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Integration of Mobile Health Apps and Web-Based Interventions in the Self-Management of Low Back Pain: A Systematic Review

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Integration of Mobile Health Apps and Web-Based Interventions in the Self-Management of Low Back Pain:

A Systematic Review

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Abstract

Background: Low back pain (LBP) is a highly prevalent public health related problem with a substantial impact on the individual's disability and daily functioning. The challenging and complex treatment of LBP requires new motivational, time and cost-effective approaches.

Objective: The aim of this study is to provide an overview of the available evidence and to determine if the included studies follow a well-structured and homogenous design that allow an effective assessment of the impact of mobile health apps and web-based interventions in the self-management of LBP.

Methods: Electronic databases such as PubMed/Medline, PubMed Central (PMC), PubMed Health, Cochrane CENTRAL and PEDro were searched from 2007 until December 2017. The search strategy included the use of MESH terms and free-text terms, combining 3 concepts: low back pain, mobile applications and self-care. Randomized control trials (RCTs) and RCT protocols using mobile health apps or web-based interventions as part of the treatment for patients with LBP were included.

Results: A total of 17 articles concerning 14 different studies - 9 randomized control trials and 8 RCT protocols - met the inclusion criteria. The nine completed RCTs included a total of 1659 participants, ranging from 51 to 398 participants per study. The majority of the participants were females and reported educational levels as partial college or higher. A wide range of outcome measures were used, although none of the studies reported on health care utilization. There was a significant variation in the reported results, even though some studies indicated improvement in certain outcomes favouring the intervention group. Three studies delivered the content through an app, accessible from multiple devices. Interactive elements were reported in every study.

Conclusions: An overview of the available evidence, concerning the integration of mobile health apps and web-based interventions in the self-management of LBP was provided. The included studies did not follow a homogenous design, reporting numerous outcomes and heterogenous data. Therefore, it was not possible to establish a clear idea of its true impact. The protocols for future trials seem to evaluate more homogenous outcomes and are likely to provide future useful data. Health care utilization and longer follow-up periods should be assessed in future trials. Apps and web-based interventions may be the solution to overcome current barriers and increase access to a quality, safe and cost-effective rehabilitation for LBP.

Keywords:

low back pain; self-management; Mobile Health apps; Mobile Health; eHealth; mHealth; Web-Based Interventions; systematic review.

Resumo

Conhecimento prévio: A dor lombar (LBP) é um problema de saúde pública com um impacto substancial na capacidade funcional do indivíduo e nas suas atividades de vida diária. O tratamento da LBP é desafiador e complexo e, por isso, requer novas abordagens que promovam uma reabilitação de qualidade, segura e de baixo custo.

Objetivo: O objetivo deste estudo é fornecer uma visão geral da evidência disponível e avaliar se os estudos incluídos seguem uma estrutura comum e homogénea que permita avaliar o impacto da utilização de apps e intervenções baseadas na web na auto gestão da dor lombar.

Materiais e Métodos: As bases de dados eletrónicas PubMed/Medline, PubMed Central (PMC), PubMed Health, Cochrane CENTRAL e PEDro foram pesquisadas de 2007 até dezembro de 2017. A estratégia de pesquisa incluiu o uso de termos MESH e termos de texto livre, combinando 3 conceitos: LBP, aplicações móveis e autocuidado/autogestão. Foram incluídos ensaios de controlo randomizado (RCTs) e protocolos de RCTs, que usam apps ou intervenções baseadas na web como parte do tratamento para doentes com LBP.

Resultados: Um total de 17 artigos relativos a 14 estudos diferentes - 9 ensaios de controlo randomizado e 8 protocolos de RCTs - cumpriram os critérios de inclusão. Os nove RCTs incluíram um total de 1659 participantes, variando de 51 a 398 participantes por estudo. A maioria dos participantes eram mulheres com níveis educacionais elevados (faculdade parcial ou superior). Nenhum estudo analisou a utilização dos cuidados de saúde. Três estudos utilizaram uma app, acessível a partir de vários dispositivos. Elementos interativos foram relatados em todos os estudos.

Conclusões: Foi fornecida uma visão geral da evidência disponível relativamente à integração de apps e intervenções baseadas na web na auto gestão da dor lombar. Os estudos incluídos não seguiram uma estrutura homogénea e apresentaram inúmeros resultados e dados heterogéneos. Desta forma, não foi possível estabelecer uma ideia clara do seu verdadeiro impacto. Os protocolos de RCTs parecem avaliar resultados mais homogéneos e provavelmente fornecerão dados úteis no futuro. A utilização dos cuidados de saúde e períodos de seguimento mais longos devem ser avaliados em ensaios futuros. Os aplicativos e as intervenções baseadas na web podem ser a solução para superar barreiras atuais e aumentar o acesso a uma reabilitação de qualidade, segura e de baixo custo.

Palavras-chave:

dor lombar; autogestão; Mobile Health apps; Mobile Health; eHealth; mHealth; intervenções baseadas na Web; revisão systemática.

Abbreviations and Acronyms

AI: artificial intelligence

AI-CBT: artificial intelligence cognitive behavioural therapy

APPS: mobile applications

CBT: cognitive behavioural therapy

FitBit: physical activity monitoring device

IVR: interactive voice response

IVR-CBT: interactive voice response cognitive behavioural therapy

LBP: low back pain

N/R: not reported

NLBP: nonspecific low back pain

NRS: numerical rating scale

PA: physical activity

RCT: randomized controlled trial

SMS: Short message service

UK: United Kingdom

US: United States

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Introduction

Low back pain (LBP) is a highly prevalent public health related problem with a substantial impact on the individual's disability and daily functioning. Despite the numerous treatment options, the overall prevalence of LBP remains at 38.9% (1). In industrialized countries, LBP is the leading cause of work absenteeism, meaning high economic healthcare costs (2).

As the population ages, the global number of individuals with low back pain is likely to increase substantially over the coming decades (1), which will contribute to further pressure on health systems. It is therefore imperative to develop new strategies that increase access to a quality, safe and cost-effective rehabilitation.

Physical exercise associated with an educational component is considered an effective intervention for LBP (3). Empowering the patient with tools that allow him to play an active role in self-managing LBP is a promising treatment strategy (4). However, a considerable number of patients face several barriers to access health professionals either for financial, time or motivational problems. Adherence to the prescribed treatment is essential, as it is considered one of the predictors of therapeutic success (5).

The integration of mobile applications or apps in the management of LBP allows the patient to control and monitor the evolution of his own rehabilitation and offers new motivational strategies that improve therapeutic adherence, already reported in areas such as Diabetes and Obesity (6,7). Also in chronic pain, interventions based on the implementation of technological means have shown to improve chronic pain, when compared to control groups (no treatment, waiting list, placebo or usual treatment) (8). In addition, apps offer the ability to monitor patients' performance and identify pain patterns and exacerbating factors.

Despite the great expansion of the apps' market, its potential as an integral part of LBP therapy has not yet been fully clarified. Thus, the purpose of this systematic review is to

provide an overview of the available evidence regarding the integration of mobile health apps and web-based interventions in the self-management of LBP as well as to determine if the included studies follow a well-structured and homogenous design.

Materials and methods

Information sources and search strategy

This systematic review was conducted in December 2017, according to the PRISMA 2009 guidelines (9). The following databases were searched: PubMed/Medline, PubMed Central (PMC), PubMed Health, Cochrane CENTRAL and PEDro. All databases were searched from 2007 until December 2017. The search strategy included the use of MESH terms and free-text terms, combining 3 concepts: low back pain, mobile applications and self-care. It was also requested the help of an experienced librarian at the UC Health Sciences Library to screen for additional articles.

The search was limited to articles published in English, Portuguese or Spanish.

The full version of the search strategy is documented for the example of PubMed in the Appendix 1.

Study selection

Identified articles from the searched databases were uploaded to Mendeley software. After the removal of duplicates identified by the duplicate detection tool, one reviewer (GM) screened the titles and abstracts of the obtained articles. The relevant studies were read in full length and assessed for eligibility. Any disagreement was solved through discussion with a second reviewer (JP). The references of the selected articles and previous systematic reviews were also screened for additional records.

Inclusion criteria

Study design: RCTs or protocols for RCTs from peer reviewed journals.

Language: studies published in English, Portuguese or Spanish.

P (Population): adults (≥18 years old) with LBP.

I (Intervention): studies of interventions that include the use of a mobile application or Web-based programs for smartphone or computer or other hand-held devices, that provides the user with information or tools that allow him to self-manage his LBP. There must be an element of interaction between the user and the interface.

C (Comparison): studies comparing the use of mobile application/web-based programs vs. non-digital/non-interactive intervention or usual treatment.

O (Outcome): if the included studies follow a well-structured and homogenous design that allows for an effective assessment of the impact of mobile health apps and web-based interventions in the self-management of LBP.

Exclusion criteria

Non randomized controlled trials and protocols.

Non-digital/non-interactive intervention.

Trials not considering pain intensity, disability or empowerment outcomes to assess the effectiveness of the intervention.

Absence of LBP definition.

Data collection and synthesis

Data was extracted on the study characteristics (country, year, definition of LBP and attrition rate); population characteristics (age, gender, education, participants number, inclusion and exclusion criteria); study design (objective, intervention, control, duration and theoretical

underpinning); outcomes and main results (time-points for outcome assessment, choice of primary outcomes, included secondary outcomes and results); description of the intervention (details on the key components, interactive element, recommended frequency and tailoring).

The characteristics of the included studies such as the population, intervention key components and available outcomes were displayed in Tables 1 to 6. Results were described as either favouring the intervention group or the control group or no difference between groups. Meta-analysis was not possible due to the heterogeneity of identified studies.

RCTs protocols were not included in the synthesis of intervention's main results.

Risk of BIAS assessment

The risk of bias was assessed using the checklist from the Cochrane Risk of Bias Tool in randomized trials. The assessment was done independently by two reviewers (GM and JP), using the previous checklist. Any disagreement was solved through discussion between the reviewers. No studies were excluded based on their risk of bias assessment.

Results

Literature search results

We identified a total of 279 articles published since 2007 until December 2017. From these, 27 were duplicate. The remaining 252 potentially relevant articles were screened based on the title and abstract, resulting in the assessment of 53 full-text articles. A total of 17 articles concerning 14 different studies - 9 randomized control trials and 8 RCT protocols - were included for the purposes of this systematic review. The PRISMA flow diagram illustrates the screening process (Fig. 1).

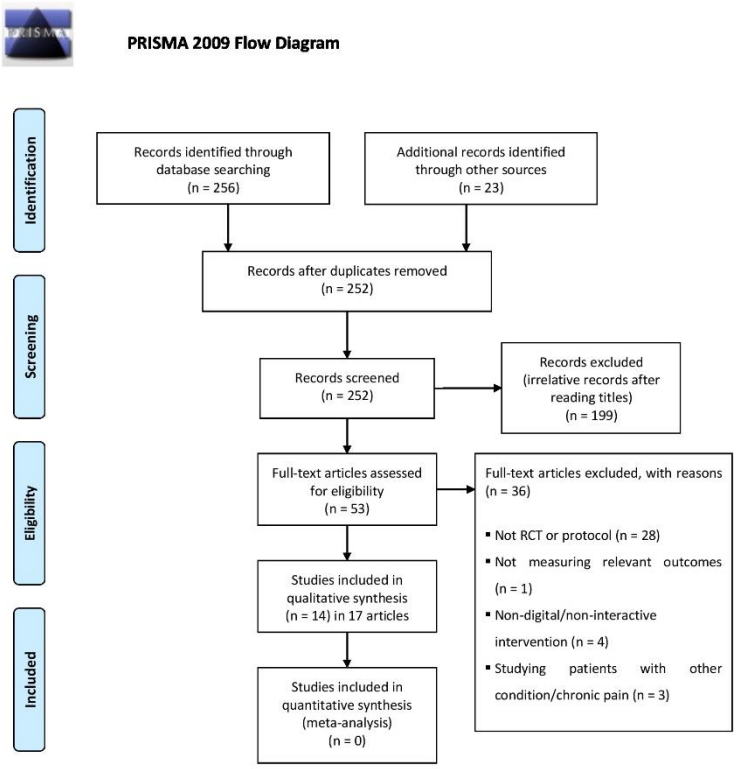

Figure 1. PRISMA Flow Diagram

Study characteristics are described in table 1. Six of the fourteen different studies were carried out in the United States (10–15), three in Germany (16–18), one in Sweden (19), one in Switzerland (20), one in Australia (21), one in United Kingdom (22) and one in Spain (23). The studies were published between 2010 and 2017. Definition of LBP varied between studies. Eight studies defined LBP as pain for at least three months (10,11,13,16,18–21). Only one study defined it as current pain or pain within the past 2 weeks (22).

Population characteristics are listed in Table 2. The nine completed RCTs included a total of 1659 participants, ranging from 51 to 398 participants per study. The mean age of the studies' population ranged between 42.5 and 57.9. One study did not reported the age of the population (11). The majority of the participants were females and reported educational levels as partial college or higher. Exclusion criteria common to all the included studies was the presence of comorbidities.

Study design and details concerning the implemented interventions are described in Table 3. Majority of the studies aimed to evaluate the effectiveness of the web-based approach compared to a control group. Studies duration lasted from 2 weeks to 12 months. Two of the fourteen studies were waitlist controlled (12,19). Four studies reported cognitive behaviour theory as theoretical underpinning (10,12,13,19).

A wide range of outcome measures were used (Table 4). No studies reported on health care utilization. Two studies demonstrated effectiveness of the intervention in pain catastrophizing and disability (17,19). One study reported positive effects on physical and behavioural outcomes, consistent at 4-month follow up, when compared with the control group (11). One study reported between-group in difference in favour of the intervention group (12). One study reported that interactive voice response cognitive behavioural therapy was noninferior to in person cognitive behavioural therapy (13).

Intervention key characteristics are reviewed in Table 5. Two studies used interactive voice response to monitor and provide feedback to the patient (13,15). Three studies delivered the content through an app, accessible from multiple devices (11,18,21). The other nine studies had the content accessed over the internet/website. Interactive elements were reported in every study. Only five of the fourteen studies did not report any tailoring (12,13,17,19,21).

Table 1. Study characteristics and definition of LBP

Study	*Country/Year*	*Definition of LBP*[a]	*Attrition rate*
Chiauzzzi et al (10)	US[b] 2010	LBP ≥10 days/month for at least 3 consecutive months.	6 months follow-up I =67/104 C =88/105
Irvine et al (11)	US[b] 2015	Nonspecific LBP within the past 3 months.	2 months follow-up I =192/199 C =197/199
Carpenter et al (12)	US[b] 2012	Noncancer LBP ≥6 months.	3 weeks follow-up I =63/70 C =68/71
Heapy et al (13) *Heapy et al*[d] (24)	US[b] 2017 2016	LBP with rating of ≥ 4 on the 0 to 10 NRS[e] for a period of ≥ 3 months and an electronic health record-verified back condition.	3 months follow-up I =52/62 C =43/63
Krein et al (14) *Krein et al*[d] (25)	US[b] 2013 2010	Patients with ≥3 outpatient encounters within the past 12 months with diagnosis of back pain without any neurologic findings (ICD-9-CM codes 724.2, 724.5, 846.0-846.9).	12 months follow-up I =102/111 C =105/118
Weymann et al (16) *Dirmaier et al*[d] (26)	Germany/2015 2013	Pain in the lower back almost every day for >12 weeks.	3 months follow-up I =96/190 C =106/188
Moessner et al (17)	Germany 2012	Noncancer LBP (ICD-10 code:M54).	3 months follow-up I =18/40 C =24/35
Amorim et al[d] (21)	Australia 2016	Chronic LBP for >12 weeks, without radicular symptoms.	-
Blodt et al[d] (18)	Germany 2014	Chronic LBP, without radicular symptoms, for ≥12 weeks and a mean pain score of ≥ 4 on a NRS[e] in the previous week.	-
Geraghty et al[d] (22)	UK[c] 2015	Current LBP (have experienced pain within the past 2 weeks) and prior LBP consultation at their general practice within the past 6 months.	-
Piette et al[d] (15)	US[b] 2016	LBP with a pain score of ≥ 4 on the 0-10 NRS[e] during at least two separate outpatient encounters in the past year.	-
Valenzuela et al[d] (23)	Spain 2015	Chronic LBP >6 months.	-

Abbreviations

[a]LBP: low back pain

[b]US: United States

[c]UK: United Kingdom

[d]Protocol of RCT

[e]NRS: numerical rating scale

Table 2. Population characteristics of the included studies.

Study	***Number***	***Demographics*** ***1. Age, mean (SD)*** ***2. Sex (%)*** ***3. Education***	***Inclusion criteria***	***Exclusion criteria***
Chiauzzzi et al (10)	N =209 I =104 C =105	1. 46.1 (12.0) 2. 67.7% female 3. 73.7% partial college or higher	Presence of back pain for ≥10 days, for ≥3 consecutive months; spinal origin of pain; English language fluency.	Nonspinal medical or systemic conditions that explain the back pain; cervical pain without low back pain; psychiatric hospitalization within past year.
Irvine et al (11)	N =398 I =199 C =199	1. N/R 2. Female: I =58.3% C =62.8% 3. Some college or higher: I =86.9% C =92.5%	Age 18 to 65 years, living in the United States; be employed at least half time, retired, or a family member of an employee at one of the four collaborating companies; LBP[a] within the past 3 months; have a working email address; respond to an online video demonstrating that they had access a computer that	Be experiencing back pain so intense it interfered with everyday life; history of medical care for back pain or prescription medications for back pain; participating in another monitored exercise program for back pain; presence of medical risks screened

			could play video on the Internet.	by an online survey.
Carpenter et al (12)	N =141 I =70 C =71	1. 42.5 (10.3) 2. 83% female 3. 54% ≤2 years of college	Non-cancer-related back pain; duration ≥6 months; mean pain rating >4; access to Internet.	Age <40 years (applied after start of study); CBT[b] within past 3 years; pain duration <6 months.
Heapy et al (13) *Heapy et al*[d] (24)	N =125 I =62 C =63 115/group	1. 57.9 (11.6) 2. 22.4% female 3. N/R	Electronic health record–verified back condition, averaging a pain score of at least 4 on the NRS[c] for at least 3 months; self-reported ability to walk 1 block; access to a touch tone telephone.	Planned surgical intervention for pain; medical or psychiatric conditions that could impair participation dementia; active psychosis; substance use disorder.
Krein et al (14) *Krein et al*[d] (25)	N =229 I =111 C =118 130/group	1. I =51.2 (12.5) C =51.9 (12.8) 2. Female: I =11% C =14% 3. Some college or higher: I =72% C =75%	Persistent back pain; ≥3 months; self-reported sedentary lifestyle (<150 min of physical activity per week); internet access.	Inability to walk one block; pregnancy.
Buhrman et al (19)	N =54 I =26 C =28	1. 43.2 (9.8) 2. 68.5% female 3. 22.2% University education <2 years	Access to Internet; chronic pain ≥3 months duration.	Planned surgery; wheelchair bound; cardiovascular disease.
Riva et al (20)	N =51 I =27 C =24	1. I =44 (13.6) C =51 (14.1) 2. Female: I =51.9% C =50% 3. University: I =33.3% C =12.7%	Age >18 years; back pain >3 months; Italian native speakers.	Concurrent involvement in other study.

Weymann et al (16) *Dirmaier et al*[d] (26)	N =382[d] I =190 C =188 N =414	1. I =52.2 (13.1)[e] C =52.7 (13.0)[e] 2. Female: I =57.5%[e] C =54.3%e 3. High educational level[e f]: I =53.4% C =51.1%	Age >18 years; chronic backpain defined as pain almost every day for period >12 weeks; diabetes type 2.	Age <18 years; duration of pain <12 weeks; lack of Internet access.
Moessner et al (17)	N =70 I =40 C =35	1. I=45.2 (10.2) C=46.6 (7.7) 2. Female: I =58.5% C =59.1% 3. N/R	Age >18 years; Prior multidisciplinary treatment for 1 week.	Cancer-related pain; Insufficient language skills; treatment duration <1 week.
Amorim et al[d] (21)	34/group	-	Age >18 years; chronic LBP[a] >12 weeks but without radicular symptoms; discharged from a hospital-based, LBP[a] physiotherapy program, but still have consistent pain; regular use of a computer or internet connected mobile or tablet device; fluency in English.	Any spinal surgery in the past 12 months; evidence spinal cord compression; severe spinal stenosis systemic disorder; comorbid health conditions; LBP[a] caused by involvement in a road traffic accident in the last 12 months; pregnancy.
Blodt et al[d] (18)	110/group	-	Age 18 to 65 years; chronic LBP[a] ≥12 weeks; mean pain score of ≥ 4 on a NRS[b] in the previous week; having a smartphone (iPhone or Android); identify LBP[a] as the primary complaint.	LBP caused by a known malignant disease, trauma or rheumatic disorder; history or planned surgery of the spinal column in the next 6 months; neurological symptoms or a history of severe acute or chronic

				disorders; alcohol or substance abuse; insufficient German language skills; current application for a pension claim; participation in another clinical trial during the previous 6 months; 'mindfulness based' therapy 6 weeks before the study or planned in the next 6 months.
Geraghty et al[d] (22)	20-30/group	-	Have experienced pain within the past 2 weeks; have access to the internet; active email address; have had a prior LBP[a] consultation at their general practice within the past 6 months for those invited directly from practice lists; be able to read/understand English.	Age <18 years; spinal pathology or systemic illness; have taken part in the study to develop the internet intervention being trialled.
Piette et al[d] (15)	N =320	-	Score ≥5 on the Roland Morris Disability Questionnaire at baseline; musculoskeletal pain (≥ moderate) for at least 3 of the prior 6 months; have a mobile phone or touch-tone land line phone.	Actively psychotic, suicidal, or severely depressed; behaviour flags related to emotional dysregulation, bipolar disorder, or active substance abuse; life threatening conditions; dementia; sensory deficits; currently receiving CBT or plans

				for surgical treatment related to their back pain.
Valenzuela et al[d] (23)	29/group	-	Age 18 to 65 years; chronic LBP[a] >6 months; able to read, speak and understand Spanish and Catalan; access to the Internet, a computer or laptop; e-mail address; accept and sign the informed consent form.	Onset age < 20 or > 55 years; non-mechanical pain; thoracic pain; previous history of carcinoma, steroid use, or HIV infection; weight loss; feeling unwell; neurological symptoms; structural spinal deformity.

Abbreviations

[a]LBP: low back pain

[b]CBT: cognitive behavioural therapy

[c]NRS: numerical rating scale

[d]Protocol of RCT

[e]Numbers of LBP population only not available; the numbers refer to the general population of the study

[f] >10 years of education

Table 3. Design of the included studies and theoretical underpinning.

Study	***Aim***	***Intervention***	***Control***	***Duration***	***Theoretical Underpinning***
Chiauzzzi et al (10)	Compare an interactive self-management Website approach versus standard text-based materials for people with chronic back pain; hypothesized improved emotional management, coping, self-efficacy to manage pain, pain levels and physical functioning.	painACTION-Back Pain Website; 2 weekly sessions across 4 weeks (total = 8 sessions); Participants were asked to spend at least 20 minutes in each session.	E-mailed a back pain guide	6 months	Cognitive behavior theory; Collaborative decision making; Motivational enhancement; Wellness activities.
Irvine et al (11)	Efficacy of a mobile-Web intervention - "FitBack" - to manage and prevent NLBP[a] occurrences.	FitBack app	Usual care	4 months	Social cognitive theory; Theory of Planned Behavior.
Carpenter et al (12)	Efficacy of an online self-help CBT[b] intervention for chronic lower back pain.	Interactive, web-based Wellness Work- book (WW).	Waitlist	6 weeks	Cognitive therapy, behavioral activation; Acceptance and commitment therapy; Mindfulness-based stress reduction.
Heapy et al (13) *Heapy et al*[d] (24)	Efficacy of interactive voice response–based CBT[b] (IVR-CBT) relative to in-person CBT[b] for chronic back pain.	Self-help manual and weekly pre-recorded therapist feedback.	Weekly, individual CBT[b] sessions with a therapist	9 months	Cognitive behavior theory.
Krein et al (14) *Krein et al*[d] (25)	Whether a pedometer based, Internet mediated intervention would reduce chronic back pain-related disability.	Pedometer with access to uploaded weekly data, a study website and an internet support group.	Usual care, plus a pedometer (monthly upload),but no access to walking goals or feedback	12 months	Social Cognitive Theory[c].

Buhrman et al (19)	Whether an Internet-based cognitive behavioural intervention would have an effect on the symptoms of chronic back pain.	Web-based multimodal pain management program based on CBT[b]; no weekly telephone support.	Waitlist	12 weeks	Cognitive behavior theory.
Riva et al (20)	Assess the impact of interactive sections of an Internet-based self-management intervention on patient empowerment, their management of the disease and ultimately, health outcomes.	Intervention group received access to back pain management website with interactive features (virtual gym, action plan, testimonials, quiz game); reminder SMS[e].	Access to website, but no interactivity	8 weeks	N/R[f]
Weymann et al (16) *Dirmaier et al*[d] (26)	Investigate effectiveness of a Web-based, tailored, fully automated intervention for patients with type-2 diabetes or chronic LBP[g] against a standard website with identical content without tailoring.	Web-based information system for patients which was tailored for individual needs and dialogue-based.	Access to information through a website without tailoring or use of dialogues	12 weeks	N/R[f]
Moessner et al (17)	Compare treatment as usual versus the participation in the aftercare program.	Individualized self-monitoring module; moderated Internet-based chat.	Treatment as usual	30 weeks	N/R[f]
Amorim et al[d] (21)	Investigate the effectiveness of a mobile health supported physical activity intervention in care seeking, pain and disability in people with chronic LBP[g].	Web app and a physical activity monitoring device (FitBit); physical activity advice booklet; face-to-face health coaching session; 12 fortnightly follow-up telephone-based health coaching sessions.	Physical activity advice booklet only	12 months	N/R[f]
Blodt et al[d] (18)	Whether an additional app-delivered relaxation would be more effective	Smartphone app providing instructions and	Usual care; relaxation techniques,	6 months	Mindfulness-Based Stress Reduction

	in the reduction of chronic LBP[g] than usual care alone.	exercises; practice relaxation techniques on at least 5 days /week for 15 minutes/day over a period of 6 months.	mindfulness meditation or any other mindfulness based training are not permitted.		
Geraghty et al[d] (22)	Explore feasibility of providing an Internet intervention for patients with LBP[g] in primary care, with and without physiotherapist telephone support (in addition to usual care), compared with usual care alone.	Usual primary care with the addition of an internet intervention ("SupportBack") or an internet intervention with physiotherapist telephone support.	Usual primary care	3 months	N/R[f]
Piette et al[d] (15)	Demonstrate that AI-CBT[h] has pain-related outcomes equivalent to standard telephone CBT[b] and that AI-CBT[h] achieves these outcomes with more efficient use of clinician resources.	One standard, hour-long telephone CBT[b] session; based on patients' IVR[i] feedback, the AI-CBT[i] engine will make recommendation to carefully step-down the intensity of each patient's CBT[b] follow-up using more brief telephone therapy sessions (15 minutes).	10 hour-long CBT[b] sessions	6 months	Cognitive behavior theory
Valenzuela et al[d] (23)	Evaluate effect of a Biopsychosocial Web-based, educational Intervention for chronic LBP based on pain intensity compared with normal care.	Biopsychosocial web- based educational intervention, not yet developed, but will be based on qualitative study including interviews with patients.	Convention-al treatment provided by their family physician	2 weeks (QUAN phase)	N/R[f]

Abbreviations

[a]NLBP: nonspecific low back pain

[b]CBT: cognitive behavioural therapy

[c]Information only stated in the protocol

[d]Protocol of RCT

[e]SMS: Short message service

[f]N/R: not reported

[g]LBP: low back pain

[h]AI-CBT: artificial intelligence cognitive behavioural therapy

[i]IVR: interactive voice response

Table 4. Study available outcomes and main results

Study	***Primary outcomes***	***Secondary outcomes***	***Measurement times***	***Main result***
Chiauzzzi et al (10)	BPI (Brief Pain Inventory); ODQ (Oswestry Disability Questionnaire); DASS (Depression/ Anxiety and Stress Scale); PGIC (Patient Global Impression of Change scale).	PCS (Pain Catastrophizing Scale); FABQ (Fear Avoidance Belief Questionnaire).	Baseline and at 1, 3 and 6 months follow-ups.	Hypothesis not supported.
Irvine et al (11)	*No primary outcome stated.*	Pain: level, frequency, intensity and duration; MPI (Multidimensional Pain Inventory Interference Scale); Dartmouth CO-OP; Prevention-helping behaviors (self-developed); WLQ (Work Limitations Questionnaire); SPS (Stanford Presenteeism Scale); PAM (Patient Activation Measures); Knowledge; Behavioral intensions; Self-efficacy; SOPA (modified); TSK (Tampa Scale of Kinesiophobia; modified).	Baseline, 8 and 16 weeks.	*No data available for primary outcome analysis.* FitBack program's positive effects on physical and behavioural outcomes (secondary outcomes) were consistent at 4-month follow-up comparisons with control subjects.
Carpenter et al (12)	SOPA (Survey of Pain Attitudes).	FABQ (Fear Avoidance Belief Questionnaire); NMR (Negative Mood Regulation scale); PCS (Pain Catastrophizing Scale); RMDQ (Roland-Morris Disability Questionnaire); PSES (Pain Self-Efficacy Scale); Demographics and pain assessment questionnaire	Baseline, 3 and 6 weeks.	Difference in favour of the intervention group on all SOPA sub-scales in the SOPA questionnaire, except "medical cure".

Heapy et al (13) *Heapy et al*[d] (24)	Pain intensity measured by the Numeric Rating Scale (NRS).	WestHaven-Yale Multidimensional Pain Inventory; Roland and Morris Disability Questionnaire (RMDQ); BDI-II (Beck Depression Inventory); Pittsburgh Sleep Quality Index; Veterans 36-item short-form (SF-36).	Baseline, 3, 6 and 9 months.	IVR-CBT[a] was noninferior to in person CBT[b] for reduction in pain intensity at all assessment points.
Krein et al (14) *Krein et al*[d] (25)	RMDQ (Roland-Morris Disability Questionnaire); SF-36 function scale.	Pain intensity (NRS, numerical rating scale); Walking (steps/day); FABQ PA (physical activity) subscale; Self-efficacy; 6-min walking test[c]; CES-D100[c](Centre for Epidemiologic Studies Depression Scale).	Baseline, 6 and 12 months.	No between group difference reported at any time-points.
Buhrman et al (19)	Coping Strategies Questionnaire – catastrophizing subscale.	Multidimensional Pain Inventory (MPI); Pain and Impairment Relationship Scale (PAIRS); Hospital Anxiety and Depression Scale (HADS); Quality of Life Inventory (QOLI).	Pre and post treatment.	Pain catastrophizing of the treated participants showed reliable improvement.
Riva et al (20)	*No primary outcome stated.*	Patient empowerment; physical exercise; medication misuse; pain burden.	Baseline, 4 and 8 weeks.	*No data available for primary outcome analysis.*
Weymann et al (16) *Dirmaier et al*[d] (26)	Knowledge (postintervention); Patient empowerment (heiQ, Health Education Impact Questionnaire; 3 months).	DCS (Decisional Conflict Scale); PDMS (Preparation for Decision Making Scale).	Baseline, post intervention and 3 months.	The tailored intervention had no effect on the total study population.
Moessner et al (17)	Pain intensity measured by the Numerical Rating Scale (NRS); SF-36 pain subscale; Roland–Morris	KPD-38 for general psychological impairment, anxiety and depression.	15 and 30 weeks.	Efficacy was demonstrated for disability and pain (SF-36 Pain subscale). For pain intensity (NRS) no

	Questionnaire (RMQ).			significant differences in post-treatment courses were found between the group.
Amorim et al[d] (21)	Care-seeking; Pain levels measured by the Numerical Rating Scale (NRS); RMDQ (Roland-Morris Disability Questionnaire).	International Physical Activity Questionnaire (IPAQ); *Actigraph* accelerometer; GAS (Goal Attainment Scale).	Baseline, weekly during intervention, 6 and 12 months.	-
Blodt et al[d] (18)	Pain intensity measured by the Numerical Rating Scale (NRS).	Mean pain intensity in the last 7 days; Mean perceived 'LBP[e]-related' stress intensity; Pain acceptance; Sick leave days; Intake of medication against LBP[e]; Suspected adverse reaction; Serious adverse events; Application of other therapies; Expectation; Adherence; Self-perceived improvement.	Daily or weekly assessment summarized in the first 3 or 6 months (provided by the app).	-
Geraghty et al[d] (22)	Feasibility outcome; *Number need to Screen;* *Recruitment rates;* *Login and usage information.*	Pain: days, duration, intensity; RMDQ (Roland-Morris Disability Questionnaire); StartBack Screen Tool; TSK; PCS; IPAQ (International Physical Activity Questionnaire); PEI (Patient Enablement Instrument); EQ-5D (Euro-Qol 5D); LBP related health care use; Time off work; CEQ (Credibility and Expectancy Questionnaire); SESE (Self-Efficacy for	Baseline and 3 months.	-

		Exercise Scale); PETS (Problematic Experiences of Therapy Scale).		
Piette et al[d] (15)	Roland Morris Disability Questionnaire (RMDQ).	Pain intensity assessed using the Numeric Rating Scale (NRS); West Haven-Yale Multidimensional Pain Inventory (WHYMPI); Profile of Mood States (POMS); Beck Depression Inventory (BDI); Patient Global Perception of Change scale; Veterans SF-12.	3 and 6 months.	-
Valenzuela et al[d] (23)	Pain intensity 100-mm VAS (visual analogue scale).	Fear Avoidance Beliefs Questionnaire (FABQ); Tampa Scale for Kinesiophobia (TSK); Pain Catastrophizing Scale (PCS); Roland-Morris Questionnaire (RMQ); Health Survey SF-36.	Baseline and 2 weeks.	-

Abbreviations

[a]IVR-CBT: interactive voice response cognitive behavioural therapy

[b]CBT: cognitive behavioural therapy

[c]Difference between RCT and protocol

[d]Protocol of RCT

[e]LBP: low back pain

Table 5. Intervention characteristics.

Study	***Mode of delivery***	***Interactive element***	***Recommended frequency***	***Tailoring***
Chiauzzzi et al (10)	Website	Log of activities and content viewed during sessions.	2 weekly sessions across 4 weeks.	Yes; Matched self-reported patient characteristics to educational content, articles and interactive tools.
Irvine et al (11)	Web app, accessible from Internet and mobile; Gain-framed text and video messages.	10-point "pain dial" and PA[a] self monitoring tool; Journal keeping function; 7- and 30-day graphs of pain.	Unlimited access; weekly reminders to visit app.	Yes; Job-type assessed by Questionnaires.
Carpenter et al (12)	Website; Text and graphic with audio narration; Animation used in educational material.	Reflective and interactive exercises.	Two times/week, across 3 weeks; email reminders.	No
Heapy et al (13) *Heapy et al*[d] (24)	Interactive voice response via telephone.	User reports pain, sleep, step count and pain coping skill practice, engaged in a progressive walking program; User receives personalized feedback.	Daily IVR assessment; weekly feedback.	No
Krein et al (14) *Krein et al*[d] (25)	Website; Graphical and written feedback; Motivational messages; Weekly news updates.	Pedometer data, used to create weekly PA[a] goals and track progress; Targeted messages; Discussion on website based e-community.	Unlimited access with weekly reminders to upload data.	Yes; Gender[b]; Written and graphical information as targeted messages[b].
Buhrman et al (19)	Website	User reports on treatment progress and homework assignments;	Weekly reports on; reminders when reports were not delivered.	No

		User receives feedback and encouragement.		
Riva et al (20)	ONESELF Website	Virtual Gym; Action Plan; Testimonials and Commentaries; Quiz Game.	Unlimited access; weekly reminders to comply with the plan.	Yes; Interactive features were added consecutively week by week.
Weymann et al (16) *Dirmaier et al*[d] (26)	Website	Simulated dialogue between user and system; User-control to navigate site by replying to at least 3 options after each text passage.	Unlimited access.	Yes; Avoidance Endurance Model; Health literacy[b]; Motivational Interviewing; Tunnelled design.
Moessner et al (17)	Internet chat; Software Web-Akquasi	Chat session moderated by a therapist	One session/week.	No
Amorim et al[d] (21)	App accessed via computer or smartphone connected with FitBit[c]	User reports PA[a] levels, pain intensity and disability; User receives encouragement based on PA[a] levels.	Unlimited access.	No
Blodt et al[d] (18)	Smartphone app	Relaxation audio files; Electronic diaries.	5 days/week over a period of 6 months; reminders/notifications to perform the exercises.	Yes; 3 different relaxation techniques; Patient-centred therapy.
Geraghty et al[d] (22)	Website	User selects PA[a] and the system generates activity goals; User can freely navigate the content.	One session/week; weekly reminder emails.	Yes; Extent of pain obstructing daily activities.
Piette et al[d] (15)	AI-CBT[e]	Patients' IVR-reported step counts, skill practice, and pain-related functioning accessed by the AI[f] engine; AI[f] engine recommends treatment step for	Daily assessment; Weekly feddback..	Yes; AI-CBT[e] will learn from experience within and across patients to improve care.

		each patient the next week.		
Valenzuela et al[d] (23)	Website; Video, 2-3D animation.	Content not yet developed.	Unlimited access.	Yes; (content not yet developed).

Abbreviations

[a]PA: physical activity

[b]Information only referred in the protocol

[c]FitBit: physical activity monitoring device

[d]Protocol of RCT

[e]AI-CBT: artificial intelligence cognitive behavioural therapy

[f]AI: artificial intelligence

Risk of BIAS assessment

Results of the nine RCTs are reported in Table 6. One study was rated as high risk of selective reporting as it reported the outcome with highest effect size as a primary outcome (12). One study had a high risk of performance bias, due to unblinded participants (19).

Table 6. Risk of BIAS assessment.

Study	***Selection bias***		***Performance bias***	***Detection bias***	***Attrition bias***	***Reporting bias***	***Other bias***
	Random sequence generation	Allocation concealment	Blinding of participants	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other sources of bias
Chiauzzzi et al (10)	Low	Unclear	Unclear	Low	Low	Unclear	Unclear
Irvine et al (11)	Unclear	Unclear	Unclear	Low	Low	Unclear	Unclear
Carpenter et al (12)	Low	Unclear	Unclear	Low	Low	High	Unclear
Heapy et al (13)	Low	Low	Low	Unclear	Low	Low	Unclear
Krein et al (14)	Low	Low	Low	Low	Low	Low	Low
Buhrman et al (19)	Low	Low	High	Unclear	Low	Low	Unclear
Riva et al (20)	Low	Low	Low	Low	Low	Low	Unclear
Weymann et al (16)	Low	Low	Low	Low	Low	Low	Unclear
Moessner et al (17)	Unclear	Unclear	Unclear	Unclear	Low	Low	Unclear

Discussion

The aim of this review was to provide an overview of the available evidence regarding the integration of mobile health apps and web-based interventions in the self-management of LBP and also to determine if the included studies followed a well-structured and homogenous design. 9 randomized control trials and 8 RCT protocols were identified. The nine completed RCTs included a total of 1659 participants, ranging from 51 to 398 participants per study.

An effective assessment of the impact of mobile health apps and web-based interventions in the self-management of LBP was difficult, since they reported a miscellaneous of outcomes

with different measurement times and did not follow a common design. The majority of the participants were female and had a high level of education, reporting partial college or higher. A lack of long term follow-up was observed. Only 4 studies had a follow up of >6 months (13,14,17,21).

Regarding the effectiveness of the interventions, there was a significant variation in the reported results. While some studies reported no between-group difference at any measurement point, others seem to report improvement in outcomes, such as pain catastrophizing, pain intensity, disability and physical outcomes. Nearly all interventions had an interactive element, either a physical activity monitoring tool, that allowed a goal setting or self-motivation; electronic diaries, removing the limitations of retrospective patients' reports; feedback and CBT based on patients' performance. Most of the apps or web-based interventions were tailored according to each patient characteristics.

Due to the numerous outcomes and heterogenous data from the different studies, it was not possible to conduct a meta-analysis. However, we noticed that in the included protocols of RCTs (15,18,21–23) there was a trend to include physical activity monitoring, electronic diaries and CBT as key components of the interactive intervention. Furthermore, they appeared to have more mutual outcomes, which hopefully will provide less heterogenous data, allowing meta-analysis.

These studies have several limitations. The majority of the participants were female and had a high level of education, which can affect the generalizability and external validity of the results. The lack of long term follow-up is also a limitation due to the chronic condition associated with LBP and, for example, the limited long term effects of regular CBT (27). None of the included RCTs measured possible outcomes for health care utilization, although one protocol defines "care-seeking" as a primary outcome for the future trial (21). This is an

important outcome that should be included in future trials, since low back pain is likely to increase substantially over the coming decades (1), with increasing burden on health services. Exclusion criteria common to all the included studies was the presence of comorbidities, which is also a limitation, because it does not represent the reality of LBP population and can influence the interpretation of the results. In risk of BIAS assessment, two studies had one item rated as high risk of bias, raising doubts about the internal validity of the study (12,19).

This systematic review was conducted according to the PRISMA 2009 guidelines (9) and followed a study selection documented in the PRISMA flow diagram (Fig. 1). On the other hand, the main limitation to this review still is the scarce and heterogenous data available. The search was limited to studies published in English, Portuguese or Spanish. However, we did not exclude any study based on language, therefore it is unlikely a relevant limitation. Unpublished studies and the grey literature were not included in this review.

Although two previous systematic reviews of web-based and digital interventions for LBP were conducted (28,29), the widespread use of health digital technologies and the extraordinary rate of an increasing number of health apps available, justifies the continuous effort to identify what components/interactive elements have an impact on the patients' management of LBP. Furthermore, apps or web-based interventions are accessible, safe and cost-effective and may be the answer to ease the pressure on health systems. Garg et al. (28) suggested that there were likely some benefits to online CBT approaches for reduced catastrophization and that further research was recommended, with longer follow-up and reporting health care utilization. Nicholl et al. (29) expressed that it is clear that the existing evidence has not yet proven the wider utility of digital interventions and suggested that future research should better characterize participants and interventions.

Conclusions

The included studies did not follow a homogenous design, reporting numerous outcomes and heterogenous data that did not allow an effective assessment of the impact of apps and web-based interventions on the self-management of LBP. While the population demographics and lack of long term follow-up affected the generalizability of the included RCTs, the protocols for future trials seem to evaluate more homogenous outcomes and are likely to provide future useful data. Health care utilization should be assessed in future trials, as it is increasingly essential to reduce the burden on health services. Longer follow-up period should be a main concern. Apps and web-based interventions may be a major contributor to the development of a new approach to LBP, overcoming the current barriers and increasing access to a quality, safe and cost-effective rehabilitation for LBP. However, the medical community should be more involved and play an active role on the development and supervision of these apps.

Appendix 1

PubMed search strategy

#68			
	Add	Search **mhealth in back pain** Schema: **all** Sort by: **PublicationDate**	4 11:32:31
#67	Add	Search **mhealth in back pain** Sort by: **PublicationDate**	0 11:32:31
#64	Add	Search **mobile apps AND exercise therapy** Sort by: **PublicationDate**	96 11:32:06
#61	Add	Search **Mobile Applications for Control and Self Management of pain: A Systematic Review** Sort by: **PublicationDate**	2 11:25:13
#60	Add	Search **(free mobile apps) AND exercise for back pain** Schema: **all** Sort by: **PublicationDate**	0 11:24:14
#59	Add	Search **(free mobile apps) AND exercise for back pain** Sort by: **PublicationDate**	0 11:24:14
#58	Add	Search **(free mobile apps) AND chronic low back pain** Schema: **all** Sort by: **PublicationDate**	0 11:23:38
#57	Add	Search **(free mobile apps) AND chronic low back pain** Sort by: **PublicationDate**	0 11:23:38
#56	Add	Search **(free mobile apps) AND exercise** Sort by: **PublicationDate**	26 11:23:14
#55	Add	Search **(apps) AND exercise** Sort by: **PublicationDate**	152 11:22:44
#54	Add	Search **(exercise for chronic low back pain) AND mobile applications**Schema: **all** Sort by: **PublicationDate**	0 11:21:57
#53	Add	Search **(exercise for chronic low back pain) AND mobile applications**Sort by: **PublicationDate**	0 11:21:56
#49	Add	**Related Articles by Review** for **PubMed** (Select **26787469**)	10 11:19:20
#42	Add	**Similar articles** for **PubMed** (Select **26787469**)	200 11:18:31
#30	Add	Search **Driscoll MA[Author]**	19 10:46:22
#29	Add	Search **Driscoll MA[AU]**	19 10:46:22
#27	Add	Search **(chronic low back pain) AND telemedicine**	10 10:45:41
#26	Add	Search **(aaplications mobile integration and exercise on chronic low back pain)** Schema: **all**	0 10:45:12
#25	Add	Search **(aaplications mobile integration and exercise on chronic low back pain)**	0 10:45:12
#24	Add	Search **((chronic low back pain) AND physical exercise) AND mobile applications** Schema: **all**	0 10:43:51
#23	Add	Search **((chronic low back pain) AND physical exercise) AND mobile applications**	0 10:43:50
#22	Add	Search **(((Low Back Pain exercise) AND mobile applications))** Schema: **all**	0 10:43:05
#21	Add	Search **(((Low Back Pain exercise) AND mobile applications))**	0 10:43:04
#20	Add	**Similar articles** for **PubMed** (Select **25511185**)	430 10:42:26
#11	Add	Search **((Low Back Pain therapy) AND mobile applications)**	4 10:34:08
#9	Add	Search **((low back pain) AND exercise) AND mobile applications**	0 10:33:33
#10	Add	Search **((low back pain) AND exercise) AND mobile applications**Schema: **all**	0 10:33:33
#8	Add	Search **low back pain**	31974 10:32:32
#1	Add	Search **(Low Back Pain) AND exercise**	3402 10:32:11
#7	Add	Search **(low back pain) AND mobile applications** Schema: **all** Filters: **Review**	0 10:31:58
#6	Add	Search **(low back pain) AND mobile applications** Filters: **Review**	0 10:31:58
#5	Add	Search **(((Low Back Pain) AND exercise)) AND Mobile Applications**Schema: **all** Filters: **Review**	0 10:31:27
#4	Add	Search **(((Low Back Pain) AND exercise)) AND Mobile Applications**Filters: **Review**	0 10:31:27
#2	Add	Search **(Low Back Pain) AND exercise** Filters: **Review**	560 10:28:13

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