Effectiveness of smartphone apps for the self-management of low back pain in adults: a systematic review

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ABSTRACT
Purpose: To explore the effectiveness of smartphone apps for the self-management of low back pain in adults.
Methods: Prospectively registered systematic review of randomised controlled trials (2008–) published in English. Studies investigating smartphone apps for the self-management of low back pain (adults ≥18 years), including ≥1 NICE low back pain and sciatica clinical guideline-recommended component and functioning without health professional input were included. Outcomes were pain, function, quality of life and adherence.
Results: Six studies were included (n = 2100 participants). All comparator groups incorporated some form of management (n = 3 physiotherapy, n = 2 GPs, n = 1 not specified). Three studies reported a significant decrease in pain intensity in the intervention group compared with the control. One study reported no significant difference between groups in pain self-efficacy. One study reported a significant reduction in disability (function) in the intervention group compared with the control. Two studies reported no between-group differences in quality of life. One study reported no correlation between adherence (app use) and change in pain intensity and one study reported that app use mediated the effect of teleconsultations on pain improvements.
Conclusions: Inconclusive evidence exists for the use of smartphone applications for the self-management of low back pain. Further research is needed.

IMPLICATIONS FOR REHABILITATION
- Smartphone apps have the potential to improve outcomes for people with LBP aligned with current self-management guidelines.
- There is a paucity of literature exploring smartphone apps for LBP self-management and current evidence is inconclusive for smartphone app use without supported care.
- Commercially available smartphone apps are not well regulated for content or alignment with evidence-based guidelines and recommendations.
- Further evaluation of commercially available apps is required to guide and instil confidence in consumers and health professionals that consumer-accessible apps may lead to improved outcomes.

Introduction
Low back pain (LBP) is a leading cause of disability worldwide and a global economic health issue [1]. Back pain impacts activity levels and workforce participation, causes psychological distress [2,3], considerable levels of pain and disability [4] and can result in hospitalisation. The economic burden of back pain can be significant [5], with both direct and indirect costs such as community health expenditures, public health programs, aids and appliances, health administration, capital expenditures, productivity loss due to absenteeism, loss of superannuation and taxation revenue, carers and welfare [6]. There is a clear need for proactive management responses and intervention programs to meet the financial and human costs of LBP.

Current LBP guidelines recommend self-management, active rehabilitation and exercise [7,8]. Numerous studies have investigated interventions for people with LBP, many incorporating principles of self-management, active rehabilitation and exercise [9–13]. Self-management requires a person to actively participate in their treatment and be responsible for the daily medical, behavioural and emotional tasks required for the management of their condition [14]. To effectively self-manage, it is essential for a person to follow a treatment plan, such as taking medication as recommended and monitor the symptoms of their condition as well as carrying out health-promoting activities, such as maintaining activity levels, and managing the impact of the condition on their well-being and personal relationships [15]. Interventions aimed at self-management must address each of these domains (medical, behavioural and emotional) in the management of a condition [14], which can often be costly, time-consuming and difficult to administer [16]. Additionally, internal and external factors, including personal and environmental
characteristics, health status, available resources, and access to the health care system, can be barriers or enablers and affect an individual’s capacity to self-manage and adhere to self-management programs long-term [16,17].

Smartphone应用程序(“apps”)是易于访问和便携的治疗模式，具有潜在的鼓励物理活动能力并促进自我管理能力的特性。智能手机已由大多数地区的开发中国家使用，这种使用正在迅速增加，随着智能手机用户预期在2021年达到38亿[18]。智能手机提供了一个容易访问的移动健康平台，可以作为促进参与健康管理和教育的工具，以增强管理所需的技能。

Methods

A systematic review protocol was prospectively registered in PROSPERO (CRD42020184486). The review was conducted and reported according to PRISMA guidelines [26].

Identification and selection of studies

Literature search

In June 2021, a systematic literature search of nine electronic databases (Medline, The Cochrane Library, Scopus, CINAHL, Pedro, LILACS, Web of Science, ProQuest and IEEEXplore) was undertaken. The search strategy was peer-reviewed by an academic librarian, and wherever possible, using a combination of keywords and subject headings for back pain and smartphone apps. The original search strategy was registered in PROSPERO, but following peer review, an additional five databases were added. An example of the search strategy (Medline) is presented in Supplementary Material Table 1. No limits were applied at this stage.

Study selection

Two independent reviewers (CD and BL) screened all citations for relevance by title and abstract. Pre-specified eligibility criteria were applied and full-text analysis for eligibility was performed by two independent reviewers (CD and BL). The full text was obtained for citations with no abstract, or where ambiguity existed. Disagreements were resolved by consensus with a third member of the research team (LL). Reference lists of included studies and relevant systematic reviews were searched by two reviewers (CD and BL) for additional studies meeting the eligibility criteria.

Eligibility criteria

The following eligibility criteria were applied:

- Design. Included studies were randomised controlled trials (RCTs).
- Population. Studies involving community-dwelling adults aged ≥18 years with non-specific LBP of any duration were included. English language restrictions and publication year restrictions, from 2008 to present, were placed on studies at full-text review stage if required. This publication year restriction was applied as the Google Play and Apple App stores opened in 2008.
- Intervention. To be included, studies must have included smartphone apps for the self-management of LBP in adults. Self-management requires a person to actively participate in their treatment and be responsible for the daily medical, behavioural and emotional tasks required for the management of their condition [14]. This review included evidence of the effectiveness of any existing apps, able to be accessed through a smartphone/tablet that provided self-management assistance for LBP with at least one NICE LBP and sciatica clinical guideline [8] recommended component. These self-management components include exercise, psychological therapy, manual therapy (or a combination of physical, psychological and manual therapy) and return to work programs. Self-management support should be provided throughout the treatment pathway with person-specific advice and information related to LBP and encouragement to perform daily activities. Exercise can be in the form of mind-body, biomechanical, aerobic or a combination that suits the individual’s preferences, needs and capabilities. Psychological therapy such as the cognitive behavioural method can be used in combination with exercise and manual therapy. Return to work should be encouraged as part of maintaining normal daily activities [8]. To be included in the review, apps could function with or without health professional input.

Comparator. Comparator groups of health professional usual care, non-digital self-management or no intervention were included.

Outcomes. Primary outcomes of interest were app effectiveness on pain (e.g., measured by pain scales such as the Visual Analogue Scale (VAS) or the Numerical Pain Rating Scale (NPRS)), QOL (e.g., measured by the Health-Related Quality of Life (HRQOL) questionnaires such as AQoL or RAND-36), and physical function (e.g., measured by questionnaires such as the Roland-Morris Low Back Pain and Disability Questionnaire, or scales such as the Oswestry Disability Index (ODI) the Back Pain Functional Scale or the Low Back Outcome Score Scale).

The secondary outcome of interest was adherence (e.g., measured by built-in app measures to evaluate app use and duration), recording of symptoms or exercise performance and adherence
questionnaires such as the RAQ-M (the Modified Rehabilitation Adherence Questionnaire) a 25-item scale evaluating adherence barriers and a diary as a non-app outcome measure.

Studies were excluded if they recruited participants with spinal pain due to pregnancy, surgery, fracture, cancer or spinal cord injury. Studies were excluded if the app focus was related only to pharmacological monitoring or if devices other than a smartphone or computer tablet were used for data collection.

Assessment of characteristics of studies

Risk of bias

The Clinical Appraisal Skills Program (CASP) checklist for RCTs [27] and the TIDier checklist [28] were used to assess the risk of bias and completeness of reporting in included studies. Two reviewers (CD and BL) independently assessed the risk of bias, and a third reviewer (LL) resolved disagreements. Final decisions were via consensus. The CASP checklist uses 11 questions (answered with either “yes”, “no”, “can’t tell” or free text responses) to address the broad areas of study validity, results and generalisability [27]. The responses to the 11 questions guided the overall risk of bias assessment for each trial. Trials were not excluded based on the risk of methodological bias. The TIDieR (Template for Intervention Description and Replication) checklist uses 12 items to guide the evaluation of completeness of reporting and replicability of interventions in published clinical trials [28].

Data analysis

Data extraction and synthesis

Using a standardised data extraction template, two reviewers (CD and BL) independently extracted study characteristic data. Both reviewers then compared and collated data extraction. Study characteristics included country, study design, population, source, sample size, participant characteristics, eligibility criteria, intervention, control/comparator, assessment time points, outcome measures, an estimate of treatment effects and summary of results. Both within and between-group statistical analyses were extracted for all relevant outcomes. Included studies were examined for similarities in participants, interventions and outcomes. In the case of heterogeneity in studies, a narrative synthesis was planned.

Results

Flow of studies through the review

Study selection

The electronic database search yielded 1815 citations. After the removal of 756 duplicates, 1059 citations were screened by title and abstract. After title and abstract screening, a further 1042 studies were excluded, resulting in 17 studies for full-text screening. A further 11 studies were removed (7 ineligible interventions, 1 ineligible study design, 1 ineligible comparator, 1 conference abstract and 1 not available in English) and no further studies

Figure 1. Flow of studies through the review.
were identified from screening reference lists. Six studies were included (Figure 1).

**Characteristics of studies**

**Description of included studies**

One of the included studies was undertaken in India, one in the USA, one in Africa (Nigeria), two in Germany and one in China. All studies were published between 2015 and 2020. A total of 2100 participants were included, ranging from eight [29] to 1245 [30] participants in individual studies. The six included studies were heterogeneous in their interventions and outcomes and although two studies [31,32] compared app use to usual care, usual care differed in each study. One study explored app use versus physiotherapy in-clinic McKenzie therapy [33]. Two studies [29,34] explored app use versus usual physiotherapy care, however, the small number of participants (n = 8) in Yang et al. [29] meant that meta-analysis was not indicated [35].

**Study population**

The characteristics of the included studies are summarised in Table 1. The duration of LBP symptoms, eligibility criteria, recruitment, content and delivery of interventions, intervention time points and outcome measures varied between studies.

**Participants**

Table 2 summarises the participant characteristics in the included studies. Participants were recruited from a variety of settings. Irvine et al. [32] did not report the mean age of the sample, the percentage of female participants was not reported by Chhabra et al. [31], and Irvine et al. [32] did not separate gender for treatment and control groups and only provided an overall result of female participants.

**Intervention**

There were five different smartphone apps identified in the included studies. Five studies used apps that were not available commercially [30–34]. The Snapcare and Kaia apps were developed by technology companies and provided to the researchers free of charge [31,34]. The telerehabilitation-based McKenzie therapy app (TMBT) was developed by the authors and the trial was partly funded by an African Doctoral Dissertation Research Fellowship (ADDRF) re-entry grant [33]. The FitBack app was specifically developed for the study and funded by a small business research grant [32]. The Pain Care app, a commercially available app not currently available in app stores in the Oceania region, was used in the final study [29].

The five included apps had similarities in their function by providing personalised and tailored activity and home exercise programs and reminders to target engagement and compliance. The Snapcare and Kaia apps both updated content based on individual needs [31,34]. The FitBack app used a self-tailored cognitive behavioural approach by targeting self-efficacy and allowing individuals to control the strategies used [32]. The TMBT app used phone calls and SMSs to encourage engagement and compliance of the personalised exercises [33], whilst the Pain Care app functioned by reminding individuals to undertake their therapist prescribed home exercise program and self-monitor pain and activity levels [29]. The FitBack and Kaia apps also provided tailored education behavioural change techniques such as a cognitive behavioural approach [32] or mindfulness and relaxation techniques [30,34].

The duration of app use differed in the six studies. The apps also differed in some other features and directions for use. In the Snapcare app participants received daily activity goals and a standard written treatment prescription from the GP [31]. Participants using the FitBack app received weekly self-care messages that encouraged self-tracking of pain and activity levels [32]. The Kaia app contained over 30 guidelines and textbook-based educational units [34]. The Pain Care and TMBT apps did not generate an exercise program and exercises were therapists prescribed [29,33].

**Comparator**

All included studies included some form of management in the comparator group/s. Three studies involved physiotherapy, two included GPs and one was not reported. Five of the six studies included two groups, intervention and comparator [29–31,33,34], whilst one study included three groups with an additional ‘alternative care’ group [32].

**Outcomes**

Five different primary outcomes were specified in the trials, however, two trials did not specify primary outcome/s [32,33]. Of those that specified primary outcomes, the number in each trial ranged from one to four.

**Pain intensity.** All six included studies measured pain intensity, with three studies using the NPRS, one a 10-point pain dial adapted from the Wong-Baker pain scale [32], one the VAS [29] and one the QVAS [33].

**Function.** Disability was reported as a primary outcome measure relating to function in three trials [29,31,33]. The Roland–Morris Disability Questionnaire (RMDQ) was used in two studies [29,33], the Oswestry Disability Index in one [33] and the Modified Oswestry Disability Index (MODI) in the other [31].

**Pain self-efficacy.** Pain self-efficacy was measured in one trial [29] using the Pain Self-Efficacy Questionnaire (PSEQ).

**QOL.** Health-related QOL was assessed in two trials, one using the SF12 [33] and the other using the SF36 [29]. Both the SF12 and the SF36 measure eight subscales related to QOL (physical function, role physical, bodily pain, general health, vitality, social function, role emotional and mental health).

**Adherence.** All six included studies measured adherence, five using built-in app measures to evaluate app use and duration, and one using phone calls and SMSs to track adherence [33]. However, only two trials specifically reported adherence findings [30,34].

**Risk of bias**

Methodological risk of bias was assessed using the CASP RCT Checklist (Table 2) [27]. None of the trials blinded participants or health care providers, one blinded assessors [31], one blinded research assistants [33] and one further trial reported single blinding but did not specify who [29]. Chhabra et al. [31] were considered the lowest risk of bias as the other five trials all presented with bias in selection, performance and detection. Three trials [30,32,34] prospectively registered protocols and four stated primary outcomes. Three trials reported intention to treat analyses [29,31,32]. Two trials [31,34] reported receiving trial funding from the technology companies providing the app, but the authors...
Table 1. Summary of included studies.

| Study            | Participants                  | Interventions                                                                 | Primary outcome measures                      |
|------------------|-------------------------------|-------------------------------------------------------------------------------|-------------------------------------------------|
| Chhabra et al. [31] | Intervention: n = 45, Mean age (years) = 41, Female (%) = not reported, Control: n = 48, Mean age (years) = 41, Female (%) = not reported | Intervention – Doctor's usual prescription + Snapcare smartphone app for 12 weeks to increase and maintain physical activity and increase engagement and compliance. | Pain intensity: NPRS (0–10), Disability: MODI (0–100) Baseline and 12 weeks with no further assessment post-intervention |
|                  |                               | Control – Usual care – Doctor’s usual prescription of medication and exercise. |                                                 |
|                  |                               | Recruitment: Private hospital outpatient spine department.                     |                                                 |
| Irvine et al. [32] | Intervention: n = 199, Alternative Care: n = 199, Mean age (years) = not reported, Female (%) = not reported | Intervention – FitBack Program – A mobile-based self-management program that provides tailored education, behaviour change and self-care strategies. Participants also had access to 30 videos on exercise and pain management. 8 weekly email reminders were sent to participants to log on to the program. | Primary outcomes not specifically stated. Pain intensity: 10 point pain dial (1–10), level, frequency and duration. Baseline, post-intervention at 8 weeks and then another 8 weeks after the intervention had ceased, but access still granted, at 16 weeks. |
|                  |                               | Recruitment: Internet.                                                         |                                                 |
| Mbada et al. [33] | Intervention: n = 21, Mean age (years) = 47, Female (%) = 67, Control: n = 26, Mean age (years) = 77 | Intervention – Tele-rehabilitation-based McKenzie therapy (TBMT) app – personalised and self-guided back care education and McKenzie extension protocol (i.e., Extension Lying Prone, Extension in Prone, and Extension in Standing). | Primary outcomes not specifically stated. Pain intensity – quadruple visual analogue scale (QVAS). Disability (Participation restriction) – Oswestry disability index (ODI). Disability (activity limitation) – Roland Morris Disability Questionnaire (RMDQ). Health-related QOL – SF-12 General Health Status Questionnaire. Baseline, 4 weeks and 8 weeks |
|                  |                               | Control – Clinic-based McKenzie therapy (CBMT) – McKenzie extension protocol (extension lying Prone, extension in prone, and extension in standing, repeated up to ten times) and a set of back care education instructions (9-item instructional guide on standing, sitting, lifting, and other activities of daily living for home). |                                                 |
|                  |                               | Recruitment: Outpatient physiotherapy department in a university teaching hospital |                                                 |
| Priebe et al. [30] | Intervention: n = 933, Mean age (years) = 42, Female (%) = 65, Control: n = 312, Mean age (years) = 37, Female (%) = 64 | Intervention – STaR-T Back questionnaire and score at commencement of treatment, high-risk patients' GPs could undertake a teleconsultation and discuss appropriate treatment with a pain specialist at the Rise-uP head office. The Rise-uP supervision platform guided communication and data flow between patients, StatConsult and Kaia. Participants granted access to the Kaia app on a smartphone 4 x a week for 3 months. Participants were encouraged to use the Kaia app on a smartphone 4 x a week for 3 months. All 3 modules included in daily use. Progress is adapted by the app daily. | Pain intensity: NPRS (0–10), Baseline (T0) and 3 months (T1) via questionnaires. |
|                  |                               | Recruitment: Facebook advertisement and participating GPs.                    |                                                 |
| Toelle et al. [34] | Intervention: n = 53, Mean age (years) = 41, Female (%) = 73, Control: n = 48, Mean age (years) = 43, Female (%) = 67 | Intervention – Kaia app – includes 3 modules 1) back pain-specific education, 2) physiotherapy/physical exercise and 3) mindfulness and relaxation techniques. Participants were encouraged to use the Kaia app on a smartphone 4 x a week for 3 months. All 3 modules included in daily use. Progress is adapted by the app daily. | Pain intensity: NPRS (0–10), Baseline, 6 weeks and 12 weeks via hardcopy questionnaires |
|                  |                               | Recruitment: Facebook advertisement and participating GPs.                    |                                                 |
declared either no financial gain or direct tech company involvement in the trial, respectively. One trial [30] reported receiving government funding for the trial and, aside from remuneration for various services rendered for those involved in the trial, no further funder involvement occurred in the trial. Mbada et al. [33] and Irvine et al. [32] reported academic funding for the trial and Yang et al. [29] did not report funding sources. The TIDieR checklist [28], presented in Supplementary Material Table 2, showed that two trials [31,32] satisfied all the checklist items and provided all the information within the primary paper. One other trial [34] also provided all the required information within the primary paper but also provided Supplementary Material for five of the checklist items (4 - What, 5 - Who, 6 - How, 7 - Where, and 8 - When and how much). Three trials [29,30,33] all lacked some detail in their reporting of the intervention, ranging from one to four items. One trial [29] lacked sufficient detail for two checklist items (4 - Who, 5 - How). One trial [33] lacked sufficient detail for two checklist items (5 - Who, 8 - When and how much) and did not report on two other items (10 - Modifications, 12 - How well: actual), item 10 was not applicable. One trial [30] did not report on one checklist item (10 - Modifications) as it was not applicable.

### Effects of interventions

Table 3 summarises the effectiveness of smartphone app interventions in the included studies.

#### Pain intensity

Pain intensity was an outcome measure in all six included studies. One study reported pain as a combination of pain intensity, duration and frequency [32] and another reported pain as that at the time of assessment, average pain, pain at its best and its worst [33]. Three of the six included trials reported a significant reduction in pain intensity in the intervention compared with comparator groups (Table 3) [30,32,34].

#### Function

Three included studies reported results on disability outcome measures related to function [29,31,33]. Although Irvine et al. [32] stated the ODI as a primary outcome in their trial registration, no results were reported for this measure. Chhabra et al. [31] reported a significant difference between group MODI scores at baseline. After adjusting for this difference, they showed a
significant reduction in disability in the intervention compared with comparator groups [31].

**Pain self-efficacy.** Pain self-efficacy was measured using the Pain Self-Efficacy Questionnaire (PSEQ) in one trial [29] which found no significant difference between intervention and comparator groups.

**Health-related QOL**

Yang et al. [29] reported that two of the eight subsections (bodily pain and mental health) of the health-related QOL measures showed significant within-group improvements in post-intervention results in the intervention group [29]. No significant between-group differences were reported [29]. Mbada et al. [33] reported that the vitality subsection showed significant between-group differences at eight weeks.

**Adherence**

Frequency of use was recommended and recorded in all studies, however, adherence was not reported in the findings for four of the six trials. Toelle et al. [34] and Priebe et al. [30] were the only included studies that specifically reported findings on participant adherence. Toelle et al. [34] reported that the intervention group used the Kaia app an average of 35 (SD = 22) of the 90 days in the trial. There was no correlation between app use and change in pain intensity (p > 0.05). This trial also measured adherence in the physiotherapy and online education comparator group. Participants attended 90% (mean = 5.39 sessions, SD = 1.22) of the six sessions, 62% of participants used the online links at six weeks and 41% at 12 weeks. The trial also reported no correlation between completed sessions and outcome measures. Priebe et al. [30] reported that the intervention group used the Kaia app on 25 days of the 90 day trial. There was no correlation between app use and change in pain intensity (p > 0.05). This trial also measured the effect of teleconsultation pain improvement and app use, and found that the effect of teleconsultation was not significant (p > 0.05) when adherence was entered as a covariant, and fully mediated by app use. All app interventions aimed to increase adherence by attempting to maintain participant engagement towards home exercising. The Snapcare app collected daily activity data based on patient use [31]. One study allowed unlimited access to the intervention (the Fitback app) but did not mention requirements for frequency of use, however, a weekly reminder was emailed to participants for the duration of the eight-week trial [32]. One trial used the Pain Care app and sent participants four reminders through the app each day, to perform exercises, for the four-week duration of the trial [29]. One trial encouraged participants to use the Kaia app at least four times a week during the three month duration of the trial [34], whilst the other trial that also used the Kaia app [30] encouraged participants to use the app as frequently as possible. One trial tele-monitored adherence via phone calls and SMSs to participants to encourage app use [33]. Although four of the six studies provided participants with a recommended frequency of use [29–31,34] none recommended duration of use per session. Although all trials recorded use data, only two [30,34] reported the results.

**Discussion**

Advances in technology have allowed for the capacity to use smartphones apps to deliver, monitor and manage health conditions such as LBP. This technology is increasingly available and an accepted adjunct to formal clinician-led health management protocols. This systematic review of the literature on smartphone apps for the self-management of LBP reports on the current evidence of effectiveness and participant adherence when using smartphone apps for self-management. Only six RCTs met the inclusion criteria. More than 10 studies were excluded due to ineligible interventions, design, comparator or not in English. It is noteworthy that there were over 40 protocol papers identified in the systematic search and demonstrates that a wave of research in this area is imminent.

After systematically reviewing the literature we have identified that the evidence for the effectiveness of smartphone apps in the self-management of LBP is limited, with methodological biases in selection, performance, detection and attrition and mixed results. None of the included studies reported blinding of health workers or study personnel, leading to a high risk of potential bias. However, double-blinding is not always possible in self-management studies such as those included in this systematic review and will always present as an increased risk of bias in performance [36]. Half of the included studies did not account for all the participants at the end of the trial, leading to a reduction in the confidence of the results without an intention to treat approach to
the statistical analyses. Finally, we cannot be confident that the results from the two included studies which did not treat the intervention and comparator groups equally were due to the intervention alone. Whilst three studies reported a significant reduction in pain intensity in the smartphone app groups compared with the control [30,32,34], three further studies reported no difference between groups [29,31,33]. The country of origin may have been a factor due to cultural differences impacting self-management outcomes [37,38]. The three studies that reported significant between-group differences were undertaken in the USA [32] and Germany [30,34] and the remaining three were undertaken in India [31], Africa [33] and China [29]. High-income countries such as Germany and the USA may have more capacity to implement health-related infrastructure, compared to middle-income countries such as China, India and Nigeria [39] and allow for people to access health services and technology. Self-management has been shown to be culturally embedded [40] and that external social-cultural factors and practices, understanding and interpretation of health management, education status and health beliefs can influence self-management behaviours and adherence to treatment recommendations [41]. This may be as a result of cultural preferences for traditional treatment options provided in the control groups [42], rather than new, technological options such as apps. Non-western social-cultural differences may also result in pain expression differences, as a result of stoicism in those that have historically experienced hardship seeing pain as a sign of weakness, or as a result of age and gender where older females are more likely to report pain [42]. The number of participants was also higher in the three studies undertaken in USA and Germany, allowing for increased power and greater certainty in the results. The significant results in one study [34] for pain intensity may have been impacted by changes in the delivery of the control group treatment, from face-to-face manual therapy to email, at six weeks. This change may account for the significant difference between groups at 12 but not at six weeks. The factors that may have affected the results of the three trials that reported on function (disability) [29,31,33], include the usual care undertaken in the control group and the duration of the interventions. Unfortunately, the 12-week intervention did not record results at four or eight weeks to allow for comparison. Interestingly, the control group in the Snapcare app study consisted of GP prescribed medication and a home exercise program [31], whilst the control groups in the Pain Care app and TBMT studies used a more "hands on" approach [29,33]. The GP prescribed medication may have decreased pain intensity allowing for improved function and affected the between-group findings. Pain self-efficacy was reported in only one study [29], and health-related QOL was reported in two studies [29,33], all with small numbers of participants and short trial durations [29,33]. None showed a significant difference between intervention and comparator groups and should be interpreted with caution.

Adherence to home exercise programs is a common challenge for people with LBP [43]. It is an important component of behaviour change and according to the Transtheoretical Model of behaviour change, it may take at least six months to change behaviour [44]. The six included studies all had intervention lengths of less than six months [29–34]. Adherence to self-management programs has frequently been reported in the literature as an essential component to improving outcomes [20,45,46]. Although, one included study used gamification to provide instant gratification and maintain engagement and adherence [31] only two studies [30,34] reported on adherence as an outcome. The studies reported no correlation between app use or completed sessions and outcome measures. This is an interesting finding and should be interpreted with caution as the results are of two studies reporting on the Kaia app with a relatively short intervention duration (12-weeks). Further research with intervention duration of at least six months [44] should be undertaken to add clarity to these results.

There was heterogeneity in content, delivery and reported outcomes among the six included studies, making comparison difficult. As a result, meta-analysis was not indicated [35]. Overall, 85% of the apps used in the six included trials are not available commercially for general consumers. The five apps used in the studies were either developed for the studies [32], the researcher was involved in the development of the app [31] or the app was provided by the technology company, for the study, free of charge [34]. Only one app was commercially acquired for the study [29]. Commercially available apps do not undergo the same level of quality control [20,25] as apps developed for research. Research apps often differ from those available commercially as they are more likely to have undergone pilot testing to ensure that they align with guideline recommendations [7,8], incorporate consumer preferences [20], and evidence-based self-management features [14] that have the capacity to improve outcomes. Further evaluation of commercially available apps is required to guide and instil confidence in consumers and health professionals that consumer-accessible apps are of reasonable quality and may lead to improved outcomes.

**Strengths and limitations**

This systematic review had several methodological strengths. The review was conducted according to PRISMA guidelines [26], the search strategy was peer-reviewed and all included studies were appraised for risk of methodological bias. The focus was on apps for self-management which is the current gold standard for the management of LBP. There are also some limitations which must be acknowledged. The small number of studies and the heterogeneity of apps, interventions and outcome measures, in the six included studies precluded the use of meta-analyses. To offset this, a detailed narrative comparison of the study outcomes was presented. One of the studies [32] did not specifically outline the process of randomisation, and numerous attempts were made to contact the authors to add clarity to the process of randomisation, but no return communication was received. As it was clearly stated in the primary paper and the protocol, that a randomised controlled trial was undertaken, it was included in the review. In 2008 the Apple App Store went live, followed by the Google play store later that year when apps became available to the wider population. As a result, apps are a relatively new addition to self-management. None of the included eligible apps required direct health professional input. This eliminated the additional self-management guidance that would normally be provided by a health professional and allowed only for the self-management support provided by the app alone. As a result, the findings of this review are generalisable to the way the general population may use smartphone apps for the self-management of LBP (i.e., download the app and apply, rather than seeing a health professional). In addition, apps available for consumer download from an app store differ from those available to health professionals and that require their input.

**Implications**

This review provides inconclusive evidence for the use of apps for the self-management of LBP. Consumer adherence data can commonly be collected via apps, allowing for the potential recording...
of use, symptoms and exercise type. These data can allow consumers to monitor self-management progress and share data with health professionals.

The use of smartphone apps for self-management is a rapidly expanding area of research as was evidenced by over 40 protocols that did not meet our inclusion criteria. This evidence will grow rapidly and an update of this review will be warranted. High quality, longer duration and larger-scale RCTs incorporating consumer and health professional preferences are necessary for future evaluation of commercially available smartphone apps for the self-management of LBP, as well as a systematic assessment of the quality of commercially available smartphone apps for the general population.

Acknowledgements

The author(s) would like to acknowledge Josephine McGill (Academic Librarian) for her valuable assistance peer-reviewing the search strategy for this systematic review.

Disclosure statement

This manuscript is a component of a chapter which contributes to the first author’s PhD thesis which is not yet submitted.

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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