Mobile Applications for Self-management of Chronic Diseases: A Systematic Review

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Abstract: Objectives: Since apps have been gaining popularity, they are also used to support the treatment of chronic diseases. However, the effectiveness of these measures has not been fully confirmed. This review deals with features that make these apps effective. Methods: In this structured literature survey, relevant studies from the year 2014 to 2019 were identified. Inclusion criteria were that the study included an app that was used to alleviate symptoms of chronic diseases or was intended to support the preventive treatment of patients. Results: Ten studies were examined in detail, of which seven found significant effects. Factors, which increase the effectiveness of mHealth apps include easy integration into everyday life, appropriate training of users, tailoring the app to the target group, focusing on improving the relationship between user and disease, and user-specific treatment of symptoms. Tracking of symptoms, education, and a chat can also increase effectiveness. Conclusions: Most of the papers reviewed showed a positive impact of mobile apps on chronic disease progression. However, a negative factor was also identified, in which patients became more involved with their illnesses as a result of the intervention, which increased the perceived severity of the illness and thus reduced the quality of life.

1 INTRODUCTION

Chronic diseases, such as type 2 diabetes (Chatterjee et al., 2017) or autoimmune thyroiditis (Antonelli et al., 2015), are a major challenge to our modern society. For example, the percentage of people affected with diabetes worldwide has almost doubled since 1980 from 4.7% to 8.5% in 2014 (Roglic, 2016). Cardiovascular diseases are also widespread, accounting for 31% of all deaths worldwide (Finger et al., 2016). In response to these new challenges to the health care system, innovative and cost-effective measures are essential. One possibility are mobile interventions via mobile apps. In the mHealth sector there are already many measures in place to improve care and save costs in the health care system (Williams, 2012). However, the effectiveness of mHealth apps as an intervention for chronic diseases is currently controversial. Therefore, this systematic review aims to investigate whether apps as a measure for therapy support have a positive (or negative) influence on the course of chronic diseases. In addition, it will be investigated which characteristics distinguish apps that have been shown to have a positive influence on the course of the disease from others, in order to identify possible positive factors influencing these apps.

2 METHODS

Studies were analyzed with regard to the participants, the intervention, length, study design, functionality of the app used, and the results produced. This was done with the aim of evaluating the influence of mHealth interventions and, where appropriate, to record general positive factors influencing the course of a disease.

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2.1 Search Strategy

A search was conducted using the ORBISplus meta-search engine[1] of the University of Oldenburg. The number of results of the following sources are written in braces after the respective source. Duplicates were automatically eliminated by the meta search engine and results from the following databases were included: Medline (194), Pubmed Central (111), Gale Academic OneFile (108), Health Reference Center-Academic of Gale (91), Directory of Open Access Journals (47), Springer Cross-Ref (40), Springer Link (34), SAGE Publications CrossRef (22), SAGE Publications (21), Oxford Academic (17), Oxford University Press CrossRef (16), Public Library of Science Cross-Ref (12), Elsevier CrossRef (12), Springer Link Open Access (7), BMJ Journals (4), Digital Commons by bpress (2), Association for Computing Machinery CrossRef (2), Mary Ann Liebert CrossRef (2), Wolters Kluwer Olvid CrossRef (2), and American Chemical Society CrossRef (1). Only scientific articles written in English and published between 2014 and 2019 were accepted. The search term used was: ”chronic disease” AND ”self-management” AND ”app” AND ”smartphone” AND (”mHealth” OR ”mobile health”).

2.2 Selection of Studies

The following inclusion criteria were used to select the studies: the study included an app; the app was used to alleviate symptoms or for the preventive treatment of a chronic disease; the effect of the app was tested in human trials involving patients. Studies were excluded: review articles; additional use of devices developed for the study; were not completed at the time of the search; there were several applications in the study, e.g. doctors also have an app as well as patients.

2.3 Data Extraction

The meta-data of the selected articles were entered into a spreadsheet, divided into the following items: Author, year, purpose of the study, nature of the sample of participating subjects, type of disease, measurements performed, results of the study, length of the intervention, name of the app, nature of the intervention, and training of the subjects to use the app.

[1]See https://plus.orbis-oldenburg.de/

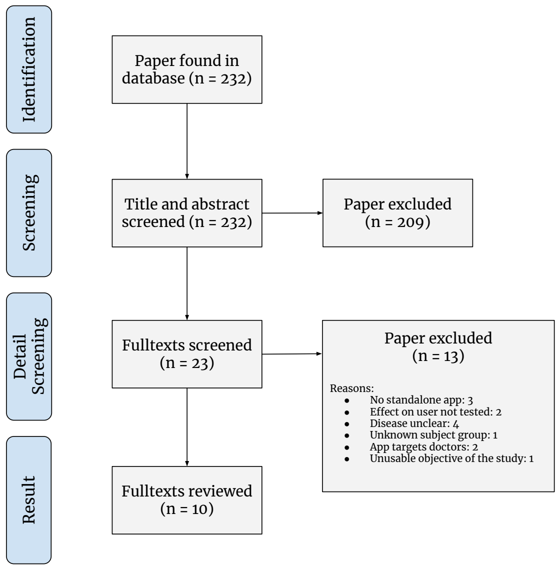

Figure 1: Article selection in style of PRISMA (Moher et al., 2009).

3 RESULTS

The flow chart in Figure 1 shows the selection process for the studies to be included. Out of 232 results of the search, ten studies met the underlying criteria. The studies found are concerned with various chronic diseases. The included apps addressed diabetes type 2, various cardiovascular diseases, obstructive sleep apnea, asymptomatic osteoporosis, gout and HIV. Of the ten selected trials, six were randomized controlled trials, while four trials lacked a control group. Seven of the ten studies could demonstrate significant effects related to the app, but there was only one study that found an improvement in the symptoms of a chronic disease due to the app used. Three studies could not show significant effects, e.g. caused by collecting mostly qualitative data via semi-structured interviews. In another, the focus of the research was not on demonstrating significant effects. Tables 1 provide an overview of the evaluated studies and Tables 2 provide a detailed insight into the respective intervention of each study.

3.1 Studies with Significant Effects

The following studies were able to demonstrate a number of different significant effects. These included improved self-management, symptom relief, better understanding of disease, changes in eating habits, greater adherence to medical interventions and more frequent visits to the doctor. The following results are all significant with $p < 0.05$. In a Norwegian study, Holmen et al. (Holmen et al., 2014) have shown that mHealth intervention can improve self-management and understanding of the disease in people with diabetes. In a New Zealand study, Eyles et al. (Eyles et al., 2017) showed that an app could significantly reduce the salt consumption of people with cardiovascular disease. Serlachius et al. (Serlachius et al., 2019) have shown in another New Zealand study that an app can increase the understanding of gout disease in people with gout, but participants perceived their disease and symptoms more negatively after the intervention, and in general their attitude to gout became more negative. In a study on mobile interventions from the USA, Schnall et al. (Schnall et al., 2018) were able to demonstrate a clear improvement in five of 13 symptoms of AIDS. In Singapore, a study by Hui Zhang et al. (Zhang et al., 2017) investigated the possibility of clarifying cardiovascular diseases using an app. It was found that the study participants had a better understanding of coronary heart disease and its consequences after the intervention. In addition, participants controlled their cholesterol levels more frequently as a result of the study. In Spain, Isetta et al. (Isetta et al., 2017) showed that an app was able to improve the adherence of patients with obstructive sleep apnea to CPAP ventilation. In the USA, Dillingham el al. (Dillingham et al., 2018) showed that the consistency of patient visits to the doctor during the phase of mHealth intervention has increased, but this was not related to the frequency of use of the app.

3.2 Studies without Significant Effects

In the following three studies no significant results could be shown for various reasons, but it is important to note that two of the three studies were more qualitative research and therefore no significant results can be deduced from them. In a Canadian study by Agarwal et al. (Agarwal et al., 2019) on the improvement of symptoms of diabetes, for example, no positive effects could be proven, according to the authors this could be due to the fact that the app was handed out to participants on an additional smartphone, with all other features of the smartphone disabled, which increases the inhibition for using the app. In a Danish study by Ravn Jakobsen et al. (Ravn Jakobsen et al., 2018) the qualitative approach was the reason why there was no significant result. Semi-structured interviews were conducted to collect information, which hardly allow a statistical evaluation, but provide information on possible positive influencing factors. Furthermore, the participants were very satisfied with the intervention, which indicates the quality of the intervention and the app. The US study by Brewer et al. (Brewer et al., 2019), which mainly dealt with the development cycle of mHealth interventions, was similarly qualitative. The influence of the developed app was tested with a survey of participant satisfaction, which was very high.

3.3 Summary of Interventions

The various interventions were characterized by the fact that they were all built around specific apps, which held similar features. Common features included reminders for doctor visits and tracking of symptoms, physical activity, mental health, personal goals or eating habits. To use the tracked information, users were often sent a therapy recommendation to reduce their symptoms or motivating messages from the app. In addition, information about the disease to be treated was often included in the apps to educate the users in order to give the participants a broader knowledge of the respective disease. In order to consolidate the knowledge acquired, playful approaches were implemented in some cases, for example in the form of various quizzes in the case of Dillingham et al (Dillingham et al., 2018). Frequently, a link to support was also directly integrated into the app to help participants with problems. The feature of connecting all users of the app via a chat to exchange information and increase motivation also appeared; this feature was rated very positively by the users. In the study by Ravn Jakobsen et al (Ravn Jakobsen et al., 2018), users were also able to view the results of their bone scans. In the study by Eyles et al. (Eyles et al., 2017), by scanning barcodes on food, users were able to determine the salt content of the food and view a purchase recommendation for the product. Apart from the apps, interventions occasionally included counseling services or reminders by text messages. The length of the interventions varied between two weeks and one year with an average length of 13.4 weeks. In six of the studies, participants received help in using the app, for example by technical support answering questions, download assistance or training by phone. A tendency can be seen that studies which did not have a support offer sometimes lost more users. This could be due to the fact that the average study participant may lack sufficient technical understanding to use the app.

4 DISCUSSION

The results of the evaluated studies have shown that mHealth interventions often lead to significant effects on the participants. These can improve the patient's situation, as found by Schnall et al (Schnall et al., 2018), or have a positive effect on other factors, such as self-management. On the other hand, there are studies that found no or only few positive developments in the participants. In the following, we discuss which factors may have had a positive influence on participants in the studies and, accordingly, may have led to a reduction in possible positive effects of the mHealth interventions. Afterwards, factors are examined that could have had a positive effect on different mHealth interventions.

4.1 Positive Factors for Intervention

As various studies have shown positive effects, features can be identified in these studies which may have had a positive effect on the progression of the disease or other areas. The fact that the study by Schnall et al. (Schnall et al., 2018) showed significant improvements in five out of 13 symptoms of AIDS may be due to the fact that the app always suggested a measure appropriate to the symptoms of the participants. This specific procedure for each individual patient can be a reason for the success of the mHealth intervention. In the study by Ravn Jakobsen et al. (Ravn Jakobsen et al., 2018), participants were able to view the results of their bone scans without having to travel to the hospital, which was considered very useful by the participants. It can be concluded from this that advantages that are exclusively attributable to the app can lead to an increase in use. General education, possibly in the context of measures to increase knowledge, can also improve understanding of a disease and thus provide a basis for further action, as shown by Zhang et al (Zhang et al., 2017). Tracking of symptoms can also have a positive influence on patients, as the study by Holmen et al. (Holmen et al., 2014) has shown a significantly better self-management among participants who used an app for the exclusive tracking of symptoms. In this context, improved self-management can again be seen as the basis for further measures to improve symptoms. In the study by Brewer et al. (Brewer et al., 2019), users reported a very high level of satisfaction with the app, averaging nine out of ten points. In this study, this can be attributed to the fact that the users were strongly involved in the development process of the app, and that there was an opportunity to exchange ideas with other participants in the app, which was also considered very useful, since one saw oneself as part of a community. From this it can be concluded that when developing an app in the field of mHealth, one should always make sure that it fits the chosen target group. In addition, contact with other affected people seems to be helpful, as this creates a sense of community among those affected, which can lead to higher motivation to improve one's lifestyle.

4.2 Negative Factors for Intervention

Various factors may have negative influence on the course of the chronic disease or on the success of the app. Among Agarwal et al. (Agarwal et al., 2019), one important factor was that an additional smartphone was distributed to participants that had all other features disabled. This additional barrier to use may have meant that no significant results were found in the study. Thus, an app should be as easy as possible to integrate into the daily life of the patients in order to maximize the usage. Another factor is help in adapting the technology. In the studies examined, the trend is evident that a lack of technical support has reduced the use of the app, since for some participants the general handling of apps is a hurdle. Some participants in the study by Ravn Jakobsen et al. (Ravn Jakobsen et al., 2018) had problems downloading the app. Therefore, the difficulty of using an app should always match the technical understanding of its users or training should be provided for users in order to attract as many users as possible to the app. It is also important to note that in the study by Serlachius et al. (Serlachius et al., 2019) the participants' understanding of the disease improved, but on the other hand the participants perceived their disease more negatively and interpreted their symptoms as more serious. Here it is positive that participants were able to develop a better understanding of their disease, but the app fails to have the desired effect if it leads to a higher psychological impact. The result is that it leads to a greater burden on the users instead of helping them. Therefore, in an app more emphasis should be placed on improving the relationship between the patient and the disease, instead of just treating the patient in relation to the to her or his illness.

5 CONCLUSION

It has been shown that mHealth interventions via smartphone apps often have a positive influence on test persons. These consist less often in an improvement of the symptoms, but more often in an improvement of the understanding of the disease or improvement of the self-management of the test persons. In addition, mHealth interventions and the apps used should meet certain criteria to increase their effectiveness. For example, the app should be easily integrated into the users' everyday life and the difficulty of its use should be adapted to the users or sufficient training should be provided. Also, the app should focus on improving the relationship between user and disease, rather than focusing solely on the disease. The feedback of an app should be specifically tailored to the symptoms of each individual user. In addition, general information about an illness and tracking of symptoms and behavior are helpful. Exclusive features, such as the quick provision of bone scans, can be a further incentive to use. By involving potential users in the development, features can be adapted to target groups, thus increasing trust in the app. A chat, which connects all users of the app with each other, can additionally increase the motivation and frequency of using an app, as it promotes a sense of community between the users. These possible positive influencing factors need further research, but they offer a fundamental guideline for the development of future mHealth apps.

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Table 1: Overview of the evaluated studies.

#	Year, Authors	Study purpose (Disease)	Characteristics of the sample	Length	App name
1	2014, Holmen et al. (Holmen et al., 2014)	Evaluate the usefulness of an app for logging symptoms and medical advice in terms of improving symptoms of type 2 diabetes. (Type 2 diabetes)	General: ($n = 151$); randomized with control group; inclusion if age ≥ 18 years; understand Norwegian; able to use systems to improve self-management; HbA1c level $> 7.0\%$;	1 year	Few Touch Application
2	2019, Agarwal et al. (Agarwal et al., 2019)	Evaluate whether the BlueStar app leads to improved HbA1c levels and improves patient self-management. (Type 2 diabetes)	General: ($n = 110$); randomized with control group; recruited from three Ontario diabetes education programs; inclusion if HbA1c $\geq 8.0\%$ in the past three months; Age ≥ 18 years; patients were part of a diabetes education program; participants have an E-Mail address; able to understand and write English; exclusion if diagnosed with type 1 diabetes; continuous monitoring of blood glucose levels; possession of an insulin pump; unable to use a computer;	6 months	BlueStar
3	2018, Schnall et al. (Schnall et al., 2018)	Evaluating the usefulness of the app mVIP in alleviating HIV-related symptoms. (AIDS)	General: ($n = 80$); randomized with control group; inclusion if age ≥ 18 years; English-speaking; diagnosed with HIV; onset of at least two HIV-related symptoms in the past week; Mini-Mental State Examination (MMSE) completed with at least 24 points; in possession of a smartphone or tablet;	12 weeks	mVIP
4	2017, Zhang et al. (Zhang et al., 2017)	Evaluate the effectiveness of an app in improving awareness and knowledge of coronary artery disease, as well as reducing stress and improving heart-related lifestyles. (Coronary heart disease)	General: ($n = 80$); randomized with control group; inclusion if age ≥ 21 years and age ≤ 65; in possession of a smartphone; English-speaking; working full-time; exclusion if diagnosed with heart disease; working in the medical sector; participating in other program related to heart disease;	4 weeks	Care4Heart
5	2015, Isetta et al. (Isetta et al., 2017)	Evaluate the effectiveness of the APPnea app in getting patients to improve adherence to continuous positive airway pressure (CPAP) use. (Obstructive sleep apnea)	General: ($n = 60$);	6 weeks	APPnea
6	2018, Ravn Jakobsen et al. (Ravn Jakobsen et al., 2018)	Evaluate the effectiveness of the My Osteoporosis Journey app in improving patients' self-management, as well as their ability to make decisions in their therapy. (Asymptomatic osteoporosis)	General: ($n = 18$); inclusion if in possession of a smartphone, Tablet or computer; Danish-speaking; age ≥ 50 years and Age ≤ 65 years; suffering from asymptomatic osteoporosis with a T-score < -2.5 in the hip or lumbar spine; exclusion if previous osteoporosis-related fractures or severe mental illness;	4 weeks	My Osteoporosis Journey
7	2019, Brewer et al. (Brewer et al., 2019)	Development and evaluation of an app for cardiovascular disease prevention in African Americans. (Cardiovascular diseases)	General: ($n = 50$) inclusion if age $>= 18$ years; basic ability to use the Internet; in possession of an Internet connection; active e-mail address; low intake of fruits and vegetables (< 5 intakes/day); ability to engage in physical activity; exclusion if participant in a regular fitness program; pregnant; visually impaired; hearing impaired; mental disorder; participation in the app development process; participation in the program associated with the study;	10 weeks	FAITH!
8	2018, Dillingham et al. (Dillingham et al., 2018)	Improving adherence to therapy among HIV-positive people using an mHealth intervention. (AIDS)	General: ($n = 77$); inclusion if newly diagnosed with HIV; prolonged break since last treatment, or increased risk for treatment discontinuation; possession of basic literacy;	12 months	Not specified
9	2017, Eyles et al. (Eyles et al., 2017)	Evaluating the usefulness of the SaltSwitch app in getting participants to reduce salt intake (Cardiovascular disease (coronary syndrome, revascularization, angina pectoris))	General: ($n = 66$); randomized with control group; inclusion if age $>= 40$ years; diagnosed with cardiovascular disease; ownership of smartphone; exclusion if acute cardiac event in the past 3 months; heart insufficiency; diagnosed with severe heart disease; refusal of medical treatment; regular use of anti-inflammatory agents; regular use of prednisolone;	6 weeks	SaltSwitch
10	2019, Serlachius et al. (Serlachius et al., 2019)	Evaluating the utility of an app in self-care habits, disease awareness, and engagement to reduce symptoms in gout patients. (Gout)	General: ($n = 72$); randomized with control group; inclusion if diagnosed with gout; age ≥ 18 years; understand English; owned a smartphone	2 weeks	Gout Central

Table 2: Intervention and results of the evaluated studies.

#	Intervention	Measurements	Results
1	Three control arms; one arm with app and health counseling; one arm without app but with health counseling and one control group; group with app: Few Touch Application includes the following features: (filling out a diary on diabetes progression; motivational feedback; monitoring eating habits; measuring blood glucose levels; monitoring physical activity; goal setting system); counseling by phone by a trained nurse; group without app but with health counseling: counseling by phone by a trained nurse	Age; gender; marital status; education level; employment; medication; HbA1c level; height; weight; blood pressure; comorbidities; willingness to improve one's health status; eating habits; quality of life as HRQL (health related quality of life); knowledge about diseases as heiQ (Health Education Impact Questionnaire); symptoms of depression using the (The Center for Epidemiologic Studies Depression scale (CES-D))	HbA1c levels decreased in all groups, including the control group; there were no significant group-specific differences in HbA1c levels; the group using the app had significantly better scores in self-management and disease understanding; older participants had higher adherence to the intervention
2	Delivery of BlueStar app on additional smartphone with all other features disabled; BlueStar includes the following features: (tracking health, blood glucose levels, and physical activity; sending motivational messages to the user)	Measurement of HbA1c level; patient's perception of his or her ability to self-manage; amount of patient's use of disease improvement opportunities	No significant differences between control and intervention group in terms of HbA1c value; also no significant differences in secondary outcomes
3	mVIP includes the following features: (logging of HIV-related symptoms; receiving a symptom-based strategy through the app to alleviate symptoms); participants were required to log their symptoms at least on a weekly basis	Medication adherence; incidence of 13 HIV-induced symptoms and their intensity; demographic background using the PROMIS-29 questionnaire	Five of 13 symptoms improved significantly in the intervention group
4	Daily SMS; 20 minute meeting; Care4Heart includes the following features: information material on coronary heart disease; two videos on relaxation techniques; functions for calculating BMI, calorie intake and risk calculation for the probability of developing coronary heart disease	Coronary heart disease questionnaire; Heart Disease Fact Questionnaire-2 (HDFQ-2) to determine patients' knowledge; Perceived Stress Scale-10 (PSS-10) to determine participants' perceived stress; behavioral Risk Factor Surveillance System (BRFSS) questionnaire to measure risk factors in participants; questionnaire on participants' opinion of the study	Significantly improved perception of coronary heart disease as the second leading cause of death in Singapore; significantly increased control of cholesterol; better understanding of coronary heart disease; no improvement in lifestyle or stress perception
5	Daily reminders to answer the obstructive sleep apnea questionnaire; APPnea includes the following features: obstructive sleep apnea treatment questionnaire; weekly BMI query; general health education	Regular obstructive sleep apnea treatment questionnaire; duration of CPAP use; satisfaction with app	Participants who used the app daily were also significantly more likely to use CPAP; participants were satisfied with the app
6	My Osteoporosis Journey includes the following features: (information on asymptomatic osteoporosis; recommendations for action; automatic availability of scans of bones taken in the laboratory; risk assessment for fractures);	Collecting data using semi-structured interviews;	The app provided a sense of confidence and reassurance; the app helped making decisions regarding therapy, as well as improving patient self-management;
7	FAITH! includes the following features: informational materials on cardiovascular diseases; tests to review what has been learned; chat to interact with other users of the app; tracking of physical activity and eating habits; recipes; videos of pastors for motivation, since the study took place in a religious context)	Questionnaire on general information about sociodemographic characteristics, smartphone use, sources of health-related information; level of interest in learning more about health-promoting behaviors and cardiovascular disease; discussion with participants about preferred features; questionnaire on satisfaction with the app	Participants were very satisfied with the app; participants rated the app as helpful in acquiring knowledge and changing lifestyles
8	PositiveLinks app includes the following features: tracking well-being and stress levels; medication adherence; various quizzes; reminders for doctor visits; shared chat for all app users; HIV informational materials; stress management techniques	General sociodemographic characteristics; CD4 cell count; viral load; consistency of physician visits; severity of viral suppression	CD4 cell count increased on average; Viral load decreased; Consistency of physician visits increased significantly; Community support in the app was considered very helpful; Participants who transitioned to continuous therapy were found to have a significantly higher rate of use; In general, no correlation was found between app use and continuous physician visits
9	Users of the app could scan food and check for salt content; weekly reminder to use the app	Measurement of salt content of purchased goods; energy content of goods; fat content of goods; systolic blood pressure; satisfaction with app; cost of goods; sodium in urine	The intervention group significantly decreased their salt intake compared to the control group during the intervention phase; there were no significant differences in secondary outcomes
10	Gout Central includes the following features: educational information about gout and tips for improving symptoms; tracker for uric acid levels and gout attacks; scheduling appointments with your doctor; tracking medication dosages; ability to contact a health care provider with questions	Mobile Application Rating Scale (uMARS, scale: 1 to 5) to assess user self-engagement; user self-assessment of self-care habits; self-assessment of current disease state	Users of the gout treatment app reported a significantly deeper understanding of the importance of the disease and found it more engaging; there was no change in participants' self-care behaviors; Gout Central users' perceptions of the disease became significantly more negative; symptoms were perceived significantly more negatively by Gout Central users, and their emotional attitudes toward the disease also became significantly more negative