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REVIEW ARTICLE

Mobile phone applications in Parkinson's disease: a systematic review☆

M. Linares-del Rey[a], L. Vela-Desojo[b,c], R. Cano-de la Cuerda[a,*]

[a] *Departamento de Fisioterapia, Terapia Ocupacional, Rehabilitación y Medicina Física, Facultad de Ciencias de la Salud, Universidad Rey Juan Carlos, Madrid, Spain*
[b] *Unidad de Trastornos del Movimiento, Servicio de Neurología, Hospital Universitario Fundación Alcorcón, Madrid, Spain*
[c] *CINAC HM Puerta del Sur, Móstoles, Madrid, Spain*

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KEYWORDS
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Abstract
Introduction: Parkinson's disease (PD) is the second most common neurodegenerative disease. However, diagnosing, assessing, and treating these patients is a complex process requiring continuous monitoring. In this context, smartphones may be useful in the management of patients with PD.
Objective: The purpose of this study is to perform a systematic review of the literature addressing the use of mobile phone applications (apps) in PD.
Materials and methods: We conducted a literature search of articles published in English or Spanish between 2011 and 2016 analysing or validating apps specifically designed for or useful in PD. In addition, we searched for apps potentially useful for PD patients in the leading app stores.
Conclusions: The literature and app searches yielded a total of 125 apps, 56 of which were classified as potentially useful in PD and 69 as specifically designed for PD (23 information apps, 29 assessment apps, 13 treatment apps, and 4 assessment and treatment apps). Numerous mobile apps are potentially useful in or specifically designed for PD management. However, scientific evidence of their usefulness is scarce and of poor quality. Further studies are needed to validate these tools and regulate their use.

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* Corresponding author.
E-mail address: roberto.cano@urjc.es (R. Cano-de la Cuerda).

PALABRAS CLAVE
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Rehabilitación

Aplicaciones móviles en la enfermedad de Parkinson: una revisión sistemática

Resumen
Introducción: La enfermedad de Parkinson (EP) es la segunda enfermedad neurodegenerativa más frecuente, pero su diagnóstico, valoración y tratamiento son complejos y requiere de una atención sanitaria continuada en el tiempo. En este sentido, las características de los teléfonos móviles inteligentes o *smartphones* hacen que se plantee su uso en el ámbito de la asistencia del paciente con EP.
Objetivo: El objetivo del presente trabajo es realizar una revisión sistemática sobre el uso de aplicaciones móviles *(apps)* en la EP.
Material y métodos: Se llevó a cabo una búsqueda bibliográfica incluyendo artículos publicados en inglés o castellano, del año 2011 hasta el 2016, y que presentasen, analizasen o validasen un sistema basado en una *app* con utilidad o diseño específico para la EP. A su vez, se llevó a cabo una búsqueda de aplicaciones móviles en los principales mercados de aplicaciones móviles.
Conclusiones: Se encontraron mediante ambas búsquedas 125 aplicaciones, de las cuales 56 se clasificaron con potencial utilidad en la EP, y 69 con un diseño específico para la EP, siendo 23 *apps* de información sobre EP, 29 *apps* de valoración, 13 *apps* de tratamiento y 4 *apps* de valoración y tratamiento. Existen un gran número de aplicaciones móviles con potencial utilidad y diseño específico en la EP; sin embargo; la evidencia científica acerca de los mismos es escasa y de baja calidad. Son necesarios estudios posteriores para validar esta tecnología, así como una regulación por parte de organismos acerca de su uso.

Introduction

Parkinson's disease (PD) is a chronic neurodegenerative disease characterised by 4 motor symptoms: bradykinesia, resting tremor, musculoskeletal stiffness, and postural instability. However, patients also display non-motor symptoms, including psychiatric alterations, neurovegetative symptoms, and cognitive alterations.[1]

PD is currently the second most frequent neurodegenerative disease, after Alzheimer disease.[2] In 2005, the World Health Organization estimated worldwide incidence of PD at 4.5-19 new cases per 100 000 person-years, with prevalence of 100-200 cases per 100 000 population.[1] The most recent report from the European Parkinson's Disease Association predicts a worldwide prevalence of 8.7 million to 9.3 million cases by 2030.[3] In Spain, around 2% of people aged over 65 are affected by PD[4]; 115 000 disabled people are diagnosed with the disease, according to the National Statistics Institute.[5] Given that PD is a chronic disease, and the constantly improving life expectancy in developed countries, these figures and the associated social and healthcare costs will inevitably rise. The costs associated with the disease range from €7000 to €17 000 per patient per year, depending on the sources consulted and the factors considered.[4,6,7]

Although the aetiology of PD is unknown, the latest theories consider it to be multifactorial, involving a combination of genetic predisposition and a range of environmental triggers.[8]

Diagnosis of PD is mainly based on clinical criteria, as no biomarkers are able to confirm the presence of the disease. This can be an obstacle in the differential diagnosis of PD, resulting in treatment delays.[9] In most cases, treatment entails the administration of a combination of levodopa and other dopaminergic drugs to compensate for dopamine depletion, the cause of most PD symptoms.[10] These patients also require complementary rehabilitation therapy, including physiotherapy, occupational therapy, speech therapy, and psychological treatment. Multidisciplinary management of the disease is of great importance[11]: in addition to pharmacological treatment of symptoms, the other therapeutic approaches aim to slow or reduce disability, improving patients' functional status and quality of life as far as possible.[12] Neurorehabilitation has been demonstrated to be effective and plays a major role in the treatment of PD.[13] Measuring the effects of this therapy requires continuous, appropriate evaluation using objective tools; this enables us to provide the best possible care and treatment at all times.[14]

Recent years have seen an increase in the use of information technology in healthcare. In the area of neurological disease, research is being conducted into new assessment and treatment technologies based on motion analysis, robotic systems, virtual reality, and telerehabilitation.[14] However, these solutions are often very costly, limiting their use in clinical practice, regardless of their effectiveness. The mass adoption of smartphones raises the question of their usefulness as a clinical tool. In PD, possible uses of the devices include increasing collaboration between team members, reducing time-/distance-related limitations in communication between patients and healthcare professionals, and tracking patient progression.[8]

Objective

We performed a systematic review of published studies on mobile applications (apps) either directly related to PD or potentially useful for management of the disease; the purpose of the review was to describe, analyse, and classify the applications identified to increase understanding of them.

Material and methods

The systematic review analysed information from biomedical databases as well as sources specific to mobile applications and new technology.

Literature search

We gathered published scientific articles addressing the design, development, and evaluation of mobile applications related to PD. The search was performed on the Academic Search Premier, MEDLINE, CINAHL, and PubMed databases, with the keywords ''Parkinson's disease,'' ''Parkinson,'' ''smartphone,'' ''mobile application,'' and ''app.''

The review included only those articles published in English or Spanish between 2011 and 2016 (2011 was selected as the lower limit because the first reference related to an app developed specifically for PD was published that year). We excluded studies with no direct relevance to PD.

The Jadad scale was used to assess the methodological quality of the articles included. The scale, also known as the Oxford Quality Scoring System,[15] is validated, simple, and quick to apply. A number of questions are used to classify studies by methodological quality: whether the study is randomised and whether the method of randomisation is described; whether the study is double blind and whether the method of blinding is described; and whether withdrawals and dropouts are described. A score of 3 or higher indicates acceptable methodological quality.

Search of other information sources

In addition to the literature search, we searched the main app marketplaces (Google Play, Apple App Store, and Windows Store) for mobile applications related to PD.

As no specific method has been described for searching and classifying mobile applications, we identified apps described in a review of neurorehabilitation apps[16] and in a list of the ''50 best Spanish-language health apps.''[17]

We initially included all those apps described in these sources that were related to neurorehabilitation, regardless of language or country of development. We then searched the terms ''Parkinson's disease'' and ''Parkinson'' in the marketplaces listed above in order to identify apps either directly related to PD or potentially useful in management of the disease, selecting apps that were available in English or Spanish. This process accounted for the therapeutic usefulness, content, quality, design, and usability of the applications. Finally, apps were categorised by purpose according to the following classification:

1. *Applications useful for PD*: apps not specifically designed for PD but potentially useful in managing the disease.
2. *Applications specifically designed for PD*: including 3 subcategories:

- *Information apps*: apps providing information on the disease, targeting healthcare professionals, patients, families, or carers.
- *Assessment apps*: apps including various tests for assessing patients with PD, analysing gait, balance, tremor, speech, and upper limb coordination, among other parameters.
- *Treatment apps*: apps providing patients and healthcare professionals with a series of guidelines for pharmacological treatment of PD or neurorehabilitation, including physiotherapy, cognitive therapy, and speech therapy.

This classification was also used for applications identified through the literature review. It should also be noted that certain applications could be assigned to more than one category. Some applications require the use of peripheral devices, such as additional sensors or fastening mechanisms; this was also noted in the analysis of results.

Results

Literature search

We gathered a total of 34 articles; 26 were finally selected following application of the inclusion and exclusion criteria.[18–43] Eight articles were excluded for either not presenting an application with usefulness for PD,[44] or not providing sufficient information on the application or the study.[45–51] The flow chart in Fig. 1 shows the number of studies identified in each database and the number of studies excluded.

Of the 26 studies identified, 23 were available in full-text format; only the abstracts were available for the remaining 3 articles.[35,40,43] Five of the final sample of articles present a mobile application or system potentially useful for PD[20] or specifically designed for management of the disease[25,28,37,38]; no results have yet been published on the usefulness of these apps for human patients. The system presented by Casamassima et al.[23] was evaluated in 2 subsequent studies.[31,41]

The tool developed by Palmerini et al.[19] and the Takac et al.[22] system were studied only in healthy individuals. The study by Butson et al.[21] targeted healthcare professionals. In several studies, all participants were patients with PD.[24,26,27,32,33,36,39,41,43] The remaining studies included both patients and healthy controls.[18,29–31,34,35,40,42] The total sample for all studies included 420 patients diagnosed with PD and 232 controls.

The articles gathered were very heterogeneous. Two evaluated applications which were not specifically designed for patients with PD but were potentially useful in this context. One presented a tool for performing the Timed Up and

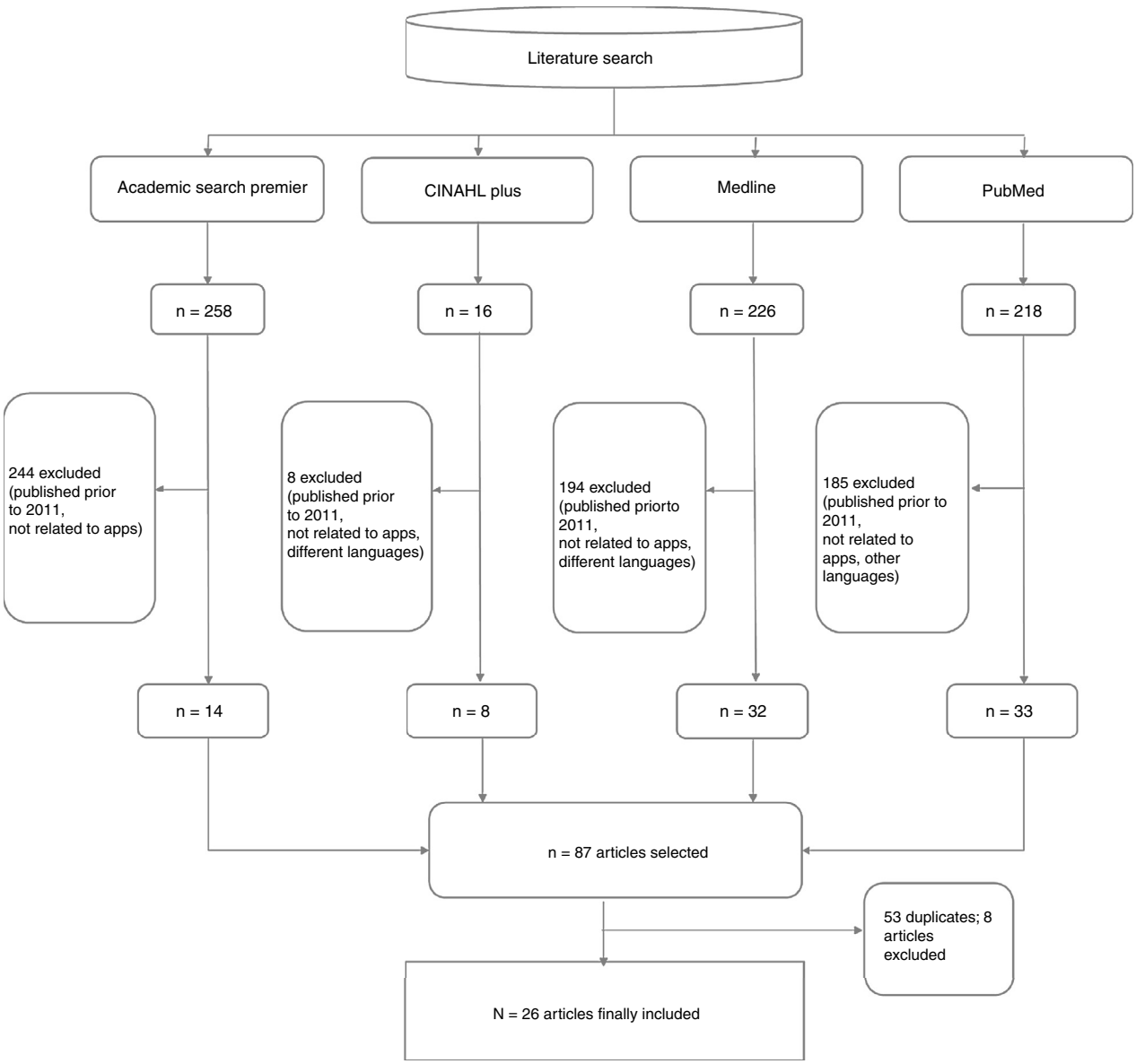

Figure 1 Flow chart illustrating the article selection process.

Go test,[19] and the other presented an application for gait assessment.[20]

Twenty-one studies assessed the usefulness of applications specifically designed for PD in assessing and treating various physical and cognitive symptoms of the disease.[18,23–38,40–43] Butson et al.[21] analyse the clinical usefulness of an application designed to assist in setting the parameters of deep brain stimulation. Takac et al.[22] evaluate a system for detecting potential episodes of freezing of gait based on an analysis of the patient's spatial context. Finally, the study by Broen et al.[39] aimed to obtain real-time data on patients' affective states.

According to the classification described above, the applications presented in the gathered studies can be classified as follows:

Assessment applications: applications for assessing resting tremor,[18,24,34,40] bradykinesia,[27] upper limb dexterity,[43] various gait parameters,[23,31,33,41,42] visual acuity,[35] various combinations of physical, cognitive, and vocal aspects of PD,[3,28,29,32,38] the spatial context of the patient,[22] and the patient's affective state.[39]

Treatment applications: these apps included 2 subcategories. Firstly, the group of applications related to medical and pharmacological treatment included an app designed by Lakshminarayana et al.[25] to improve self-management and treatment adherence, and an app designed by Butson et al.[21] to facilitate clinical decision-making regarding deep brain stimulation parameters. The second subcategory were apps focusing on gait rehabilitation. These included apps using rhythmic auditory[23,26,28,41] or vibratory cueing[42] for training gait and to treat freezing of gait. Another rehabilitation therapy application, described by Van der Kolk et al.,[37] was designed to improve motivation in an exercise-based treatment programme. The CuPid system, described by Casamassima et al.,[23] Ferrari et al.,[31] and Ginis et al.,[41] may be classified either as a treatment app or as an

assessment app; the same is true of the REMPARK app presented by Sama et al.[28]

We identified no publications on apps providing information on PD. The studies gathered do not address the costs of the applications nor whether their use was restricted to healthcare professionals or patients. It should also be noted that 4 of the systems presented required additional motion sensors,[20,23,26,31,32,41] while other studies used devices for fastening the smartphone to the patient's body.

The methodological quality of the studies was poor, with the study by Ginis et al.[41] being the only one scoring 3 on the Jadad scale. Certain studies could not be assessed with the scale, either because they only described an action protocol for future lines of research, or because the full texts were not available.

Table 1 shows the most relevant characteristics of the articles included in the literature review. To summarise, we analysed 26 articles presenting 24 different systems based on mobile applications; 2 were useful for PD management and 22 were specifically designed for the disease. The latter group included 15 assessment apps, 5 treatment apps, and 2 applications for both assessment and treatment.

Search of other information sources

In our search of the main mobile application marketplaces, we identified 103 available apps related to PD. Of these, 49 were available only for Apple devices, 39 for Android devices, and 6 for Windows Phone devices; 11 applications were available for both Apple and Android devices; and one was available in all 3 marketplaces. Fig. 2 illustrates the search process.

In terms of cost, 74 apps were free and 29 were paid. Apps targeted patients with PD in 45 cases, healthcare professionals in 34 (but did not include any filter or identity authentication to prevent use by non-professionals), and both groups in 24.

By category, 54 apps were not specifically designed for management of PD but were considered useful, and 49 were specifically designed for the disease. Table 2 summarises the characteristics of the applications identified.

The first group includes 23 apps providing information on various neurological diseases, 15 for improving speech, 7 for testing upper limb function, 2 addressing self-management of medication and symptom monitoring, and 2 for administering various neurological assessment scales. The remaining apps are designed for improving telephone usability and saliva control, performing cognitive exercises, following up patients, and to serve as design tools for the 3D printing of objects to assist patients with neurological diseases.

The second group includes 23 applications providing information on the disease, 16 designed to assess various signs and symptoms, and 8 assisting in treatment. A further 2 applications were assigned to both the treatment and the assessment categories.

Eight of the assessment apps tested multiple aspects of PD (sleep, gait, voice, activities of daily living, and mood), 5 assessed resting tremor, 2 included the UPDRS scale, and one included a finger tapping test. Treatment applications were based on physical exercise in 3 cases, speech therapy in 2, auditory cueing for treating gait in 2, and self-management and monitoring of pharmacological treatment in one case. One of the applications included in both the assessment and treatment groups monitored movement, tremor, and sleep and included a metronome for gait rehabilitation; the other assessed gait and also included a metronome. Fig. 3 includes a graphical representation of the mobile applications for PD available in the main marketplaces.

Two of the applications found in our search of the app marketplaces have previously been analysed by Lakshminarayana et al.[25] and Lopez et al.[26]; therefore, the applications identified through both searches amounted to a total of 125, of which 56 were potentially useful for PD and 69 were specifically designed for management of the disease (23 information apps, 29 assessment apps, 13 treatment apps, and 4 assessment and treatment apps).

Discussion

The term ''eHealth'' refers to the use of information technology in the field of health, either for follow-up and treatment of various diseases or for public health surveillance and stimulating new research.[52] New technology may constitute a response to one of the greatest challenges of neurodegenerative diseases: long-term treatment viability and patient assessment. These tools are intended to be universally accessible, including for disabled people. Another advantage of these devices is that they improve communication between healthcare professionals and patients, as well as within both groups. There is ample opportunity for PD management to benefit from new technology. As the disease mainly affects motor function, a majority of patients present functional difficulties which constitute an obstacle to attending consultations and receiving continuous follow-up. Therefore, technological advances may be of use in following up these patients, for example in the analysis of tremor, motor fluctuations, or freezing.[53]

The World Health Organization defines mHealth, one component of eHealth, as medical or public health practice supported by the use of mobile devices and the systems incorporated in these devices.[54] Sales of mobile devices have increased rapidly in recent years; in 2015, there were over 7.3 billion devices, more than one per person worldwide.[55] This has led to an increase in the number of applications available in the main marketplaces, with the Google Play and Apple App Store platforms offering over 2 million apps.[55] Around 97 000 of these are dedicated to health and medicine.[17] In the present review, we selected applications cited in articles indexed in biomedical databases or listed on the app marketplaces as being related to PD. However, given the large number and variety of apps available, it is probable that other apps would be useful in this field. These would include those dedicated to physical exercise, cognitive tasks, or medication or dietary monitoring. Reasons for the non-inclusion of such apps in our study would be the difficulty of classifying them and the constant appearance of new applications and updates. According to the latest Doctoralia report,[56] the most widely used applications are those providing health information (86% of survey respondents), followed by apps focusing on physical exercise (77%),

Table 1 Main characteristics of the studies included in the review.

Article	Participants	Intervention	Results	Jadad score
Arora et al.[29]	*N* = 20 (10 healthy individuals + 10 PD)	Evaluation of an app comprising various tests (voice, posture, gait, finger tapping, and response time) in patients with PD and in controls	The system showed 96.2% sensitivity and 96.9% specificity for discriminating between patients and controls.	0
Bot et al.[38]	*N* = 0	Presentation of a protocol to validate mPower, an application designed to assess memory, tapping, voice, and gait in patients with PD	Not available	Not applicable
Broen et al.[39]	*N* = 5 (PD)	Evaluation of the use of smartphones to apply a sampling method	The sampling method was shown to be able to detect diurnal motor fluctuations through data from the questions included.	0
Butson et al.[21]	*N* = 5 (healthcare professionals)	Study of an app-based system for selecting the most appropriate deep brain stimulation parameters in 4 patients	A significant reduction was observed in decision-making time for all patients.	0
Casamassima et al.[23]	*N* = 0	Presentation of a system for assessing and treating gait alterations through biofeedback. Additional sensors required	Not available	Not applicable
Ellis et al.[30]	*N* = 24 (12 healthy individuals + 12 PD)	Evaluation of an app-based system for assessing and treating gait alterations, comparing against data obtained with footswitch sensors and a pressure sensor mat, in different situations	All measurement tools identified significant differences between the patient and control groups for gait parameters.	1

Table 1 (*Continued*)

Article	Participants	Intervention	Results	Jadad score
Ferrari et al.[31]	*N* = 28 (12 healthy individuals + 16 PD)	Evaluation of a system for assessing gait, comparing against data obtained with a mat and with cameras. Additional sensors required	The different measurement systems returned similar data. The system showed high test-retest reliability.	1
Ferreira et al.[32]	*N* = 22 (PD)	Evaluation of the viability and usability of the SENSE-Park system in PD patients. Additional sensors required	Patients had a good opinion of the application's assessment system.	0
Fraiwan et al.[40]	*N* = 42 (21 healthy individuals + 21 PD)	Evaluation of the usefulness of an application for detecting resting tremor	Results from the app showed 95% accuracy.	Not applicable
Ginis et al.[41]	*N* = 40 (PD)	Evaluation of the CuPid system for gait rehabilitation in various conditions, with and without the application. The researchers evaluated balance, gait, endurance, and quality of life. Additional sensors required	Both groups showed improvements in primary outcomes. The group using the application significantly improved in balance and maintained quality of life.	3
Ivkovic et al.[42]	*N* = 20 (10 healthy individuals + 10 PD)	Evaluation of the usefulness of an app in gait rehabilitation using tactile cueing	The system was effective for regulating heel tapping.	1
Kim et al.[33]	*N* = 15 (PD)	Evaluation of the sensitivity of an application for detecting freezing of gait	The application showed high sensitivity and specificity for detecting freezing of gait with the smartphone in different positions.	0

Table 1 (*Continued*)

Article	Participants	Intervention	Results	Jadad score
Kostikis et al.[18]	*N* = 20 (10 healthy individuals + 10 PD)	Presentation of a system (web application) for detecting resting tremor of the hand in patients with different diseases	Significant differences were observed between patients and controls in the measurement of acceleration with the application. The application enabled detection of tremor with the accelerometer.	0
Kostikis et al.[24]	*N* = 23 (PD)	Presentation of a system (web application) for detecting resting tremor of the hand in patients with PD, compared against the UPDRS	A correlation was observed between data obtained from the app and UPDRS scores.	0
Kostikis et al.[34]	*N* = 45 (20 healthy individuals + 25 PD)	Evaluation of a system for detecting resting tremor in patients with PD and controls	The application very accurately discriminated between patients and controls.	1
Lakshminarayana et al.[25]	*N* = 0	Presentation of an application focusing on self-management of PD	Not available	Not applicable
Lee et al.[43]	*N* = 103 (PD)	Validation of an application measuring motor function, compared against the MDS-UPDRS	A strong correlation was observed between data obtained from the app and MDS-UPDRS scores.	Not applicable
Lin et al.[35]	*N* = 103 (71 healthy individuals + 32 PD)	Evaluation of the usefulness of an app measuring visual acuity in PD patients	The app may be useful for assessing visual acuity.	Not applicable
Lopez et al.[26]	*N* = 10 (PD)	Evaluation of the ListenMee system for gait rehabilitation in patients with PD. Additional sensors required	Gait velocity, cadence, and stride length improved significantly.	0

Table 1 (*Continued*)

Article	Participants	Intervention	Results	Jadad score
Palmerini et al.[19]	*N* = 49 (healthy individuals)	Participants performed the Timed Up and Go test while wearing the smartphone.	The test showed a strong correlation with the app's measurements, particularly for step duration ($R = 0.93$).	0
Pan et al.[36]	*N* = 40 (PD)	Presentation of an application designed to assess disease severity by measuring tremor and gait difficulty	The application showed high sensitivity and specificity.	1
Printy et al.[27]	*N* = 26 (PD)	Presentation of an application for assessing bradykinesia in PD patients, compared against the UPDRS motor subscore	The application was able to classify disease status as more severe or less severe with an accuracy of 94.5%.	1
Sama et al.[28]	*N* = 0	Presentation of the REMPARK system for assessing and treating gait alterations	Not available	Not applicable
Takac et al.[22]	*N* = 12 (healthy individuals)	Evaluation of a system for assessing patients' environment, tracking position and orientation, and detecting freezing of gait	The application accurately tracked patients' position and orientation.	0
Van der Kolk et al.[37]	*N* = 0	Presentation of an application designed to motivate PD patients taking an exercise programme	Not available	Not applicable
Wagner and Ganz[20]	*N* = 0	Presentation of a system based on insoles with footswitches for assessing gait	Not available	Not applicable

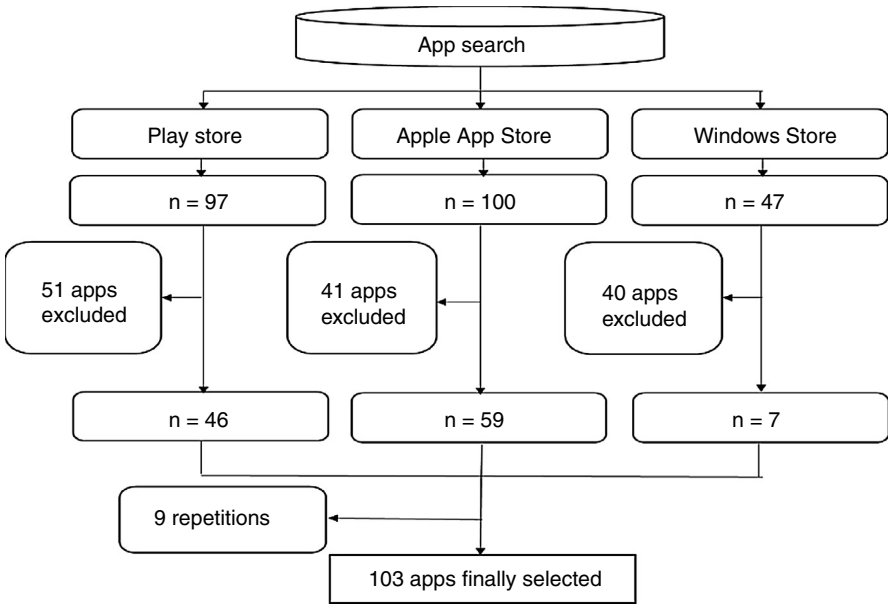

Figure 2 Results of the search of mobile application marketplaces.

diet (66%), and medication management (66%). These data coincide with those obtained in our search of the main app marketplaces: both in the group of specifically designed apps and the group of useful apps for PD, information apps constituted the largest subgroup. However, the literature search identified no studies on this type of app; it is therefore necessary to consider the accuracy of the information provided by mHealth apps.

While some applications were developed by foundations or associations specialising in PD, such as the National Parkinson Foundation (Parkinson's Toolkit and Parkinson's Central) and the Michael J. Fox Foundation (Fox Insight App), many lack the opinions, approval, or support of such bodies. In 2013, the United States Food and Drug Administration (FDA) published user and developer guidelines (updated in 2015) on future regulations in the sector,[57] in the light of the potential of mobile applications to transform healthcare and the consequent need to review their safety. The European Commission also considers that recommendations about health apps require them to be classified and verified; to that end, it has published a directory containing information on numerous health applications.[58]

The results of our literature search show that mobile devices are able to track the position and orientation of healthy individuals[22] and may be used to perform certain tests, such as the Timed Up and Go[19] and some tasks from the UPDRS.[43] Other applications are able to discriminate between controls and patients with PD with a reasonable degree of accuracy,[18,29–31,34] as well as between different stages of the disease.[27,36] Some apps have been shown to be able to accurately detect resting tremor.[24,40] Gait assessment apps have also been found to be effective for detecting heel taps[42] and freezing of gait.[33] Some studies have demonstrated significant improvements in several aspects of gait.[26,41] However, their findings should be interpreted with caution given the poor methodological quality of the studies and the small number of participants.

Other literature reviews have addressed the use and usefulness of mobile apps for other diseases. A 2012 Cochrane review concluded that there was very limited evidence that mobile phone messaging interventions may have a positive impact on self-management in patients with chronic diseases.[59] In 2013, another Cochrane review on the effectiveness and viability of using apps to facilitate self-management among patients with asthma[60] found insufficient evidence to advise either healthcare professionals or patients about the approach. Whitehead and Seaton[61] published a systematic review on self-management apps for chronic diseases, finding that the applications have potential to improve symptom management in patients with cardiovascular disease, chronic lung disease, and diabetes mellitus.

In the field of motion analysis in neurorehabilitation, 2 reviews support the use of sensors and mobile devices in patients with neurological diseases. According to Bloc et al.,[62] it is possible to use sensors to monitor physical activity in neurological patients, even those with severe conditions. With reference to PD specifically, Hubble et al.[63] support the use of sensors to detect differences in balance between healthy individuals and patients with the disease; this may be useful for early detection of the disease and in assessing the risk of falls. These findings may explain the use of additional sensors in 4 of the systems studied in the present review.

In the context of mHealth, Zaki and Drazin[64] found 111 apps potentially useful for neurosurgery students and professionals. However, the authors stress the lack of reliable opinions on the majority of the applications and note that this type of system may entail some degree of ethical and legal risk with respect to the protection of patients' data. The study by Sánchez-Rodríguez et al.[16] is the only systematic review performed to date on mobile applications for neurorehabilitation. These researchers classified applications into 5 categories, concluding that the available

Table 2 Main characteristics of mobile applications for Parkinson's disease.

Name	Operating system	Cost[a]	Description	Users	Classification
AAC Text to Speech	iOS	Free	Voice recording to increase volume or speech	Patients	Useful for PD
ARAT Action Research Arm Test	Android	Free	Upper limb assessment	HC professionals + patients	Useful for PD
DAF Assistant	iOS	9.99	Feedback to improve speech	Patients	Useful for PD
DAF Assistant Legacy	iOS	9.99	Stimuli to improve clarity and fluency of speech	Patients	Useful for PD
DAF Professional	iOS/Android	4.99	Designed to improve speech and oral expression	Patients	Useful for PD
DAF Professional Lite	Android	Free	Clearer speech and reduced stuttering	Patients	Useful for PD
Daily Rx	Android	Free	Information on numerous diseases	HC professionals + patients	Useful for PD
Brain Injury	Android	Free	Guidelines and advice for patients with neurological diseases	HC professionals + patients	Useful for PD
Easy Speak AAC	iOS	39.99	Support for spoken communication by telephone	Patients	Useful for PD
Tremor	Android	Free	Information on tremor	HC professionals + patients	Useful for PD
Genomapp	Android	Free	Information on genetic diseases	HC professionals + patients	Useful for PD
Guideline Central	Android	Free	Collection of clinical practice guidelines	HC professionals	Useful for PD
Handbook of Natural Medicine	Android	Free	Information on alternative medicine	HC professionals + patients	Useful for PD
Help Talk	Android	Free	Assistance for oral communication	Patients	Useful for PD
Homeopathic Guide	Android	Free	Information on homeopathy	Patients	Useful for PD
iReflex	iOS	0.99	Assessment of reflexes	Patients	Useful for PD
MedOcloc Pill Reminder	Android	Free	Medication self-management	Patients	Useful for PD
Mega Icon Launcher	Android	Free	Improved smartphone usability	Patients	Useful for PD
Miniatlas Sistema Nervioso Central	iOS	9.99	Atlas of the nervous system and information on neurological diseases	HC professionals + patients	Useful for PD
Montfort iTUG clinic	iOS	Free	Instrumented Get Up and Go Test	HC professionals	Useful for PD
Movement Disorders	iOS	Free	Scientific publication on movement disorders	HC professionals + patients	Useful for PD
MyTherapy Pastillero	Android	Free	Medication self-management	Patients	Useful for PD
NeuroLinks	iOS	Free	Assistance in diagnosis and treatment of PD	HC professionals	Useful for PD
Neurología en preguntas cortas	iOS	0.99	Information on neurological diseases	HC professionals	Useful for PD
Neurology Now	Android	Free	Official publication of the American Academy of Neurology	HC professionals	Useful for PD

Table 2 (*Continued*)

Name	Operating system	Cost[a]	Description	Users	Classification
Neurology Pocket	iOS	9.99	Information on various neurological diseases	HC professionals	Useful for PD
Neurology Today	Android	Free	Official publication of the American Academy of Neurology	HC professionals	Useful for PD
NeuroScores	iOS/Android	Free	Scales used in neurological examinations	HC professionals	Useful for PD
One Ring	iOS	Free	Device for monitoring resting tremor	HC professionals	Useful for PD
Pacing Board Pocket	iOS	1.99	Stimuli to improve speech	Patients	Useful for PD
ParkPen	Android	Free	Pen designed for PD patients	Patients	Useful for PD
Prognosis: Neurology	Android	Free	Information on neurological diseases	HC professionals	Useful for PD
Portafolio Médico	Android	Free	Information on numerous diseases	HC professionals	Useful for PD
Response Measurement	Android	Free	Measurement of response time to stimuli	HC professionals + patients	Useful for PD
Rx Wiki	Android	Free	Information on numerous diseases and drugs	Patients	Useful for PD
Senior Care Manager	iOS	Free	Patient follow-up system	Patients	Useful for PD
Sináptica TEVA	iOS/Android	Free	Application for the Sináptica congress	HC professionals	Useful for PD
Speak Better	iOS	24.99	Tactile stimuli to improve clarity and fluency of speech	Patients	Useful for PD
Speech Pacesetter	iOS	9.99	Tactile stimuli to improve clarity and fluency of speech	Patients	Useful for PD
Speech Pacesetter Lite	iOS	Free	Tactile stimuli to improve clarity and fluency of speech	Patients	Useful for PD
Speech Tool	iOS	Free	Voice volume training	Patients	Useful for PD
SpeechCompanion	Android	1.49	Speech therapy exercises	Patients	Useful for PD
StudyMyTremor	iOS	3.99	Resting tremor monitoring	Patients	Useful for PD
Swallow Prompt	iOS/Android	1.99	Assistance with saliva control	Patients	Useful for PD
Taptimal	iOS	Free	Finger tapping test	Patients	Useful for PD
Tippy Tap-Alfabeto	iOS	Free	Finger tapping game	Patients	Useful for PD
Tremor Test	iOS	9.99	Measurement of resting tremor	HC professionals + patients	Useful for PD
Voice Analyst	iOS	12.99	Voice tone and volume analysis	HC professionals	Useful for PD
Voice Analyst Lite	Android	Free	Voice recording and tone and volume analysis	HC professionals + patients	Useful for PD
Word or Color Dot	Android	0.99	Cognitive exercises	Patients	Useful for PD
Workstation en trastornos del movimiento	iOS/Android	Free	Database with information on movement disorders	HC professionals	Useful for PD
World Neurology	iOS	Free	Official publication of the World Federation of Neurology	HC professionals + patients	Useful for PD

Table 2 (*Continued*)

Name	Operating system	Cost[a]	Description	Users	Classification
Miniatlas Psiquiatría	Windows Phone	2.99	Atlas of the central nervous system	HC professionals	Useful for PD
Neurology	Windows Phone	Free	Information on neurological diseases	HC professionals	Useful for PD
AD/PD 2015	iOS/Android	Free	Official application for the 12th International Conference on Alzheimer's & Parkinson's Diseases and Related Neurological Disorders	HC professionals	Information
Alzheimer's and Parkinson's Disease	iOS	Free	Information on PD and Alzheimer disease	HC professionals + patients	Information
Azilect Realidad Aumentada	Android	Free	Demonstration of rasagaline action	HC professionals + patients	Information
Learning Neurology Quiz	iOS	1.99	Information on neurological diseases	HC professionals	Information
MDS Congress	Android	Free	Official application of the 2014 congress of the Movement Disorder Society	HC professionals	Information
Parkinson	Windows Phone	0.99	Information on PD	Patients	Information
Parkinson Enfermedad	Android	Free	Information on research	HC professionals + patients	Information
Parkinson Info App	iOS	Free	Database with information on PD	HC professionals + patients	Information
Parkinson's Central	iOS/Android	Free	Information on PD	Patients	Information
Parkinson's Disease	iOS/Android	1.99	Information on PD	HC professionals	Information
Parkinson's Disease	Android	Free	Information on PD	HC professionals	Information
Parkinson's Disease	Windows Phone	2.99	Information on PD	Patients	Information
Parkinson's Disease an Overview	Windows Phone	Free	Information on PD	HC professionals + patients	Information
Parkinson's Disease Monitor	iOS	Free	Scientific publication on PD	HC professionals	Information
Parkinson's Disease Point of Care	iOS	Free	Information on PD diagnosis, treatment, and management	HC professionals	Information
Parkinson's Easy Call	Android	Free	Assisted telephone dialling	Patients	Information
Parkinson's Toolkit	iOS/Android	Free	Clinical practice guidelines for treatment of PD	HC professionals	Information
Parkison's Disease Facts	Android	Free	Collection of PD statistics, relevant details, and treatment information	HC professionals + patients	Information
PD Headline News	iOS	Free	Publications on PD	HC professionals + patients	Information
Rides for Parkinson's	iOS	Free	Transport for PD patients	Patients	Information

(*Continued*)

Name	Operating system	Cost[a]	Description	Users	Classification
TEVA Parkinson	Android	Free	Organisation of clinical histories	HC professionals	Information
World Parkinson Congress	iOS	Free	Programme of the 2010 World Parkinson Congress	HC professionals	Information
Earlystimulus	Android	Free	Criteria for deep brain stimulation	HC professionals	Information
DopaFit	Android	Free	Exercises for PD patients	Patients	Treatment
iParkinsons	iOS	99.99	Treatment for speech dysfunction in PD	Patients	Treatment
ListenMee App	Android	121	Cueing to improve gait	Patients	Treatment
Music Therapy	Android	Free	Cueing to improve gait	Patients	Treatment
Parkinson Exercises	iOS/Android/Windows Phone	4.22	Exercise videos for PD patients	Patients	Treatment
Parkinson's Speech Aid	iOS	Free	Repeats voice at greater volume or speed	Patients	Treatment
uMotif	iOS/Android	Free	Follow-up of symptoms, medication, and activity	HC professionals + patients	Treatment
PD Warrior	Android	Free	Exercises for PD patients	Patients	Treatment
DigiTap	iOS	2.99	Finger tapping test	HC professionals	Assessment
Lift Pulse	iOS	Free	Recording of resting tremor	HC professionals	Assessment
MDS UPDRS	iOS	5.99	MSD-UPDRS scale	HC professionals	Assessment
My Parkinson's Disease Manager	iOS	Free	Monitoring and storage of PD data	Patients	Assessment
myHealthPal	iOS	Free	Monitoring and self-management of PD	Patients	Assessment
myParkinson's	Android	Free	Measurement of upper limb resting tremor	HC professionals + patients	Assessment
Parkinson: Symptom Graph Create	Android	Free	Graph plotting to monitor PD	HC professionals + patients	Assessment
Parkinsons	iOS	5.99	Scales used in assessment of PD	HC professionals	Assessment
Parkinson's Diary	iOS	Free	Monitoring of ADL, mood, and physical fitness	Patients	Assessment
Parkinson's Test	Android	Free	Test for diagnosing and assessing PD	HC professionals + patients	Assessment
PD Me	iOS	Free	PD monitoring	Patients	Assessment
Prognosis	Windows Phone	Free	Tests for assessing gait, sleep, voice, and upper limbs	HC professionals	Assessment
TR_Meter	iOS	Free	Measurement of resting tremor	HC professionals	Assessment
Tremor Tracer	iOS	3.99	Tremor assessment	HC professionals + patients	Assessment
Tremor12	iOS	Free	Resting tremor monitoring	Patients	Assessment
UPDRS	iOS	Free	UPDRS questionnaire	HC professionals	Assessment
Beats Medical Parkinsons Treatment	iOS/Android	Free	Monitoring and treatment of movement, speech, and dexterity	Patients	Assessment + treatment
Fox Insight App	Android	Free	Monitoring of activity, tremor, and sleep	Patients	Assessment + treatment

HC: healthcare.
[a] Costs shown in euros.

Figure 3 Graphical representation of the classification of apps for Parkinson's disease.

evidence supporting their use as adjuvant therapy in certain neurological diseases was of low quality.

App usability is another important factor to consider. Only one study analysed the feasibility of implementation and the usability of an application for patients with PD.[32] The review by Zapata et al.[65] demonstrates the importance of adapting applications to the real needs of target users to improve their implementation and usefulness.

All the reviews cited above note the need for additional, better quality research in this field in order to provide useful, reliable tools for patients and healthcare professionals. Our literature search also found protocols for validation studies of various applications.[25,37,38] Furthermore, the European Commission recently launched initiatives to encourage research into new technologies for PD; these include the CuPid[23,31,41] and REMPARK[28] systems. This line of research is currently being explored through the development of the PD_manager platform and the mPark application[66] by the Universidad Politécnica de Madrid's Life Supporting Technologies research group. Other projects are being conducted by private organisations; these include the Mementum application.[67] Finally, it should be noted that large companies are also conducting projects including PD assessment apps; these include Apple, with the above mentioned mPower app, and the pharmaceutical company Roche.[68] The available evidence on these tools is likely to expand greatly in the coming years; analysis of these data is necessary to confirm the usefulness of these health apps.

Our search of the main mobile application marketplaces identified 103 apps that are potentially useful in the management of PD, of which 49 are available only for Apple devices, 39 for Android devices, and 6 for Windows Phone devices; 8 are available both for Apple and for Android devices; and one is available for all 3 operating systems. Seventy-four apps are free of cost and 29 are paid; 45 target patients with PD, 34 target healthcare professionals, and 24 target both groups. However, apps targeting healthcare professionals exclusively do not limit access by other users; including this type of control, for example by requiring professional association membership numbers or passwords, or through other mechanisms, may be beneficial to ensuring that the content of such apps is better exploited. As mentioned previously, numerous authors and such regulatory agencies as the FDA state the need to review these applications in order to ensure patient safety. Meulendijk et al.[69] describe the 9 essential requirements for health apps from the perspective of patients: accessibility, certifiability, portability, privacy, safety, security, stability, trustability, and usability. Most of the apps found in the application marketplaces have not been validated in context; nor have they been supervised or approved by healthcare agencies, as proposed by Meulendijk et al.[69]

This review has several limitations. Firstly, the studies analysed are of poor methodological quality and include small samples. Furthermore, apps were selected according to developers' descriptions; information may therefore be incomplete. The constant change and evolution of app marketplaces means that the applications presented in this review may become unavailable in the future, or other apps may not have been included as they were not registered at the time of the search.

Conclusions

Numerous mobile applications are potentially useful or specifically designed for the management of PD. However, despite the available evidence, the poor methodological quality of the studies identified prevents us from recommending generalised use of these apps. We identified 125 applications cited in published articles in biomedical databases and in app marketplaces; of these, 56 were potentially useful in PD and 69 were specifically designed for the disease. Of the latter group, 23 offered information on the disease, 29 were based around assessment, 13 were designed to treat aspects of the disease, and 4 offered both assessment and treatment.

The potential benefits and risks associated with mHealth give rise to a need for official regulation and for further research in the field; this would provide both healthcare professionals and patients with safe, reliable tools for the care and management of PD.

Conflicts of interest

None.

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