

# Progressive Speech Function Deterioration in Parkinson's Disease: A Four - Month Study of Marathi - Speaking Individuals

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**Abstract:** ***Introduction:** A large number of individuals with Parkinson's disease (PD) develop problems with speech. Around 80–90% experience voice changes; 45–50% shows alterations in articulation. Perceptually, speech is typified as monopitched, monoloud, imprecise and dysfluent. Associated acoustic changes can be voice fundamental frequency (F0), reduced variability of F0, decreased sound intensity, lower harmonic to noise ratio. The progressive deterioration patients experience can be physically, emotionally, and financially devastating. This study focused on changes in speech functions (if any) of individuals with PD over a period of 4 months. **Materials and Method:** A total of 12 Marathi speaking individuals with PD mean age of 66 years were included in the study. Assessments included a detailed case history, clinical assessment of dysarthria (DAP), and cognitive screening (MOCA). The speech functions were assessed thrice; initial assessment (1<sup>st</sup> Assessment), assessment after 2 months (2<sup>nd</sup> Assessment), and assessment after 4 months (3<sup>rd</sup> Assessment) on each participant over a period of 4 months. Speech functions were assessed perceptually and acoustically. **Results and Conclusions:** Present study documented change in speech functions perceptually as well as acoustically in individuals with PD over a period of 4 months. There was a significant difference found across 3 assessments for oro - motor structures, oro - motor functions and speech sub - system and acoustic of speech in individuals with PD. Thus, it indicated deterioration in oro - motor structures, oro - motor functions, one or more parameters of speech sub - systems, however not in speech intelligibility of individuals with PD. **Speech Characteristics in Individuals with Parkinson's disease: A Follow up Study***

**Keywords:** Acoustic analysis, Dysarthria, Parkinson's disease, Speech intelligibility, Speech sub - system

## 1. Introduction

An important source of disability in patients with Parkinson's Disease (PD) is progressive loss of the ability to communicate which might impact various parts of their life (1). Approximately 75% to 90% individuals with PD develop dysarthria during the course of the disease (2 - 3). Problems in communicating can lead to feelings of frustration, depression and withdrawal. The progressive deterioration experienced by individuals can be physically, emotionally, and financially devastating. By the time the disease has run most individuals with PD experience impairments in their motor skills, communication, social participation, swallowing, emotional health, and cognition. People living with PD can have different problems with their communication due to changes in their voice, speech systems, intelligibility and facial expressions (2 - 4). The stage when the speech problems might emerge is different for everyone and the symptoms vary from person to person, however, changes in voice are many a times first indication of disease (3). Few studies have reported that long term

change (ranging from 1 year to 12 year) in speech and voice of individuals with PD measured perceptually and/or acoustically over minimum interval of 1 year (5 - 8). However, none have focused on measuring subtle changes in speech function with progression of disease systematically over short - term period which might affect communication. There are sparse literatures documenting changes in speech of individuals with PD with progression of disease in Indian context. Therefore, this study aimed to investigate changes in speech functions; oro - motor structures and functions, speech sub system, speech intelligibility, and acoustic parameters of speech in individuals with PD over a period of 4 months.

## 2. Method and Materials

A total of 12 (M=7, F=5) Marathi speaking individuals with PD having median age of 67 years and age range from 52 to 84 years were selected. They were diagnosed as PD by a medical professional with its duration ranging from 3 to 14 years and stage from I to V (9) (Table 1).

**Table 1:** The participant's demographic details along with stage and duration of disease, type and severity of dysarthria, and associated problems observed among individuals with PD

PD No	Age	Gender	PD stage	Duration of PD (in years)	Dysarthria type	Dysarthria severity	Associated problems
1	63	F	IV	4	Hypokinetic	Moderate	Dysphagia
2	64	F	II	7	Hypokinetic	Mild	None
3	52	M	I	3	Hypokinetic	Minimal	None
4	59	F	III	3	Hypokinetic	Mild	None
5	82	M	IV	3	Hypokinetic	Moderate	Dysphagia
6	71	M	IV	12	Hypokinetic	Moderate	Dysphagia
7	84	F	V	8	Hypokinetic	Severe	Dysphagia
8	73	M	III	4	Hypokinetic	Moderate	Dysphagia
9	67	M	V	10	Hypokinetic	Severe	Dysphagia
10	54	F	III	9	Hypokinetic	Moderate	None
11	65	M	IV	8	Hypokinetic	Moderate	Dysphagia
12	67	M	II	14	Hypokinetic	Mild	None

Participants were diagnosed as hypokinetic dysarthria with severity ranging from minimal to severe by an experienced Speech language pathologist. Participants with no known language; cognitive, psychiatric, pulmonary and hearing disorder were included in the study. For cognitive screening Montreal Cognitive Assessment in Marathi, (MOCA) (10) was used. In which, participants who obtained  $\geq 26/30$  were included. Participants who had less than 26 score were excluded from the study. However, participants with coexisting swallowing problems were included. Individuals with PD in which dysarthria was persisting for minimum 3 months were included. Individuals with mild to moderately severe dysarthria with PD were considered in the study. Individual who was able to comprehend the basic instructions for the given task were included. Individual who did not take speech therapy for at least last 6 months were selected.

Materials used in the study were; (a) Dysarthria Assessment Protocol - DAP (11) for clinical assessment of dysarthria, and (b) PRAAT software (12) for acoustic analysis. DAP is a clinical protocol used for assessment of dysarthria. It includes case history sheet that provided information about background details, complaint, history and current state of patient. There is main 2 parts in DAP; Part A which includes 2 sections and Part B which includes 4 sections. Section 1 of Part A assesses physical status Gait and Stance, Reflexes, post morbid handedness, Activities of daily living, feeding whereas, its Section 2 includes examination of Oral - Motor Structure; Face, Lips, Tongue, Palate & Uvula, Jaws. In Part B, Section 3 includes examination of Oral Movement where different tasks are given for assessing range, rate and strength of lip, tongue, jaw and soft palate movements. Part B Section 4 includes Perceptual Examination of Speech is done for respiration, phonation, articulation, resonance and prosody. Part B - Section 5 includes Speech Intelligibility Assessment across words, sentences, question elicited sentences (QES), and narration. In addition, DAP also provides a Global Severity rating based on findings of each section which gives overall severity of dysarthria.

### 3. Procedure

A detailed case history of the participant was taken which included the demographic data, medical history, neurological findings, nature and onset of the problem. The assessment included examination of the oro - motor structures, oro - motor functions, examination of speech sub

- systems and speech intelligibility. Premorbid speech language, swallowing, cognitive history along with the current status of the individual were also checked. The severity of dysarthria was assessed using DAP severity rating scale. To check speech intelligibility, stimuli of DAP Section - 5 Speech Intelligibility was given to each participant and their speech sample was recorded. Stimulus included words, sentences, QES from list 2 of DAP and narration sample. Each individual's recording was done in individual's comfortable position. The stimulus was recorded using Sony UX 560 F Digital voice recorder which had a sampling rate of 44.1 kHz and bit rate of 16kbps along with the automated noise cancellation facility. The microphone was placed 8 - 10cms away from the individual's mouth. The perceptual analysis of recorded sample from each participant (DAP Speech Intelligibility Section) was done by an experienced Speech language pathologist. The listener heard the speech sample of each individual with PD. The samples were randomized for each participant, stimuli types and order of presentation. The listener rated the intelligibility of each participant for all stimuli on a scoring sheet. The recorded samples of each participant were acoustically analysed on PRAAT software and following parameter extracted (a) Fundamental frequency - F0 range and average F0, (b) Intensity - I0 range and average I0, (c) Formant frequency - F1 and F2 of vowels /a/, /i/, and /u/, and, (d) Rate parameters - speaking rate and articulation rate, (e) Transition - F2 transition duration and F2 slope. The same procedure was done for 3 times over a period of 4 months.

#### Statistical analysis:

The statistical analysis was carried out using SPSS software (Version.16 Inc). The values acquired for the speech parameters were subjected to the Shapiro - Wilk test and then results indicated that some data was normally distributed and some was not normally distributed but the protocol was using rating scale; hence parametric statistical analysis was carried out. Friedman's ANOVA test was done to calculate change in speech parameters and Pair wise comparison across the 3 assessments was done using Wilcoxon's signed rank test for speech parameters.

4. Results

Changes in oro - motor structure and function of individuals with PD

For each participant, the oro - motor structure and oro - motor functions was assessed on DAP Section 2 and Section

3 respectively. Descriptive statistics was applied to calculate median and range of scores obtained for oro - motor structures and oro - motor functions across 3 assessments (Table 2).

Table 2: Median and Range of Oro - motor structures and functions, speech functions, F0 range, I0 range, speaking rate and F2 slope scores obtained by individuals with PD

Descriptive Statistics	1 <sup>st</sup> Assessment	2 <sup>nd</sup> Assessment	3 <sup>rd</sup> Assessment	Friedman's ANOVA		
				X <sup>2</sup>	Df	p
<b>Oro - motor structures (DAP - Section 2)</b>						
Median	24.50	27.50	31.50	23.53	2	0.00
Range	8.00	11.00	10.00			
<b>Oro - motor functions (DAP - Section 3)</b>						
Median	73.50	80.00	82.50	22.16	2	0.00
Range	54.00	67.00	64.00			
<b>Speech functions (DAP - Section 4)</b>						
Range	34.00	31.00	38.00			
<b>Fo range</b>						
Median	153.48	38.59	178.65	13.5	2	0.00
Range	260.41	135.79	108.08	0		
<b>Io Range</b>						
Median	21.79	85.03	11.30	6.50	2	0.03
Range	42.28	25.41	23.97			
<b>Speaking rate</b>						
Median	3.43	3.07	3.02	11.65	2	0.00
Range	2.15	2.26	2.17			

Median scores were highest at 3<sup>rd</sup> followed by 2<sup>nd</sup> and lowest at 1<sup>st</sup> assessment for both (Figure 1). A total of 10 individuals with PD had difficulties in oro - motor structures. Increase in frequency and type of deviances was noted for oro - motor structure especially presence of reduced wrinkling on forehead for 7 individuals, drooling for 6 individuals, lip tremors for 2 individuals, tongue deviation for 7 individuals and tongue tremors for 4 individuals was gradually noted over 3 assessments. These results might indicate the changes in oral structures even for a short period of time. The changes in structures were commonly noted for tongue, lips, and jaw. With the

progression of the disease in oro - motor functions reduced strength was found in 11 individuals, Difficulties in rate and reduction of range was observed. In which, for lips 10 had difficulties and for tongue 6 individuals had difficulties. A significant main effect was seen for scores obtained on oro - motor structures and oro - motor function by individuals with PD across 3 assessments on Friedman's ANOVA test (Table 2). The results indicate that oro - motor structures and oro - motor functions scores obtained by PD significantly change over 4 months. The results reveal that the severity level is increase in most of the individuals with PD over a period of time.

Table 3: Pair - wise comparisons across three assessments on Oro - motor structures and functions, speech functions, F0 range, I0 range, and speaking ratescores obtained by individuals with PD

<b>Wilcoxon Signed Rank test</b>			
<b>Oro - motor structures (DAP Section 2)</b>			
	1 <sup>st</sup> Assessment - 2 <sup>nd</sup> Assessment	2 <sup>nd</sup> Assessment - 3 <sup>rd</sup> Assessment	1 <sup>st</sup> Assessment - 3 <sup>rd</sup> Assessment
Z	3.06	3.08	3.08
P	0.002	0.002	0.002
<b>Oro - motor functions (DAP Section 3)</b>			
Z	3.06	2.99	3.06
P	0.002	0.003	0.002
<b>Speech functions (DAP Section 4)</b>			
	1 <sup>st</sup> Assessment - 2 <sup>nd</sup> Assessment	2 <sup>nd</sup> Assessment - 3 <sup>rd</sup> Assessment	1 <sup>st</sup> Assessment - 3 <sup>rd</sup> Assessment
Z	2.94	2.40	3.06
P	0.003	0.01	0.002
<b>Fo Range - Wilcoxon Signed Rank test</b>			
	1 <sup>st</sup> Assessment - 2 <sup>nd</sup> Assessment	2 <sup>nd</sup> Assessment - 3 <sup>rd</sup> Assessment	1 <sup>st</sup> Assessment - 3 <sup>rd</sup> Assessment
Z	2.27	3.05	2.10
P	0.02	0.00	0.01

Io Range - Wilcoxon Signed Rank test			
	1 <sup>st</sup> Assessment - 2 <sup>nd</sup> Assessment	2 <sup>nd</sup> Assessment - 3 <sup>rd</sup> Assessment	1 <sup>st</sup> Assessment - 3 <sup>rd</sup> Assessment
Z	0.70	2.51	1.96
p	0.48	0.01	0.05

Speaking rate - Wilcoxon Signed Rank test			
	1 <sup>st</sup> Assessment - 2 <sup>nd</sup> Assessment	2 <sup>nd</sup> Assessment - 3 <sup>rd</sup> Assessment	1 <sup>st</sup> Assessment - 3 <sup>rd</sup> Assessment
Z	1.68	2.83	2.04
p	0.09	0.00	0.04

### Changes in speech subsystems of individuals with PD

A significant main effect was seen for scores obtained on speech functions by individuals with PD across 3 assessments on Friedman's ANOVA test (Table 2). The results showed that there was a change in scores obtained for speech subsystems (DAP Section 4) across 3 assessments indicating deterioration in speech functions of individuals with PD over the period of 4 months. Values of speech subsystem were increased for these individuals across 3 assessments. Higher median scores were noted at 3<sup>rd</sup> compared to 2<sup>nd</sup> and 1<sup>st</sup> assessment (Figure 2). Speech characteristics were increased in number and its severity was observed over 3 assessments for all the 12 participants across all speech subsystems; in respiration a total 10 individuals had difficulties, 8 individuals had difficulties in phonation, 10 had abnormality in articulation, in resonance 4 individuals had difficulties and total 11 individuals had difficulties in prosody. The results showed a statistically significant high score of speech functions at 3<sup>rd</sup> compared to 1<sup>st</sup>, 3<sup>rd</sup> compared to 2<sup>nd</sup>, and 2<sup>nd</sup> compared to 1<sup>st</sup>. A reduction in breathing rate was noted for 2 individuals, severity of speech breathing was noted for 8 individuals. A change in phonation was noted for 8 individuals; wherein hoarse voice followed by harsh quality and deterioration of quality in voice was noted for 8 individuals, monopitch and monoloudness was noted in 6 individuals, and a reduction in loudness was noted in 8 individuals. Imprecise articulation was noted in 7 individuals, repeated phonemes in 5 individuals, palilalia in 4 individuals and DDK rate in 2 individuals. A presence of hypernasality was noted in 2 individuals and nasal air emission was noted in 2 individuals.

Changes in prosody were observed in 11 individuals; with reduced stress noted in 3 individuals, excess stress was noted in 7 individuals, abnormality of rate of speech was noted in 11 individuals out of these 3 individuals had a fast rate and 8 had slow rate of speech, reduced intonation was noted in 6 individuals, monoloudness was observed in 6 individuals, an increase in number and duration of pauses was noted in 8 individuals and reduced number of pauses was noted in 3 individuals.

### Changes in speech intelligibility of individuals with PD

Descriptive statistics was done to calculate median and range of scores obtained for speech intelligibility across stimuli; words, sentences, QES (question elicited sentences) and narration across 3 assessments. The median value of speech intelligibility did not vary across 3 assessments for sentences and narration. However, it reduced slightly from 1<sup>st</sup> and 2<sup>nd</sup> assessment compared to 3<sup>rd</sup> at word level and reduced from 1<sup>st</sup> to 2<sup>nd</sup> and 3<sup>rd</sup> assessment at QES level (Figure 3).

### Changes in acoustic parameters of speech in individuals with PD

Pair wise comparison across the 3 assessments was done using Wilcoxon's signed rank test for F0 Range. The score for F0 Range and I0 Range is increase within a time of 4 months which shows there is change in F0 Range and I0 Range. High median scores for F0 Range and I0 range were observed on 2<sup>nd</sup> followed by scores at 1<sup>st</sup> and then at 3<sup>rd</sup> assessment. Statistically significant change was not observed across 3 assessments for formant frequency of vowels (/a/, /i/, /u/). High median scores for speaking rate were observed on 3<sup>rd</sup> followed by 1<sup>st</sup> and then at 2<sup>nd</sup> assessment. A significant main effect was seen for scores obtained on F2 transition duration on Friedman's ANOVA test.

## 5. Discussion

### Changes in Oro - motor structures and functions of individual with PD

Increase in frequency and type of deviances noted for oro - motor structure, especially presence of reduced wrinkling on forehead (n=7), drooling (n=6), lip deviation (n=6), lip tremors (n=2), tongue deviation (n=7), and tongue tremor (n=4) was gradually noted over three assessments for many participants (n=10). These results might indicate changes in oral structures even over a short period of time. Similar results are shown in literature where they have reported deterioration in oral structures in individuals with PD as the disease progress (13). The changes in structures were commonly noted for tongue, lips, and jaw, whereas, reduced strength (n=11), rate (n=10) and range (n=6) for lips and tongue was observed for oro - motor functions. Most commonly faced oro - motor components in progression of PD were related to speech and swallowing (13). They also found development of a mask like face and decreased movement around mouth were commonly noticed.

### Changes in speech sub systems of individuals with PD

Increased number of speech characteristics and its severity was observed over 3 assessments for all participants (n=12) across all speech systems; respiration (n=10), phonation (n=8), articulation (n=10), resonance (n=4), and, prosody (n=11). Among 12 individuals with PD 10 had difficulties in respiration which was changed over a period of time. Reduction in breathing rate were observed (n=2). It was also noted that severity increase in speech breathing over a period of time (n=8). A similar result was highlighted that difficulties in respiratory support for speech were found in 89% of individuals with PD (14).

A total of 8 individuals had abnormality in phonation which is increased across 3 assessments. Hoarse voice followed by harsh and deterioration in quality of voice were found (n=8).

Monopitch (n=6), Monoloudness (n=6), and reduced loudness (n=8) were noted. A supporting result was noted that imprecision of consonants was more common compare to vowels in individuals with PD (14). It was noticed that 10 individuals with PD had difficulties in articulation. More difficulties were observed in imprecise articulation (n=7), followed by repeated phonemes (n=5), and palilalia (n=4), few have difficulty in DDK (n=2). Few participants had difficulties in resonance (4) that is presence of hypernasality (n=2) and nasal air emissions (n=2) were observed. Majority of individuals with PD had difficulties in (11) prosody. It was noticed that reduced stress (n=3), excess stress (n=7), abnormalities of rate of speech (n=11) out of that 3 had fast rate and 3 had slow rate of speech, reduced intonation (n=6), monoloudness (n=6), increase number and duration of pauses (n=8), reduced number of pauses (n=3).

#### Changes in speech intelligibility of individuals with PD

The median value of speech intelligibility did not vary across 3 assessments for sentences and narration. However, it varies for words and QES. In one longitudinal study it was highlighted that deterioration was seen in overall speech intelligibility over time (5). However, it was not found in current study because the time span for the current study was very short.

#### Change in Acoustic parameters of speech of individuals with PD

For average F0 significant change was not noted. However, a significant change was noted in median of F0 range. A significant difference was found in range values of F0 when compared to healthy group (15). Mean F0 was elevated in males over a period of time. However, it was not elevated in female speakers with PD (5). In current study the mean F0 was not changed even for male because the study was done for very short period of time. The significant change was noted in I0 range. However, the median score was not changed significantly for average I0. A supporting finding was highlighted that an overall lower intensity level and difficulty in I0 range was noted in individuals with PD (16). A similar finding was noted that as the disease progress a reduction is seen in voice intensity of individuals with PD (17). Acoustically it was found that in both early and later stage of PD have lower mean intensity levels compare to normal subjects (18). Formant frequencies for vowels (/a/, /i/, /u/) were not changed. The median of speaking rate was changed but the significant change was not found in articulation rate. Over a period ranging from 25 to 32 months a progressive decline in speech rate was found (5). Accordance with current study it was also noted that speech rate is reduced in individuals with PD (19). For articulation rate a significant difference was not found in current study. A significant difference was not found in overall articulatory rate between PD patients and normal subjects (20). The author suggested that there is negative correlation was found between articulation rate and duration of disease. Hence, the significant change was not noted in articulation rate. F2 slope was changed but F2 transition was not changed in individuals with PD over a period of 4 months. Accordance with current result it was found in one study that compare to normal subjects a reduction is noted in F2 slope in individuals with PD (21).

## 6. Conclusion

This study shows changes in different aspects of speech and non - speech function in individuals with Parkinson's disease over a short - term period of four months. These changes were noticeable at neuromuscular level for oro - motor structures, its functions and at various levels of speech sub - systems; respiration, phonation, articulation, resonance as well as prosodic variables but not for speech intelligibility. These deficits in speech and oro motor structure and functions were indicate deterioration at different levels of speech production for PD over four months. These subtle changes could be captured by acoustic measures wherein changes in F0 range, I0 range, F2 slope and speaking rate were obtained but not noticeable by listeners while estimating speech intelligibility. These changes in acoustic variables could be well correlated with changes perceptual speech characteristics observed in speech of PD over a short period of four months like; reduction in loudness level, monopitch, increased severity in voice quality, articulation imprecision, and perceived fast speaking rate. The study gave insight about subtle change in speech function for a very short period of time which might be useful for the regular follow up and monitoring of speech functions in PD. This might help in planning, regularly monitoring and improvising therapy goals for effective intervention. The longitudinal study is required to monitor different speech dimensions and overall speech performance in PD by supplementing perceptual assessment with acoustic. However, further work is also required to establish appropriate methods of speech assessments which fulfill the demands of validity and reproducibility, time and cost effectiveness, and describe the functional disability of patients.

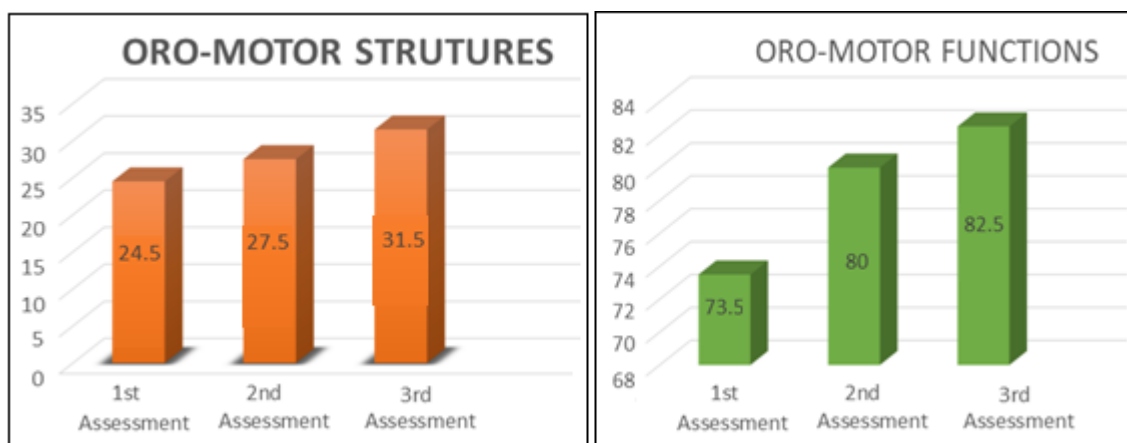
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## Figures



**Figure 1:** Median of oro - motor structures and oro - motor functions score obtained for individuals with Parkinson's disease across three assessments

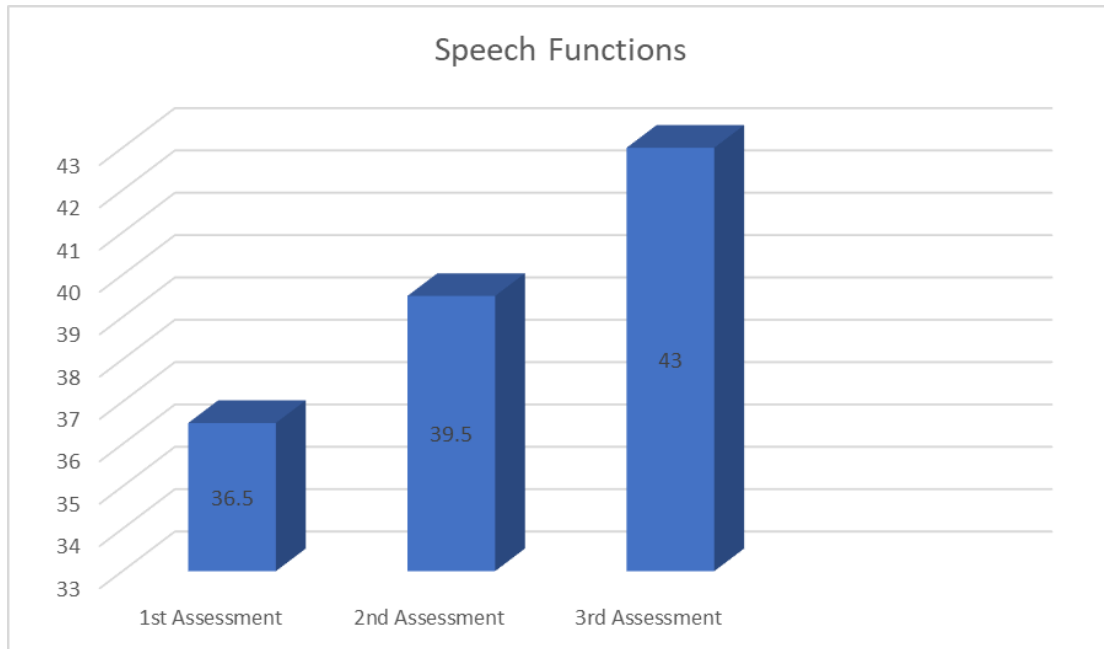


Figure 2: Median of speech functions score obtained for individuals with Parkinson’s disease across three assessments

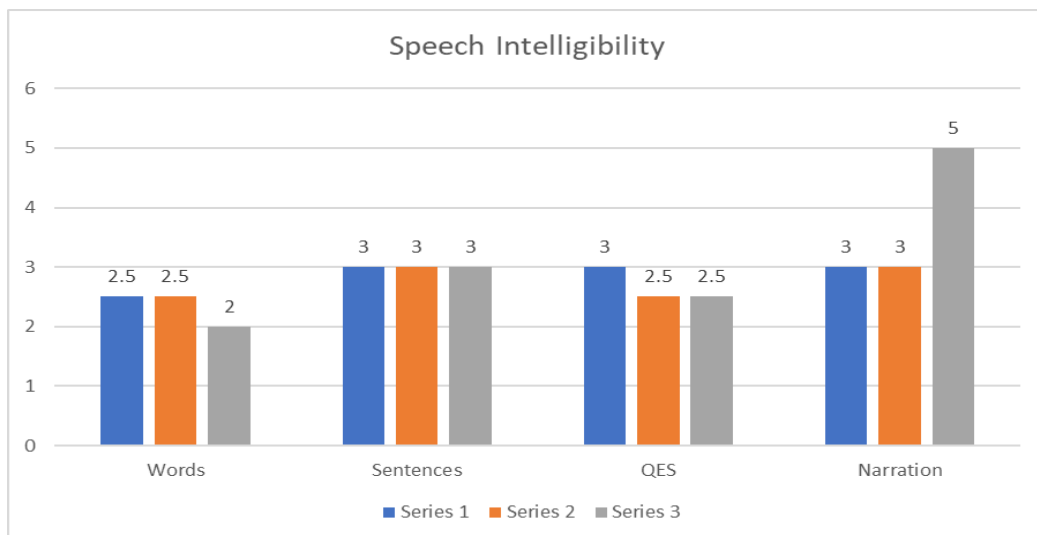


Figure 3: Median of speech intelligibility scores obtained for individuals with Parkinson’s disease across three assessments

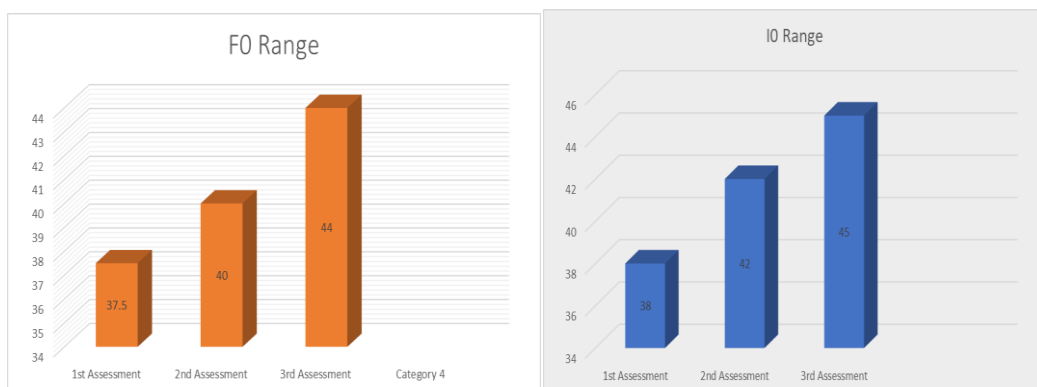
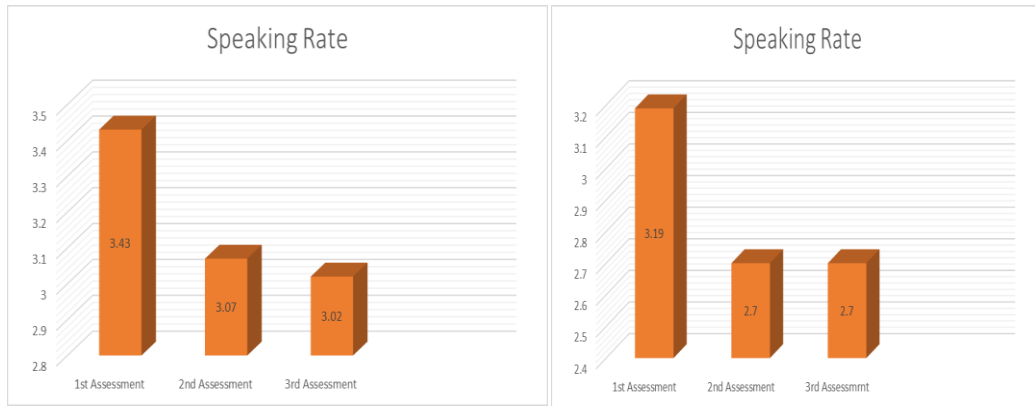


Figure 4: Median of F0 range and I0 range score obtained for individuals with Parkinson’s disease across three assessments



**Figure 9:** Median of speaking rate and articulation rate score obtained for individuals with Parkinson’s disease across three assessments