Mobile Health Apps for Self-Management of Rheumatic and Musculoskeletal Diseases: Systematic Literature Review

Aurélie Najm, Laure Gossec, Catherine Weill, David Benoist, Francis Berenbaum, Elena Nikiphorou

1Department of Rheumatology, Nantes University Hospital, Nantes, France
2INSERM UMR 1238, Nantes University of Medicine, Nantes, France
3INSERM UMR S1136, Institut Pierre Louis d’Epidémiologie et de Santé Publique, Sorbonne Université, Paris, France
4Rheumatology department, Pitié Salpêtrière Hospital, AP-HP, Paris, France
5Bibliothèque interuniversitaire de Santé, Paris Descartes University, Paris, France
6Department of rheumatology, Sorbonne Université, INSERM CRSA Saint-Antoine, AP-HP, Saint Antoine Hospital, Paris, France
7Department of Inflammation Biology, School of Immunology and Microbial Sciences, Faculty of Life Sciences & Medicine, King’s College London, Paris, France

Abstract

Background: Although the increasing availability of mobile health (mHealth) apps may enable people with rheumatic and musculoskeletal diseases (RMDs) to better self-manage their health, there is a general lack of evidence on ways to ensure appropriate development and evaluation of apps.

Objective: This study aimed to obtain an overview on existing mHealth apps for self-management in patients with RMDs, focusing on content and development methods.

Methods: A search was performed up to December 2017 across 5 databases. For each publication relevant to an app for RMDs, information on the disease, purpose, content, and development strategies was extracted and qualitatively assessed.

Results: Of 562 abstracts, 32 were included in the analysis. Of these 32 abstracts, 11 (34%) referred to an app linked to a connected device. Most of the apps targeted rheumatoid arthritis (11/32, 34%). The top three aspects addressed by the apps were pain (23/32, 71%), fatigue (15/32, 47%), and physical activity (15/32, 47%). The development process of the apps was described in 84% (27/32) of the articles and was of low to moderate quality in most of the cases. Despite most of the articles having been published within the past two years, only 5 apps were still commercially available at the time of our search. Moreover, only very few studies showed improvement of RMD outcome measures.

Conclusions: The development process of most apps was of low or moderate quality in many studies. Owing to the increasing RMD patients’ willingness to use mHealth apps for self-management, optimal standards and quality assurance of new apps are mandatory.

(JMIR Mhealth Uhealth 2019;7(11):e14730) doi: 10.2196/14730

KEYWORDS

mobile health; self-management; arthritis; telemedicine; musculoskeletal diseases
Introduction

Background

Mobile health (mHealth) connects patients, their families, and health care professionals by creating a network with mobile and specialized devices with wearable sensors, recording health parameters, and gathering health data. Health information can be subsequently converted and transferred to physicians and other health care professionals involved in the care of patients via medical application interfaces. By enabling patients to access and share their health information, mHealth empowers patients to become more engaged and to take initiative in self-management and shared management of their health.

Since the first description of the concept of mHealth [1], its popularity has exponentially increased. This is primarily because of the fast expanding technological advances including the development of smartphones and fourth generation mobile communication system networks. The impressive popularity of mHealth apps in the last decade is reflected by the number of downloads in recent years, exceeding 200 million in 2010 [2].

On the wider mHealth market, various apps have been developed for different purposes. The latter include apps for disease prevention among healthy users [3] and apps for people with existing chronic health conditions [4]. A recent study, for example, demonstrated that apps can contribute to improve disease control in people with diabetes [5], hypertension [6], or asthma [7] and can help for the monitoring and self-management of obesity [8], mental health diseases [9], and multimorbidities [10]. A total of 17.3 million people report having rheumatic and musculoskeletal diseases (RMDs), the most frequent being low back pain and osteoarthritis (OA) [11]. As RMDs have multidimensional consequences on health, the increasing availability of apps has an important role to play in enabling people with RMDs to better self-manage their health [12]. Moreover, in a recent study of people with rheumatoid arthritis (RA), 86% agreed that an app to support self-management would be useful and welcomed [13]. This being said, the dramatic increase and adoption of mHealth apps and the business it generates raise some fundamental questions, such as (1) How is the scientific content controlled? and (2) How can we make sure that apps are appropriate for patients?

Objectives

Despite the growing enthusiasm for this topic among physicians and researchers, there is a lack of evidence describing the development and evaluation of apps for people with RMDs that fulfill quality requirements for their implementation as part of routine care. This formed the rationale for this systematic review of literature as part of a larger project to inform points to consider for the development, evaluation, and implementation of mHealth apps for self-management of RMDs. The overarching aim of this systematic review was to obtain a clear view on existing mHealth apps for patients with RMD. Specific objectives were to better characterize (1) the target population of available apps, (2) their purpose and content, and (3) strategies of mHealth app development.

Methods

Search Strategy

A systematic literature review (SLR) was performed following the preferred reporting items for systematic reviews and meta-analyses methodology [14]. The search was performed using the Cochrane Library, EMBASE, MEDLINE, PsyChINFO, Web of Science, and gray literature (internet and international rheumatology societies’ websites) up to December 2017. Relevant keywords and Medical Subject Headings terms relative to 3 key domains were used: RMDs, self-management, and mHealth (see Multimedia Appendices 1 and 2). The search strategy was developed with support from 2 experienced librarians (DB and CW). The clinical questions and inclusion criteria were predefined according to the population, intervention, control, and outcomes (PICO) statement [15]. PICO is a framework that allows to facilitate literature search and to formulate the scientific questions. The target population was patients with any RMDs. The intervention was the description or use of any apps for self-management, irrespective of whether these apps were connected or not to a device.

Any articles describing the development, evaluation, usability, accessibility, effectiveness, and assessment of patient-reported outcomes (PROs) collected through the internet or through electronic apps, and satisfaction over the use of an app for disease self-management, were included. English language was applied as a limit for the articles. Double screening by 2 independent reviewers (AN and EN) was performed for all abstracts against inclusion/exclusion criteria with agreement of 99% in selected papers. Disagreements were resolved by discussion.

Data Analysis

Data regarding type of app, target population, country of development, themes and objectives, development process, funding sources, and functionality of the app were collected. The development process was classified into 3 main categories: (1) patients or health care providers involved in both design and funding sources, and functionality of the app were collected. The development process was classified into 3 main categories: (1) patients or health care providers involved in both design and evaluation but not in the design process, and (3) neither patients nor health care providers involved in the design or evaluation phases.

The commercial availability of the app was also checked on Google and Apple Store. Owing to the vast heterogeneity of the included studies, a meta-analysis was not considered appropriate. Descriptive statistics were performed using GraphPad Prism (GraphPad Software, San Diego)

Results

Systematic Literature Search Output

The search identified 562 abstracts. Manual search through screening of national societies and patient associations’ home pages yielded 1 additional reference. After duplicate exclusion, 475 abstracts were screened based on title and abstract. From these, 56 articles were identified as potentially relevant and selected for full-text assessment. After full-text assessment, 32
articles were considered suitable for inclusion in the analysis (Figure 1).

Figure 1. Flow chart summary of the systematic literature review, article identification, screening, and final selection. mHealth: mobile health.

General Study Characteristics
Out of the 32 included studies, 28 were observational studies and 4 were randomized controlled trials (RCTs). Description of the objective for each study, the target disease, the country of origin, name of the app, and the type of data collected by the app of each RCT [16-21] and observational studies [22-47] is detailed in Multimedia Appendix 3 [48].

Target Disease of Mobile Health Apps, Country of Origin, and Funding Sources
Out of the 32 included articles, 13 (40%) referred to an app linked to a connected device. Most of the apps (26/32, 81%) were designed for the use of patients living with a specific rheumatic disease, distributed as follows: RA (11/32, 34%), fibromyalgia (5/32, 15%), juvenile idiopathic arthritis (4/32, 12%), OA (3/32, 9%), psoriatic arthritis and ankylosing spondylitis (AS; 3/32, 9%), spine disease (1/32, 3%), and ankle sprain (1/32, 3%). The other apps (6/32, 18%) were either designed for multiple diseases (eg, AS, RA, and systemic lupus erythematosus) or for the general population but used by patients living with RMDs in some studies. The great majority of the apps were developed in the United States (11/32, 34%), Japan (4/32, 12%), Canada (3/32, 9%), and Norway (3/32, 9%).

The funding sources were cited in 93% (30/32) of the articles and reported to be private in 34% (11/32) of the cases. The funding source was reported to be academic in 62% (20/32) of the articles.

Purposes and Data Collected by Mobile Health Apps
Most of the apps were designed for self-monitoring and collection of specific outcome measures (22/32, 68%), the latter including patient-reported outcome measures (pain, fatigue, sleep, mood, and global well-being) and disease activity scores. Furthermore, many allowed self-visualization of the health data as a trend (17/22, 77%), such as disease activity scores and physical activity (measured by the number of steps). A few apps (7/32, 21%) aimed to promote physical activity through daily reminders and education on physical activity programs. For instance, 2 apps were designed to support coping mechanisms around pain management with relaxation therapy. Finally, 2 apps were designed primarily to help medication adherence through a tick-box option on the app when the medication is taken or through sending daily reminders with the possibility for the patient to edit the frequency of the reminders. None of the apps were reported as having the status of medical device. Most of the apps addressed multiple disease features (detailed in Table 1).
### Table 1. Features addressed by the different apps for rheumatoid arthritis and other rheumatic and musculoskeletal diseases.

| Features addressed by the apps | Rheumatoid arthritis apps | Apps designed for other rheumatic and musculoskeletal diseases |
|-------------------------------|---------------------------|---------------------------------------------------------------|
|                               | Value, n (%)              | Value, n (%)                                                                 |
| Pain                          | 7 (22)                    | 13 (41) JIA, OA, fibromyalgia, PsA/AS, and spine disease         |
| Fatigue                       | 4 (13)                    | 9 (28) JIA, OA, and fibromyalgia                                 |
| Physical activity             | 2 (6)                     | 9 (28) JIA and OA                                                |
| Sleep                         | 1 (3)                     | 8 (25) JIA, OA, and fibromyalgia                                 |
| Disease Activity Score        | 8 (25)                    | 1 (3) PsA/AS                                                    |
| Health Assessment Questionnaire| 6 (19)                   | 2 (6) JIA and PsA/AS                                            |
| Mood                          | 0 (0)                     | 6 (19) JIA, OA, and fibromyalgia                                 |
| Global well-being (Short Form 36) | 1 (3)               | 6 (19) OA                                                      |
| Morning stiffness             | 1 (3)                     | 4 (13) JIA and PsA/AS                                            |
| Depression/anxiety            | 1 (3)                     | 2 (6) Fibromyalgia                                              |
| Medication/adherence          | 1 (3)                     | 3 (9) JIA, OA, and fibromyalgia                                 |
| Tender joint count            | 1 (3)                     | 3 (9) JIA                                                       |
| Gait                          | 4 (13)                    | 0 (0) __d                                                       |
| Social support                | 0 (0)                     | 2 (6) JIA                                                       |
| Work                          | 0 (0)                     | 2 (6) JIA                                                       |
| Grip                          | 1 (3)                     | 0 (0) __                                                        |

*aJIA: juvenile idiopathic arthritis.

*bOA: osteoarthritis.

*cPsA/AS: psoriatic arthritis/ankylosing spondyloarthritis.

*dNot applicable.

### Development Process of the Apps

The development process of the app was not described at all in 9% (3/32) of the studies (Table 2). Only 15% (5/32) of articles stated that patients were included in the development of the apps. A qualitative phase occurred in only 18% (6/32) of the cases [19,27,30,33,36,37]. This qualitative phase consisted of individual interviews (4 different studies), patient focus group (1 study), or patients focus groups and individual interviews (1 study). A mixed method approach was undertaken in 2 of those studies, with the addition of a patient survey or a Delphi procedure.

Health professionals and/or physicians were involved in the development or evaluation phase in 40% (13/32) of the studies.
Table 2. Description of the development phase and funding sources of the apps.

| Reference | Quality of design and evaluation phase | Health care provider involvement | Patient involvement | Qualitative phase | Funding/development |
|-----------|----------------------------------------|----------------------------------|---------------------|------------------|---------------------|
| Li et al, 2017 [16] | N/A<sup>a</sup> | N/A | N/A | N/A | Private |
| Skrepnik et al, 2017 [17] | B<sup>b</sup> | - | +<sup>d</sup> | - | Private |
| Kristjansdottir et al, 2013 [18] | A<sup>e</sup> | - | + | + | Public |
| Kristjansdottir et al, 2013 [19] | A | - | + | + | Public |
| Paxton et al, 2018 [20] | B | - | + | - | Private |
| Harmelink et al, 2017 [21] | B | - | + | - | Private |
| Buitts et al, 2010 [22] | B | - | + | - | Public |
| Kvien et al, 2005 [23] | B | - | + | - | Public |
| Heiberg et al, 2007 [24] | B | - | + | - | Not reported |
| Richter et al, 2008 [25] | B | + | + | - | Public |
| Stinson et al, 2008 [26] | A | + | + | + | Public |
| Stinson et al, 2006 [27] | A | + | + | + | Public |
| Garcia-Palacios et al, 2014 [28] | B | + | + | - | Public |
| Nishiguchi et al, 2016 [29] | B | - | + | - | Public |
| de la Vega et al, 2018 [30] | A | + | + | + | Public |
| Salaffi et al, 2013 [31] | B | - | + | - | Private |
| Yen et al, 2016 [32] | B | + | + | - | Public |
| Khurana et al, 2016 [33] | A | - | + | + | Private |
| Kim et al, 2016 [34] | B | - | + | - | Public |
| Cai et al, 2017 [35] | A | + | + | + | Public |
| Revenas et al, 2015 [36] | A | + | + | + | Public and private |
| Synnott et al, 2015 [37] | B | + | + | - | Public |
| Bromberg et al, 2016 [38] | B | - | + | - | Public |
| Bromberg et al, 2014 [39] | B | - | + | - | Public |
| Okifuji et al, 2011 [40] | B | - | + | - | Private |
| Nishiguchi et al, 2014 [41] | B | + | + | - | Public |
| Shinohara et al, 2013 [42] | B | - | + | - | Not reported |
| Walker et al, 2017 [43] | B | + | + | - | Private |
| Yamada et al, 2012 [44] | B | - | + | - | Public |
| Espinoza et al, 2016 [45] | N/A | N/A | N/A | N/A | Private |
| Kim et al, 2016 [46] | B | + | + | - | Public |
| Twiggs et al, 2018 [47] | N/A | N/A | N/A | N/A | Private |

<sup>a</sup>Not applicable.

<sup>b</sup>Patients or health care providers involved in the evaluation but not in the design process.

<sup>c</sup>Absent.

<sup>d</sup>Present.

<sup>e</sup>Patients or health care providers involved in both design and evaluation phases.

**Evaluation of the Apps**

Physicians were rarely involved in app evaluation (5/32, 15%). Patients were more frequently involved in app evaluation but mostly indirectly through their adherence to the app (12/32, 70%). A total of 17 apps proposed a direct evaluation through the use of a satisfaction scale (12/32, 70%) and/or an open or closed questionnaire (9/32, 52%). Satisfaction scores and comments were generally positive.
Commercial Availability of the Apps
Moreover, 16 (50%, 16/32) articles included in this review were published between 2016 and 2017. Only a few apps described in the publications were commercially available (4/32, 12%) at the time of our web-based search; all were free of cost.

Quality of the Available Apps
We performed quality score on the apps, which were existing in the different online stores (iTunes and Google Play) using a validated app quality score, the Mobile Application Rating Scale (MARS) [48]. The MARS includes different quality subscale scores, which rate engagement, functionality, aesthetics, and information. The score was calculated for the available apps. MARS for the ReaApp (Google Play) was 3.01 out of 5 and 3.8 out of 5 for the iGetBetter app (iTunes). The other apps were either not available online (28/32) or not in English language (1/32) or not accessible for free (1/32).

Effectiveness of the Apps
A total of 2 RCTs were included in the SLR, 1 study in OA [17] and 1 in fibromyalgia [18,19]. In the trial by Skrepenik et al [17], patients were randomized in 2 groups: a mobile OA app along with a wearable activity monitor with (intervention group) or without feedback (control group). A significant increase in the number of steps per day (1199 vs 467, P=.03) as well as a reduction in pain from baseline during the 6-min walk test was shown in the intervention group. The trial by Kristjandottir et al [19] included a smartphone-delivered intervention with diaries and personalized feedback to patient living with fibromyalgia. The primary endpoint was met with a reduction of catastrophizing score in the treated group (mean 9.20, SD 5.85) compared with the control group (mean 15.71, SD 9.11; P<.001).

Discussion
Principal Findings
To our knowledge, this is the first piece of work to identify literature published on self-management mHealth apps for patients living with RMDs. Our search yielded heterogeneous studies, referring to heterogeneous apps designed either for a specific rheumatic disease or for multiple diseases and also for the general public/healthy population. The large quantity and variety of information that was collected by the app and the relevance of collecting this information as part of a self-management initiative are questionable and not always clearly outlined.

The development process of most apps has been insufficient or not described in the screened existing literature, which raises questions around their credibility. Importantly, most of the apps, despite being designed for patient use, involved neither patients nor health care providers in their development phase. These findings are in line with recently published work, showing that health care professionals were involved in only 35% (n=7) of the apps designed for RA patients [49]. This is a major concern as the absence of involvement of the relevant stakeholders might lead to inappropriate development tailored for the eventual user, including lack of assurance of content approval by specialists.

Our results highlight the unmet need for a standardization process to facilitate the convoluted and demanding processes required to develop mHealth apps. This matter goes beyond the scope of self-management apps for patients. For instance, Buijink et al [50] showed in a previous study that most mHealth apps designed for health care professionals were lacking authenticity details; authors, manufacturers, and distributors were not listed; and references were unavailable or out of date. Indeed, as mHealth apps are considered as medical devices by the US Food and Drug Administration, they should be subject to rigorous regulation [50]. These findings are consistent with our own findings and observations; indeed, the provenance and design process of the app as well as developers and funding sources are lacking details in many papers. Indeed, funding sources were not cited in more than half of the studies, which makes it difficult to identify clearly the nature of beneficiaries of such apps.

Moreover, despite more than half of the studies included in this review being published in the past 2 years, only a handful of apps were commercially available at the time of our search. This highlights the high turnover of apps developed for this purpose. One speculation could be that some of the apps were used in only 1 center and therefore have never been available for public use.

Strengths and Limitations
It should be noted that our systematic review did not specifically address the question of reviewing apps existing in the Apple store. We focused on published literature on self-management mHealth apps, regardless of the type of RMDs. The very heterogeneous nature of the literature published on this topic and the relatively low number of relevant publications on the subject constitute the main limitations of this study. To ensure a most informative literature review, aside from systematically exploring the literature and other possible sources of information, we extracted data from the apps’ content and development procedure when it was provided. The latter revealed that many apps were usually focusing on selected aspects of disease self-management. Most were giving the patients the opportunity to enter selected PROs, especially fatigue, pain, and sleep, and also collected information on physical activity. Disease activity scores were more rarely (28.2%) collected by the apps. No relevant data were available on the quantitative use of apps.

Our work is in line with a recent study by Grainger et al who assessed the quality of RA apps specifically, highlighting the fact that of the 19 apps analyzed, only 1 had functionality to allow both the calculation of a validated composite disease activity measure and the ability to track calculated patient data [51]. Another recent work showed that most of the apps designed for patients living with RA did not offer a comprehensive experience. Comparably with what we found in the literature, not all apps (75%) offered a symptom tracking experience, and when it was the case, only a few apps allowed collecting PROs, joint counts, and laboratory results [49].

Thinking forward, a development process under specific guidelines or recommendations is mandatory to improve physicians’ as well as patients’ confidence in future apps.
Having a meticulous development process in place can enhance appropriateness for the specific purpose they have been designed for, their scientific content and accuracy. By regulating the development process, the health care providers will also validate reliability of the scientific content and regulatory rules to ensure data protection and patient safety.

Conclusions

In conclusion, despite patient willingness to use mHealth apps for self-management of their RMDs, better endeavors are needed to provide an optimal standard and ensure the quality and safety of new apps. This work will be used to further inform European League Against Rheumatism (EULAR) points to consider for development, evaluation, and implementation of mHealth apps for self-management of RMDs by patients. We hope through this work to stimulate some careful considerations around mHealth app development and evaluation, which will lead to a general effort to improve their value.

Acknowledgments

The authors would like to thank their task force members: Loreto Carmona, Gerd Burmester, Axel Finckh, Annamaria Iagnocco, Rik Lories, Francisca Sivera, Maxime Dougados, Zoltan Szekanecz, Marie Kostine, John Pauling, Christophe Richez, Sofia Ramiro, Dieter Wieck, Petra Balážová, Simon Stones, Valentin Ritschl, and Yeliz Prior. EULAR funded this project (project number CLI102).

Conflicts of Interest

None declared.

Multimedia Appendix 1

Search strategy for the hierarchical systematic literature review on mHealth Apps for disease self-management in patients with rheumatic and musculoskeletal diseases. [PDF File (Adobe PDF File), 81 KB - Multimedia Appendix 1]

Multimedia Appendix 2

Venn Diagram demonstrating an example of article retrieval numbers using the largest database (Pubmed). N=435 represents the overlapping papers across three key domains searched. [PDF File (Adobe PDF File), 29 KB - Multimedia Appendix 2]

Multimedia Appendix 3

Summary table of all 32 articles included in the review and type and purposes of studies included. [PDF File (Adobe PDF File), 103 KB - Multimedia Appendix 3]

References

1. C. Cisco - Global. 2014. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2017–2022 White Paper URL: http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.html [accessed 2019-09-10]
2. Matthews J, Win KT, Oinas-Kukkonen H, Freeman M. Persuasive technology in mobile applications promoting physical activity: a systematic review. J Med Syst 2016 Mar;40(3):72. [doi: 10.1007/s10916-015-0425-x] [Medline: 26748792]
3. Whitehead L, Seaton P. The effectiveness of self-management mobile phone and tablet apps in long-term condition management: a systematic review. J Med Internet Res 2016 May 16;18(5):e97 [FREE Full text] [doi: 10.2196/jmir.4883] [Medline: 27185295]
4. Hartz J, Yingling L, Powell-Wiley TM. Use of mobile health technology in the prevention and management of diabetes mellitus. Curr Cardiol Rep 2016 Dec;18(12):130. [doi: 10.1007/s11886-016-0796-8] [Medline: 27826901]
5. Bashshur R, Shannon G, Krupinski E, Grigsby J. The taxonomy of telemedicine. Telemed J E Health 2011;17(6):484–494. [doi: 10.1089/tmj.2011.0103] [Medline: 21718114]
6. Alessa T, Abdi S, Hawley MS, de Witte L. Mobile apps to support the self-management of hypertension: systematic review of effectiveness, usability, and user satisfaction. JMIR Mhealth Uhealth 2018 Jul 23;6(7):e10723 [FREE Full text] [doi: 10.2196/10723] [Medline: 30037787]
7. Farzandipour M, Nabovati E, Sharif R, Arani MH, Anvari S. Patient self-management of asthma using mobile health applications: a systematic review of the functionalities and effects. Appl Clin Inform 2017 Oct;8(4):1068-1081 [FREE Full text] [doi: 10.4338/ACI-2017-07-R-0116] [Medline: 29241254]
8. Oh B, Yi GH, Han MK, Kim JS, Lee CH, Cho B, et al. Importance of active participation in obesity management through mobile health care programs: study of a randomized controlled trial. JMIR Mhealth Uhealth 2018 Jan 3;6(1):e2 [FREE Full text] [doi: 10.2196/mhealth.8719] [Medline: 29298749]
9. Niendam TA, Tully LM, Iosif AM, Kumar D, Nye KE, Denton JC, et al. Enhancing early psychosis treatment using smartphone technology: a longitudinal feasibility and validity study. J Psychiatr Res 2018 Jan;96:239-246. [doi: 10.1016/j.psychres.2017.10.017] [Medline: 29126059]

10. Gray CS, Gill A, Khan AI, Hans PK, Kuluski K, Cott C. The electronic patient reported outcome tool: testing usability and feasibility of a mobile app and portal to support care for patients with complex chronic disease and disability in primary care settings. JMIR Mhealth Uhealth 2016 Jun 2;4(2):e58 [FREE Full text] [doi: 10.2196/mhealth.5331] [Medline: 27256035]

11. Palazzo C, Ravaud JP, Papelard A, Ravaud P, Poiraudere S. The burden of musculoskeletal conditions. PLoS One 2014;9(3):e90633 [FREE Full text] [doi: 10.1371/journal.pone.0090633] [Medline: 24595187]

12. Dixon WG, Michaud K. Using technology to support clinical care and research in rheumatoid arthritis. Curr Opin Rheumatol 2018 May;30(3):276-281 [FREE Full text] [doi: 10.1097/BOR.0000000000000485] [Medline: 29369089]

13. Azevedo R, Bernardes M, Fonseca J, Lima A. Smartphone application for rheumatoid arthritis self-management: cross-sectional study revealed the usefulness, willingness to use and patients' needs. Rheumatol Int 2015 Oct;35(10):1675-1685. [doi: 10.1007/s00296-015-3270-9] [Medline: 25903352]

14. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009 Jul 21;6(7):e1000097 [FREE Full text] [doi: 10.1371/journal.pmed.1000097] [Medline: 19621072]

15. Richardson WS, Wilson MC, Nishikawa J, Hayward RS. The well-built clinical question: a key to evidence-based decisions. ACP J Club 1995;123(3):A12-A13. [doi: 10.7326/ACPIC-1995-123-3-A12] [Medline: 7582737]

16. Li LC, Sayre EC, Xie H, Clayton C, Feehan LM. A community-based physical activity counselling program for people with knee osteoarthritis: feasibility and preliminary efficacy of the Track-OA study. JMIR Mhealth Uhealth 2017 Jun 26;5(6):e86 [FREE Full text] [doi: 10.2196/mhealth.7863] [Medline: 28652228]

17. Skrepnik N, Spitzer A, Altman R, Hoekstra J, Toselli R. Assessing the impact of a novel smartphone application compared with standard follow-up on mobility of patients with knee osteoarthritis following treatment with Hylan G-F 20: a randomized controlled trial. JMIR Mhealth Uhealth 2017 May 9;5(5):e64 [FREE Full text] [doi: 10.2196/mhealth.7179] [Medline: 28487266]

18. Kristjánsson Ó, Fors EA, Eide E, Finset A, Stensrud TL, van Dulmen S, et al. A smartphone-based intervention with diaries and therapist feedback to reduce catastrophizing and increase functioning in women with chronic widespread pain. Part 2: 11-month follow-up results of a randomized trial. J Med Internet Res 2013 Mar 28;15(3):e72 [FREE Full text] [doi: 10.2196/jmir.2442] [Medline: 23538392]

19. Kristjánsson ÓB, Fors EA, Eide E, Finset A, Stensrud TL, van Dulmen S, et al. A smartphone-based intervention with diaries and therapist-feedback to reduce catastrophizing and increase functioning in women with chronic widespread pain: randomized controlled trial. J Med Internet Res 2013 Jan 7;15(1):e5 [FREE Full text] [doi: 10.2196/jmir.2249] [Medline: 23291270]

20. Paxton RJ, Forster JE, Miller MJ, Gerron KL, Stevens-Lapsley JE, Christiansen CL. A feasibility study for improved physical activity after total knee arthroplasty. J Aging Phys Act 2018 Jan;26(1):7-13 [FREE Full text] [doi: 10.1123/japa.2016-0268] [Medline: 28338406]

21. Harmelink KE, Zeegers AV, T van der Sanden MW, Staal JB. The effectiveness of the use of a digital activity coaching system in addition to a two-week home-based exercise program in patients after total knee arthroplasty: study protocol for a randomized controlled trial. BMC Musculoskelet Disord 2017 Jul 5;18(1):290 [FREE Full text] [doi: 10.1186/s12891-017-1647-5] [Medline: 28679400]

22. Bults RG, Knoppel DF, Widya IA, Schaake L, Hermens HJ. The myofeedback-based teletreatment system and its evaluation. J Telemed Telecare 2010;16(6):308-315. [doi: 10.1258/jtt.2010.006004] [Medline: 20798424]

23. Kvien TK, Mowinckel P, Heiberg T, Dammann KL, Dale Ø, Annerud GJ, et al. Performance of health status measures with a pen based personal digital assistant. Ann Rheum Dis 2005 Oct;64(10):1480-1484 [FREE Full text] [doi: 10.1136/ard.2004.034347] [Medline: 15843456]

24. Heiberg T, Kvien TK, Dale Ø, Mowinckel P, Annerud GJ, Songe-Møller AB, et al. Daily health status registration (patient diary) in patients with rheumatoid arthritis: a comparison between personal digital assistant and paper-pencil format. Arthritis Rheum 2007 Apr 15;57(3):454-460 [FREE Full text] [doi: 10.1002/art.22613] [Medline: 17394232]

25. Richter JG, Becker A, Koch T, Nixdorf R, Willers M, Monsen R, et al. Self-assessments of patients via Tablet PC in routine patient care: comparison with standardised paper questionnaires. Ann Rheum Dis 2008 Dec;67(12):1739-1741. [doi: 10.1136/ard.2008.090209] [Medline: 18647853]

26. Stinson NJ, Petroz GC, Stevens BJ, Feldman BM, Streiner D, McGrath PJ, et al. Working out the kinks: testing the feasibility of an electronic pain diary for adolescents with arthritis. Pain Res Manag 2008;13(5):375-382 [FREE Full text] [doi: 10.1155/2008/326389] [Medline: 18958308]

27. Stinson NJ, Petroz GC, Tait G, Feldman D, Streiner D, McGrath PJ, et al. e-Ouch: usability testing of an electronic chronic pain diary for adolescents with arthritis. Clin J Pain 2006;22(3):295-305. [doi: 10.1097/01.ajp.0000173371.54579.31] [Medline: 16514331]
28. Garcia-Palacios A, Herrero R, Belmonte MA, Castilla D, Guixerues J, Molinari G, et al. Ecological momentary assessment for chronic pain in fibromyalgia using a smartphone: a randomized crossover study. Eur J Pain 2014 Jul;18(6):862-872. [doi: 10.1002/ep.22149] [Medline: 24921074]

29. Nishiguchi S, Ito H, Yamada M, Yoshitomi H, Furu M, Ito T, et al. Self-assessment of rheumatoid arthritis disease activity using a smartphone application. Development and 3-month feasibility study. Methods Inf Med 2016;55(1):65-69. [doi: 10.3414/ME14-01-0106] [Medline: 26391694]

30. de la Vega R, Roset R, Galán S, Miró J. Fibroline: a mobile app for improving the quality of life of young people with fibromyalgia. J Health Psychol 2018 Jan;23(1):67-78. [doi: 10.1177/1359105316650509] [Medline: 277225285]

31. Salaffi F, Gasparini S, Ciapetti A, Gutierrez M, Grassi W. Usability of an innovative and interactive electronic system for collection of patient-reported data in axial spondyloarthritis: comparison with the traditional paper-administered format. Rheumatology (Oxford) 2013 Nov;52(11):2062-2070. [doi: 10.1093/rheumatology/ket276] [Medline: 23955646]

32. Garcia-Palacios A, Herrero R, Belmonte MA, Castilla D, Guixeras J, Molinari G, et al. Ecological momentary assessment for rheumatoid arthritis patients and providers. Appl Clin Inform 2016 Nov 2;7(4):1007-1024 [FREE Full text] [doi: 10.4338/ACI-2016-03-RA-0036] [Medline: 27803949]

33. Khurana L, Durand EM, Gary ST, Otero AV, Gerzon MC, Beck J, et al. Subjects with osteoarthritis can easily use a handheld touch screen electronic device to report medication use: qualitative results from a usability study. Patient Prefer Adherence 2016;10:2171-2179 [FREE Full text] [doi: 10.2147/PPA.S94247] [Medline: 27822018]

34. Kim CH, Chung CK, Choi Y, Shin H, Woo JW, Kim S, et al. The usefulness of a mobile device-based system for patients’ self-assessment of disease activity via WebApp. Rheumatology (Oxford) 2017 Oct 1;56(10):1707-1712 [FREE Full text] [doi: 10.1109/EMBC.2013.6611235]

35. Cai RA, Beste D, Chaplin H, Varakliotis S, Sufﬁeld L, Josephs F, et al. Developing and evaluating JIApp: acceptability and usability of a smartphone app to improve self-management in young people with juvenile idiopathic arthritis. JMIR Mhealth Uhealth 2017 Aug 15;5(8):e121 [FREE Full text] [doi: 10.2196/mhealth.7229] [Medline: 28811270]

36. Revenäs Å, Opava CH, Martin C, Demmelmaier I, Keller C, Asenlöf P. Development of a web-based and mobile app to support physical activity in individuals with rheumatoid arthritis: results from the second step of a co-design process. JMIR Res Protoc 2015 Feb 9;4(1):e22 [FREE Full text] [doi: 10.2196/resprot.3795] [Medline: 25665589]

37. Synnott J, Pedlow K, Bleakley C, Davies R, Nugent C, Moral-Munoz J, et al. ReApp – A Mobile App for the Rehabilitation of Ankle Sprains. In: Proceedings of the Conference on Ambient Intelligence for Health. 2015 Presented at: AmIHEALTH’15; December 1-4, 2015; Puerto Varas, Chile p. 61-67. [doi: 10.1007/978-3-319-26508-7_6]

38. Bromberg MH, Connelly M, Anthony KK, Gil KM, Schanberg LE. Prospective mediation models of sleep, pain, and daily function in children with arthritis using ecological momentary assessment. Clin J Pain 2016 Jun;32(6):471-477 [FREE Full text] [doi: 10.1097/AJP.0000000000000298] [Medline: 26340651]

39. Bromberg MH, Connelly M, Anthony KK, Gil KM, Schanberg LE. Self-reported pain and disease symptoms persist in juvenile idiopathic arthritis despite treatment advances: an electronic diary study. Rheumatol Immunol 2014 Feb;66(2):462-469 [FREE Full text] [doi: 10.1002/art.38223] [Medline: 24504820]

40. Okifuji A, Bradshaw DH, Donaldson GW, Turk DC. Sequential analyses of daily symptoms in women with fibromyalgia syndrome. J Pain 2011 Jan;12(1):84-93 [FREE Full text] [doi: 10.1016/j.jpainsym.2010.05.003] [Medline: 20591745]

41. Nishiguchi S, Ito H, Yamada M, Yoshitomi H, Furu M, Ito T, et al. Self-assessment tool of disease activity of rheumatoid arthritis by using a smartphone application. Telemed J E Health 2014 Mar;20(3):235-240. [doi: 10.1089/tmj.2013.0162] [Medline: 24404820]

42. Shinobara A, Ito T, Ura T, Nishiguchi S, Ito H, Yamada M, et al. Development of Lifelog Sharing System for Rheumatoid Arthritis Patients Using Smartphone. In: Proceedings of the 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. 2013 Presented at: EMBC’13; July 3-7, 2013; Osaka, Japan p. 7266-7269. [doi: 10.1109/EMBC.2013.6611235]

43. Walker UA, Mueller RB, Jaeger VK, Theiler R, Forster A, Dufner P, et al. Disease activity dynamics in rheumatoid arthritis: patients’ self-assessment of disease activity via WebApp. Rheumatology (Oxford) 2017 Oct 1;56(10):1707-1712 [FREE Full text] [doi: 10.1093/rheumatology/kex229] [Medline: 28957553]

44. Yamada M, Aoyama T, Mori S, Nishiguchi S, Okamoto K, Ito T, et al. Objective assessment of abnormal gait in patients with rheumatoid arthritis using a smartphone application. Rheumatol Int 2012 Dec;32(12):3869-3874. [doi: 10.1007/s00296-011-2283-2] [Medline: 22193221]

45. Espinoza F, le Blay P, Coulon D, Lieu S, Munro J, Jorgensen C, et al. Handgrip strength measured by a dynamometer connected to a smartphone: a new applied health technology solution for the self-assessment of rheumatoid arthritis disease activity. Rheumatology (Oxford) 2016 May;55(5):897-901. [doi: 10.1093/rheumatology/kew006] [Medline: 26867731]

46. Kim K, Pham D, Schwarzkopf R. Mobile application use in monitoring patient adherence to perioperative total knee arthroplasty protocols. Surg Technol Int 2016 Apr;28:253-260. [doi: 27042789]

47. Twigg J, Salmon L, Kolos E, Bogue E, Miles B, Roe J. Measurement of physical activity in the pre- and early post-operative period after total knee arthroplasty for osteoarthritis using a Fitbit Flex device. Med Eng Phys 2018 Jan;51:31-40. [doi: 10.1016/j.medengphy.2017.10.007] [Medline: 29117912]
48. Stoyanov SR, Hides L, Kavanagh DJ, Zelenko O, Tjondronegoro D, Mani M. Mobile app rating scale: a new tool for assessing the quality of health mobile apps. JMIR Mhealth Uhealth 2015 Mar 11;3(1):e27 [FREE Full text] [doi: 10.2196/mhealth.3422] [Medline: 25760773]

49. Luo D, Wang P, Lu F, Elias J, Sparks JA, Lee YC. Mobile apps for individuals with rheumatoid arthritis: a systematic review. J Clin Rheumatol 2019 Apr;25(3):133-141. [doi: 10.1097/RHU.0000000000000800] [Medline: 29933327]

50. Buijink AW, Visser BJ, Marshall L. Medical apps for smartphones: lack of evidence undermines quality and safety. Evid Based Med 2013 Jun;18(3):90-92. [doi: 10.1136/eb-2012-100885] [Medline: 22923708]

51. Grainger R, Townsley H, White B, Langlotz T, Taylor WJ. Apps for people with rheumatoid arthritis to monitor their disease activity: a review of apps for best practice and quality. JMIR Mhealth Uhealth 2017 Feb 21;5(2):e7 [FREE Full text] [doi: 10.2196/mhealth.6956] [Medline: 28223263]

Abbreviations

AS: ankylosing spondylitis
EULAR: European League Against Rheumatism
MARS: Mobile Application Rating Scale
mHealth: mobile health
OA: osteoarthritis
PICO: population, intervention, control, and outcomes
PROs: patient-reported outcomes
RA: rheumatoid arthritis
RCT: randomized controlled trial
RMDs: rheumatic and musculoskeletal diseases
SLR: systematic literature review

©Aurélie Najm, Laura Gossec, Catherine Weill, David Benoist, Francis Berenbaum, Elena Nikiphorou. Originally published in JMIR mHealth and uHealth (http://mhealth.jmir.org), 26.11.2019. This is an open-access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR mhealth and uhealth, is properly cited. The complete bibliographic information, a link to the original publication on http://mhealth.jmir.org/, as well as this copyright and license information must be included.