Feasibility, Satisfaction and Effectiveness of a Smartphone Application-based Voice and Speech Training Program for Parkinson's Disease: Single Arm Pretest-Posttest Study

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Submitted to: Journal of Medical Internet Research
on: June 12, 2024

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Abstract

Background: The majority of people with Parkinson's disease experience difficulties with voice and speech with disease progression, which leads to speech therapy. However, given their increasingly limited mobility, face-to-face speech therapy might be inaccessible. These accessibility issues can be addressed by an mHealth app.

Objective: This study was conducted to examine the feasibility, satisfaction, and effectiveness of a smartphone-based application for voice and speech therapy in patients with Parkinson's disease.

Methods: A single-arm, rater-blinded, pretest-posttest study was conducted between September to November, 2023. PD patients with voice and speech problems who have no problem with using Android smartphone were recruited. Participants downloaded the researcher-developed mHealth app on their smartphone and participated in a patient-tailored 5-week home-based speech training program. To verify feasibility, adherence was monitored and satisfaction was assessed by a phone survey at the end of the app use. Acoustic analysis and auditory-perceptual assessments were evaluated for effectiveness.

Results: Thirty patients were initially recruited, but two of them withdrew. Twenty-five participants completed all the training sessions while three dropped out. The adherence was above 90% in twenty participants, 70-90% in four and below 70% in four. Satisfaction was 75% among the twenty-four people who participated in the survey. Significant improvement were observed in all acoustic measures and in the speech -language pathologist's auditory-perceptual assessments after app use. The maximum phonation time increased from 11.15 seconds before use to 14.01 seconds after use (P =.003). The average vocal intensity increased from 71.59dB before use to 73.81dB after use in both sustained phonation and reading tasks (P<.001). Improvements in voice quality were observed in all components of the GRBAS(P <.001). In addition, 58.33% of participants in the survey reported improved voice after app use.

Conclusions: This study demonstrates that home-based, self-training speech therapy provided through an mHealth app can be a feasible solution for patients with Parkinson's disease.

(JMIR Preprints 12/06/2024:63166)
DOI: https://doi.org/10.2196/preprints.63166

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Keywords: Parkinson’s disease; speech therapy; mHealth; home-based training; self-delivered; digital health care; app; feasibility; voice therapy

Introduction

During the progression of Parkinson's disease (PD), around 75% of patients experience difficulties with their voice and speech functions at some stage [1]. The main characteristics of speech include breathy phonation, hoarseness, low speech volume, inaccurate articulation, and monotonous speech. These symptoms worsen over time. As a result, they may experience a lower quality of life in physical, emotional, functional and social aspects. It also makes communication, daily living and social participation more difficult.

Speech therapy is usually based on face-to-face treatment with a speech-language pathologist (SLP). However, this can be challenging for PD patients, a degenerative disorder that gradually impairs mobility [2]. Additionally, there are accessibility issues such as distance, travel time, waiting time, and costs [3]. This becomes an important factor for poor adherence to treatment. Limited accessibility reduces adherence to treatment, which negatively affects the improvement of the patient's voice and speech problems. Therefore, resolving accessibility issues should be considered essential in speech therapy [4]. Medical accessibility issues can be resolved through mobile health (mHealth) care program, which has the potential to bring medical services into the digital age, thereby facilitating self-health management. If PD patients embrace and use mHealth, it can be beneficial not only to their health, but also in terms of time and medical costs [5]. The usability and feasibility of mHealth for PD patients has been actively researched in recent years. However, most of these studies are limited to areas such as medication management, physical activity and exercise outcomes [6]. Moreover, while the feasibility and effectiveness of telerehabilitation with involvement of SLPs have been demonstrated in various studies [7], research on home-based self-delivered speech therapy platforms with minimal therapist involvement is still uncommon.

Thus, in this study, we aimed to assess the feasibility of smartphone application (app) designed for PD patients which provides a home-based self-delivered speech therapy with the minimal involvement of SLPs. We also evaluated the satisfaction and effectiveness of the application.

Methods

Participants

Participants were recruited from the Movement Disorders Clinic of Department of Neurology at Seoul National University Hospital from September to November, 2023. The inclusion criteria were: (i) PD patients reporting voice problems and speech difficulties; (ii) Android smartphone user without visual or auditory difficulties in using apps; (iii) without laryngeal dysfunctions caused by other diseases. Exclusion criteria were (i) illiterate; (ii) recent (<6 months) history of speech therapy; (iii) difficulty in operating a smartphone due to cognitive and motor dysfunction; (iv) limited access to internet at home.
This study was approved by the Seoul National University Hospital Ethics Committee (IRB No. H-

2308-040-1456 and H-2401-010-1499). All participants gave their informed written consent prior to participation.

Study Design

This study is a single-arm, rater-blinded, pretest-posttest design to evaluate the feasibility, satisfaction and effectiveness of an mHealth program among individuals with PD.

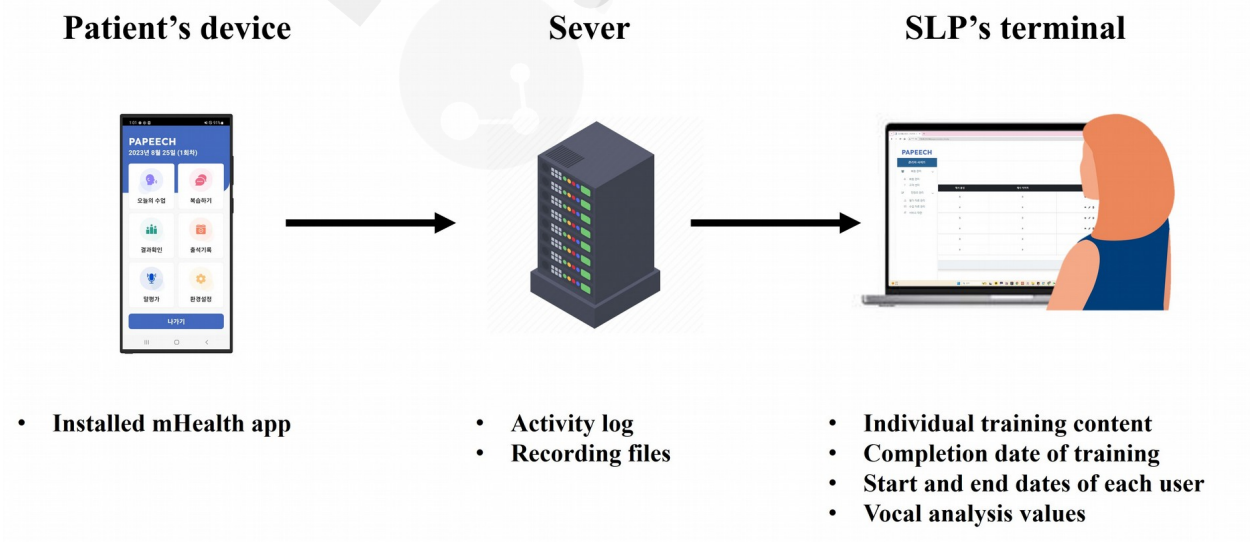
mHealth App and Training Program

We developed an Android-based smartphone app for voice and speech training (Figure 1). The app consists of patient's device (patient's own smartphone), a server and a SLP's terminal (laptop or desktop computer). All the content for patient evaluation and training, which was developed by the SLPs is stored on the server.

Participants downloaded the mHealth app onto their smartphones at the hospital. Afterward, they were invited to complete a 5-week home-based training program following the registration and user approval process for participation. The SLPs ensured that the installed app was functioning correctly and educated the participants on how to use it. The server transmitted the content to the devices of approved participants. This content was designed with a user-friendly UI/UX. A sufficiently large font size was used to accommodate older users, and the size and spacing of the buttons were appropriately adjusted to consider motor symptoms such as hand tremors. Additionally, if the participants have used a smartphone before, the design was made simple and intuitive enough for them to operate without difficulty. This is because the goal was for patients to use the app independently for evaluation and training during the study, without assistance from clinicians, including SLPs, or caregivers.

All speeches practiced in the session were recorded. The recorded files and the associated activity logs are all stored on the server. The SLP's terminal is designed for monitoring the entire process, allowing the SLP to check each participant's start and end dates of training, their individual training content, and the analysis of the recorded speeches within the training. SLPs did not interact with the patient or server in real-time during evaluation or training.

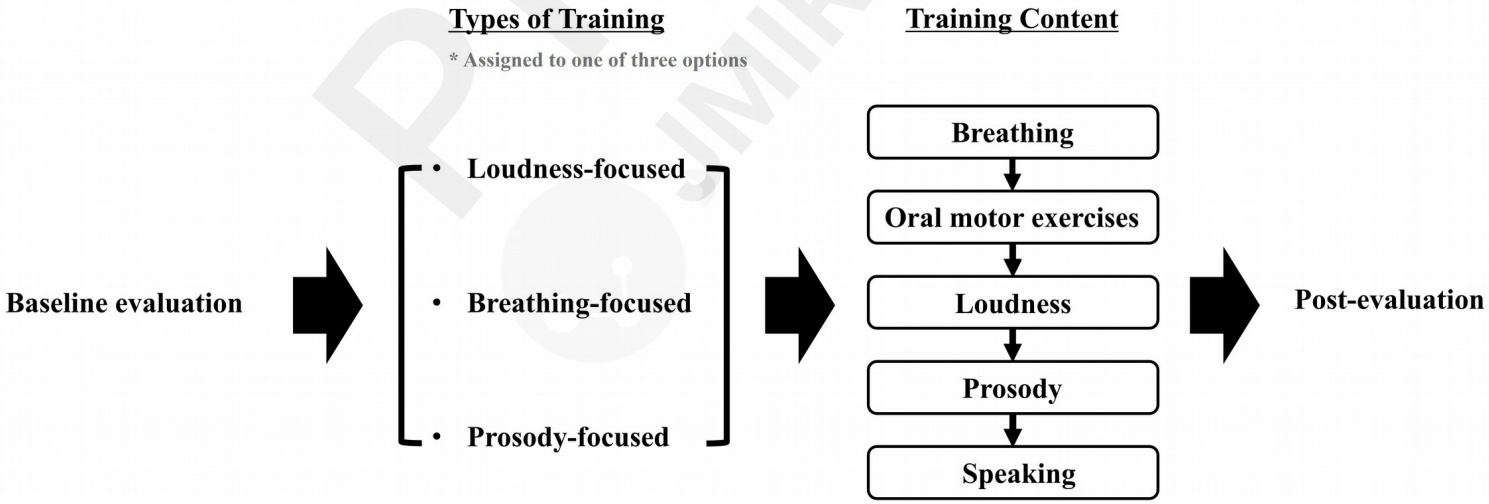
Figure 1. A simplified overview of the composition of the mHealth app.



Based on the results of self-administered baseline evaluation (see below), each participant was assigned to one of three different types of training: loudness-focused, breathing-focused and prosody-focused training. The training content comprised five stages: breathing, oral motor exercises, loudness, prosody, and speaking (Figure 2). For each stage, multiple training programs with different difficulty levels are prepared beforehand and the program with most suitable difficulty level for the particular participant is selected, thus providing patient-tailored treatment.

This 5-week home-based training program consists of a total of 20 sessions, each lasting approximately 20-30 minutes. Participants were instructed to use the app at least four days a week, one session for a day. To minimize attrition, SLPs monitored the participant's daily use of app using the dashboard equipped in the SLPs' terminal. If necessary, SLPs called the patients to encourage training. The app also includes a pop-up alarm to remind users of each day's training.

Figure 2. Contents and structure of the speech training program.



Measuring Adherence, Satisfaction and Effectiveness

To verify adherence, we created a webpage for SLPs to monitor the participants' completion of app training sessions in real time. The overall adherence was calculated by dividing the number of training sessions completed by the total number of sessions prescribed [8]. The number of

participants who withdrew from the study was also identified.

The Satisfaction survey was conducted by phone within a week of either completing or discontinuing the app use. Their satisfaction levels were gauged using a 5-point Likert scale anchored by ‘very satisfied’ (5) to ‘very dissatisfied’ (1), aiming to derive the Customer Satisfaction (CSAT) score. The CSAT score is calculated by dividing the number of positive responses (those who rated 4 or 5) by the total number of responses.

To assess the effectiveness, we conducted both acoustic analysis and auditory perceptual assessments at baseline and at the completion of app use. The tasks included sustained phonation of the vowel /a/, reading three short sentences, and reading a 28-word passage from a Korean standardized ‘Ga-eul’ passage. All tasks were recorded using the built-in microphone of each participant's smartphone and were stored on the server. During the recording, participants were instructed to sit upright and remain still, maintaining a distance of approximately 30cm between their mouth and the smartphone microphone.

The acoustic analysis was conducted using Praat software (version 6.4.04) embedded in the app. The analysis included the maximum phonation time (MPT) of the vowel /a/ and the mean vocal intensity (including pauses) for each task, measured in sound pressure level (SPL) dB.

The auditory perceptual assessment was performed on all tasks using the GRBAS scale, which is widely used to assess the severity of voice quality. It contains grade (G), which is the overall degree of hoarseness, roughness (R), breathiness (B), asthenia (A), and strain (S). Two experienced SLPs, each with over 10 years of clinical experience, conducted the ratings on a 4-point Likert scale from 0 (normal) to 3 (severe). The baseline and post-training evaluation voice files pair were provided in random order in WAV format without any identifying information about the order. Furthermore, participants who completed all app usage were asked, during a phone survey, to self-report any changes in their overall voice quality after the training.

Statistical Analysis

Data were analyzed using SPSS version 29.0 for Windows. Frequency analysis was conducted to examine adherence, satisfaction, and self-reported voice quality changes. Paired sample t-tests were conducted to determine if there were significant changes in the maximum phonation time during sustained phonation of the vowel /a/ before and after app usage, as well as to assess for significant changes in vocal intensity in all tasks. The normality of the data was tested using the Shapiro–Wilk test. To analyze the reliability of the average agreement rate between evaluators for the auditory perceptual assessment of GRBAS scores, Intraclass Correlation Coefficients (ICCs) were calculated.

Results

Participants’ Characteristics and Adherence

Thirty patients with PD were initially recruited, but two withdrew due to health problems not related PD. A total of 28 PD patients participated in the study and used the app. Participant characteristics are summarized in Table 1. Based on the results of baseline evaluation, 20 were assigned to the loudness-focused training program and the remaining eight participated in the breathing-focused training program. None were assigned to the prosody-focused training program. Twenty-five participants (15 males, 10 females; mean age: 68.04 ± 7.81 years, mean disease duration: 7.32 ± 4.78 years, H&Y scale ranged from 1 to 4, mean: 2.39 ± 0.88) completed all the training sessions while three dropped out. One participant lost from contact and the other two dropped out due to: (i) problems with internet connection; (ii) too busy, respectively. They completed only 12, 3 and 4

sessions respectively.

The adherence was above 90% in 20 participants, 70-90% in four and below 70% in four (Figure 3A).

Table 1. Demographic characteristics of the participants (N=28).

Subgroup	Value
Age (years)	67.5±8.16 (range: 51-81)
Sex, n (%)	
Male	17 (60.7)
Female	11 (39.3)
Disease duration (years)	7.54±4.73 (range: 1-19)
H&Y scale, n (%)	
Mean	2.39±0.88
1	3 (10.7)
2	15 (53.6)
3	6 (21.4)
4	4 (14.3)
Type of training program, n (%)	
Loudness-focused	20 (71.4)
Breathing-focused	8 (28.6)
Prosody-focused	0 (0)

Satisfaction

After using the app, 24 participants took part in the survey on satisfaction (Figure 3B). Eleven (45.83%) responded ‘very satisfied’, seven (29.17%) ‘moderately satisfied’, six (25%) ‘neither’ and none answered ‘moderately dissatisfied’ or ‘very dissatisfied’. The CSAT score was 75%. Most were satisfied with the convenience of being able to practice at their own home, citing it as the primary reason. None reported any technical difficulties.

Effectiveness

Acoustic analysis and perceptual assessment results are presented in Table 2. Significant differences were observed in all acoustic measurements (P<0.05).
Significant differences in voice quality in all components of GRBAS scale were observed between before and after using the app. The inter-rater reliability between the two raters was fair to good (ICC=0.440).

Among the 24 who took part in the survey (Figure 3C), fourteen (58.33%) reported their voice ‘getting better’, nine (37.50%) ‘no change’, one (4.17%) ‘unsure’ and none reported ‘getting worse’.

Table 2. Changes in MPT, vocal intensity, and GRBAS scale before and after using the app (N=25).

Variable	Before	After		
	Mean (SD)		*t*	*P*-value
MPT (seconds)	11.15(5.38)	14.01(5.64)	-3.273	*.003*
Vocal intensity				
Sustained phonation (dB)	72.32(5.04)	75.67(3.75)	-4.761	*<.001*
Reading short sentences (dB)	72.59(4.09)	74.04(4.08)	-3.164	*.004*
Reading ‘Ga-	69.64(4.55)	71.59(3.61)	-3.546	*.002*

eul' passage (dB)				
All tasks (dB)	71.59(4.39)	73.81(3.48)	-4.462	<.001
GRBAS scale				
Grade	1.14(1.02)	0.86(0.90)	4.968	<.001
Roughness	0.80(0.94)	0.61(0.76)	3.999	<.001
Breathiness	0.93(0.92)	0.59(0.76)	6.827	<.001
Asthenia	0.52(0.74)	0.16(0.47)	7.187	<.001
Strain	0.49(0.70)	0.31(0.56)	4.148	<.001

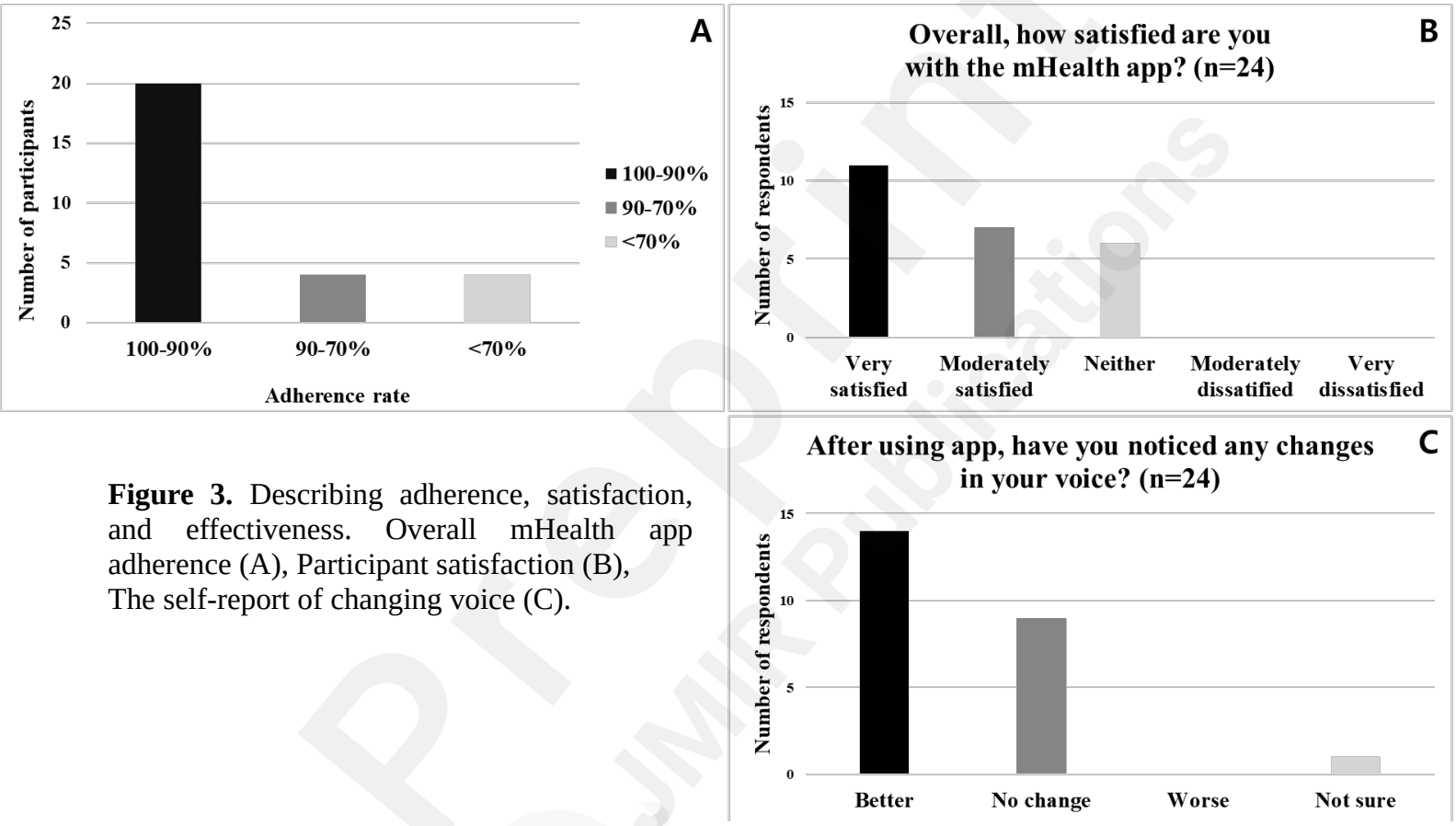


Figure 3. Describing adherence, satisfaction, and effectiveness. Overall mHealth app adherence (A), Participant satisfaction (B), The self-report of changing voice (C).

Discussion

Principal Findings

The aim of this study was to investigate the feasibility of PD patients independently performing voice and speech training at home using a smartphone app as an alternative to traditional face-to-face therapy. The study involved SLPs to develop an mHealth app based on speech training content commonly used on PD patients, and evaluated patients' adherence to treatment schedules, satisfaction with app-based therapy, and treatment effectiveness.

Our study indicates that speech therapy delivered through a mHealth app is a feasible solution for PD patients. Twenty out of 25 participants who completed the app showed an adherence rate of over 90%. Given that dropout rates in fields requiring various health behavior changes reach 30-60%, an adherence rate of over 90% can be considered sufficiently high and indicative of successful

adherence [9]. It is typically stated that an adherence rate of over 80% is necessary for optimal therapeutic efficacy, and our study has achieved this.

About 75% of participants were satisfied with the app use and improvements in voice and speech were observed both in objective and subjective evaluations. This is similar to the satisfaction rate (70%) of an internet-based telerehabilitation application for speech therapy [10] and is also comparable to a study reporting satisfaction rate of 82.6% with the smartphone app for people with aphasia [11].
Another notable point is that positive results were obtained for both objective and subjective ratings for voice. It is generally known that acoustic assessments highly correlate with SLP's auditory perceptual ratings but have a low correlation with patient subjective assessments [12,13]. This indicates that there is a discrepancy between the degree of voice impairment assessed by the assessor and by the patients. The consistency in our results among three methods of evaluation indicates the robustness of effectiveness.

The advancement of mobile and electronic technologies has increased interest in non-face-to-face therapy, which has been further accelerated by the COVID-19 pandemic. This can help address medical accessibility issues. If non-face-to-face methods are proven to be as usable and effective as face-to-face therapy, they will be a more convenient way to receive medical services. Previous studies have confirmed its feasibility and effectiveness in various rehabilitation fields, such as speech, motor and cognition [14-16]. In addition, the benefits of online treatment reported include time and cost savings and reduced caregiver burden. Along with these benefits, a key advantage of mHealth apps is that they enable patients to take an active role in managing their condition. Previous studies indicate that the integration of mHealth technology into therapy is an optimized clinical pathway for patients [17]. Although the number of studies is limited compared to real time teletherapy provided by therapists, there are a few that have confirmed the usefulness and effectiveness of app-based therapies [5,18-20]. These include reports of significant improvements in pronunciation and speech volume in people with PD who received speech therapy using a homegrown software [20]. This finding is in line with our results and illustrates the potential of mHealth app as a feasible approach to speech rehabilitation.

In contrast to the high adherence in our study, a previous study investigating the usability of an mHealth app developed to address walking, speech, and dexterity symptoms in PD patients reported low adherence and effectiveness [21]. The adherence to speech exercises was 66.8% (±26.5%). In the study, participants in the intervention group were instructed to independently complete exercises using the provided mHealth app on their personal smartphones once a day for approximately 90 days. This app required practicing various areas such as mobility exercises in addition to speech, and it took about 30 minutes to complete all sessions. This may have placed a physical and mental burden on the users.
Additionally, considering that appropriate feedback and interaction with therapists generally impact the adherence and effectiveness of therapy, the extent to which sufficient feedback was automatically provided within the app may have also influenced these outcomes. In our app, not only does it provide reminder functions through pop-up alarms, but it also provides different feedback each time whenever the patient performs a task (e.g., 'Good job! Squeeze your abdomen and speak louder!'). Such feedback may have positively influenced the patient's continued use. Furthermore, over 50% of the participants in the previous study experienced technological issues with the app, which may have interfered with the outcomes. In our app, we tried to create the user interface elderly-friendly as much as possible and to ensure seamless operation of the app. As a result, there were no reports of technical issues, and this also could have affected adherence, effectiveness, and satisfaction.

Limitations and Future Directions

However, our study has several limitations. Because the primary aim of this study was to evaluate feasibility and this is an uncontrolled study, the effectiveness observed in our study should be interpreted with caution. Larger randomized controlled trials are needed to provide more robust results on effectiveness. In addition, consideration of factors that may affect the usability of the mHealth app, such as disease severity and digital literacy [22] of patients from the recruitment stage, would be useful to evaluate the potential for introducing this app to a broader PD population.

Secondly, we were unable to conduct functional assessments to determine whether participants' voice issues improved in real-life communication situations. This could be quantitatively measured using the Voice-Related Quality of Life (V-RQOL) tool. In general, studies have shown that after face-to-face speech therapy, such as the Lee Silverman Voice Treatment (LSVT) or the SPEAK OUT!® Voice program, patients exhibit improved Voice-Related Quality of Life (V-RQOL) scores [23, 24]. In future research, utilizing such questionnaires could provide a deeper measurement of the effects.

In addition, future research could consider longitudinal studies to evaluate the long-term effects and sustainability of mHealth apps. Patient adherence is crucial for treatment effectiveness and improvement in their health status. Nevertheless, most existing studies have short durations, limiting research on factors affecting mHealth app adherence [25]. Tracking changes in user adherence over extended periods could help develop user retention strategies. Furthermore, the accumulated data could be used to analyze user behavior patterns and develop predictive models.

Conclusions

Despite the small sample size of this study, this study supports the feasibility of self-delivered speech therapy at home for patients with PD. Especially considering the age of the participants, the mHealth app we developed is not only suitable for elderly users but also proves to be satisfying for them.

Acknowledgements

This study received no funding. We sincerely thank all the participants for their involvement in this study. We also extend our gratitude to the two SLPs, Professor Seung Jin Lee and Professor Jung Wan Kim, for their assistance with the auditory perceptual assessment.

Authors’ Contributions

Study concept and design: Han-Joon Kim, Jiae Kim, Sol-Hee Lee. Acquisition, analysis, or interpretation of data: Han-Joon Kim, Jiae Kim, Sol-Hee Lee. Drafting of the paper: Han-Joon Kim, Sol-Hee Lee. Critical revision of the paper for important intellectual content: Han-Joon Kim, Jiae Kim, Sol-Hee Lee. All authors have approved the submitted version and have agreed both to be personally accountable and to ensure that questions are appropriately investigated, resolved, and the resolution documented in the literature.

Conflicts of Interest

none declared

Abbreviations

App: application
ICCs: intraclass correlation coefficients
mHealth: mobile health
MPT: maximum phonation time
PD: Parkinson’s disease

SPL: sound pressure level
SLP: speech-language pathologist

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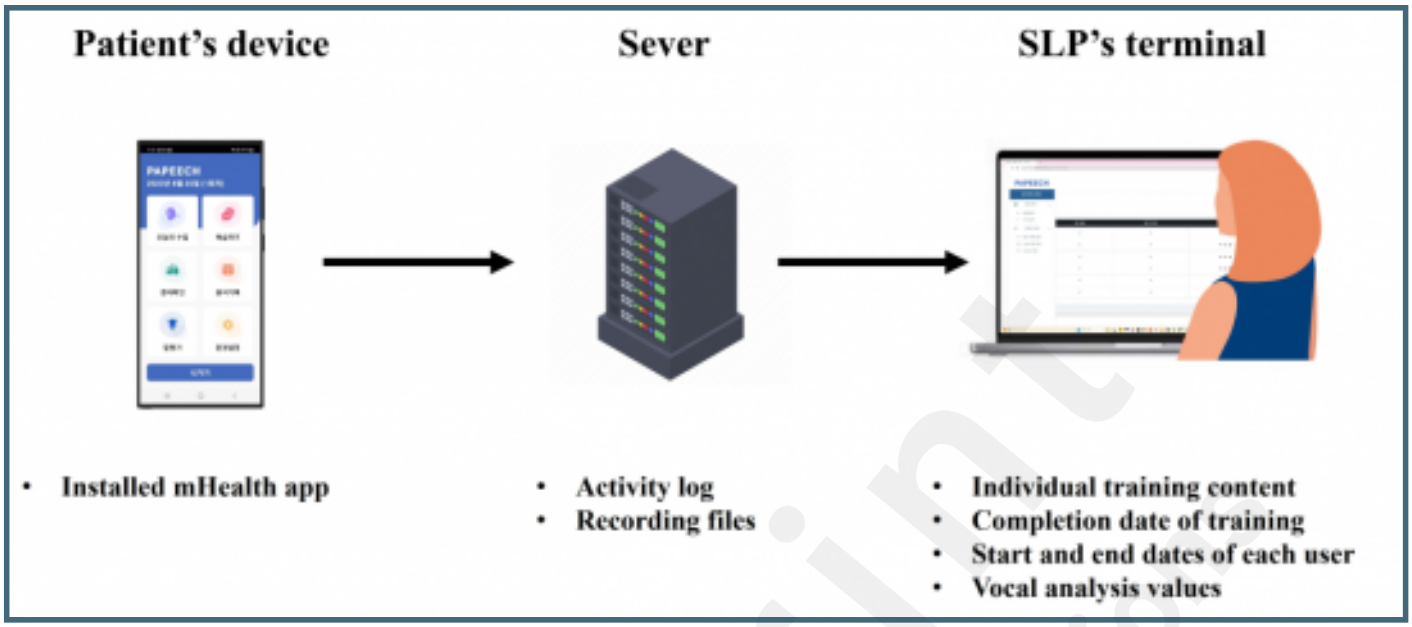
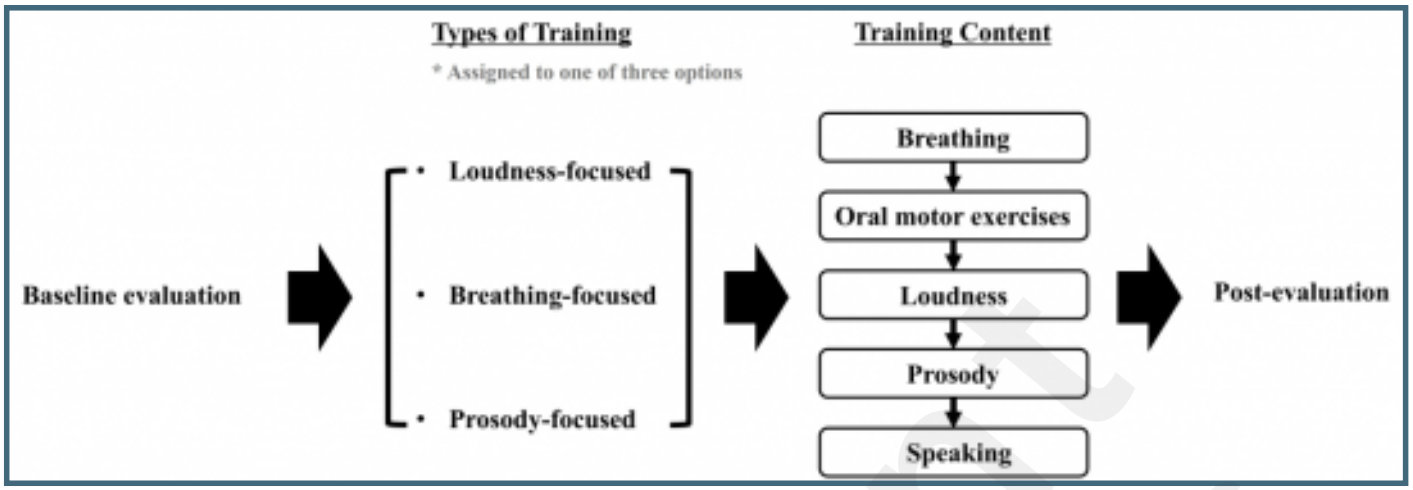
Supplementary Files

Figures

A simplified overview of the composition of the mHealth app.



Contents and structure of the speech training program.



Describing adherence, satisfaction, and effectiveness. Overall mHealth app adherence (A), Participant satisfaction (B), The self-report of changing voice (C).