Archives of the Balkan Medical Union
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vol. 57, no. 1, pp. 71-83
March 2022

REVIEW ARTICLE

APPLICATION OF IT TECHNOLOGY IN THE MANAGEMENT OF VOICE-SPEECH DISORDERS AND PHONIATRIC REHABILITATION

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Received 16 Jan 2022, Accepted 21 Febr 2022
https://doi.org/10.31688/ABMU.2022.57.1.09

Abstract

Introduction. Up to date, various mobile medical apps were proposed, including digital platforms for diagnoses of speech impairment. The review aims to assess the effectiveness of mobile health (m-Health) platforms for patients with speech and voice disorders.
Material and methods. We conducted a systematic review of studies published between 2008 and 2021. 234 articles from PubMed, Web of Science, and Cochrane Library databases were pre-selected for the review. Only articles related to the use of medical applications for smartphones, tablets, or computer devices studies were included in the analysis.
Results. A total of 111 full-text articles were assessed for eligibility, and 37 were included in this study. The selected reports cover research on the use of mobile applications for therapy, rehabilitation assistance, and

Résumé

L'application de la technologie informatique dans la gestion des désordres du mécanisme verbal voix-parole et la réhabilitation phoniatrique

Introduction. De nos jours, diverses applications médicales mobiles (applications) ont été proposées, y compris des applications pour le diagnostic des troubles de la parole. La revue présentée vise à analyser un certain nombre de solutions et à évaluer l'efficacité des plateformes de santé mobile (m-santé) utilisées dans la pratique clinique pour les patients souffrant de troubles de la parole et de la voix.
Matériel et méthode. Une revue systématique des études publiées entre 2008 et 2021 a été réalisée. Les 234 articles des bases de données PubMed, Web of Science et Cochrane Library ont été présélectionnés

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diagnoses. In terms of application, mobile apps have been developed for patients (children and adults) with speech disorders caused by autism, neuro-developmental speech impairment, Parkinson's disease, aphasia, voice disorders, etc.

Conclusions. The analysis showed that the m-Health market offers various mobile applications for persons with speech impairments (as an adjuvant tool for therapy and rehabilitation). Despite the existence of a range of m-Health applications for patients with speech disorders, there is a need for further large-scale studies aimed at studying their effectiveness, safety, and reliability.

Keywords: speech disorders, aphasia, dysarthria, mobile applications, telemedicine, m-Health.

List of abbreviations

ASD – autism spectrum disorder
SM – selective mutism
DLD – developmental language disorder

pour la revue. Seules les études liées à l'utilisation d'applications médicales pour smartphones, tablettes ou appareils informatiques ont été incluses dans l'analyse.

Résultats. Un total de 111 articles en texte intégral a été évalué pour l'éligibilité, et 37 ont été inclus dans cette étude. Les rapports sélectionnés englobent des recherches sur l'utilisation d'applications mobiles à des fins de thérapie, d'aide à la réadaptation et de diagnostic. En termes d'application, des applications mobiles ont été développées pour les patients (enfants et adultes) souffrant de troubles de la parole causés par l'autisme, les troubles neurodéveloppementaux de la parole, la maladie de Parkinson, l'aphasie, les troubles de la voix, etc.

Conclusions. L'analyse a montré que le marché de la m-santé offre diverses applications mobiles pour les personnes ayant des troubles de la parole (en tant qu'outil adjuvant pour la thérapie et la rééducation). Malgré l'existence d'une gamme d'applications m-santé pour les patients souffrant de troubles de la parole, il est nécessaire de poursuivre les études à grande échelle visant à étudier leur efficacité, leur sécurité et leur fiabilité.

Mots-clés: troubles de la parole, aphasie, dysarthrie, applications mobiles, télémédecine, m-Santé

Introduction

Up to date, a wide range of mobile applications have been proposed and integrated into the healthcare systems to improve the diagnoses, treatment, and management of various disorders. Digital mobile health (m-Health) platforms encompass several various technological solutions, including telehealth and remote patient monitoring. The recent situation with COVID-19 pandemics demonstrated the high potential of digital health systems over the traditional approaches[1]. In fact, mobile health apps have been actively utilized in various areas, including detection, screening, remote patient monitoring, data analysis, and treatment of infected patients. The Global Observatory for eHealth of the World Health Organization defines m-Health as "medical and public health practice supported by mobile devices such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices"[2].

In 2013, the number of app downloads on Apple iTunes (which sells apps only for iOS devices such as iPad, iPhone, and iPod touch [all Apple Inc., Cupertino, CA]) reached 50 billion[3]. Apart from iOS platforms, there is a high number of downloads for Android devices (Google Inc., Mountain View, Calif.), as well[4]. The rapid development of mobile technologies led to the expansion of the scope of use of m-Health systems. As a result of its combination with telemedicine (remote diagnoses and treatment of patients using telecommunication technologies), a range of digital platforms was proposed and implemented to solve problems with consultations, patient monitoring, remote treatment, etc[5].

In addition, there is a stable growth of several applications of digital technologies for people with different types of disabilities[6], such as speech impairment and writing disorders that cause communication and social problems[7]. A speech disorder is a general term encompassing a wide range of disabilities and differences associated with the impaired articulation of speech, fluency, and/or voice sounds[8].

In fact, neurological diseases such as autism, Parkinson's disease, or dementia can cause difficulties with communicating and social activity[9]. In this context, mobile technologies could be helpful for improving various aspects of speech and language intercommunication, for example, for collecting data, recording conversational patterns, and developing communication skills[10]. Despite the number of reviews and analytical reports on mobile applications for speech disorders[11,12], there is a lack of information on their efficacy, safety, and clinical relevance.

In this regard, the presented review aimed at analysing the m-Health platforms used in clinical practice for patients with speech and voice disorders.

Materials and methods

The study was conducted in accordance with the recommendations of the Cochrane Guidelines for Systematic Reviews of Interventions version 5.1.0[13,14], in accordance with the guidelines for preferred reporting clauses for systematic reviews and meta-analyses (PRISMA) statement[14].

Data Sources and Search Strategy

The following databases were searched: PubMed, Web of Science, and Cochrane Library (no time limit). Search strategies were performed using a combination of free text terms and MeSH terms ("Speech Disorders" [Mesh]) OR "Aphasia" [Mesh]) OR "Dysarthria" [Mesh]) AND "Mobile Applications" [Mesh]) OR "Telemedicine" [Mesh]. Articles were selected in two stages. First, in the course of the above searches, articles by title were checked for relevant research. Second, the full texts of these shortlisted articles have been downloaded and assessed against the inclusion criteria.

All articles have been uploaded and revised in EndNote version X6 (Clarivate Analytics, New York, USA). Duplicates have been removed using EndNote software and manually. In addition, we employed the Rayyan online screening tool to search for articles[15]. No restrictions were applied to the date of publication.

Procedure of the Data Extraction

Two members of review independently extracted the data on study characteristics, intervention details and outcomes. Disagreements were resolved by oral discussion or resolved by a third author. Data were collected using a data extraction spreadsheet developed specifically for this study.

Criteria for considering studies for this review

Inclusion criteria were as follows: all clinical trials or randomized controlled trials, case-control studies, case reports, pilot tests using mobile applications or any Tele-Health/ m-Health technologies with the release of baseline data (aimed at improving the ongoing therapy or rehabilitation of patients with speech impairment). The analysis included publications written exclusively in English.

Only studies on the use of medical mobile applications were included in the analysis. The analysed applications (apps), depending on the functionality, were sub-divided into several groups: 1) an additional tool to improve communication skills (speech development), 2) apps for improving diagnoses, and 3) apps for rehabilitation.

Exclusion criteria

The studies conducted before 2008 were excluded from the analysis (the first Apple smartphones with the iOS operating system was released on June 29, 2007)[16]. The following publications were excluded from the analysis: review articles, systematic reviews, editorials, books and chapters books, conference proceedings, descriptions of research design (or research protocols) or descriptions of any mobile applications only under development, pilot studies without providing preliminary data. Articles discussing mobile applications in a different context were also excluded from the analysis: for example, research on the bio-effects of radiation from mobile phones.

Results

Study selection

The characteristics and main features of the analysed studies are presented in Table 1. Figure 1 shows a systematic procedure for searching and selecting the literature. Our initial query returned 234 potentially relevant records, from which 30 duplicates were eliminated. After examining the titles and abstracts, 67 entries were deleted (that did not correspond to the topic "speech disorders"). A total of 111 studies were assessed for eligibility, after which 37 studies were included in the analysis. For the analysis, we selected studies published between 2014 and 2021.

The analysis showed that studies on the use of mobile applications were carried out in the following countries: USA[17-35], China[36], Spain[37,38], Australia[9,39,40], Turkey[41], Pakistan[42], Canada[43], Italy[44], Brazil[45], Great Britain[5,46,47], Switzerland[48], South Korea[49]. There is a range of studies on the use of digital platforms for the treatment of speech disorders and pathology of the vocal cords (improvement / development of communication skills, speaking, reading, speech recognition)[5,9,17-24,26-28,30-32,34,36,37,39-45,48], rehabilitation[25,29,33], diagnoses of speech disorders[47,49-51], and the use as auxiliary devices for medical personnel working with patients with speech disorders[35,38,46].

Mobile applications were used for the management of speech or vocalization disorders in children for the following pathologies: autism[17,19-21,26,30,36,37], selective mutism[18], developmental language disorder[39,46], and speech sound disorder[40,41,44]. At the same time, the digital platforms were also proposed for the use predominantly in adults: communication disability[33], hearing- and speech-impairment[42], speech disorders due to intellectual and developmental disabilities[22],

Table 1. Apps and tools for therapy of speech disorders.

N°	*Authors, country, year*	*App or tool name; main content;*	*Speech disorder type or cause*	*Participants number and characteristics*	*Follow-up time*	*Rehabilitation properties*	*Mode of delivery/Platform (cost)*	*Functionalities*	*Outcomes/ efficiency*	*Limitations*
Apps/tools for use in impairment of functional communication skills of patients with neurodevelopmental disorders										
1	**Alzrayer et al.**[19], USA, 2017	**"Proloquo2Go"** app; for increasing multistep requesting skills by using content of picture library;	Autism spectrum disorder (ASD)	Children; 8-10 y.o.; n=4;	N/A	-	iOS-Apple iPad II;	Communication skills improvement	Effective in increasing multistep requesting;	Some of the participants were partially under the control of the verbal cue to use the iPad; the tendency of the participants to exhibit challenging behaviours resulted in a contrived requesting task; the variability in clinical and demographic characteristics of the participants; the lack of social validity data;
2	**Muharib et al.**[17], USA, 2019	**"Proloquo2Go"** app;	ASD and/or developmental disability	Children; 6-8 y.o.; n=3;	twice a day 5-10 min (with a break of 5 to 20 min), 3 to 4 times a week, over the course of 11 weeks	-	iOS-Apple iPad (Version 11.2.2);	Communication skills development	Effective in increasing both iPad1 #-based and vocal requesting of all participants	Issues related to vocal requesting; study did not measure the length of utterance or require participants to vocalize the full name of two-word items; one participant had experience with another communication application previously;
3	**An et al.**[36], China, 2017	**"Yuudee"** app; to make requests by using content of 39 categories of pictures;	Minimally verbal children with ASD	Children; 3-6 y.o.; n=10;	n=8 30-min sessions, 1-2 sessions per week for 5 weeks.	-	iOS-iPad/ iPad Mini; Android;	Communication skills improvement	Effective for helping minimally verbal children with ASD make Requests; all children made progress in requesting items during the training;	no follow-up sessions; the training sessions and evaluations were conducted only in a classroom; data on whether and how much the parents trained their children to use Yuudee at home wasn't collected; there was no control group;
4	**Bunnell et al.**[18], USA, 2018	**Mobile app**;	Selective mutism (SM)	Children; 5-17 y.o.; G1: n=5 using mobile (i.e., Apple iPad) apps; G2:n=5 g using other therapeutic tools/ activities (tBT); G3: n=5 shaping using reinforcement alone (rBT).	n=2, ≤ 55-min treatment sessions, conducted within the same week	-	Pilot study; iOS- Apple iPad;	Speech improvement	Mobile apps provide some utility during the treatment of SM	a single case design strategy with a randomized assignment to treatment groups; small sample size; the presented protocol is not intended as a comprehensive treatment for SM;
5	**Cabielles-Hernandez et al.**[37], Spain, 2017	**"Chain of Words"** tool; by repeating words, creating sentences with the pictograms from ARASAAC	ASD	Children with special educational needs.	N=10, 15 minsessions for vocabulary and 7 sessions for sentences	-	Testing and validation of tool ; for tablet Devices;	Communication skills improvement	Mobile devices may be another supporting tool to be used with children suffering from ASD	Preliminary results;
6	**Carson et al.**[39], Australia, 2020	**"Reading Doctor®" (RD)** apps; Consists on 3 parts: Letter Sounds™1 Pro, followed by Blending Sounds™ 1 Pro and finally Spelling Sounds™ 1 Pro.	Developmental language disorder (DLD)	Children; 4-5 y.o.; IG:n=14 CG:n=10	IG: twice a week in three RD apps for an 8-week period 20-25 min; CG: usual preschool programme;	-	Pilot study; iOS- iPad;	Improvement of literacy skills	RD software can support code-based reading readiness among pre-school children with DLD in the months just prior to school entry	Preliminary results; single-centre study;

N°	*Authors, country, year*	*App or tool name; main content;*	*Speech disorder type or cause*	*Participants number and characteristics*	*Follow-up time*	*Rehabilitation properties*	*Mode of delivery/Platform (cost)*	*Functionalities*	*Outcomes/ efficiency*	*Limitations*
7	**Dural et al.**[41], Turkey, 2018	**"Turkish Articulation Therapy Application" (TARTU)**; for computer-aided remote articulation therapy	Speech sound disorder	Children, 5 y.o.; n=1 TARTU app; n=1 paper-printed material;	N=12 sessions 3 times a week +2 follow-up sessions;	-	iOS-iPad;	Articulation improvement	TARTU did not play an important role in the success of the articulation therapy on the participants	A single subject study; having only word and sentence levels;
8	**Caron et al.**[20], USA, 2018	**"Transition to Literacy" (T2L)** software;on the sight word reading skills	ASD and complex communication needs	Children; 6-14 y.o.; n=5;	3–4 sessions per week length 15 min	-	Augmentative and alternative communication (AAC) app with T2L features;	Improvement of the sight-word reading skills	Positively impact the sight-word reading of all participants during a structured task (identification of 12 targeted sight words).	Preliminary results; small sample size; study focused on an isolated skill – sight-word reading – with a small set of target words;
9	**Irwin et al.**[21], USA, 2015	**"Listening to Faces" (L2F)** app to assist in perception of the spoken words.	ASD	Children; n=4	3 days/ week (10 min each session) for 12 weeks.	-	iOS-iPad;	App for audio-visual speech perception	Children improved their performance on an untrained auditory speech-in-noise task	Preliminary results;
10	**Hair et al.**[40], Australia, 2019	**"PocketSphinx" (PS)** app for speech recognition in child speech therapy	Disordered speech	Children, 7-9 y.o.; n=7;	N/A	N/A	Android-Samsung Tab A 10.1 tablet (for the audio recording)	Speech recognition	Successful model for capture speaker-specific word production variations	Study focuses only on word recognition;
11	**Halim et al.**[42], Pakistan, 2015	**"Microsoft® Kinect"** tool for detecting gestures stored in the dictionary with an accuracy of 91%	Hearing- and Speech-impairment	Adults; 19-36 y.o.; n=10;	N/A	-	3D depth camera (Kinect);	Communication tool	87% participants agreed that the system was useful.	Small sample size; dictionary has a low performance on particular n=20 gestures;
12	**Holyfield et al.**[22], USA, 2020	**"The EasyVSD"** app with the T2L feature	Intellectual and developmental disabilities (IDD) ASD, (Down syndrome and cerebral palsy);	Adults; 22-55 y.o.; n=6;	1to 5 20 min sessions per week during 8 months.	-	Android-Samsung tablet;	Improvement of the single-word reading skills	AAC apps effective in single-word reading.	Small sample size; The lack of control of intervention setting and number of intervention sessions;
13	**Ireland et al.**[9], Australia, 2016	**"Harlie"** app for making conversation with the user on a variety of topics	Parkinson disease and developmental speech disorders	Adult, 27-87 y.o.; n=33;	once a day, between 8AM – 8PM via randomly call	-	App for smartphone;	Tool for measuring voice, communication outcomes, educational and supportive role	App can be used for measuring voice and communication outcomes	Overview/testing study
14	**Horin et al.**[23], USA, 2019	**"Beats Medical Parkinsons Treatment"** app to treat gait, speech and dexterity in people with Parkinson's disease	Damage of gait, speech and dexterity in people with Parkinson's disease	Adults; >30 y.o.; IG: n=17 with Parkinson use the app; CG: n=20 with Parkinson had traditional routine;	12 weeks;	+	iOS- iPhone;	Therapeutic tool /improvement speech	App alone was not adequate to treat symptoms of gait, speech or dexterity in people with Parkinson's disease	Small sample size; absence of feedback function via app;

N°	*Authors, country, year*	*App or tool name; main content;*	*Speech disorder type or cause*	*Participants number and characteristics*	*Follow-up time*	*Rehabilitation properties*	*Mode of delivery/Platform (cost)*	*Functionalities*	*Outcomes/ efficiency*	*Limitations*
15	**Hyppa-Martin et al.**[24],USA, 2019	**"The DynaVox Vmax™"** tool with embedded or non-embedded visual scene displays (VSDs)	ASD	Adult, 19 y.o.; n=1;	12 intervention sessions+ 1 maintenance session	-	Tool for augmentative communication;	Speech-generating tool	Efficiency of embedded or non-embedded VSDs was an equal	Only 1 participant; absence of comparative group; lack of IOA;
16	**Kurland et al.**[25], USA, 2014	**"iBooks Author™"** software (2 books contained Objects and one contained Actions) for speech improvement in the post-stroke period.	Post-stroke aphasia.	Adults,55-81 y.o.; n=5;	20 minutes, five or six days per week 6-month period	+	iOS- iPhone;	Speech rehabilitation app (home practice program)	App had a great potential for personalized home practice to maintain and augment traditional aphasia rehabilitation	Pilot study; Small sample size; absence of comparative group;
17	**Mallet et al.**[43], Canada, 2016	**Mobile tablet programmed** app	Post-stroke communication deficits	Adults,35-92 y.o.; n=29;	at least one hour per day	+	iOS- iPad;	Therapeutic tool /improvement speech	97%, and 96% of patients scored the mobile tablet-based communication therapy as at least moderately convenient 3/5 or better with 5/5 being most "convenient"	Pilot study; Small sample size; absence of comparative group; did not assess the long-term retention and adherence;
18	**Laubscher et al.**[26], USA, 2019	**"GoVisual1™"** app with video visual scene displays (video VSDs) for communication	ASD	Child with ASD, 8y.o.; n=1;	Baseline and intervention phases 2-month period; Sessions occurred 3–5 times per week	-	iOS- iPad;	Communication tool;	The usage of video VSDs intervention support communication for children with ASD and limited speech during pretend play with their peers.	Pilot study; a single-case study;
19	**Laures-Gore et al.**[27], USA, 2021	**App** (had 1 = baseline phase and presented pictures only; 2 = intervention phase and presented the script plus pictures);	Aphasia after stroke (naming impairment)	Adults,37-68 y.o.; n=4;	Once per day	+	Android-tablet;	Speech improvement;	N=2 participants showed improvement in naming items following an imagery script	Pilot study; small sample size;
20	**Lorusso et al.**[44], Italy, 2018	**"TagWriter"** app; consists on several parts: introduction; story; picture; song; puzzle;	Language impairment (LI)	Children, 4-6 y.o.; n=14;	N=1, 45-minute speech therapy session	+	Nexus 10 Tablet and NFC tags;	Communication tool (for therapy)	a valuable aid to support and enhance communication abilities in children with LI	Preliminary data; prototype limited number of activities;
21	**Meltzner et al.**[28], USA, 2018	**System with the surface electromyographic (sEMG) signals** for subvocal speech recognition	Speech impairments (laryngectomy)	Adults, 20-42 y.o.; n=19;	N/A	-	sEMG-based speech recognition system (prototype wireless Trigno™ Mini sensors);	Communication tool	An alternative modality of communication in speech impairments	Testing;

N°	Authors, country, year	App or tool name; main content;	Speech disorder type or cause	Participants number and characteristics	Follow-up time	Rehabilitation properties	Mode of delivery/Platform (cost)	Functionalities	Outcomes/ efficiency	Limitations
22	**Ramsberger et al.**[29], USA, 2014	**Different 3 apps;**	Aphasia	Participants (3 cases): 1)Case 1: 33y.o.; post-stroke aphasia; 2) Case 2: aphasia after traumatic brain injury; 3) Case 1: 79 y.o.; post-stroke aphasia;	N/A	+	1) iOS-iPad (e-mail messages); 2) iPad (to play games using a Microsoft Xbox), free to download; 3)Android App Notepad Pro (for conversations) (U.S. $1.99);	Speech rehabilitation apps	best-practice guidelines for integrating apps in aphasia rehabilitation	Case reports; absence of comparative groups;
23	**Silva et al.**[45], Brasil, 2021	**"Talk Around It"** app with exercises for word-finding (naming)	Cognitive-communication disorder (CCD)	Adult, 72 y.o.; n=1;	50-min sessions during 13 weeks (at least 3 times a week over the 4-week period)	+	Android;	Language skills improvement	App promoted improvement in lexical access ability; occurrence of anomia events reduced;	Case reports; absence of comparative groups;
24	**Simmons et al.**[30], USA, 2016	**"SpeechPrompts"** tool to treat prosodic and other communication impairments	Prosodic Deficits in ASD	n=40 students (5-19 y.o.) with aphasia; n=10 speech-language pathologists (SLPs);	At least once each week for 8 weeks	-	iOS-iPad (N/A); Contained two primary features: VoiceMatch and VoiceChart;	Therapeutic tool	App has potential to be a useful tool in the treatment of prosodic disorders	Pilot study;
25	**Stark et al.**[5], UK, 2018	2 Apps were used: **Language Therapy©** (had 4 categories: Reading, Naming, Comprehension and Writing); **Bejeweled©;**	Post-stroke chronic aphasia	Adult, 54-87 y.o.; n=7; G1:n=3; firstly used Bejeweled©(4 weeks), than used Language Therapy © (4 weeks); G2: n=4; firstly used Language Therapy© (4 weeks), than used Bejeweled © (4 weeks);	20 minutes per day	+	iOS-iPad;	Language skills improvement /Automatic feedback	Therapy via apps beneficial for chronic expressive aphasia.	Pilot study;
26	**Uslu et al.**[48], Switzerland, 2020	**"High-frequency telerehabilitation speech and language therapy" (teleSLT)** app compared to high-frequency telerehabilitative cognitive training (teleCT	Post-stroke chronic aphasia	A randomised controlled, evaluator-blinded multicentre superiority trial;n=100 outpatients; IG: devoted 80% of their training time to teleSLT and the remaining 20% (24 min/day) to teleCT assigned by a speech and language therapist; CG: vice versa;	4 weeks (7days per week), 2hours a day independently at home by using the teleSLT and teleCT application	+	iOS-12.9-inch iPad Pro tablet-computer;	Language skills improvement		Lack of compliance to the training time over a 4-week duration might result in bias; Person-centric outcomes (quality of life, speech improvements) may limit generalization;

N°	*Authors, country, year*	*App or tool name; main content;*	*Speech disorder type or cause*	*Participants number and characteristics*	*Follow-up time*	*Rehabilitation properties*	*Mode of delivery/Platform (cost)*	*Functionalities*	*Outcomes/ efficiency*	*Limitations*
27	**van Leer et al.**[32], USA, 2017	**"Cepstral peak prominence" (CPP)** app for patient self-monitoring of voice quality	Voice disorders	Adolescents and adults 16-72 y.o.; n=14 produced sustained phonation and connected speech tasks with CPP app;	N/A	+	iOS devices (iPhones, iPods, and iPads);	Therapeutic tool	App has potential to assist and motivate patients in the achievement of resonant voice production at home.	Participants did not receive clinician assistance in achieving resonant voice; CPP calculation limited to iOS devices;
28	**van Leer et al.**[31], USA, 2019	App with **"fake phone call"** file;	Voice disorders	Adults, 22-56 y.o.; n=11;	Received a simulated call four times daily for 1 week	+	iOS software app;	Therapeutic tool	App had a positive effect on vocal self-evaluation skill	Preliminary results; Only for iOS devices; findings are limited to individuals with mild to moderate hyper functional dysphonia; only self-as-model recordings were examined;
29	**Wang et al.**[33], USA, 2018	**"EuTalk™"** tablet-based communication app for communication	Communication disability	Adults, 20-64 y.o.; n=20;	N/A	+	Android-Samsung Galaxy Tab 10.1;	Language skills improvement/ rehabilitation	App has a great potential to maximize users' communication effectiveness, enhance language skills, and ultimately improve users' quality of life.	Preliminary results; Short study period; a small sample size;
30	**Wendt et al.**[34], USA, 2019	**"SPEAKall!®"** app with Picture Communication Symbols™4 (PCS™) and colored photographs to communicate using digitized and/or synthesized speech	Severe ASD	Adolescents and young adult, 14-23 y.o.; n=3;	Twice a week for 30 to 40 min 1-2 sessions of 20 trials each, with a break in between	-	iOS-iPad;	Speech improvement;	App increased requesting skills (requesting, speech production) for all three participants across intervention and maintenance phases	Small sample size; findings may limit to certain cohorts; generalization was tested after the completion of intervention;
				Diagnostic tool						
31	**Brandenburg et al.**[50] , Australia, 2016	**"CommFit™"** to explore the use of talk time, as measured by the CommFit app, as an indicator of participation for people with aphasia	Aphasia	Adults; 28-84 y.o.; IG: n=12 with aphasia; CG: n=7 non-aphasic adults;	6 h a day for 14 days	-	iOS- iPhone 4 and a Plantronics Voyager Pro + Bluetooth headset;	Diagnostic tool/ for measurement talk time	On people with aphasia, talk time showed a correlation with participation status, and no correlation with impairment or activity limitation	Participants sampled only 6 h of their day; participants self-selected to participate in this study;
32	**Choi et al.**[49], South Korea, 2015	**"Mobile aphasia screening test" (MAST)** for for detecting aphasia in patients with stroke	Post-stroke aphasia	Adults, 22-77 y.o.; IG: n=30 with aphasia after stroke; CG: n=30 non-aphasic patients after stroke;	N/A	-	Pilot study; iOS-iPad;	Diagnostic tool/ screening	MAST may be a convenient and cost-effective alternative to the existing aphasia screening tests for patients with stroke	The automatic scoring system in the program workflow did not allow the subjects to change their response;
33	**Guidi et al.**[51], Italy, 2015	**App** for analysing running speech	Bipolar disorder	Adult,36 y.o.; n=1;	14 weeks, and the picture commenting task was performed 15 times while at home	-	Android app is integrated in a software tool of the PSYCHE Platform System;	Diagnostic tool	Use of the app for the voiced segmentation procedure could allow to estimate speech features related to F0 variability within each voiced segment.	Only for Android devices; single-case study;

N°	*Authors, country, year*	*App or tool name; main content;*	*Speech disorder type or cause*	*Participants number and characteristics*	*Follow-up time*	*Rehabilitation properties*	*Mode of delivery/Platform (cost)*	*Functionalities*	*Outcomes/ efficiency*	*Limitations*
34	**Mat Baki et al.**[47], UK, 2015	**"OperaVOX"** use for the acoustic analysis instead of Multidimensional Voice Program (MDVP)	Voice disorders (vocal fold pathologies)	Adults; Patients with voice disorders: n=50; volunteers: n=50;	Recording the voice twice within 15 min	-	iOS-iPod;	Diagnostic tool	OperaVOX is statistically comparable to 'gold standard' (MDVP) for most principal phonatory outcome measures.	Only acoustic parameter included;
Apps of tools to assist speech-language pathologists/ or to have remote communication with parents										
35	**Marin et al.**[38], Spain, 2021	**"NAO" robot;** when the user speaks, the NAO Robot recognizes the voice and finds speech failures	To assist speech-language pathologists who are related to speech sounds /articulation disorder patients	Test sessions of the robotic platform with speech-language pathologists supervision and analysing the experience of real patients;	N/A	-	Testing and validation of tool ; Application Programming Interface (API) either from Python or from Apache CORDOVA;	Platform to perform an exercise for articulation disorders	Several improvements were identified and human robot interaction was easy when the exercises were perceived as games with the support of mobile devices software integrated with robot	Preliminary qualitative data;
36	**Stockwell et al.**[46], UK, 2019	2 apps: **"KeepCam captured looped video"**, and **"Relate allowed captured video"** to be shared with the therapist and annotated with text	Cerebral palsy or non-progressive motor disorder affecting gross motor movements and speech	Children, 1-2 y.o.; n=5;	Intervention was provided by a research speech and language therapist in six once-weekly home visits, each lasting 50–70 min	-	Smartphone app+ additional devices (Bluetooth, etc.);	To increase communication frequency, including vocal/ verbal output	Parents indicated positive experiences of the programme and remote coaching via the apps	Preliminary study; Slow recruitment rate and loss of participants;
37	**van Zyl et al.**[35], USA/South Africa, 2018	**"hearSpeech"** app for speech recognition, using monosyllabic word lists (+an audiometer was connected as a measurement control)	For audiologists	Adults, 18-30 y.o.; n=100;	N/A	-	Android-Samsung Galaxy J2;	Diagnostic tool/ speech recognition	Valid method for measuring word recognition scores, and can support standardisation and accessibility of recorded speech audiometry	Only for Android devices; Test-retest reliability was not evaluated;

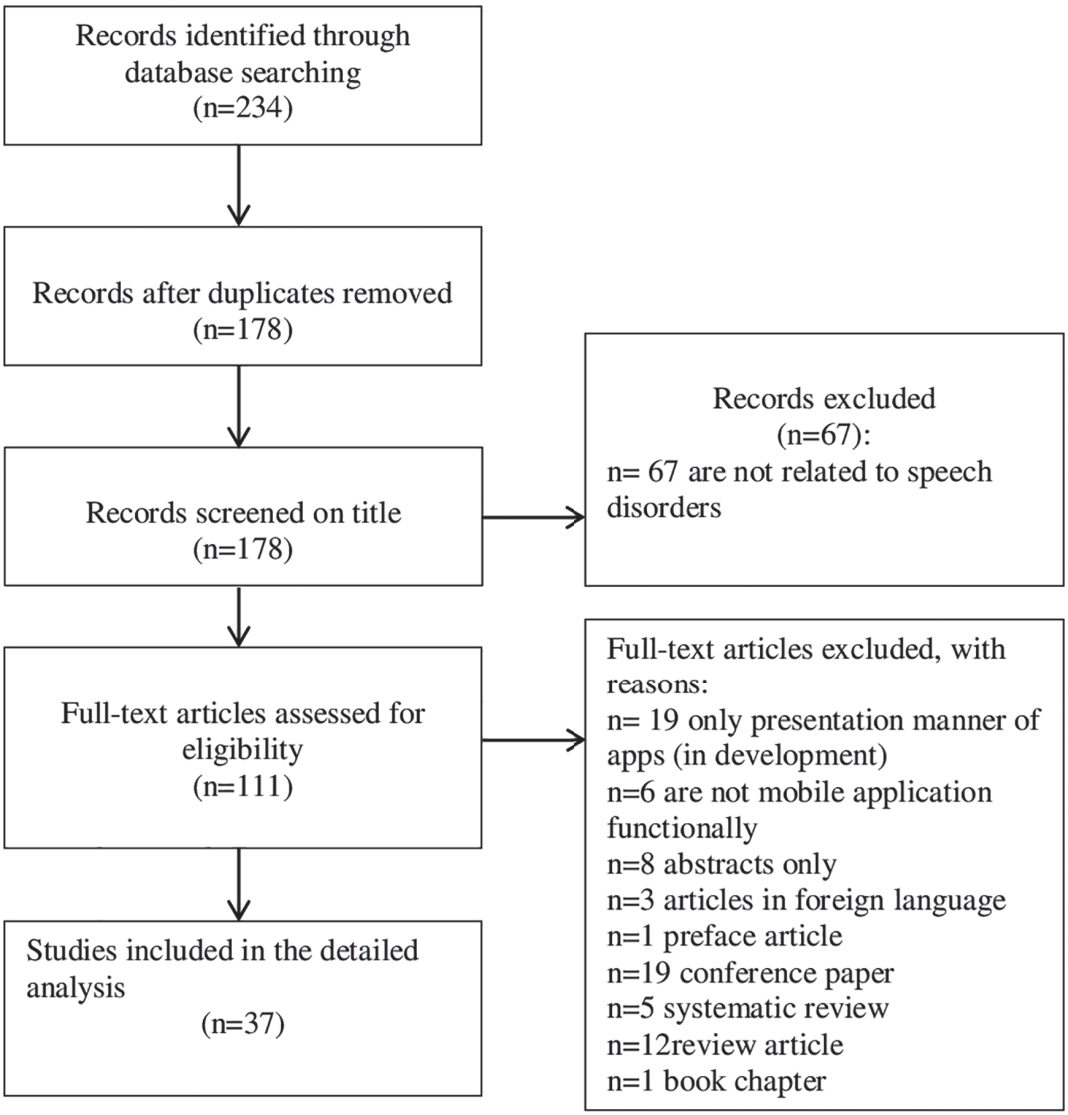

Figure 1. PRISMA flow chart for study selection process.

speech pathology due to Parkinson disease[9,23], autism[24,34], aphasia[50], post-stroke aphasia[5,25,27,29,43,48,49], vocal/ voice disorders[28,31,32,47], cognitive-communication disorder[45], and bipolar disorder[51].

Discussion

The speech production requires the integrity of many systems and organs: phonological (cognitive and linguistic), articulatory (sensorimotor), praxis (planning / programming the spatial-temporal parameters of articulatory movements for speech) and prosodic (stress, intonation and voice quality, conveying meaning and effect)[52]. The impairment of each component of the speech production system can lead to a problem with speech. It can be caused by a range of psychological, neurological, or physical problems.

Communication disorders might have a widespread impact on all aspects of life. They reduce the ability of self-expression, independence, and often affect self-esteem and attitudes[53].

An analysis of the available medical applications for smartphones/ tablets or computer devices showed a significant progress in the use of the m-Health systems in patients with speech disorders. However, studies on mobile applications were mainly pilot ones[26,27,39,43]. Moreover, the studies were predominantly based on a small sample with single participants[17,18,21,41], and often with the absence of a control group[25,29,43].

In addition, some studies on mobile applications have not been shown to be effective as a full-fledged tool for the treatment of speech disorders of any aetiology[23,41].

In many studies included in our review, in children with speech pathology, the use of mobile applications had a positive therapeutic effect. It could be directly related to the cognitive, developmental nature of the functionality of these mobile applications or computer devices[54]. Some of the apps had a game format[26]. However, in an earlier systematic review of mobile applications for children, assessing the content and quality of mobile applications according to the Mobile App Rating Scale (MARS) with speech impairments, only a small part of apps was considered very high quality or therapeutically useful[12].

Apart from that, in another published review (MARS scale), an analysis of downloadable mobile applications for adults with speech disorders was carried out by Vaezipour et al[11]. The results indicated the lack of interactive and attractive elements in apps, which is a decisive factor in maintaining independent speech therapy[11]. The authors pointed out that modern mobile apps for speech pathology demonstrated a low level of evidence of clinical efficacy[11]. The results of our analysis indicated that there is a need for further research with a focus on human factors, user experience, convenience, and a patient-centred design approach.

Conclusions

At present, the m-Health market offers various mobile applications as auxiliary tools for the therapy and the rehabilitation of persons with speech impairments. In general, despite the existence of a different range of m-Health platforms for speech disorders, there is a lack of full-fledged approbation of these applications. Therefore, there is a need for further large-scale studies aimed at investigating effectiveness, safety, clinical relevance, and reliability of health digital platforms.

Authors Contributions:

Y.A. and A.T. conceived the original draft preparation. Y.A., A.T., N.P., and Y.R. were responsible for conception and design of the review. Y.A., A.D., and R.T. were responsible for the data acquisition. T.A, A.B., B.I. and Y.A. were responsible for the collection and assembly of the articles/published data, and their inclusion and interpretation in this review. All authors contributed to the critical revision of the manuscript for valuable intellectual content. All authors have read and agreed with the final version of the manuscript.

Compliance with Ethics Requirements:

"The authors declare no conflict of interest regarding this article"

"No funding for this study"

Acknowledgments

"The authors are thankful to the S.D. Asfendiyarov Kazakh National Medical University for the administrative and technical support."

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