A Nonspeech Investigation of Tongue Function in Parkinson’s Disease

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Background. Nonspeech investigations of tongue function in persons with Parkinson’s disease (PD) have generally reported impaired tongue strength, endurance, and fine force control. However, these investigations did not specifically evaluate the relative contribution of age effects to the deficits in tongue function observed. Furthermore, the relationship between these nonspeech measures of tongue function and the speech disorder present in PD remains equivocal. Therefore, the current study investigated the strength, rate of repetitive movement, fine force control, and endurance of the tongue in three groups of participants.

Methods. Participants in the study included 14 older adults with PD and imprecise consonant articulation, 11 neurologically healthy older adults, and 15 neurologically healthy young adults. All participants were assessed using a comprehensive nonspeech assessment battery of tongue function.

Results. The results of the investigation revealed similar levels of tongue strength, rate of repetitive movement, and endurance between the persons with PD and the older control participants. Significant age effects were noted, with both groups demonstrating significantly reduced functioning on those measures when compared to young control participants. However, the three participant groups had similar levels of fine force control. No relationship was found between the nonspeech measures of tongue function employed and the severity of consonant imprecision.

Conclusion. The nonspeech measures used failed to provide useful diagnostic information regarding the physiologic basis of perceived articulatory dysfunction in the persons with PD who were examined.

Speech disorders affect 60% to 80% of persons with Parkinson’s disease (PD) (1) and strongly influence their quality of life (2). In particular, articulatory disorders (e.g., consonant imprecision) have been reported in 45% of persons with PD (3). Previous research has contended that reduced strength and endurance of the articulators may contribute to the speech disorder associated with PD (4). Furthermore, impaired fine motor control has also been cited as a possible factor underlying the articulatory imprecision (5–7). The physiologic mechanism responsible for the articulatory disorder present in PD is unknown (4). Furthermore, without direct instrumental investigation of the articulatory subsystem, it is impossible to determine which physiologic mechanism (or mechanisms) contributes to imprecision of consonants.

Nonspeech measures of tongue function have previously been used in an attempt to determine whether a physiologic deficit in tongue function is present in persons with PD. These studies indicate a general pattern of variation in tongue strength and an overall trend toward tongue weakness in the persons examined (4,8–10). Furthermore, instability of the lingual musculature (8,11) and impaired tongue endurance have also been reported (9). However, the relationship, if any, between these nonspeech measures of tongue function and actual speech output remains controversial (12). Specific to PD, the results of previous studies have been equivocal. Some studies have reported the presence of, or trend toward, significant correlations between nonspeech measures of tongue function and speech production (4), whereas others have reported an absence of significant correlations (9).

Because PD is a disorder of middle to late life (13), the effect of aging on the speech mechanism must also be considered. Previous investigations have noted that reduced tongue strength occurs as a consequence of increased age (14–16). Although previous investigations have matched persons with PD to controls of similar age (4,9–11), direct comparisons of tongue strength, endurance, rate of repetitive movements, and fine force control have not been conducted in persons with PD, older control participants, and young control participants. This information is important if we are to determine which particular articulatory deficits, if they exist, are related to the aging of the lingual musculature and which are the products of the disease itself.

Therefore, our aim in the current study was to assess the strength, rate of repetitive movement, fine force control, and endurance of the tongue in three groups: participants with PD and consonant imprecision, older control participants, and young control participants. In addition, another goal was to determine whether a relationship exists between the degree of consonant imprecision evidenced by persons with PD and their performance on nonspeech measures of tongue function.

Methods

Participants

The participant group consisted of 14 persons, 13 men and 1 woman, with PD that was diagnosed by a neurologist. The mean age of the group with PD was 68.36 years (SD = 8.52 years) and the age range was 56 to 83 years. Table 1 lists
specific biographical and medical details of the participants with PD. We judged participants as appropriate for inclusion in the study if they exhibited a perceptible speech disturbance involving imprecision of consonants as assessed by two speech-language pathologists. Exclusion criteria included history of any neurologic disease or disorder with the exception of PD, previous neurosurgical intervention for PD, a history of speech disorders with the exception of that associated with PD, surgery that involved the lips or tongue, drug or alcohol abuse, or dementia. All persons with PD exhibited hearing adequate to participate in the study. In contrast, however, participants did not report any hearing loss and all exhibited hearing adequate to participate in the study.

### Procedures

We rated the participants with PD on both perceptual and instrumental measures of articulatory function. In contrast, we examined participants from the OC and YC groups based on the instrumental assessment of tongue function only. A speech-language pathologist judged that the control group participants exhibited perceptually normal speech.

#### Perceptual assessment of articulatory function

We included two examinations of articulatory function in the perceptual component of the current investigation. First, a speech-language pathologist rated each participant on the tongue function component of the Frenchay Dysarthria Assessment (17), an evaluation of oral motor function. For each participant, we rated features including appearance, movement, and function according to a nine-point rating scale. On this scale, a score of eight (or “a”) indicated normal function and a score of zero (or “e”) indicated no function.

Second, participants read a standard passage (the Grandfather Passage) that was audiotaped and their speech was later judged independently by two qualified speech-language pathologists on the articulatory parameters of precision of consonants, length of phonemes, and precision of vowels using a perceptual rating scale (18). On this scale, a rating of one = no impairment, two = just noticeable impairment, three = moderate impairment, and four = severe impairment for precision of consonants and precision of vowels. However, for length of phonemes the ratings were: one = no impairment, two = just noticeable prolongation of phonemes, three = a moderate degree of prolongation of phonemes, four = a just noticeable prolongation of length of phonemes, five = normal length of phonemes, six = a moderate reduction in length of phonemes, and seven = a severe reduction in length of phonemes.

If the judges differed in their perceptual ratings for a particular parameter, a further rating session was conducted. During this rating session, both judges conferred to produce a single consensus rating for each dimension. We used this rating in the analysis of the results. Interjudge reliability was calculated by comparing the results of the judges on the three perceptual parameters. A Spearman’s rho rank correlation indicated a high mean degree of reliability in which rho = .93 (p < .001) between the two judges. The speech samples of 4 of the 14 participants (29%) were rated by each judge so that a measure of intrajudge reliability could be calculated (rating 1 vs rating 2). Results revealed that both judges displayed a high degree of intrajudge reliability. Judge 1 obtained a correlation coefficient of rho = .94 (p < .001), and judge 2 obtained a correlation coefficient of rho = .85 (p = .001).

#### Instrumental assessment of articulatory function

We used a tongue pressure transducer system that consisted of an air-filled rubber bulb connected to a pressure transducer. The bulb was a 1-ml pliable latex rubber pipette bulb attached to a solid cylindrical plastic piece that acted as a bite block (Figure 1). A thin flexible rubber tube was passed through the midline of the bite block that connected the tongue bulb to the pressure transducer. A groove was cut into the bite block to aid placement of the incisors and to standardize the placement of the bulb among the participants. Furthermore, the groove ensured correct placement of the tongue in the anterior two thirds of the mouth for the duration of the assessment. During each assessment, a disposable sterile plastic sleeve was placed over the tongue.

### Table 1. Biographical and Medical Details of the 14 Persons With Parkinson’s Disease

<table>
<thead>
<tr>
<th>Participant</th>
<th>Sex</th>
<th>Age, Years</th>
<th>Post-Onset Years</th>
<th>Hoehn &amp; Yahr</th>
<th>Consonant Imprecision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>62</td>
<td>6</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>74</td>
<td>4</td>
<td>2.0</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>83</td>
<td>16</td>
<td>2.0</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>63</td>
<td>20</td>
<td>4.0</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>79</td>
<td>10</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>67</td>
<td>8</td>
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<td>2</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>73</td>
<td>6</td>
<td>3.0</td>
<td>2</td>
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<tr>
<td>8</td>
<td>M</td>
<td>63</td>
<td>3</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>61</td>
<td>8</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>71</td>
<td>5</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>81</td>
<td>13</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>64</td>
<td>2</td>
<td>2.0</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>60</td>
<td>8</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>56</td>
<td>10</td>
<td>3.0</td>
<td>2</td>
</tr>
</tbody>
</table>

Notes: Hoehn & Yahr = Participant’s rating on the Parkinson’s disease clinical disability scale (Hoehn & Yahr, 1967).

For severity of consonant imprecision, 1 = no impairment, 2 = just noticeable imprecision, 3 = moderate imprecision, and 4 = severe consonant imprecision.

M = male; F = female.
bulb as a sanitation precaution. We used a pressure transducer (model R22k; Modus Instruments, Clinton, MA) in the investigation. The pressure transducer exhibited a range of 0 to 10 PSI and an accuracy of ±0.5% of the maximum range. This allowed for nonlinearity and hysteresis. The DC output from the pressure transducer was digitized online at a sampling rate of 25 Hz. We used a purpose-written, in-house software program to display the output of the system from each task in kilopascals.

Before beginning the assessments, we instructed each participant on the operation of the tongue bulb. The tongue bulb was then placed in the participant’s mouth and he or she was instructed to squeeze the bulb with the anterior portion of the tongue (not the tip) against the hard palate while keeping the jaw in a fixed position. This was achieved by having the participant bite down on the grooved section of the bite block. As a result, jaw stabilization was maintained and the pressures generated by the tongue could be assessed independently of potential jaw movement contributions. A research assistant provided further assistance with jaw stability and correct tongue bulb positioning by holding the tongue bulb in place.

The tongue transducer assessment protocol consisted of five nonspeech tasks used to provide information regarding the strength, rate of repetitive movement, fine pressure control, and endurance of the tongue musculature. We used a maximum pressure-based scaling board, and thus the target pressure of each participant was referenced to his or her maximal tongue pressure (MTP) rather than to a predetermined pressure level. As a result, each participant was first required to produce his or her MTP as a measure of overall tongue strength. The tasks included in the assessment protocol were as follows:

1. MTP: The participants were instructed to press their tongues as hard as they could against the tongue bulb (and subsequently the hard palate) and then relax. The participants completed three trials of this task.
2. Fine tongue pressure control (FTPC): The participants were instructed to press their tongues against the tongue bulb until a pressure of 50%, 20%, and 10% of their MTP was reached (as indicated by a visual display). Once reached, a trace moved across the screen that corresponded to time and pressure level. The participants were required to maintain their tongue pressure at the set pressure level for 5 seconds. The participants completed two trials of this task.
3. Repetition of MTP: Participants were instructed to squeeze their tongues as hard as they could against the tongue bulb and then relax at a rate of one repetition per second for 10 seconds. The participants completed two trials of this task.
4. Fast rate of repetitions of MTP: Participants were instructed to squeeze their tongues against the tongue bulb as hard as they could and then relax as many times as possible during a 10-second period. They completed two trials of this task.
5. Sustained submaximal tongue pressure (SSTP): Participants were instructed to sustain 50% of their own MTP for as long as possible (as indicated on a visual display). Timing ended when the participants’ pressure levels remained consistently below 40% of their MTP. The participants completed two trials of this task.

We measured all pressures generated from these tasks in kilopascals. Participants were allowed adequate rest breaks between trials. We used only each participant’s best attempt in subsequent data analysis. We extracted eight measures of tongue functioning from the five tasks. These measures were as follows:

1. Maximum tongue pressure.
2. Fine tongue pressure control at 50% of the participant’s maximum pressure (FTPC50).
3. Fine tongue pressure control at 20% of the participant’s maximum pressure (FTPC20).
4. Fine tongue pressure control at 10% of the participant’s maximum pressure (FTPC10).
5. Mean tongue pressure over 10 repetitions of MTP.
6. Mean number of repetitions during a fast rate MTP task.
7. Mean pressure generated during the fast rate MTP task.
Table 2. Frequency of Occurrence and Degree of Severity of Each Articulatory Speech Dimension Exhibited by the Persons With Parkinson’s Disease (N = 14)

<table>
<thead>
<tr>
<th>Speech Dimension</th>
<th>Incidence of Deviation in PD Group</th>
<th>Severity of Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Precision of consonants</td>
<td>14</td>
<td>100.00</td>
</tr>
<tr>
<td>Phoneme length</td>
<td>10</td>
<td>71.43</td>
</tr>
<tr>
<td>Precision of vowels</td>
<td>7</td>
<td>50.00</td>
</tr>
</tbody>
</table>

Notes: PD = Parkinson’s disease; N = number of participants exhibiting the particular deviant speech feature.

8. Sustained submaximal tongue pressure (a measure of tongue endurance in seconds).

RESULTS

Perceptual Assessment

Speech sample analysis.—As a group, the participants with PD demonstrated a mean score of 2.43 (SD = 0.65) on the parameter of precision of consonants. This result indicated that the participant group displayed a just noticeable to moderate impairment in consonant precision. When we evaluated participant scores individually, all participants displayed at least a just noticeable degree of consonant imprecision in their speech sample. Nine participants demonstrated a mild degree of consonant imprecision, four participants showed a moderate degree of consonant imprecision, and one participant had severe consonant imprecision. Table 2 lists the frequency of occurrence and degree of severity of the articulatory speech dimensions in the participants with PD.

The participant group with PD achieved a score of 4.29 (SD = 1.07) for length of phonemes. This result indicated that, overall, the participants’ phonemes were of a normal length. However, the group mean was affected by the presence of both increased and decreased phoneme lengths in the participant group. Seventy-one percent of the participants with PD were perceived to exhibit deviant phoneme lengths. Eight participants displayed mildly affected length of phonemes. Of these participants, six showed a reduction in length of phonemes and two had a prolongation of phoneme length. One participant with a moderate deficit demonstrated a reduction in phoneme length, whereas the other had a moderate degree of prolongation of phonemes (Table 2).

The participant group with PD demonstrated a mean rating of 1.64 (SD = 0.74) for precision of vowels. This indicated that participants exhibited vowel production that was normal to just noticeably imprecise. When the occurrence of this deficit was evaluated, only 50% of participants were perceived to display vowel imprecision. Five demonstrated a just noticeable imprecision of vowels, whereas two participants had a moderate imprecision of vowels (Table 2).

Frenchay dysarthria assessment.—Analysis revealed that the participants with PD had deficits in tongue function. Group mean scores (and standard deviations) on the parameters measured are reported in the text after the parameter. Results indicated that the group with PD exhibited mild abnormality of the tongue at rest (M = 7.07, SD = 0.92). In addition, tongue protrusion (M = 6.29, SD = 1.07), elevation (M = 5.21, SD = 1.05), and lateral movement (M = 6.21, SD = 1.37) were all completed slowly but with normal movement. Furthermore, the group exhibited mild difficulty in the alternate motion task (M = 6.21, SD = 1.19), evidencing some incoordination and slowness. During speech production, tongue movement was slightly inaccurate with occasional mispronunciations (M = 6.14, SD = 0.86).

Instrumental analysis of tongue function.—After initial screening of the data set, we excluded the results of two participants from the OC group from analysis as outliers on the SSTP (endurance) task. The two participants had SSTP scores of 122.70 and 212.27 seconds. These endurance scores were 11 and 22 standard deviations above the group mean for endurance, respectively. Thus, we removed their data from analysis for the parameter of SSTP only. Because the YC group included more female participants, Mann-Whitney U tests were also conducted on all results of the YC group to determine whether any sex effects existed in the data. The results of the Mann-Whitney U tests indicated that no significant differences existed between the male and female participants in this group on any parameters (p > .144).

After these initial screening procedures, we evaluated the data for homogeneity of variance. We considered homogeneity of variance for each of the parameters of tongue function using Levene’s test for homogeneity of variance (19). The variance assumption was violated in six of the eight parameters. As a result, we used the nonparametric Kruskal-Wallis one-way analysis of variance in all data analysis procedures. We applied a significance level of p ≤ .05 across all comparisons. We conducted post hoc analyses using Mann-Whitney U tests, again with a significance level of p ≤ .05.

Comparison of Instrumental Measures of Tongue Function Across the Three Groups

Table 3 shows the mean and standard deviation scores obtained by the three participant groups across physiologic measures of tongue function. Statistical analysis revealed significant differences (p < .01) between the three groups on the parameters of MTP, mean pressure across 10 repetitions of MTP, rate of fast repetition of MTP, mean pressure during fast repetition of MTP, and SSTP. We found no significant differences (p > .05) between the three groups on the parameters of FTPC at 50%, 20%, and 10% of MTP. Such a result indicated that participants in the three groups had similar levels of fine force control of the tongue at these levels of pressure.

Post hoc analysis revealed that for the parameter of MTP, both the participants with PD and those in the OC group had significantly reduced MTPs when compared with the
of MTP (kPa); FRMTP-R below the 10% target pressure); RMPT fine tongue pressure control at 50% of MTP (standard deviation [SD] of pressure changes above and below the 50% target pressure); FTPC20 = fine tongue pressure control at 20% of MTP (SD of pressure changes above and below the 20% target pressure); FTPC10 = fine tongue pressure control at 10% of MTP (SD of pressure changes above and below the 10% target pressure); RMPT = mean pressure following 10 repetitions of MTP (kPa); FRMTP-R = mean number fast repetitions of the MTP (rate); FRMTP-P = mean pressure during the fast repetition of MTP task (kPa); SSTP = sustained submaximal tongue pressure (a measure of endurance in seconds).

YC participant group (p < .05). Furthermore, both the participants with PD and the OC participants had significantly reduced MTP across 10 repetitions when compared with the YC group (p < .05). Furthermore, participants with PD and OC participants had significantly reduced numbers of fast repetition MTP tasks (p < .05), mean pressure during fast repetition MTP values (p < .01), and SSTP values (p < .01) when compared with YC participants. These results indicated that both the participants with PD and the OC participants demonstrated significantly reduced numbers of repetitions and tongue pressures on the fast rate task and significantly reduced SSTPs (or endurance) when compared with the YC participants. No significant differences were revealed between the participants with PD and the OC participant group on any of the parameters investigated. This result indicated that the participants with PD and the OC group had similar levels of MTP, mean pressure across 10 repetitions of MTP, number of repetitions in the fast rate task, mean pressure across all repetitions on the fast rate task, and the SSTP task (p > .05). Table 4 shows the results of the post hoc analysis.

Relationship Between the Severity of Perceived Consonant Imprecision and Instrumental Measures of Tongue Function

Because we found no significant differences between the participant group with PD and the OC participant group on any measure of tongue function, we thought that a relationship may exist between the severity of perceived consonant imprecision and the instrumental measures of tongue function. Therefore, we further separated the participant group with PD into two groups: one group of nine participants who had a mild degree of perceived consonant imprecision and a second group of five participants who had either a moderate or severe degree of perceived consonant imprecision. Again, we used the Kruskal-Wallis analysis of variance to determine whether significant differences existed between the three groups on instrumental measures of tongue function. Table 5 shows the mean and standard deviation scores and results of the Kruskal-Wallis analysis of variance.

We found no significant differences between the three groups on any of the eight instrumental measures of tongue function (p > .05). These results indicated that persons with mild degrees of consonant imprecision and those with moderate to severe degrees of consonant imprecision had levels of functioning on instrumental measures of tongue function that were similar both to themselves and to OC participants.

Table 3. Comparison of the Mean Values Obtained From the Tongue Transducer Assessment by the Persons With Parkinson’s Disease (N = 14), Older Adult Control Group (N = 13), and Young Control Group (N = 15)

<table>
<thead>
<tr>
<th>Tongue Parameter</th>
<th>PD Group Mean</th>
<th>PD Group SD</th>
<th>OC Group Mean</th>
<th>OC Group SD</th>
<th>YC Group Mean</th>
<th>YC Group SD</th>
<th>χ²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTP</td>
<td>27.53</td>
<td>12.64</td>
<td>27.60</td>
<td>4.89</td>
<td>36.92</td>
<td>6.44</td>
<td>10.27</td>
<td>.006*</td>
</tr>
<tr>
<td>FTPC50</td>
<td>2.11</td>
<td>2.42</td>
<td>2.05</td>
<td>1.11</td>
<td>1.42</td>
<td>0.58</td>
<td>3.33</td>
<td>.189</td>
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<tr>
<td>FTPC20</td>
<td>1.09</td>
<td>0.94</td>
<td>1.30</td>
<td>0.85</td>
<td>0.93</td>
<td>0.42</td>
<td>1.16</td>
<td>.561</td>
</tr>
<tr>
<td>FTPC10</td>
<td>0.81</td>
<td>0.70</td>
<td>0.78</td>
<td>0.83</td>
<td>0.55</td>
<td>0.28</td>
<td>0.24</td>
<td>.888</td>
</tr>
<tr>
<td>RMPT</td>
<td>21.65</td>
<td>12.22</td>
<td>21.73</td>
<td>5.58</td>
<td>31.68</td>
<td>6.42</td>
<td>11.35</td>
<td>.003*</td>
</tr>
<tr>
<td>FRMTP-R</td>
<td>15.50</td>
<td>10.46</td>
<td>12.12</td>
<td>2.57</td>
<td>18.73</td>
<td>4.54</td>
<td>10.96</td>
<td>.004*</td>
</tr>
<tr>
<td>FRMTP-P</td>
<td>20.76</td>
<td>10.44</td>
<td>21.61</td>
<td>4.44</td>
<td>30.93</td>
<td>5.36</td>
<td>14.59</td>
<td>.0011</td>
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<tr>
<td>SSTP</td>
<td>26.31</td>
<td>14.65</td>
<td>23.85</td>
<td>8.70</td>
<td>49.85</td>
<td>23.60</td>
<td>9.31</td>
<td>.009*</td>
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</table>

Notes: *p < .1.

Table 4. Post Hoc Comparison of Mean Values Obtained From the Tongue Transducer Assessment by the Persons With Parkinson’s Disease (N = 14), Older Control Group (N = 13), and Young Control Group (N = 15)

<table>
<thead>
<tr>
<th>Tongue Parameter</th>
<th>PD Versus OC Mean</th>
<th>PD Versus OC SD</th>
<th>OC Versus YC Mean</th>
<th>OC Versus YC SD</th>
<th>χ²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTP</td>
<td>88.00</td>
<td>.905</td>
<td>55.00</td>
<td>.029*</td>
<td>26.00</td>
<td>.001</td>
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<td>RMPT</td>
<td>89.00</td>
<td>.943</td>
<td>53.00</td>
<td>.023*</td>
<td>22.00</td>
<td>&lt;.001</td>
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<tr>
<td>FRMTP-R</td>
<td>90.50</td>
<td>.981</td>
<td>57.00</td>
<td>.017*</td>
<td>21.00</td>
<td>&lt;.001</td>
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<tr>
<td>FRMTP-P</td>
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<td>.616</td>
<td>41.00</td>
<td>.004*</td>
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<tr>
<td>SSTP</td>
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<td>47.00</td>
<td>.010*</td>
<td>32.00</td>
<td>.0081</td>
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Notes: *p = .05.

Table 5. Comparison of the Mean Values Obtained From the Tongue Transducer Assessment by the Participant Group With Mild Consonant Imprecision (N = 9), Participant Group With Moderate Consonant Imprecision (N = 5), and Older Control Group (N = 13)

<table>
<thead>
<tr>
<th>Tongue Parameter</th>
<th>Mild Group Mean</th>
<th>Mild Group SD</th>
<th>Mod/Sev Group Mean</th>
<th>Mod/Sev Group SD</th>
<th>OC Group Mean</th>
<th>OC Group SD</th>
<th>χ²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTP</td>
<td>27.42</td>
<td>12.42</td>
<td>27.72</td>
<td>14.32</td>
<td>27.60</td>
<td>4.89</td>
<td>0.10</td>
<td>.952</td>
</tr>
<tr>
<td>FTPC50</td>
<td>2.09</td>
<td>2.88</td>
<td>2.14</td>
<td>1.53</td>
<td>2.05</td>
<td>1.11</td>
<td>2.73</td>
<td>.255</td>
</tr>
<tr>
<td>FTPC20</td>
<td>1.12</td>
<td>1.10</td>
<td>1.03</td>
<td>0.66</td>
<td>1.30</td>
<td>0.85</td>
<td>0.92</td>
<td>.631</td>
</tr>
<tr>
<td>FTPC10</td>
<td>0.76</td>
<td>0.72</td>
<td>0.90</td>
<td>0.73</td>
<td>0.78</td>
<td>0.83</td>
<td>0.13</td>
<td>.936</td>
</tr>
<tr>
<td>RMPT</td>
<td>22.56</td>
<td>11.86</td>
<td>20.02</td>
<td>14.11</td>
<td>21.73</td>
<td>5.38</td>
<td>0.35</td>
<td>.840</td>
</tr>
<tr>
<td>FRMTP-R</td>
<td>17.89</td>
<td>11.70</td>
<td>22.10</td>
<td>6.79</td>
<td>21.73</td>
<td>2.57</td>
<td>1.66</td>
<td>.435</td>
</tr>
<tr>
<td>FRMTP-P</td>
<td>21.36</td>
<td>11.02</td>
<td>19.67</td>
<td>10.43</td>
<td>21.61</td>
<td>4.44</td>
<td>0.13</td>
<td>.936</td>
</tr>
<tr>
<td>SSTP</td>
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<td>13.67</td>
<td>28.67</td>
<td>17.71</td>
<td>23.85</td>
<td>8.70</td>
<td>0.48</td>
<td>.788</td>
</tr>
</tbody>
</table>

Notes: Mod/Sev = moderate–severe; OC = older adult control; MTP = maximum tongue pressure (kPa); FTPC50 = fine tongue pressure control at 50% of MTP (standard deviation [SD] of pressure changes above and below the 50% target pressure); FTPC20 = fine tongue pressure control at 20% of MTP (SD of pressure changes above and below the 20% target pressure); FTPC10 = fine tongue pressure control at 10% of MTP (SD of pressure changes above and below the 10% target pressure); RMPT = mean pressure following 10 repetitions of MTP (kPa); FRMTP-R = mean number fast repetitions of the MTP (rate); FRMTP-P = mean pressure during the fast repetition of MTP task (kPa); SSTP = sustained submaximal tongue pressure (a measure of endurance in seconds).
DISCUSSION

The results of our investigation revealed no significant differences in tongue strength, rate of repetitive movements, or tongue endurance among persons with PD and the group of OC participants. However, we did note age effects with both the participant group with PD and the OC group, all of whom had significantly reduced tongue strength, rate of repetitive movements, and tongue endurance when compared with the YC participants. Levels of fine force control were similar across all three groups. Investigation of the severity of consonant imprecision and its relationship to nonspeech measures of tongue function revealed no significant differences between participants with mild consonant imprecision or moderate to severe consonant imprecision and the OC participants on any instrumental parameters. Therefore, our findings indicate that nonspeech measures of tongue function did not distinguish the groups on the basis of articulatory precision. Furthermore, the study provides preliminary evidence to suggest that oral motor exercises may be of minimal benefit to increase articulatory precision in persons with PD.

Tongue Strength, Rate of Repetitive Movements, Fine Force Control, and Endurance in Persons With Parkinson’s Disease and Perceived Consonant Imprecision

We did not expect to find comparable levels of tongue strength in participants with PD and the OC participants based on the results of previous research. Although investigators have reported mixed results from previous research, most studies in this area have reported reduced tongue strength in persons with PD (4,8–10). Interestingly, all participants with PD in the current investigation had a perceptible speech disorder, and their overall severity of PD, as a group, was similar to that of a previous group study (9). However, tongue strength varied widely among the participants with PD in the current study. The combination of wide interparticipant variability and small participant numbers may have contributed to our lack of significant findings for tongue strength.

Our results revealed a significant reduction in tongue strength with advanced age. Both the participants with PD and the OC participants had significantly reduced tongue strength when compared with the YC participants. This result was comparable to previous studies of tongue strength in aging that reported trends toward or significant deteriorations in tongue strength with advancing age (14–16). The exact reasons for this deterioration in tongue strength are unknown, although reduced tongue thickness (20) and atrophy of muscle fibers and a reduction in their numbers have been suggested (15,16). Furthermore, the presence of increased lipofuscin, an “age pigment,” in the lingual muscle of older persons may also have contributed to their reduced strength (15).

Given the results of our study, it appears that although aging did decrease tongue strength in persons with PD and the older controls, it did not significantly affect the speech production abilities of the either group. Under ordinary circumstances, speech production does not require the high levels of strength demanded in maximum performance tasks (12). Therefore, consistent with previous studies (14,15,20), although we noted decreased muscle function in the current group, it did not appear to affect the communication abilities of those we examined.

We noted further evidence of age-related deterioration in lingual function in repetitive movement tasks. We found no significant difference between the group with PD and the OC group on the task that required 10 repetitions of maximum rate, or on the number of repetitions and their mean pressure level in a maximum rate, maximum pressure task. However, both of these groups had significantly reduced scores on all three of these tasks when compared with the YC participants. No published articles have reported a task such as this in participants with PD or older persons, so we cannot make direct comparisons. However, one possible reason for the slowed repetitive movements demonstrated by both the older participants and those with PD could be general articulatory or neuromotor slowness associated with aging.

A previous study (21) reported that alternate motion rates were significantly slower in older persons (mean age, 74 years; age range, 67 to 88 years) than in younger persons (mean age, 23 years; age range, 18 to 28 years). The authors stated that these slower alternate motion rates allowed the participants increased time to control the task (21). It is possible that the reduced number of repetitions demonstrated by both the OC and PD participants in the current investigation occurred as a result of controlled slowness, which allowed the participants time to control the task and thus to perform it adequately. The reduced maximum pressures generated in this task were probably a result of decreased tongue strength in both groups.

The three participant groups had similar levels of fine force control in our investigation. This result compared favorably with those of a previous study that also reported normal levels of tongue stability in a group of 15 persons with PD (9). However, these findings are in contrast to those of previous studies that noted impaired fine force control of the tongue in persons with PD (11,22). One explanation for the discrepant findings may be the nature of the experimental tasks used. The current study, and that of Solomon and colleagues (9), required a participant to sustain a percentage of their own maximum tongue strength as the measure of force control. In contrast, the studies that reported deficits in fine force control in persons with PD used ramp-and-hold experimental tasks in their design. When a ramp-and-hold design is used, a set force must be sustained. This set force is the same for all participants (those with PD and their matched controls) in the investigation. It is possible that deficits were noted in the ramp-and-hold experiments because they did not account for reductions in overall strength and endurance that may have occurred as a result of PD.

In our study, tongue endurance was similar in the participants with PD and the OC participants. Furthermore, the levels of endurance for both groups were significantly reduced when compared with the YC group. This result indicated that higher levels of fatigue were present in the lingual musculature of older adults with and without a neurologic disorder. A previous investigation also reported similar levels of endurance in participants with PD and age-matched controls in the presence of tongue weakness (4). The authors reasoned that the nature of the endurance
measurement task affected endurance scores (4). In their study, and in the current investigation, endurance was measured by maintaining 50% of the participant’s MTP for as long as was possible. Therefore, in persons with a lower MTP, the pressure required to maintain in the endurance task was less and, therefore, they could sustain that lower pressure for as long as the controls. As a result, the task may have required reduced levels of effort in persons with PD (4).

In the current investigation, both the participant group with PD and the OC group had comparable MTPs, which were reduced when compared with the YC speakers. It appears, therefore, that task effect did not result in the current finding and that the physiologic mechanisms of aging were responsible for the findings of reduced endurance (or increased fatigue) in both the PD and OC participant groups. We acknowledge, however, that more variance existed at a group level in the participants with PD than in the OC group. Consequently, it is possible that the results of some of the individual participants from the group with PD reflected, to some extent, the influence of the disease process and not simply the aging process.

Our finding of normal levels of endurance (when compared with participants of similar age) do, however, directly contradict the findings of Solomon and colleagues (9), who reported significantly reduced levels of endurance (and tongue strength) in a cumulative analysis of 36 persons with PD compared with age-matched control participants. It is possible that the increased numbers of participants in the study by Solomon and colleagues (9) resulted in statistically significant results between the groups. Furthermore, the results of our investigation show high levels of between-participant variability in the three groups. This variability may also have contributed to the lack of a significant finding on the parameter of endurance.

**Relationship Between Severity of Perceived Consonant Imprecision and Instrumental Measures of Tongue Function**

Previous studies using instrumental assessment of tongue function have tried to determine whether a relationship exists between certain perceptual parameters of speech production and nonspeech measures of tongue function (4,8,9,23,24). However, the relationship between instrumental assessments of tongue function and speech remains controversial (23). In the current investigation, we found no significant difference between participants with mild or moderate to severe consonant imprecision and healthy age-control participants on nonspeech measures of tongue function. These results, therefore, indicate that nonspeech measures of tongue function such as those that we used could not discriminate between participants based on perceived levels of articulatory impairment.

Although similar analysis has not been undertaken before in persons with PD, a previous study (25) did investigate the orofacial strength and force control of two groups of participants (20 participants in total) with speech disorders subsequent to traumatic brain injury. The study rated the participants with such injury as “more intelligible” and “less intelligible” based on their sentence intelligibility scores and revealed that the “more” and “less” intelligible participants were not significantly different across any of the parameters investigated with the exception of maximum voluntary contraction. The authors concluded that the nonspeech measures used did not distinguish the two groups based on intelligibility (25); however, they hypothesized that because intelligibility was a broad classification category influenced by several factors, investigation of more precise perceptual parameters (i.e., hypernasality, imprecision, and so forth) may be of increased value (25).

Although we used the more precise rating of precision of consonants, nonspeech measures of tongue function again could not distinguish groups of participants on this basis. The current study, therefore, provides preliminary evidence to suggest that nonspeech measures of tongue function do not distinguish participants with PD based on their levels of consonant imprecision. However, further research using a greater number of participants is needed to support this theory. Future investigations may also compare the perceptual ratings to measures of fine force control and endurance to determine whether any relationship exists between these parameters and perceptual ratings of speech production.

**Conclusion**

Our results revealed that persons with PD and perceived consonant imprecision had tongue strength, rate of repetitive movement, and endurance similar to those of nonneurologically impaired persons of a similar age. However, the nonspeech assessment did reveal significant age effects, with younger control participants showing significantly increased tongue strength, rate of repetitive movement, and endurance when compared with both the persons with PD and the older control participants. All three participant groups had similar levels of fine force control of the tongue.

We also tried to discern whether certain nonspeech parameters of tongue function were related to the degree of consonant imprecision. Comparison of tongue function among participants with mild consonant imprecision, those with a moderate or severe degree of consonant imprecision, and healthy older controls revealed no significant results. Based on these results, no relationship appears to exist between the nonspeech measures of tongue function that we used and articulatory precision. Our results tend to support the arguments of previous authors who questioned the role of nonspeech measures of assessment in speech pathology (12).

It appears, therefore, that nonspeech measures fail to provide useful diagnostic information regarding the physiologic basis of the articulatory deficits in persons with PD. Furthermore, it is likely that oral motor exercises for increasing articulatory precision in persons with PD would be of minimal benefit. Investigative techniques focused on assessing the rate of tongue movement, its timing in speech tasks, and the configuration of the tongue on the hard palate during speech may be more useful in further advancing the understanding of the articulatory disorder present in PD.

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REFERENCES


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