NEUROLOGÍA

REVIEW ARTICLE

Mobile applications in children with cerebral palsy☆

M. Rodríguez Mariblanca, R. Cano de la Cuerda*

Departamento de Fisioterapia, Terapia Ocupacional, Rehabilitación y Medicina Física, Facultad de Ciencias de la Salud, Universidad Rey Juan Carlos, Madrid, Spain

Abstract

Introduction: Cerebral palsy (CP) is one of the most common developmental disorders. Technological development has enabled a transformation of the healthcare sector, which can offer more individualised, participatory, and preventive services. Within this context of new technology applied to the healthcare sector, mobile applications, or apps, constitute a very promising tool for the management of children with CP.

Objective: The purpose of this article is to perform a systematic review of the information published about various mobile applications either directly related to CP or with potential to be useful in the context of the disease, and to describe, analyse, and classify these applications.

Material and methods: A literature search was carried out to gather articles published in English or Spanish between 2011 and 2017 which presented, analysed, or validated applications either specifically designed or potentially useful for CP. Furthermore, a search for mobile applications was conducted in the main mobile application markets.

Conclusions: A total of 63 applications were found in biomedical databases and mobile application markets, of which 40 were potentially useful for CP and 23 were specifically designed for the condition (11 for information, 3 for evaluation, and 9 for treatment). There are numerous mobile applications either specifically designed for or with potential to be useful in the field of CP. However, despite the existing scientific evidence, the low methodological quality of scientific articles makes it impossible to generalise the use of these tools.

© 2017 Sociedad Española de Neurología. Published by Elsevier España, S.L.U. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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

PALABRAS CLAVE
App;
Apps;
Aplicaciones móviles;
eHealth;
Parálisis cerebral
infantil;
mHealth

Aplicaciones móviles en la parálisis cerebral infantil

Resumen

Introducción: La parálisis cerebral infantil (PCI) es una de las discapacidades más comunes del desarrollo. Gracias a la tecnología, el sector sanitario tiene la posibilidad de transformarse para ofrecer servicios más individualizados, participativos y preventivos. Dentro de este contexto de nuevas tecnologías aplicadas al sector sanitario, el fenómeno de las aplicaciones móviles o *app* resulta muy prometedor en la PCI.

Objetivo: El objetivo del presente trabajo es realizar una revisión sistemática acerca de la información publicada sobre las diferentes aplicaciones móviles creadas, relacionadas directamente con la PCI o con utilidad potencial en ella, con el fin de describirlas, analizarlas y clasificarlas para su mejor conocimiento.

Material y métodos: Se llevó a cabo una búsqueda bibliográfica que incluyó artículos publicados en inglés o castellano, del año 2011 al 2017, y que presentasen, analizasen o validasen un sistema basado en una app con utilidad o diseño específico para la PCI. A su vez, se llevó a cabo una búsqueda de aplicaciones móviles en los principales mercados de aplicaciones móviles.

Conclusiones: Se encontraron 63 aplicaciones en bases de datos biomédicas y en mercados específicos de *app*, de las cuales 40 presentaban potencial utilidad en la PCI y 23 estaban diseñadas específicamente para la PCI: 11 de estas eran de carácter informativo, 3 de valoración y 9 de tratamiento. Existe un gran número de aplicaciones móviles con potencial utilidad, así como con diseño específico en el campo de la PCI. Sin embargo, pese a la cierta evidencia científica existente, la baja calidad metodológica de los artículos científicos hace que no se pueda generalizar su uso.

© 2017 Sociedad Española de Neurología. Publicado por Elsevier España, S.L.U. Este es un artículo Open Access bajo la licencia CC BY-NC-ND (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Cerebral palsy (CP) is one of the 3 most common developmental disorders, affecting patients throughout their lives.[1] The term CP refers not to a single entity, but to a group of heterogeneous, persistent developmental disorders of movement and postural control limiting patients' activity, attributed to non-progressive, non-immutable lesions to the developing brain in the pre-, peri-, or postnatal period.[1–4] The upper age limit is subject to debate, but lesions occurring up to 2 years of age are accepted.[5] These motor disorders are usually accompanied by comorbidities that constitute a significant burden for patients and their relatives. These include epilepsy; sensory, cognitive, or perceptual alterations; communication and behavioural disorders; and secondary musculoskeletal disorders.[6,7] CP thus represents the leading cause of motor disability in paediatric patients[8] and the second most frequent cause of severe intellectual disability.[1] The global prevalence of PC is estimated at 1.5-3 cases per 1000 live births.[2] A study conducted in 2007 estimated global prevalence at 2.4 cases per 1000 live births.[8] Recent studies have demonstrated that this rate (currently estimated at 2.1 cases per 1000 live births[7]) has remained stable over the last 10 years.[8]

A cascade of interactions between multiple risk factors and external events leads to the development of CP in the foetus or newborn. These risk factors can be classified as prenatal, perinatal, and postnatal.[2] Perinatal factors have the greatest influence on risk of CP; the most significant is premature birth, followed by small size for gestational age and low birth weight.[2,9,10] Multiple studies consider male sex a risk factor for CP, with a male-to-female prevalence ratio of approximately 1.4:1.[9]

CP can be classified by neurological subgroup and by functional ability. Neurological subtype is determined according to the limbs affected (monoparesis, hemiparesis, tetraparesis, diparesis, triparesis, or double hemiparesis), clinical signs and symptoms (spasticity, dyskinesia/dystonia, or ataxia), and muscle tone (normotonic, hypotonic, or hypertonic).[6,7] The Surveillance of Cerebral Palsy in Europe programme recommends the Gross Motor Function Classification System, a reliable classification of prognostic significance that focuses more on children's functional capacity than on their limitations.[2]

Early diagnosis is essential to determining and implementing appropriate treatment strategies as soon as possible: in practice, early treatment onset is thought to improve treatment effectiveness.[11] Clinical warning signs include delay in achieving motor milestones, seizures, weak suck, persistent closed fist, and reduced head circumference velocity. However, most patients do not present clear symptoms in the early stage; in current clinical practice, most children with CP are diagnosed at 1 or 2 years of age.[10] The use of neuroimaging techniques, neurological examination, and neurophysiological assessment improves prediction. MRI reveals abnormalities in 70%-90% of children with CP.[12] Treatment objectives should be established according to patient assessment and agreement between family members and professionals involved in the patient's care; patients should also participate in this process wherever possible.[13,14]

In recent years, with widespread access to information, advances in information and communications technology applied to the healthcare sector are bringing about changes to traditional approaches to neurological care.[15] These technologies offer an opportunity to transform the sector, with more personalised, participatory, and preventive services. In this context, the phenomenon of mobile applications (apps) offers great promise in CP care. For instance, the *Saliva Tracker* app, developed by the Murdoch Children's Research Institute, helps the parents and carers of children with the condition to control drooling. Numerous other scientific organisations are developing and validating assessment and treatment tools for educators and healthcare professionals specialising in CP.[16] There is a need for studies to classify and analyse the evidence on the available mobile apps and whether they should be recommended for patients, relatives, or medical professionals in the context of CP.

Objective

We performed a systematic review of published studies on apps either directly related to or potentially useful for CP management; the purpose of the review was to describe, analyse, and classify the applications identified.

Material and methods

We performed a systematic review of published studies on apps specifically designed for use with children with CP or of potential benefit in management of the disease. We also analysed other sources of information (app marketplaces).

Literature search

We gathered published scientific articles addressing the design, development, and evaluation of mobile apps related to CP. The literature search was performed on 5 databases (Academic Search Premier, CINAHL, Medline, Scopus, and PubMed) using the keywords ''cerebral palsy,'' ''app,'' ''mobile applications,'' ''tablet,'' ''iPad,'' ''eHealth,'' and ''smartphone.''

Selection of articles

The literature search was filtered to include articles written in English or Spanish and published between 2011 and February 2017 on the above-cited databases. We excluded all articles not directly related to CP in childhood and those addressing apps mainly targeting language difficulties and alternative and complementary therapies for communication.

The methodological quality of the articles was assessed using the Jadad scale, also known as the Oxford Quality Scoring System,[17] the most widely used evaluation scale worldwide. Methodological quality is rated on a scale from 0 to 5, with a score of 3 or more signalling acceptable quality. Points are awarded for a number of criteria: randomisation of participants, description of the randomisation method,

implementation of blinding, and description of the method of blinding.

Search of other information sources

In addition to the literature search, we searched for apps related to CP on the main app marketplaces: Google Play (Android), the Apple App Store (iOS), and the Windows Store (Windows Phone). No applications were initially excluded, regardless of language or the country where they were developed. We subsequently excluded apps that were not available in English or Spanish. We then assessed the therapeutic usefulness, content, quality, design, and usability of the apps. As well as searching app marketplaces, we reviewed published technical reports on apps[15,18] in order to identify any additional apps potentially useful for CP. Finally, given the lack of any official classification of apps according to their purpose, we categorised all apps as follows:

Applications potentially useful for CP: all apps not specifically designed for CP but potentially useful in managing the disease due to their function and design.

Applications specifically designed for CP, divided into the following subcategories: (1) information apps: apps providing information on the disease, targeting patients, families, or carers; (2) assessment apps: apps enabling assessment of patients' status (physical and functional status, range of movement, gait analysis, visual perception, fine motor skills, etc.) using various methods; and (3) treatment apps: apps focused on management of patients with CP.

Apps could be assigned to more than one category. They were also categorised by target audience: healthcare professionals, carers or family members, and patients themselves. Some apps targeted more than one group.

Results

Literature search

The initial literature search yielded 177 articles, 149 of which were excluded according to our selection criteria. Of the remaining 28, more detailed analysis excluded a further 23, leaving a total of 5.[19–23] The flow chart in Fig. 1 shows the number of studies identified in each database and the number of articles excluded. Other studies were excluded for the following reasons: (1) article did not present a mobile app of use for CP management in the healthcare context[24–28]; (2) apps were of potential use for CP management but were designed for computers and not smartphones or tablets[1,29–31]; (3) article presented an app for CP in adults[32]; (4) apps were related to alternative/complementary treatments for communication[33]; or (5) insufficient information was available on the app or study.[34]

The Jadad scale revealed poor methodological quality. The scale could not be applied to those articles that only presented protocols for subsequent lines of research. Of the 5 articles selected, 3 focused on apps specifically designed for CP, and the remaining 2 were potentially useful for managing the condition. Table 1 shows the most relevant characteristics of the articles selected from the literature review.
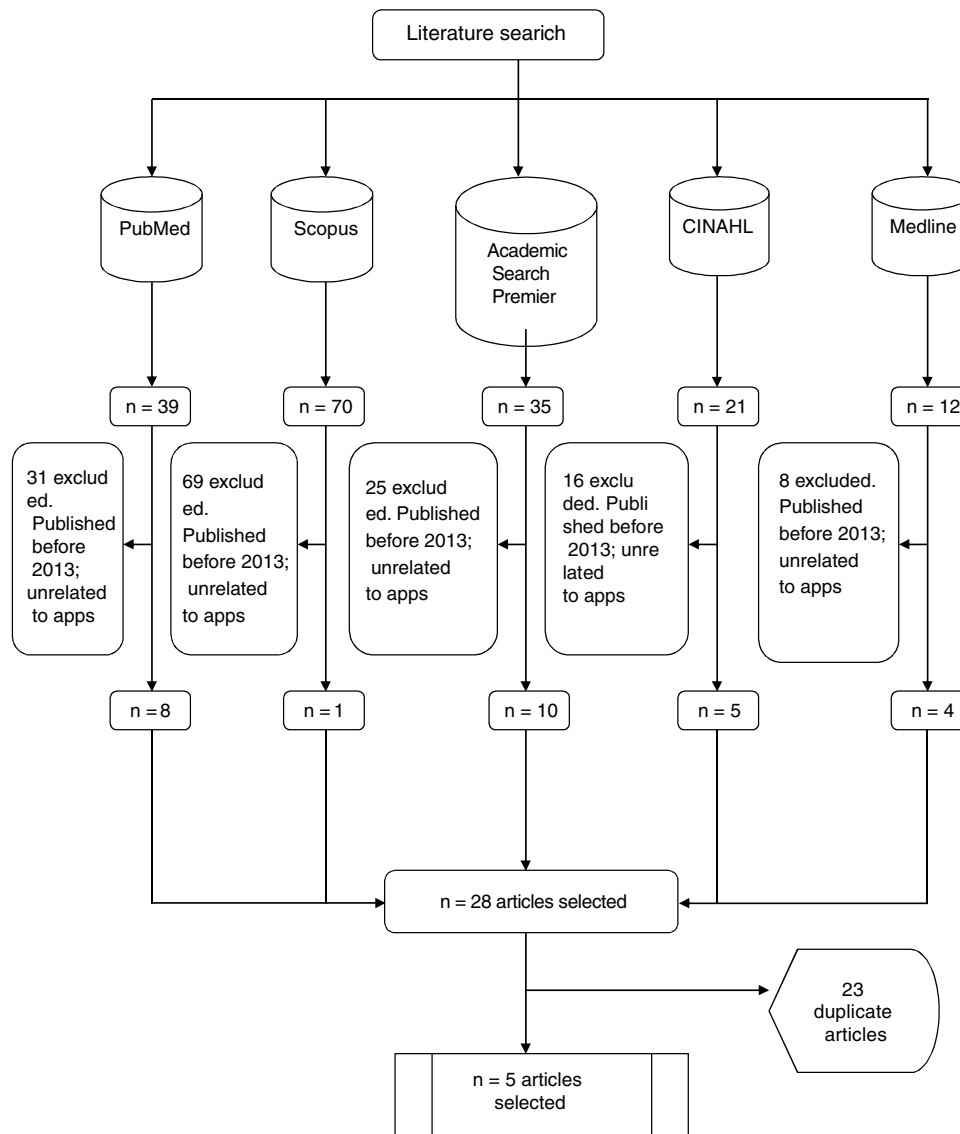
Figure 1 Flow chart illustrating the article selection process.

Two apps were considered potentially useful for CP.[21,23] The article by Spittle et al.[21] describes a protocol for a prospective study aiming to develop a tool (the *Baby moves* app) for assessing general movement in order to detect increased risk of CP or other neurodevelopmental diseases in infants. To date, no validation study has been performed to recommend the app's use.

Bertucco et al.[23] used a specifically developed iPad app, *Fitts index of performance*, to assess whether Fitts's law is applicable to a touchscreen tablet device, both for healthy children and for children with dystonia, with a view to its use as a diagnostic tool. The results support the usability and validity of Fitts's law as a quantitative diagnostic tool in children with dystonia, finding that movement time and information transmitted in relation to task accuracy were correlated with age and disease severity.

Of the studies of apps specifically designed for CP, 2 only included patients with CP,[19,22] whereas the study by Pu et al.[20] also included a control group. The latter study aimed

to develop an app for effective correction of pes equinus in patients receiving gait rehabilitation therapy; the app emits an auditory signal when a toe-walking stride is detected. It also has an option for forwarding data to healthcare professionals, parents, and carers. The app was found to be useful in gait rehabilitation, with a false positive rate of 1.6% and a false negative rate of 3%. However, the study was of poor methodological quality, which limits the validity of the results.

Kulkarni et al.[19] analyse the clinical usefulness of an app designed to assess the risk of hip dysplasia in children with CP. The app was highly effective in identifying the risk of hip dysplasia, but only when used by healthcare professionals, showing high inter-rater reliability. The app showed 98% sensitivity, a positive predictive value of 93%, and a negative predictive value of 93%. Berrezueta-Guzmán et al.[22] analysed an app for communication and stimulation of motor skills with multimedia content, for use during sessions using pictograms to complement learning. The application was

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

Study	Participants	Intervention	Results	Jadad score
Kulkarni et al.[19]	N = 42 (patients with CP)	Analysis of the *HipScreen* app as a tool for assessing the percentage of hip migration in patients at risk of developing hip dysplasia	The app showed high inter-rater reliability, with 98% sensitivity, a positive predictive value of 93%, and a negative predictive value of 93%.	1
Spittle et al.[21]	N = 0	Protocol for validating *Baby Moves*, an app for assessing general movement as an additional tool for identifying infants with high risk of CP or other neurodevelopmental disorders	Not available	Not applicable
Berrezueta-Guzmán et al.[22]	N = 47 (patients with CP; age, 7-12)	Evaluation of an Android app with 2 main modules: an electronic device for detecting and recording the patient's hand/head movements, and a mobile app for communication and learning processes	Using the app as an aid for communication, the researchers noted a reduction in the time needed for therapy; the app supported stimulation of motor skills. 89% of patients felt comfortable and met treatment objectives.	0
Bertucco and Sanger[23]	N = 44 (16 children with dystonia, 15 healthy children, and 13 healthy adults)	Evaluation of an app for assessing motor skills in order to identify patients with dystonia. Additional sensors required	Reduced Index of Performance scores in children with dystonia	2
Pu et al.[20]	N = 16 (4 patients with spastic diplegia, 4 with congenital hemiplegia, and 8 healthy controls)	Evaluation of a system using an auditory signal to correct toe-walking gait. Additional sensor required	The app was found to be useful in gait rehabilitation, with a false positive rate of 1.60% and a false negative rate of 3%.	1

found to be effective for reducing the time needed for communication in training sessions for patients limited to head movement, as well as for stimulating motor skills. However, the study's poor methodological quality constitutes a limitation for recommending the tool's use. As future lines of research, the authors propose developing an SMS notification module for communication with patients' families and an intelligent module that automatically selects exercises and activities based on the patient's profile.

According to the classification described above, the apps are categorised as follows: (1) apps potentially useful for CP: assessment of dystonia[23] and EMG evaluation[21]; (2) assessment apps: assessment of risk of hip dysplasia[19]; and (3) treatment apps: gait training[20] and development of motor skills.[22]

Search of other information sources

In our search of the main app marketplaces, we identified 58 apps related to CP. Fifteen were available for Apple devices only, 31 for Android devices only, and one for Windows Phone only. A further 8 apps were available for both

Android and Apple devices, 2 were available for Apple and Windows Phone, and one appeared on all 3 marketplaces. Fig. 2 illustrates the search process.

Thirty-six apps were available free and 16 were paid; 6 had a free version with some content available for purchase, or had a free beta version and a paid premium version. Regarding language, 32 were in English only, 18 were in Spanish only, and 8 were available in both languages. By user group, 25 apps targeted patients with CP only, 12 targeted healthcare professionals only, and 5 targeted relatives and carers only; 8 were designed for use both by relatives and by patients, 3 were for patients and healthcare professionals, and 5 targeted relatives and healthcare professionals.

According to the classification described above, the apps identified are categorised as follows: 38 were potentially useful for CP, despite not being designed specifically for this purpose, and 20 were designed specifically for the disease (Fig. 3). Table 2 summarises the main characteristics of these apps (name, platform, price, brief description, target group, classification, and language).

The apps of potential use for CP included 7 intended to inform healthcare professionals about various neurological diseases; a noteworthy example is *Baby's motor milestones*,
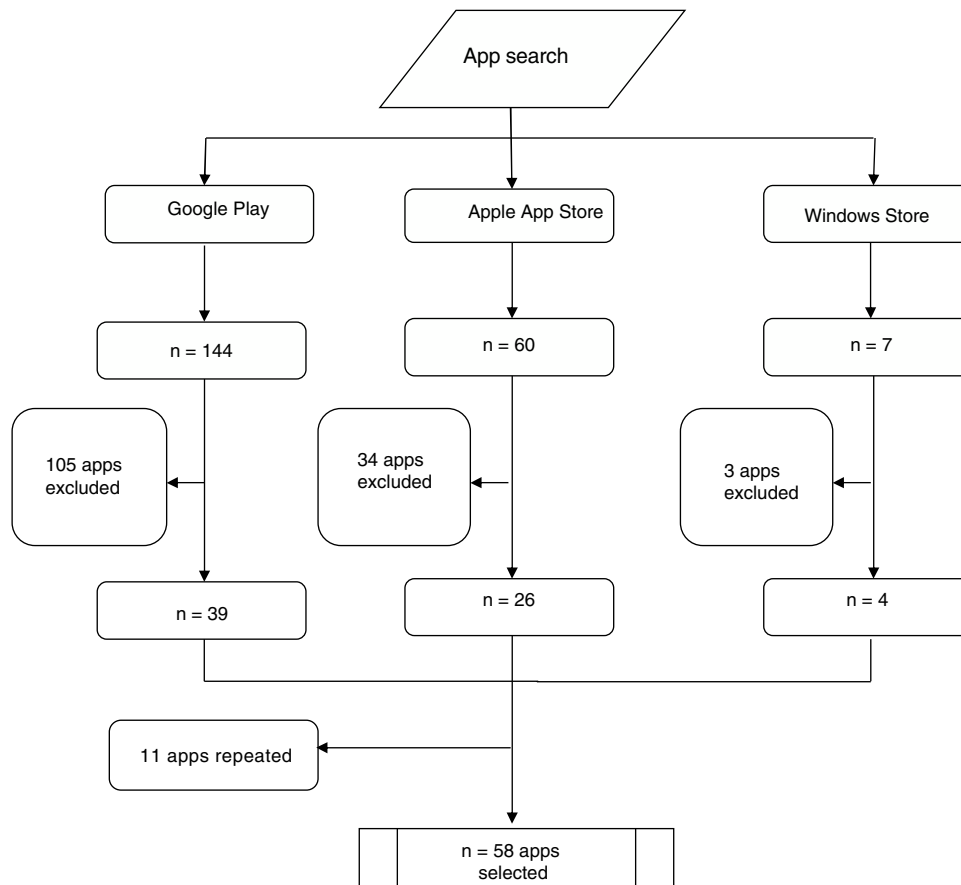
Figure 2   Results of the search of mobile app marketplaces.

which offers particularly relevant information. Five apps focused on developing motor skills, 2 on developing coordination, and 2 on strength exercises, with one providing information on evaluation scales. Other apps provided information on special education, lifestyles, or epilepsy; or aimed to improve concentration, hand-eye coordination and fine motor skills, or visual and auditory perception; the *Swallow Prompt* app serves as a tool to manage drooling.

The apps specifically designed for CP included 11 providing information on the disease or related issues and 2 for patient assessment (one for the risk of hip displacement and another for submitting data to a study evaluating information on CP). The remaining 7 apps focused on treatment of CP, particularly through games intended to improve overall function, including motor skills, attention, and visual and auditory perception; and to facilitate learning during or alongside rehabilitation sessions. Two apps (*Ped PT Strengthening Ex-Abs* and *Ped PT Strengthening Ex-Back*) focus on improving muscle strength. Finally, *CPtoys App* specifically focuses on treatment of the upper limbs, and has an option to personalise training programmes according to each child's situation.

The search of app marketplaces did not yield any of the same apps as those found through the literature search; scientific study should be a determining factor for recommending a healthcare app. However, the *CPUP Hip Score* app, which assesses the risk of hip displacement, is similar to that developed by Kulkarni et al.[19]

Together, the 2 searches identified 63 applications, of which 40 were potentially useful for CP and 23 were specifically designed for the disease (11 information apps, 3 assessment apps, and 9 treatment apps).

Discussion

We identified 63 apps, of which 40 were potentially useful for CP and 23 were specifically designed for the disease; of the latter group, 11 provided information, 3 were designed for assessment, and 9 focused on treatment.

Over the last 10 years, information and communications technology has been an emerging area in healthcare.[35] The World Health Organization refers to the use of these technologies for health as eHealth[36]; the most advanced form, mHealth (mobile health),[37] refers to the rapid expansion of the use of mobile devices in healthcare and the use of healthcare apps on mobile devices[38]; this area continues to grow exponentially.[39] The term mHealth is defined as ''the use of mobile wireless technologies for public health,''[36] demonstrating the increasing importance of this resource for healthcare provision and public health, given the ease of use, broad reach, and great popularity of these devices. The success of health apps may lie in the fact that they increase access to information on health behaviour, services, abilities, and disease management. They also assist healthcare
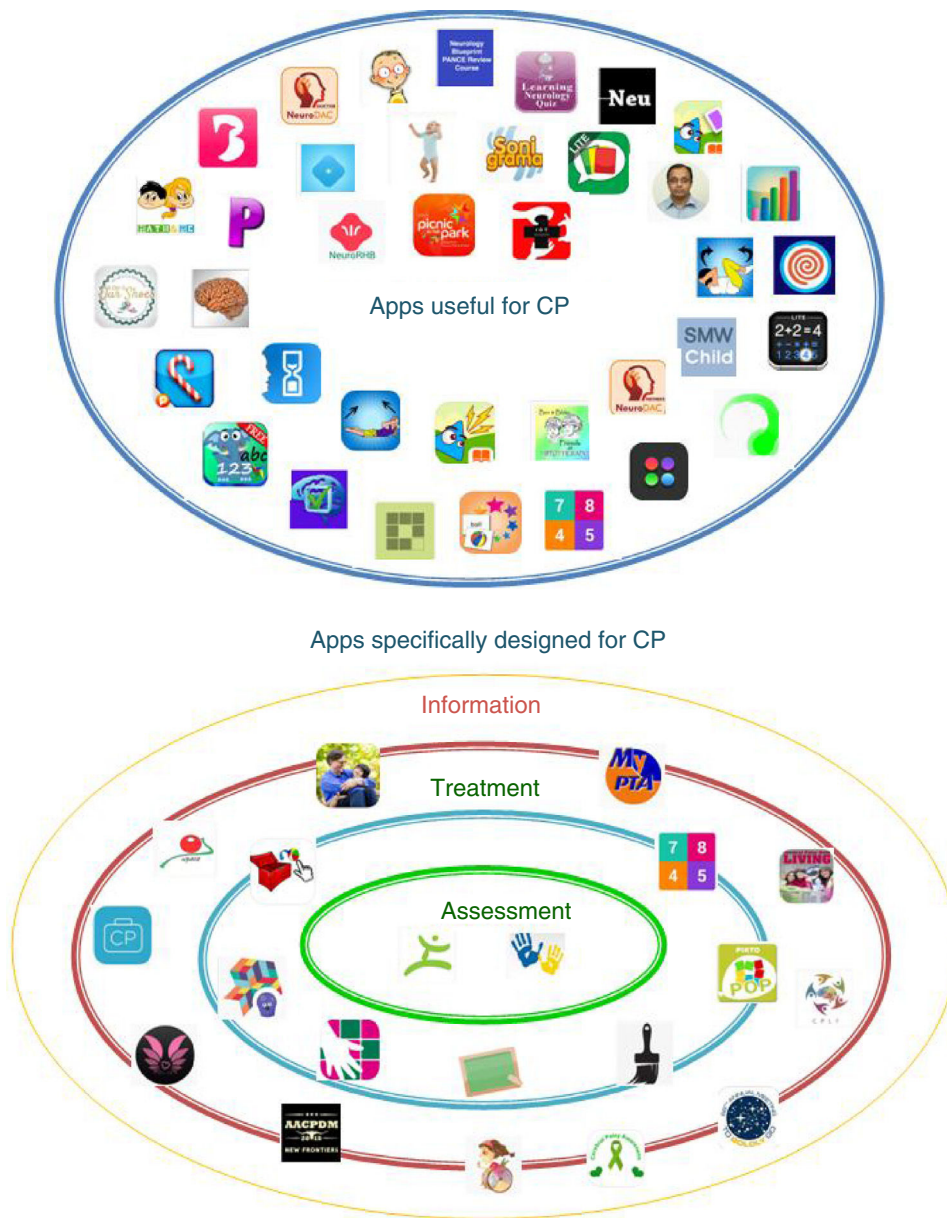
Figure 3 Graphical representation of the classification of apps for cerebral palsy.

professionals in gathering patient data, which is beneficial for early detection of disease.[36,40] Furthermore, these apps facilitate communication with healthcare professionals, giving rise to new types of relationship between patients and their relatives or healthcare professionals; this entails numerous benefits for all parties, optimising consultation times and improving treatment adherence and long-term patient monitoring.[40]

Smartphone sales between 2015 and early 2016 are calculated at around 1.6 billion units, with Android and Apple devices representing 97.8% of sales. The reach of mobile devices is greater than ever. The Cisco Virtual Networking Index Mobile report concludes that there will be 11.6 billion connected devices (smartphones, tablets, and laptop computers) by 2020, of which 72% will be smart devices.[40] This has led to an increase in the number of apps available on the main marketplaces, with the Google Play and Apple App Store platforms offering over 2 million apps.[41] Around 97 000 of these are dedicated to health and medicine.[18]

Broekman et al.[42] report an increasing trend in the development of apps targeting young children; the highest rate was recorded between 2009 and 2011, with 58% of the 100 top-selling apps falling into this category. At this stage of life, parents play a key role in the selection and use of apps for children; however, very little is currently known about how parents' needs are prioritised. A healthcare project run at children's hospitals by the Murdoch Children's Research Institute included mHealth tools intended to facilitate diagnosis and monitoring of disease, to increase patient participation, and to improve adherence to pharmacological treatment/rehabilitation for disorders including autism spectrum disorders and CP.[43]

Table 2 Main characteristics of mobile applications for cerebral palsy.

Name	Platform	Price	Brief description	Target group	Classification	Language
AACPDM 2015 (American Academy for Cerebral Palsy and Developmental Medicine)	Android	Free	Information on the conference, discussion topics, and real-time interaction	Healthcare professionals	Information	EN
AACPDM 68th Annual Meeting	iOS	Free	Annual meeting of the AACPDM	Healthcare professionals	Information	ES/EN
A Day In Our Shoes	Android	Free	Information on special education, legislative issues, and state benefits. Communication between parents	Relatives	Useful for CP	EN
Baby's Motor Milestones	Android	Free	Milestones in a baby's motor development	Patients and healthcare professionals	Useful for CP	EN
Ben & Blake At Hippotherapy!	Android	€1.56	Information on hippotherapy	Patients and relatives	Useful for CP	EN
Birdhouse — for Special Needs	Android	Free with paid content	Organisation of medical information, therapy, and interventions	Relatives	Useful for CP	EN
Candy Cards	iOS	€0.99	Game for developing motor skills	Patients	Useful for CP	EN
Cerebral Palsy	iOS, Android, and Windows Phone	Free	Information on CP Official app of the Cerebral Palsy Lanka Foundation Connects with other international organisations	Relatives and healthcare professionals	Information	EN
Cerebral Palsy Daily Living	iOS	Free with paid content	Guide on CP with images and videos	Patients, relatives, and carers	Information	EN
CPL Picnic in the Park	iOS	Free	Educational cartoons on healthy lifestyles	Patients and relatives	Useful for CP	EN
CP passport	iOS and Android	Free	Users can save information on drugs, doses, physiotherapy sessions, etc.	Patients	Information	EN
CPtoys App	iOS	€2.99	Specific, individualised treatment of the upper limbs	Healthcare professionals and relatives	Treatment	ES/EN
CPUP Hip Score	Android	Free	Assesses risk of hip displacement	Healthcare professionals	Assessment	EN
Daño cerebral	Android	Free	Treatment and understanding of a disease	Patients and healthcare professionals	Useful for CP	ES
DigiColor Calculator	Android	Free with some paid content	Improves visual recognition of numbers	Patients	Treatment	ES

Table 2 (*Continued*)

Name	Platform	Price	Brief description	Target group	Classification	Language
Dr Vivek Dutt Paeds Ortho Doc	Android	Free	Real-time consultation of information	Relatives	Useful for CP	EN
DrOmnibus	Android	Free	Guidelines for developing basic skills	Healthcare professionals and relatives	Useful for CP	EN
Guía de parálisis cerebral para niños	iOS	€2.99	Simple information with daily tips for stimulation	Patients	Information	EN ES
iOT Session	Android	Free	Treatment in various areas: bilateral coordination, fine motor skills, etc. Relatives can record progression.	Patients and relatives	Useful for CP	EN
iSECUENCIAS	iOS and Android	€2.69	Information on healthy habits for personal autonomy	Patients	Useful for CP	ES
Just Say Hi	iOS and Windows Phone	Free	Information. Videos on disability	Patients and relatives	Useful for CP	EN
La calle de Renata	Android	Free	Support for understanding disability in general and CP in particular	Patients	Information	ES
Learning Neurology Quiz	Android	€1.45	Study or review of matters related to neurology	Healthcare professionals	Useful for CP	EN
Learny PCI or Plataforma PCI	iOS and Android	Free	Educational platform focused on learning and rehabilitation	Patients	Treatment	ES
Match it fun	iOS	€0.99	Training of basic skills	Patients	Useful for CP	EN
Math&Me	Android	Free	Mathematics game specifically targeting children with intellectual and physical disabilities	Patients	Useful for CP	EN
MyEpilepsyDiary	iOS and Android	Free	Epilepsy diary	Relatives and patients	Useful for CP	ES
My PTA	Android	Free	Information on physiotherapy	Relatives and carers	Information	EN
Neon Dodge	Android	Free	Games for developing motor skills	Patients	Useful for CP	ES
NeuroDAC Members	Android	Free	Advice on diagnosis and treatment	Healthcare professionals	Useful for CP	EN

Table 2 (*Continued*)

Name	Platform	Price	Brief description	Target group	Classification	Language
NeuroDAC Doctor	Android	Free	Provides physicians with their patients' clinical data	Healthcare professionals	Useful for CP	EN
NeuroAttention	Android	Free	Improves concentration	Patients	Useful for CP	EN
Neurología	Windows Phone	Free	Information on neurological diseases	Healthcare professionals	Useful for CP	ES
Neurología en preguntas cortas	Android	Free	Information on neurological diseases	Healthcare professionals	Useful for CP	ES
Neurology PANCE Review Course	Android	€18.99	Information on neurological diseases	Healthcare professionals	Useful for CP	EN
NeuroScores App	iOS and Android	Free	Scales used in neurological examinations	Healthcare professionals	Useful for CP	ES
Palabras especiales	iOS	€12.99	Increases vocabulary and develops hand-eye coordination and fine motor skills	Patients	Useful for CP	ES/EN
Panther Math Paper Lite	iOS	€9.99	Mathematics training	Patients	Useful for CP	EN
Parálisis cerebral: Burns, atención primaria y pediatría	iOS	€2.99	Self-study and understanding of CP	Healthcare professionals and relatives	Information	ES/EN
Pediatric Physical Therapy Exercises — Abdominals	iOS and Android	Free with paid content	Abdominal strength training exercises with images: 10 free and 52 paid	Healthcare professionals	Useful for CP	ES/EN
Pediatric Physical Therapy Strengthening Exercises — Back	iOS	Free with paid content	Back strength training exercises with images: 10 free, the rest paid	Patients and healthcare professionals	Useful for CP	EN
Picto Cuento	Android	Free	Pictograms for improving attention and motivation	Patients and relatives	Useful for CP	ES
Picture Pusher	iOS	€0.99	Improves fine motor skills	Patients	Treatment	EN
PiktoPop: Explotar globos	Android	Free	Training of cognitive skills and neurodevelopment	Patients	Treatment	ES

Table 2 (*Continued*)

Name	Platform	Price	Brief description	Target group	Classification	Language
Piktosaac Pictogramas Autismo	Android	Free	Pictograms to support language education and stimulation	Patients	Useful for CP	ES
Pinf Hry Launcher	iOS and Windows Phone	Free	Games for improving memory, colour recognition, writing, etc.	Patients	Treatment	ES/EN
Preescolar Juegos en Español	Android	Free	Learning of alphabet, spelling, vocabulary, and basic arithmetic	Patients	Useful for CP	ES
Series 1	Android	Free	Skills development: fine motor skills, visual perception, etc.	Patients	Useful for CP	ES
Show me where: Child — paid	Android	€8.99	Images for indicating the location and type of pain	Relatives and healthcare professionals	Useful for CP	EN
Sonigrama	Android	Free	Game for stimulating visual and auditory attention	Patients	Useful for CP	ES
Speech Cards Lite	iOS	Free with paid content	Flashcards for improving communication, vocabulary, and comprehension	Patients	Useful for CP	EN
Swallow Prompt	iOS	€0.99	Support for controlling drooling	Patients	Useful for CP	ES/EN
Switch Access Trainer	iOS	Free	Motor skills training	Patients	Useful for CP	EN
TherApp	Android	Free	Study of children with CP	Healthcare professionals	Assessment	ES
The Paige Project	iOS and Android	Free	Guide for carers and access to a page for collaboration with the association	Relatives, carers, and the general public	Information	EN
TiltPaint	Android	Free	Development of manual dexterity through drawing	Patients	Treatment	EN
UPACE San Fernando	Android	Free	CP patients' association	Patients and relatives	Information	ES
Zap It Fun	iOS	€0.99	Training of attention and hand-eye coordination	Patients	Useful for CP	EN

EN: English; ES: Spanish.

Our study analyses applications related to CP identified in a search of biomedical databases and app marketplaces. However, given the immense number and variety of apps available, it is likely that other potentially useful apps (such as those for developing fine motor skills or hand-eye coordination, or providing information for parents or carers) may not have been included due to the difficulty of categorising them and the constant expansion of the market. Similarly, the heterogeneity of the disorders included under the term cerebral palsy and the associated comorbidities mean that other potentially useful apps (such as those for controlling epilepsy and communication or behavioural disorders) may not have been analysed. According to the Doctoralia report on health and the Internet,[44] published in 2015, the most widely used applications are those providing health information (86% of survey respondents), followed by apps focusing on physical exercise (77%), diet (66%), and medication management (66%). This appears to coincide with the results of our search of the main app marketplaces: information apps were the most numerous both in the group of specifically designed apps and in the group of potentially useful apps for CP. However, the literature search identified no studies on this type of app; it is therefore necessary to question the accuracy of the information provided by some mHealth apps.

The findings from our literature search indicate that mobile devices are useful for performing certain patient evaluations, such as estimating the risk of hip dysplasia in children with CP[19] and detecting dystonia, given the precision of touchscreens[23]; however, the poor methodological quality of the studies analysed represents a limitation for recommending routine use of these apps. Other apps aim to support diagnosis of CP, among other neurodevelopmental disorders.[21] However, caution should be exercised when interpreting this information, given the very poor methodological quality of the majority of the studies analysed.

The US Food and Drug Administration (FDA) acknowledges that progress in digital health offers an opportunity for better, more efficient patient care and improved health outcomes. This gives rise to the need for many medical devices to be interoperable with other types of device and with various types of health information technology,[45] which may explain the use of additional sensors, as was the case for 2 of the apps analysed in this review.[20,23] While one of the main issues facing the use of apps is the lack of effective security legislation, patients appear to be comfortable using apps or web tools to submit health information.[16,45]

Although some apps were developed by foundations or associations specialising in CP, such as UPACE San Fernando and the Cerebral Palsy Lanka Foundation (*Cerebral Palsy* app), many have not been approved by such bodies. Guidelines published for developers and users provide information on the FDA regulations for the sector.[45] The main issue with these regulations is the constant innovation in mHealth apps, which makes it very difficult for developers to obtain FDA approval quickly enough to keep up to date.[46]

Our findings show that while a range of apps are available for management of CP, very few are scientifically validated, making this an interesting field of research. Other literature reviews describe mobile applications in other areas or for other diseases, and the effectiveness of these apps. A 2014 review by Juárez-Giménez[39] assessed the potential effectiveness of apps as tools for pharmacotherapy consultation and for improving adherence to prescribed treatments. The author concludes that while they may improve treatment adherence, given the great accessibility and low cost of apps, the evidence on their use is limited. To date, these apps are considered a potentially useful strategy for improving adherence. In 2017, a review by Linares-del Rey et al.[47] studied apps designed for patients with Parkinson's disease, identifying a broad range of apps, many of which were developed by foundations and other organisations. However, the limited evidence and the lack of an appropriate means of evaluating the apps prevents generalisations being made regarding their use. In a recent report, Leijdekkers and Gay[46] argue that mHealth would be part of a possible solution for implementing changes in healthcare provision, particularly for the prevention and treatment of chronic disease; our results may further support this.

Our study has a number of limitations. Firstly, we may have consulted too few databases, and we limited the articles selected to those written in English and Spanish. Furthermore, the app market is constantly changing and evolving; we may therefore have failed to identify some relevant apps, and new apps may have become available after the publication of this review.

Conclusions

We identified 63 apps cited in published articles in biomedical databases and on app marketplaces; of these, 40 were potentially useful for CP and 23 were specifically designed for the disease. Of the latter group, 11 offered information on the disease, 3 focused on assessment, and 9 were designed to treat aspects of the disease.

Numerous mobile apps are potentially useful or specifically designed for CP. However, despite the available scientific evidence, the poor methodological quality of the studies identified prevents us from recommending generalised use of these apps.

The potential benefits and risks associated with mHealth give rise to a need for further research and for official regulation of the sector. This would guarantee the reliability and safety of using this technology, providing healthcare professionals, patients with CP, and their relatives and carers with an effective adjuvant tool for diagnosis or treatment of the disease.

Conflicts of interest

None.

References

1. Sulaiman NH, Ghazali M. Learning through playing for children with cerebral palsy. J Teknologi. 2016;78:63—72.
2. Campistol-Plana J, Arroyo HA, Póo Argüelles P, Ruggieri V. Neurología para pediatras: enfoque y manejo práctico. Madrid: Editorial Médica Panamericana; 2011.

3. Blair E. Epidemiology of the cerebral palsies. Orthop Clin North Am. 2010;41:441—55.

4. Bosanquet M, Copeland L, Ware R, Boyd R. A systematic review of tests to predict cerebral palsy in young children. Dev Med Child Neurol. 2013;55:418—26.

5. Koman LA, Smith BP, Shilt JS. Cerebral palsy. Lancet. 2004;363:1619—31.

6. Colver A, Fairhurst C, Pharoah P. Cerebral palsy. Lancet. 2014;383:1240—9.

7. Oskoui M, Gazzellone M, Thiruvahindrapuram B, Zarrei M, Andersen J, Wei J, et al. Clinically relevant copy number variations detected in cerebral palsy. Nat Commun. 2015;6:7949.

8. Oskoui M, Coutinho F, Dykeman J, Jette N, Pringsheim T. An update on the prevalence of cerebral palsy: a systematic review and meta-analysis. Dev Med Child Neurol. 2016;55:509—19.

9. Mcintyre S, Taitz D, Keogh J, Goldsmith S, Badawi N, Blair E. A systematic review of risk factors for cerebral palsy in children born at term in developed countries. Dev Med Child Neurol. 2013;55:499—508.

10. Herskind A, Greisen G, Nielsen JB. Early identification and intervention in cerebral palsy. Dev Med Child Neurol. 2015;57:29—36.

11. Granild JB, Rackauskaite G, Flachs EM, Uldall P. Predictors for early diagnosis of cerebral palsy from national registry data. Dev Med Child Neurol. 2015;57:931—5.

12. Lee RW, Poretti A, Cohen JS, Levey E, Gwynn H, Johnston MV, et al. A diagnostic approach for cerebral palsy in the genomic era. Neuromolecular Med. 2014;16:821—44.

13. Strobl W, Theologis T, Brunner R, Kocer S, Viehweger E, Pascual-Pascual I, et al. Best clinical practice in botulinum toxin treatment for children with cerebral palsy. Toxins. 2015;7:1629—48.

14. Shamsoddini A, Amirsalari S, Hollisaz M, Rahimnia A, Khatibi-Aghda A. Management of spasticity in children with cerebral palsy. Iran J Pediatr. 2014;24:345—51.

15. Sánchez-Rodríguez MT, Collado-Vázquez S, Martín-Casas P, Cano-de la Cuerda R. Apps en neurorrehabilitación. Una revisión sistemática de aplicaciones móviles. Neurologia. 2018;33:313—26.

16. Petris A, Macleod P, Dromey J. Technology convergence. Australas Biotechnol. 2016;26:26.

17. Jadad AR, Moore RA, Carroll D, Jenkinson C, Reynolds DJ, Gavaghan DJ, et al. Assessing the quality of reports of randomized clinical trials: is blinding necessary? Control Clin Trials. 1996;17:1—12.

18. Mugarza, F., Informe *app* salud en español. In: Informe de las mejores 50 *app* de salud en español. The App Intelligence. Madrid: Zeltia; 2011.

19. Kulkarni V, Davids J, Bagley A. Smartphone app for community-based hip surveillance program for children with cerebral palsy: a preliminary study. Dev Med Child Neurol. 2016;58:64.

20. Pu F, Fan X, Yang Y, Chen W, Li S, Li D, et al. Feedback system based on plantar pressure for monitoring toe-walking strides in children with cerebral palsy. Am J Phys Med Rehab. 2014;93:122—9.

21. Spittle A, Olsen J, Kwong A, Doyle L, Marschik P, Einspieler C, et al. The Baby Moves prospective cohort study protocol: using a smartphone application with the General Movements Assessment to predict neurodevelopmental outcomes at age 2 years for extremely preterm or extremely low birthweight infants. BMJ Open. 2016;6:e013446.

22. Berrezueta-Guzmán J, Coronel-Maldonado F, Serpa-Andrade L, Robles-Bykbaev V. A didactic transmitter to support the communication and learning process of children with cerebral palsy. MATEC Web Conf. 2016;42:5004.

23. Bertucco M, Sanger T. Speed-accuracy testing on the Apple iPad (R) provides a quantitative test of upper extremity motor performance in children with dystonia. J Child Neurol. 2014;29:1460—6.

24. Lin C, Lin M, Chen S. Motion sensing technology on rehabilitation for children with physical disabilities. Lect Notes Comput Sci. 2013;8011:500—7.

25. Condado PA, Lobo FG. A system for controlling assisted living environments using mobile devices. Proceedings of the 17th international ACM SIGACCESS conference on computers & accessibility. Lisbon, Portugal; 2015. p. 33—8.

26. Gulmans J, Vollenbroek-Hutten M, van Gemert-Pijnen L, van Harten W. A web-based communication system for integrated care in cerebral palsy: experienced contribution to parent—professional communication. Int J Integ Care. 2012;12:e9.

27. Imms C, Wallen M, Elliott C, Hoare B, Randall M, Greaves S, et al. Minimising impairment: protocol for a multicentre randomised controlled trial of upper limb orthoses for children with cerebral palsy. BMC Pediatr. 2016;16:70.

28. Godinho R, Condado PA, Zacarias M, Lobo FG. Improving accessibility of mobile devices with EasyWrite. Behav Inf Technol. 2015;34:135—50.

29. Kurschl W, Augstein M, Stitz H. A user modelling wizard for people with motor impairments. ACM. 2013:541—50.

30. Martín-Ruiz M, Maximo-Bocanegra N, Luna-Oliva L. A virtual environment to improve the detection of oral—facial malfunction in children with cerebral palsy. Sensors. 2016;16:444.

31. Ramón JM, Perales FC, Amengual E. Integration of EEG-based brain computer interfaces in serious games. ITA. 2013:367—70.

32. Borges L, Filgueiras L, Maciel C. A customized mobile application for a cerebral palsy user. ACM. 2013:6—7.

33. Tong J, Zhang P, Xiao R, Ding L. The portable P300 dialing system based on tablet and Emotiv Epoc headset. Conf Proc IEEE Eng Med Biol Soc. 2015;2015:566—9.

34. Galarraga O, Vigneron V, Dorizzi B, Khouri N, Desailly E. Predicting postoperative knee flexion during gait of cerebral palsy children. Comput Methods Biomech Biomed Eng. 2015;18:1940—1.

35. Davis T, DiClemente R, Prietula M. Taking mHealth Fforward: examining the core characteristics. JMIR Mhealth Uhealth. 2016;4:e97.

36. World Health Organization. eHealth. Available from: http://www.who.int/topics/ehealth/en/ [accessed 15.06.16].

37. Abrahamyan S, Balyan S, Muradov A. Development of m-health software for people with disabilities. 2016;9790:468—79.

38. Yang CC. Intelligent systems for security informatics. 1.ª ed Ámsterdam: Elsevier/Academic Press; 2013.

39. Juárez-Giménez JC. Apps farmacológicas para el paciente. Farm Hosp. 2014;204:33.

40. Morera EP, de la Torre-Díez I, Garcia-Zapirain B, López-Coronado M, Arambarri J. Security recommendations for mHealth app: elaboration of a developer's guide. J Med Syst. 2016;40:152.

41. Ditrendia, Informe Mobile en España y en el mundo 2015, 2015. Available from: http://www.ditrendia.es/wp-content/uploads/2015/07/Ditrendia-Informe-Mobile-enEspa%C3%B1a-y-en-el-Mundo-2015.pdf [accessed 3.02.17].

42. Broekman FL, Piotrowski JT, Beentjes HW, Valkenburg PM. A parental perspective on *app* for young children. Comput Hum Behav. 2016;63:142—51.

43. Macleod P, Dromey J. Digital health at the Murdoch children's research institute. A new model for the convergence of health and technology. Australas Biotechnol. 2015;25:14—5.

44. Doctoralia. Primer informe Doctoralia: salud e Internet 2015. 2015. Available from: http://insights.doctoralia.es/informe-doctoralia-sobresalud-e-Internet-2015/ [accessed 3.02.17].

45. Food and Drug Administration's. The mobile medical applications. Guidance for Industry and Food and Drug Administration Staff, 2015. Available from: http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/Guidan ceDocuments/UCM263366.pdf [accessed 3.02.17].

46. Leijdekkers P, Gay V. Mobile *app* for chronic disease management: lessons learned from myFitnessCompanion. Health Technol. 2013;3:111—8.

47. Linares-del Rey M, Vela-Desojo L, Cano-de la Cuerda R. Aplicaciones móviles en la enfermedad de Parkinson: una revisión sistemática. Neurología. 2019;34:38—54, http://dx.doi.org/10.1016/j.nrl.2017.03.006.