on seven parameters. Since we only recruit male subjects, only male controls are compared and discussed with other studies. It shows that male controls in the current study tend to have higher F0 than those male controls in the normative threshold and the other two studies. Jitt and Shim in the male controls in the current study have similar results as the study of Xue and Deliyski rather than the normative threshold or the results of Wang and Huang. Moreover, RAP, PPQ, APQ in the male controls in the current study have lower than the normative threshold. On the other hand, NHR in the male controls in the current study are much lower than the normative threshold while quite similar to those reported in study of Xue and Deliyski. The possible reason may be the different age population. Xue and Deliyski restricted their subjects to elderly controls with a mean age of 75.43 years old, close to the age of the control subjects in the present study. The normative threshold developed by Kay Elemetrics may have been from subjects not recruited from the elderly population. Wang and Huang also recruited subjects from 20 to 49 years old, clearly not elderly.

Table 7. Mean value of seven voice parameters in control group compared with previous literatures

| Parameters | Controls (in current study) | Normative threshold (Kay Elemetrics) | | Elderly control (Xue and Deliyski) | | Controls (Wang and Huang) | |
|---|---|---|---|---|---|---|---|
| **Sex** | M | M | F | M | F | M | F |
| **F0 (Hz)** | 158.40 ± 34.20 | 145.22 ± 23.41 | 244.00 ± 27.46 | 127.62 ± 29.18 | 187.70 ± 42.15 | 121.30 ± 16.40 | 213.40 ± 25.40 |
| **Jitt (%)** | 1.79 ± 1.30 | 0.59 ± 0.53 | 0.63 ± 0.35 | 2.10 ± 1.55 | 2.02 ± 2.03 | 0.56 ± 0.23 | 0.66 ± 0.27 |
| **RAP (%)** | 1.08 ± 0.79 | 0.35 ± 0.33 | 0.38 ± 0.21 | – | – | – | – |
| **PPQ (%)** | 1.05 ± 0.80 | 0.34 ± 0.29 | 0.37 ± 021 | – | – | – | – |
| **Shim (%)** | 4.95 ± 2.25 | 2.52 ± 1.00 | 1.20 ± 0.8 | 5.54 ± 3.51 | 5.34 ± 4.51 | – | 1.83 ± 2.60 |
| **APQ (%)** | 3.80 ± 1.51 | 1.99 ± 0.80 | 1.40 ± 0.53 | – | – | – | – |
| **NHR** | 0.16 ± 0.04 | 12.2 ± 0.01 | 11.20 ± 0.01 | 0.18 ± 0.08 | 0.20 ± 0.11 | – | – |

Note:
F0 = Average Fundamental Frequency
Jitt = Jitter Percent
RAP = Relative Average Perturbation
PPQ = Pitch Perturbation Quotient
Shim = Shimmer Percent
APQ = Amplitude Perturbation Quotient
NHR = Noise to Harmonic Ratio
In x ± y, x refers to the mean value while y refers to standard deviation.

**4.2 Maximum Sound Prolongation (MSP) and S/Z Ratio**

In the present study, the PD group had a poorer performance on the MSP of the sound /a/, and three fricatives, /f/, /s/, as well as /z/. According to Colton, Casper, and Leonard, MSP can measure one's respiratory capacity and phonatory control. It seems that the PD group does not have enough respiratory and phonatory control. Kent, Kent, and Rosenbek assert that MSP is associated with phonation volume, especially vital capacity, and also air flow through the larynx. It seems that the PD group has poorer vital capacity, and also weaker air flow through the larynx.

As regards MSP of fricatives, they are associated with the S/Z ratio. According to Kent, Kent, and Rosenbek, measuring the sustained fricative phonation can provide information about individual's articulatory and phonatory performance. The current study finds no significant difference between PD group and control group in terms of S/Z ratio, which resembles with the Gamboa et al.'s finding. According to Boone, however, the S/Z ratio is larger for subjects with laryngeal impairments. Eckel and Boone further point out that an S/Z ratio tends to be in excess of 1.4 in dysphonic subjects with laryngeal pathology while control subjects have about only 1.0 for S/Z ratio. Chu et al. also state that when the S/Z ratio is larger than 1.4, there might be laryngeal-related disorders. It seems that PD subjects in the current study and in Gamboa et al. do not show serious laryngeal impairments. Since this present study is a preliminary study, further information about severity of laryngeal impairments is not included. Further research is needed to verify the relation between laryngeal impairments and S/Z ratio.

## 5. CONCLUSION

With the average age of populations all over the world increasing, Parkinson's disease has become a noticeable health problem, and is expected to increase in the future. Parkinson's disease (PD), also termed idiopathic parkinsonism, is a neurodegenerative disorder mainly denoted by a loss of dopaminergic neurons (Lang and Lozano; Widnell; Li, Li, and Wang; Olanow, Stern, and Sethi; Patel et al.). The goal of the present study is to assess the differences in speech performance between a PD group and controls by employing three measures: (1) voice quality, (2) maximum sound prolongation (MSP), (3) S/Z ratio. Sixteen male patients diagnosed with PD with a Hoehn & Yahr Stage 2 to 4 were recruited from a hospital in Southern Taiwan. Sixteen controls, matched for age, sex, and native language with the PD patients, also participated in this study. The present study has collected data by only taking sound recording in which maximum performance tasks is performed.

To answer the research question about the speech deficits found in PD patients with dysarthria, the results show that although voice quality and S/Z ratio did not statistically distinguish PD patients from controls, PD patients performed statistically poorer on maximum sound prolongation than controls. They are relatively unable to sustain certain sounds. Maximum sound prolongation seems to be better indicator to differentiate patients with voice problems, compared with voice quality and S/Z ratio.

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## Appendix

Appendix . Simple health evaluation form for controls

**健康狀況評估**

姓名：______________

日期：______________

◆ 過去病史

1. 您是否經醫師診斷有下列疾病？□無 □有(請勾選下列的疾病，可複選)

□高血壓 □糖尿病 □腦中風 □血脂肪過高 □尿酸過高 □心臟病

□腎臟病 □肝病 □氣喘 □肺結核 □甲狀腺疾病 □失眠症 □精神病

□癌症(部位：______________) 其他__________________________

曾經手術：□無 □有(請描述在什麼時候開？在哪裡開？開什麼刀？)

____________________________________________________________________

2. 您是否有經醫師診斷有神經相關疾病？□無 □有(請勾選下列的疾病，可複選)

□巴金森氏症 □舞蹈症 □癲癇 □失智症 □顏面神經麻痺 □暈眩

□三叉神經痛 □肌肉痠痛(部位： ) 其他_________________

◆ 簡易動作檢測

1. 觀察受試者靜止時四肢是否有顫抖現象。

□無 □偶爾且較少出現 □輕微但常常出現或但中度較少出現 □中度且常常出現 □很嚴重且常常出現

2. 請輪流將一隻手的大拇指和食指相互快速連續點擊觸碰。

□正常 □輕微較慢 □中度緩慢 □嚴重緩慢 □幾乎無法執行

3. 請輪流將一隻腳腳掌快速連續點擊觸碰地板。

□正常 □輕微較慢 □中度緩慢 □嚴重緩慢 □幾乎無法執行

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