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REVIEW **Open Access**

Effectiveness of smartphone-based applications in low-back pain rehabilitation: a systematic review and meta-analysis

Ishani Tayshete[1], Chris McCarthy[1], Adekola Ademoyegun[2*], Tadesse Gebrye[1], Francis Fatoye[1] and Chidozie Mbada[1]

Abstract

Background Telerehabilitation is an innovative approach used to deliver care to patients with low-back pain (LBP) and overcome barriers to access. This review aimed to summarise the effectiveness of smartphone-based applications on pain, disability, and quality of life (QoL) of patients with LBP.

Methods The Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines and the Physiotherapy Evidence Database (PEDro) were used. Four electronic databases were searched (MEDLINE, Web of Science, Scopus, CINAHL) for eligible randomised control trials employing physiotherapy interventions via smartphone application in patients with LBP published in English from 2015 to January 2025. Data on pain, disability, and QoL were extracted and analysed.

Results The search yielded 1540 studies. After screening for duplicates, titles, and abstracts, 90 met the eligibility criteria for a full review; however, only 15 studies met the criteria for analysis. The data of 4195 adult patients with LBP was extracted from the included studies. Eight studies compared smartphone-based interventions to in-person physiotherapy. Four studies compared to usual medical care. Two studies compared the education control group, and one employed home exercises with an information sheet. There are three studies of poor quality with a high risk of bias, 10 studies of fair quality with a moderate risk of bias, and only two studies of outstanding quality with a low risk of bias. The pooled results of four studies (1606 patients) comparing smartphone-based apps and usual care in reducing pain showed no significant difference between the two groups (standardized mean difference [SMD] = −0.597; 95% CI −1.342 to 0.148; p = 0.116). Similarly, no significant differences were observed between the two groups in reducing disability, when three studies involving 925 patients were pooled (SMD = −0.846; 95% CI −2.071 to 0.379; p = 0.176), and improving QoL (SMD = 1.359; 95% CI −0.798 to 3.516; p = 0.217) when two studies (878 patients) were pooled.

Conclusion This review indicates that smartphone-based application interventions may offer comparable benefits to usual care in reducing pain and disability and improving QoL and serve as a viable alternative to other interventions for patients with LBP.

Keywords Low-back pain, Smartphone apps, Disability, Pain, Quality of life

*Correspondence:
Adekola Ademoyegun
aademoyegun@gmail.com
[1] Department of Health Professions, Manchester Metropolitan University, Manchester, UK
[2] Department of Physiotherapy, Osun State University Teaching Hospital, Osogbo PMB 5000, Nigeria

Introduction

Low-back pain (LBP) is the leading cause of disability globally, affecting about 10% of the world's population [1]. Accordingly, LBP is one of the leading conditions and the most frequent reason patients seek medical attention in primary and emergency care [2]. With varying degrees of impairment, dysfunction, potential aetiologies, chronicity, and definitions, low back pain is a symptom rather than a clinical entity [3, 4]. The sequalae of low back pain are numerous, including a decrease in work productivity, absenteeism, physical deterioration, decline in daily activities and quality of life, and higher medical costs [5–9].

There is a proliferation of interventions to manage individuals with LBP, and the choice of a particular intervention is based on the classification of LBP nature [10]. However, a recent report [1] indicates a paucity of proven effective treatment and continued reliance on low-value health care. Nonetheless, a guideline suggests exercise, psychotherapy, and self-management for LBP [11]. Furthermore, evidence indicates that exercises, pain neuroeducation (PNE), and home exercise benefit patients with LBP [12–14], and implementation of self-management requires a paradigm shift from patients being overly dependent on healthcare providers to active participants in the care delivery [15]. Coupled with the need to have a secure, affordable, simple, and accessible self-management intervention for patients with LBP [16, 17], digital healthcare interventions were introduced [18–20]

During the COVID-19 pandemic, digitally supported rehabilitation rose to continue providing patients with health care [21–24]. Programmes for digital telerehabilitation may be able to address these issues while increasing participation and lowering costs and have produced results that are comparable to those of in-person therapy [25]. Telerehabilitation has evolved into a resource- and money-efficient way to manage LBP [26, 27]. Expectedly, owing to high smartphone penetration worldwide, with a rate of 60.4% in 2024 [28], numerous commercially available applications are now available for healthcare monitoring and administration [29].

Subsequently, scoping reviews and systematic reviews/meta-analyses are populating because of the need to ascertain the feasibility and effectiveness of these applications. A systematic review [16] conducted on digital support interventions for the self-management of LBP, based on randomised controlled trials (RCTs) or RCT protocol studies published between 2000 and 2016, found that the evidence was highly varied. As a result, no definite conclusions regarding the effectiveness of these interventions could be drawn. The included studies in the review lacked details on participants and intervention rationale, making the results hard to interpret and generalise. Only one study favoured digital interventions. Also, the quality assessment revealed varying degrees of bias. As a result, the findings do not provide sufficient information to make a clinical decision on implementing digital interventions for self-management of patients with LBP. Another systematic review and meta-analysis [30] evaluated the effect of mHealth interventions on LBP compared with standard care in terms of pain and disability. The review included studies with varied methodologies, limiting the internal validity of the findings. Additionally, it compared mHealth with usual care, potentially excluding comparisons with other therapies [31].

Also, a recent review [32] included studies that measured the effect of e-health on patients with chronic LBP and compared it with usual care or other therapies. The review encompassed studies with diverse methodologies but excluded those that combined e-health with other interventions. This exclusion meant that some potentially relevant studies were not included in the review. Furthermore, other systematic reviews included heterogeneous patients of varying conditions including patients with low back and neck pain [33] and patients with back pain following spinal surgery [34]. Scala et al. in their review incorporated studies of different designs and patients with mixed diagnoses irrespective of the clinical course [35], and since the review of Didyk et al. [36], other studies have been published [37–43].

There is a need for a more recent review that addresses the shortcomings of earlier studies and analyses new studies that may have been published based on more rigorous methodologies in the evolving field of digital health. Thus, unlike previous reviews, which provided only narrative or qualitative syntheses, the present review not only includes newly published studies but also introduces a meta-analysis for a more robust evaluation of the evidence. This systematic review and meta-analysis aimed to summarize the effectiveness of smartphone-based applications on pain, disability, and quality of life of patients with LBP.

Method

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The search included the following databases: MEDLINE, CINAHL, Scopus, Web of Science, and International Health Technology Assessment Database (IHTAD). All these databases returned yields, except IHTAD. A systematic search was performed by the reviewer using the following search terms: "low back pain" OR "back pain" OR "musculoskeletal pain" AND "smartphone app" OR "mobile phone app" OR "mobile phone" OR "digital health" OR telerehabilitation OR telehealth OR "mobile- web app" OR "digital care" OR "digital health intervention" OR ehealth OR 'clinical software" OR "internet-mediated intervention" OR mhealth. The databases were searched with several combinations of search terms. The search included articles published between the years 2015 and January 2025. Search results were exported to Endnote, and duplicates were removed. The details of the search terms included in each database along with filters, fields, expanders, and restrictions/limiters used are presented in Table 1.

A population, Intervention, Comparison, Outcome, Design (PICO) strategy was used to define the eligibility criteria in this review. Table 2 shows PICO describing the inclusion and exclusion criteria of this systematized review.

Two reviewers (IT and CM) screened the title and abstract of studies according to the eligibility criteria and studies that met the criteria were analysed further. A third reviewer (TG) arbitrated any conflict resulting from the title/abstract screening. Full texts of eligible studies were analysed by the two reviewers. PRISMA flowchart depicts the study selection process in Fig. 1.

Data extraction

The reviewers (IT and CM) extracted data related to the study from each study. Duplicates were electronically removed from results using the Endnotes "Find Duplicates" option. The remaining studies were sought for retrieval. Studies that met the preset PICOS inclusion criteria were eligible for the systematic review. All data was extracted into a word table. These included the first author's name, year, country, sample, participant characteristics (i.e., sex, age, and sample size), outcome measures, study design, intervention details, follow-up duration, and summary of main results.

Data synthesis

The risk of bias in the included studies was assessed using the Physiotherapy Evidence Database (PEDro) scale, which has been designed explicitly for RCTs of physiotherapy interventions [44]. Studies were scored depending on the total score, as "poor," a score of four to five as "fair," a score of six to eight as "good," and a score of nine to ten as "outstanding" [45, 46]. A meta-analysis was conducted and forest plots were created using comprehensive meta-analysis software (Biostat, New Jersey, USA), V.3 for Windows. The standardized mean difference (SMD) with a 95% confidence interval (95% CI)

Table 1 Literature search strategy

Databases	Search terms	Expanders/limiters/filters	No. of yields
MEDLINE	("Low back pain" OR "back pain" OR "musculoskeletal pain") AND ("smartphone app" OR "mobile phone app" OR "mobile phone" OR "digital health" OR telerehabilitation OR telehealth OR "mobile-web app" OR "digital care" OR "digital health intervention" OR ehealth OR "clinical software" OR "internet-mediated intervention" OR mhealth)	Limiters—date of publication: 20150101–20250131; English Language; publication type: randomised controlled trial Search modes—Boolean/Phrase	215
CINAHL	("Low back" OR "back pain" OR "musculoskeletal pain") AND ("smartphone app" OR "mobile phone app" OR "mobile phone" OR "digital health" OR telerehabilitation OR telehealth OR "mobile-web app" OR "digital care" OR "digital health intervention" OR ehealthOR "clinical software" OR "internet-mediated intervention" OR mhealth)	Limiters—published date: 20150101–20250131; English Language; Publication Type: randomised controlled trial Search modes—Boolean/Phrase	65
Web of Science	"Low back" OR "back pain" OR "musculoskeletal pain" (All Fields) and "smartphone app" OR "mobile phone app" OR "mobile phone" OR "digital health" OR telerehabilitation OR telehealth OR "mobile-web app" OR "digital care" OR "digital health intervention" OR ehealth OR "clinical software" OR "internet-mediated intervention" OR mhealth (All Fields)	Document type: Article Language: English Time span: 2015–01-01 to 2025–01–31 (Index Date)	928
Scopus	(TITLE-ABS-KEY ("low back pain""back pain" OR "musculoskeletal pain") AND TITLE-ABS-KEY ("smartphone app" OR "mobile phone app" OR "mobile phone" OR "digital health" OR telerehabilitation OR telehealth OR "mobile-web app" OR "digital care" OR "digital health intervention" OR ehealth OR "clinical software" OR "internet-mediated intervention" OR mhealth))	Document type: Article Keyword limited to: randomised controlled trial Language: English Year range:2015–2025	328
International Health Technology Assessment Database	"low back pain" OR "back pain" OR "musculoskeletal pain" AND "smartphone app" OR "mobile phone app" OR "mobile phone" OR "digital health" OR telerehabilitation OR telehealth OR "mobile- web app" OR "digital care" OR "digital health intervention" OR ehealth OR 'clinical software" OR "internet-mediated intervention" OR mhealth	Publication year: 2015–2025	0

Table 2 Inclusion and exclusion criteria

	Inclusion criteria	Exclusion criteria
Population	• Adult patients with low back pain (≥ 18 years old) • Both males and Females	• Studies involving musculoskeletal conditions other than low back pain
Intervention	• Smartphone-based applications for delivering physiotherapy treatment	• Cross-sectional, qualitative, feasibility, protocol, or pilot studies • Studies not available in full-text • Studies published in languages other than English • Studies mainly delivering interventions other than physiotherapy • Studies not providing adequate information on the smartphone app intervention
Comparator	Usual care, exercises, placebo, education, face-to-face interventions, no treatment	
Outcome	Pain, disability, and quality of life outcome measures	

was estimated to determine the overall effect. The heterogeneity of the included studies was evaluated by tau squared (τ^2). The alpha level was set at $p < 0.05$. Additionally, a sensitivity analysis was performed using the leave-one-out method.

Results

A total of 1540 studies were identified by searching through different databases. These included 215 from MEDLINE (2015–2025), 65 from CINAHL (2015–2025), 328 from Scopus, and 928 from Web of Science (2015–2025). After removing 1222 duplicate records, 318 articles were left, which were screened based on the eligibility criteria. Two hundred twenty-eight were removed after screening the title and abstract of the studies and were further narrowed down to 90 studies. Further, the full text was screened according to the eligibility criteria, of which 63 studies were excluded as the studies employed interventions other than physiotherapy by other health care professionals such as occupational therapy, cognitive therapy delivered by nursing staff, psychotherapy, and pain processing therapy or were qualitative or pilot studies. Five studies were excluded as they focused on patients with widespread chronic pain rather than specifically on LBP. Additionally, four studies based on other conditions that manifested as back pain were also excluded. Two studies, which were based on multiple joints but did not report separate data for patients with LBP, were also excluded. Lastly, a digital intervention study on LBP that did not use a smartphone-based app was excluded from the review. Overall, a total of 15 studies met the criteria and were included in the review.

Descriptive characteristics of studies

A total of 15 studies from 11 countries that met the inclusion criteria were included in this review. Three studies were from Germany [37, 47, 48], two studies from Nigeria [26, 49], two from the Netherlands [38, 50], one from India [51], one from Norway, Denmark [52], one from the USA [53], one from Japan [39], another one was from Turkey [40], one from Finland [41], one from Spain [42], and lastly one from China [43].

The studies were published between 2015 and January 2025. The sample size to measure the effect of smartphone-based support in the included studies ranged from 47 to 1245. The included 7 studies were on non-specific LBP [38, 43, 47, 48, 50, 52, 53]. Five studies were on chronic LBP [39–42, 51]. Two studies were on chronic non-specific LBP [26, 50]. One was on non-specific and degenerative LBP [37]. The follow-up period of these studies ranged from 4 weeks to 12 months. The data of 4195 adult patients with LBP was extracted from 15 included studies. Fourteen out of 15 studies were RCTs while one study [49] had a quasi-experimental design which followed the design of RCT. The details of the studies are presented in Table 3.

PEDro results

The Physiotherapy Evidence Database (PEDro) assessed the quality of the included studies (Table 4). A higher score indicates a methodologically high-quality study, and assessment of the Pedro scale's validity as a tool for quality assessment [54, 55]. The authors state that a score of four is regarded as "poor," a score of four to five as "fair," a score of six to eight as "good," and a score of nine

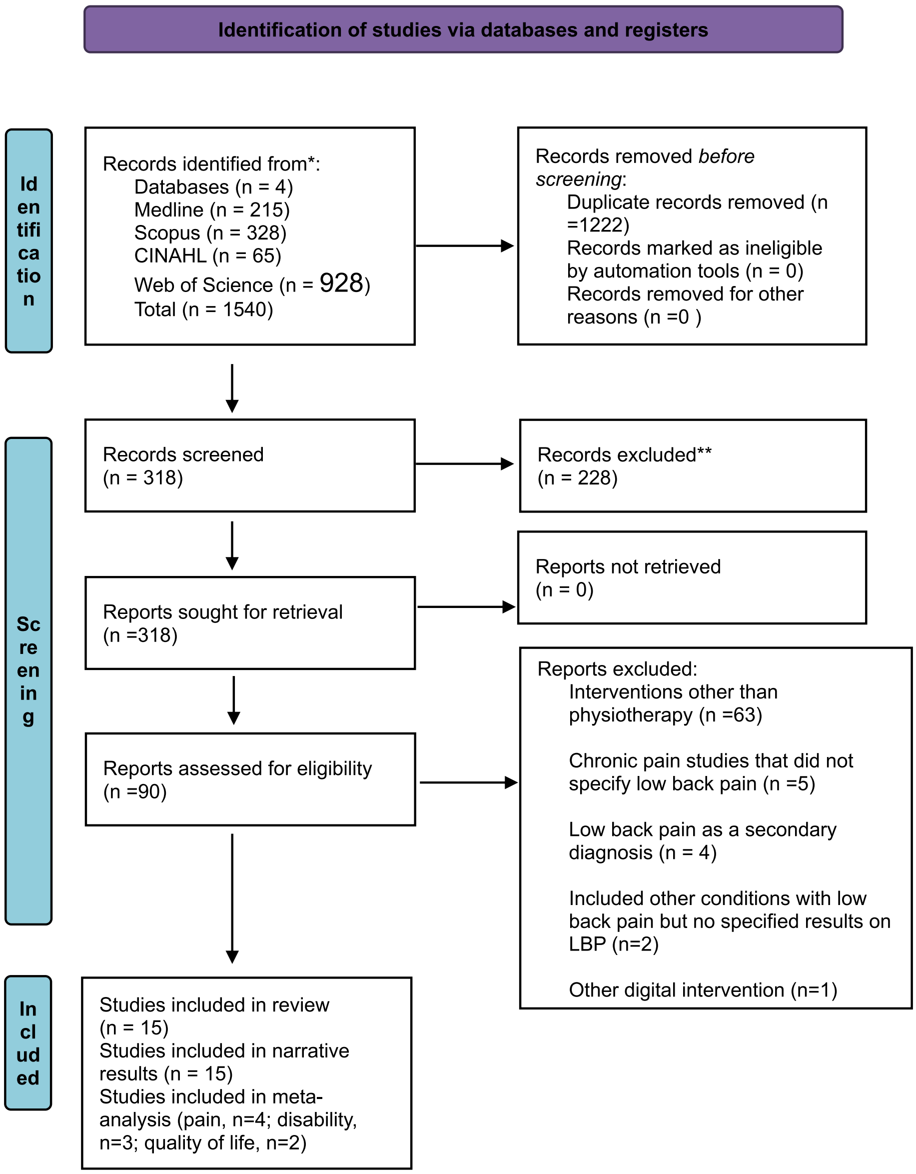

Fig. 1 PRISMA flow chart

to ten as "outstanding" [45, 46]. All included studies specified the eligibility criteria. Also, all studies randomised patients into groups. Despite the eligibility criteria being specific, it can be noted that only six studies had similar patient baseline characteristics [40–43, 47, 52]. 11 studies attempted to conceal the allocation through sealed opaque envelops, using electronic algorithms or computer-generated allocation and by using independent research who is not involved in assessment or treatment of the patients [26, 38, 40–43, 48–52].

Studies were lacking in blinding; only two studies blinded the participants [43, 50], five studies blinded the outcome assessor [26, 40, 42, 50, 51], and there was a lack of blinding therapists employing the interventions in all the studies. Eleven studies reported the outcome measure data of more than 85% of participants whom they allocated [37–43, 50–53]. However, out of the 11 studies, only eight analysed the data and included them in the results [37, 38, 41, 42, 50–53]. All studies reported statistical analysis and between-group differences. Based on the scoring of Pedro, four studies are of poor quality and have a high risk of bias [39, 47–49], and nine studies have fair quality and have a moderate risk of bias [26, 37, 38, 40–42, 51–53], whereas only two studies are of outstanding quality and have a low risk of bias [43, 50].

Table 3 Descriptive characteristics of studies

Study details	Sample characteristics	Measured variables	Intervention	Follow-up	Summary of results
Irvine 2015 [53] Country: USA	Non-specific LBP Sample size = 597 (M = 239, F = 358) Age: **	Physical measures- Back pain, Functionality, Quality of life and well-being, Dartmouth CO-OP Behavioural measures - Prevention-helping behaviours, Worksite measures – work productivity, presenteeism, Other constructs-patient activation measure, theory of planned behaviour construct- knowledge, behavioural intentions, self-efficacy, attitude towards pain, catastrophizing of pain	3-Arm randomised controlled trial TG (n = 199): Unlimited access to videos on pain, pain management, cognitive, behavioural strategies, and instructional videos on strength training and stretching exercises, and ergonomics through FitBack app Alternative care group (n = 199)—received 8 emails with links to 6 websites with information about LBP Usual care group (n = 199): Emails to complete the assessments Over the 8 weeks	8,16 weeks	At 16 weeks, TG outperformed the usual care group in physical, behavioural, and worksite outcome measures and outperformed alternative care in behavioural, current back pain, and worksite outcome measures Significant difference was found in the TG and control group in functionality, quality of life, and well-being (P = 0.001) Additionally, TG was superior to both groups on other construct outcome measures except for catastrophizing of pain did not improve in any between-group comparison, at both points of follow-ups
Chhabra 2018 [51] Country: India	Chronic LBP Sample size = 93 (M =, F =)** Age*: TG: 41.4 (14.2) CG: 41.0 (14.2)	NRPS, MODI, CSS	Single-blinded RCT TG (n = 45): App group: Written prescription of medicine and dosage + Via snap care app- Daily activity goals regarding back and aerobic exercises based on patients' fitness and capability, a set of home exercises, 4 km daily walk in a single stretch, and 2 sets of daily 7 back exercises, encouraged to perform daily activities independently, used game model to engage patients CG (n = 48): Conventional group: written prescription of medicine and dosage from a physician + recommended level of physical activity (home exercises) 12-week intervention	12 weeks	Both groups demonstrated improvements in NRPS and MODI (P < 0.05). TG was superior to CG in improving the MODI score (P < 0.001). Additionally, TG also showed improvement in CSS (P < 0.05)

Table 3 (continued)

Study details	Sample characteristics	Measured variables	Intervention	Follow-up	Summary of results
Mbada 2019 [49] Country: Nigeria	Chronic non-specific LBP Sample size = 47 (M = 13, F = 34) Age*: TG: 50.0 ± 10.7 CG: 47.3 ± 11.6	QVAS, ODI, RMDQ, SF-12 (GHS, HRQoL), BSME	Quasi-Experimental Study TG (n = 21): Telerehabilitation-based McKenzie therapy group Videos on exercises – 1–3 exercises were on graded extension activities in prone lying and exercise 4 is extension activities in standing accompanied with back hygiene instructions via the TBMT app CG: Clinical-based McKenzie therapy (CMBT) group (n = 26) McKenzie extension protocol + back care education Thrice weekly for 8 weeks	4 and 8 weeks	Across the two points of follow-up, within-group analysis showed significant changes by both groups on QVAS (P = 0.001), BSME (P = 0.001), RMDQ (P = 0.001), ODI (P = 0.001), and GHS (P = 0.001), respectively In the 4 th week, between groups analysis revealed no significant differences (P > 0.05) In the 8 th week, there were no significant differences between the two groups'treatment outcomes (mean changes) except for the SF-12 item "vitality," where the TG had a significantly higher mean change (P = 0.011)
Toelle 2019 [47] Country: Germany	Nonspecific LBP Sample size = 94 (M = 28, F = 66) Age*: TG: 41 (10.6) CG: 43 (11.0)	NRS (11-point) German version of HFAQ, GCPS, VR-12, MQS, Kaia App Activity	Randomised controlled trial TG: Kaia App Group (n = 48) Back pain education, physiotherapy/physical exercises, mindfulness, and relaxation techniques were administered via the Kaia App Additionally, websites for patient education regarding LBP and management along with motivating messages were sent via email (for 3 months) CG (n = 46): Six individual face-to-face physiotherapy session-tailored exercises and manual therapy. Additionally, websites for patient education regarding LBP and management along with motivating messages were sent via email (for 6 weeks)	6 and 12 weeks	At 12 weeks, TG (M = 2.70 (SD = 1.51)) showed a significantly lower pain intensity score on NRS compared to the control group, M = 3.40 (SD = 1.63). No significant between group differences were noted in pain and other outcome measures
Suman 2019 [50] Country: Netherland	Nonspecific LBP Sample size = 779 (M = 339, F = 440) Age*: TG- 55.7 (13.9) CG- 56.6 (14.6)	BBQ, RDQ-24, EQ-5D-3L, PRDOISQ	Cluster randomised controlled trial TG (n = 331): Interventional group-multifaceted eHealth strategy – informative website providing self-management advice provided LBP exercise tips, video messages through a mobile app, digital monthly newsletters, and social media platform forums through which communication with healthcare providers, researchers, and other patients Control group (n = 448)- digital patient information letter	3,6, and 12 months	No significant between-group differences were noted in outcome measures

Table 3 (continued)

Study details	Sample characteristics	Measured variables	Intervention	Follow-up	Summary of results
Priebe 2020 [48] Country: Germany	Nonspecific LBP Sample size = 1245 Age*: TG: 42.0 (12.4) (M = 35%, F = 65%) CG: 37.0 (12.6) (M = 36%, F = 64%)	NRS, Depression-Anxiety-Stress-Scale, Hannover Functional Ability Questionnaire, VR-12, GCPS	Cluster-randomised controlled trial TG (n = 933): Rise-uP algorithm- classifying patients based on the risk of developing back pain, access to the Kaia app and teleconsultation depends on the level of risk of LBP CG (n = 312): Standard care with consideration to "National guideline for the treatment of non-specific back pain"	3 months	At 3 months, TG showed a significantly stronger decrease in NRS compared to CG (P < 0.001). Except for the anxiety-stress scale, the remaining outcome measures showed a statistically significant differences between groups (P < 0.001)
Fatoye 2020 [26] Country: Nigeria	Non-specific chronic LBP Sample = 47 Age*: TG- 47.3 (11.6) CG- 50.0 (10.7)	ODI	Randomised controlled trial TG (n = 21): Telerehabilitation-based McKenzie therapy (TBMT) group: McKenzie extension protocol and back care education via TBMT smartphone video app CG (n = 26): Clinical-based McKenzie therapy (CMBT) group: McKenzie extension protocol in different positions with movement 10 times repeated	4, 8 weeks	Both groups demonstrated significant improvement at the 4 th and 8 th week in within-group analysis (P < 0.001). However, no significant difference was found between group analyses (P > 0.05)
Sandal 2021 [52] Country: Denmark, Norway	Nonspecific low back pain Sample size = 461 (M = 206, F = 255) Age*: TG: 48.3 (15.0) CG: 46.7 (14.4)	Primary outcome measures: RMDQ, Secondary outcome measures: NRS (average and worst pain intensity) Pain Self-Efficacy Questionnaire, Fear-Avoidance Beliefs Questionnaire physical activity subscale, Brief Illness Perception Questionnaire, EuroQol-5 Dimension questionnaire, EuroQol visual analog scale, Saltin-Grimby Physical Activity Level Scale, Global Perceived Effect scale	Randomised controlled trial TG (n = 232): Weekly physical activity goals, strength and flexibility exercises, and daily educational messages via the SELFBACK app + usual care CG (n = 229): Usual care- Instructed to manage their lower back pain by following the advice and the treatment suggested by their clinician	6 weeks, 3, 6, and 9 months	At 3 months, RMDQ scores in the TG group −0.79 (95% CI, −1.51 to −0.06; P = 0.03) lowered compared to the control group, and this effect was sustained till 9 months In secondary outcome measures, between-group differences at 3 months revealed that TG favoured over CG in other outcome measures (P ≤ 0.001), except for Fear-Avoidance Beliefs Questionnaire, physical activity, EuroQol-5 Dimension questionnaire had no significant differences at both points of follow-up. The differences were sustained at 9 months

Table 3 (continued)

Study details	Sample characteristics	Measured variables	Intervention	Follow-up	Summary of results
Weise 2022 [37] Country: Germany	Unspecific or degenerative pain of the lower back Sample size = 213 (M = 100, F = 113) Age*: TG: 57.4 (13.8) CG: 57.3 (13.5)	VNRS	Pragmatic, randomised controlled trial TG (n = 108): Interventional group—ViViRA app-4 exercises per day for 12 weeks Additionally, audio and video demonstrations of exercises and progression are done by an algorithm (3 days x week) CG (n = 105): Exercises lasting 15–25 min given by a physiotherapist over 6–12 sessions	2, 6, and 12 weeks	Between-group differences, pain scores significantly improved in TG in 2nd, 6th, and 12 th week (P < 0.01) At 12 weeks, there was an average difference in pain scores between the two groups of − 2.44 (95% CI 2.92 to 1.95; P < 0.01) in favour of the TG
Koppenaal 2022 [38] Country: Netherland	Nonspecific LBP Sample size = 208 (M = 106, F = 102) Age*: TG: 48.10 (15.08) CG: 47.26 (13.58)	Primary outcome measures: ODI Secondary outcome measures: NRS (11-point), Activ8, Fear-Avoidance beliefs Questionnaire, Pain Catastrophizing scale, General self-efficacy scale, short form patient activation measure, EuroQo1-5D-5L, Exercise Adherence Rating scale	Prospective multicentre cluster randomised controlled trial TG (n = 104): Stratified blended physiotherapy (E-exercise LBP app)- self-management informative videos, videos of exercises, and goal-oriented physical activity modules via smartphone app CG (n = 104): Face-to-face physiotherapy group-information about LBP, self-management guidance, importance of adequate physical activity behaviour, Evidence-based interventions such as mobilizations, Cognitive behavioural approach, Treatment according to the recommendations of the LBP guidelines of the Royal Dutch Society of Physiotherapy Content and progression and duration (3–12 weeks) of the treatment were tailored ACCORDING to patients' risk for developing persistent back pain determined by Keele STarT Back Screening Tool	3 months	Both groups improved across ODI but no significant between group difference was noted. However, TG demonstrated statistically significant between-group differences in fear-avoidance beliefs Questionnaire (P < 0.001) and Exercise Adherence Rating scale (P = 0.03) for the secondary outcomes Additionally, in patients with high risk of LBP, TG demonstrated statistically significant between group difference across ODI (P = 0.01), and NRS (P = 0.03) fear-avoidance beliefs Questionnaire (P = 0.04)

Table 3 (continued)

Study details	Sample characteristics	Measured variables	Intervention	Follow-up	Summary of results
Özden 2022 [40] Country: Turkey	Chronic LBP Sample = 50 (M = 20, F = 30) Age*: TG- 40.1 ± 1.6 CG- 42.3 ± 1.6	TUG, FTST, VAS, ODI, SF-36, TSK, EARS	Two-armed randomised controlled trial TG (n = 25): Video-based telerehabilitation-exercise program through Fizyoweb software through which online activity monitoring along with a messaging platform to communicate with therapists CG (n = 25): Exercise sheet with description and images of exercises Exercise program for both groups: lumbar and LE stretching exercises, strengthening exercises of abdominal muscles, lumbar muscles, bridging, spine mobility, and McKenzie's extension, William flexion exercises Once a day × 8 weeks	8 weeks	At 8 weeks, TG showed significant improvements across all the outcome measures (P < 0.05). Also, TG was superior to CG across all outcome measures (P < 0.05)
Itoh 2022 [39] Country: Japan	Chronic LBP Sample: 99 (M = 55, F = 44) Age*: TG- 47.9 (10.2) CG- 46.9 (12.3)	QQ Method, WPAI-GH, NRS, RDQ-24, EQ-5D-5L, TSK-11, K-6	Randomised, parallel-group study TG (n = 48): Exercise group- Artificial intelligence-assisted chat bot sent exercise instructions and daily activity modification tips through the LINE app, Seacaide- a mobile messaging app was used for communication and provided evidence-based CBT approach information, a guide of exercises and Pharmacotherapy CG (n = 51): Routine medical care and pharmacotherapy 12 weeks	12 th week	TG showed significant improvement (mean differences) compared to CG in NRS (P = 0.04), EQ-5D-5L (P = 0.03), and TSK-11 (P = 0.04). No significant differences were found in other measures
Villatoro-Luque 2023 [42] Country: Spain	Chronic LBP Sample size = 68 (M = 34, F = 34) Age*: TG: 41.85 (10.37) CG: 44.29 (11.19)	Pain in movements of the lumbar spine Pain and ROM in: rocking backward test, knee extended test, double SLR The Tampa Scale of Kinesiophobia	Single-blind, two-armed randomised controlled trial TG: TLRH Group (n = 34): six weekly instructional exercise program videos via WhatsApp videoconference Control group (n = 34): Face-to-face guidance with each of the six exercises (2 weekly sessions over 8 weeks)	8 weeks, 12 weeks (only TSK)	In the knee extended test, statistically significant differences for the time-by-group interaction were found in the knee extension test- the ROM of the right (P = 0.001) and left (P = 0.042) legs and pain (P = 0.043) Additionally, compared to CG, TG demonstrated a statistically significant improvement in kinesiophobia with a medium Effect size (d = 0.509)

Table 3 (continued)

Study details	Sample characteristics	Measured variables	Intervention	Follow-up	Summary of results
Cui 2023 [41] Country: Finland	Chronic LBP Sample = 140 (*M* = 45, *F* = 95) Age*: TG- 50.50 (22.00) CG- 54.50 (20.00)	ODI, NRPS, intention to undergo surgery, analgesics Consumption, FAB questionnaire GAD-7, IPAQ, WPAI, Engagement, Patient Satisfaction	Parallel-group, randomised controlled study TG ($n = 70$): Digital intervention group- a tailored exercise and CBT program. The exercise supports through audio–video cues through tracker straps around the thoracic and lumbar regions. Education program through a smartphone app consisted of articles on anatomy, pain, exercise, physiology, and fear-avoidance behaviour (3 sessions per week for 8 weeks) CG ($n = 70$)- evidence-based face-to-face physiotherapy sessions consisted of mobility and strengthening exercises, stretching education, manual therapy and modalities (2 sessions per week for 8 weeks)	8 weeks	Both groups demonstrated significant improvement in ODI score ($P < 0.001$), NRPS ($P < 0.001$), and other outcome measures but no significant between group difference was noted in any outcome measures
Shi 2024 [43] Country: China	Nonspecific LBP Sample = 54 (*M* = 21, *F* = 32) Age*: TG- 39.11 (10.45) CG- 38.23 (11.55)	Primary outcomes: ODI Secondary outcomes: NPRS, FABQ, SF-36	Randomised, parallel-group study TG ($n = 27$): The app was designed based on a user-centered theory to provide patients with a platform for self-management interventions. Upon initiation of the exercise, the patients were to follow the instructions provided in the video to complete each action in the regimen. (3 sessions per week for 8 weeks) CG ($n = 27$): Face-to-face exercise intervention (3 sessions per week for 8 weeks)	8 weeks	Both groups demonstrated significant improvement in ODI, NPRS, FABQ, and SF-36 scores ($P < 0.05$). However, there were no significant differences in all the outcome measures between the two groups

M males, *F* females, *Age** given in mean (SD), ** not given, *TG* treatment group, *CG* control group, *NRPS* numerical rating pain scale, *MODI* Modified Oswestry Disability Index, *CSS* Current Symptom Score, *QVAS* Quadruple Visual Analogue Scale, *RMDQ* Roland Morris Disability Questionnaire, *SF-12* short form survey, *GHS* general health status, *HRQoL* health-related quality of life, *BSME* Biering-Sørensen Test of Static Muscular Endurance, *NRS* numerical rating scale, *HFAQ* Hanover Functional Ability Questionnaire, *GCPS* Graded Chronic Pain Scale, *VR-12* Veterans RAND 12-Item Health Survey, *MQS* Concomitant Pain Medication Questionnaire, *BBQ* Back Beliefs Questionnaire, *ODI* Oswestry Disability Index, *PRDOISQ* Productivity and Disease Questionnaire, *VNRS* verbal numerical rating scale, *TUG* Timed Up and Go, *FTST* five times sit to stand test, *VAS* visual analogue scale, *SF-36* short form suvery-36, *TSK-11* Tampa Scale for Kinesiophobia, *EARS* Exercise Adherence Rating Scale, *QQ method* quantity and quality method, *WPAI-GH* Work Productivity and Activity Impairment Questionnaire: General Health, RDQ-24–24-item Roland-Morris Disability, *K6* Kessler Screening Scale for Psychological Distress, *ROM* range of motion, *SLR* straight leg raise, *FAB* Fear Avoidance Belief Questionnaire, *GAD-7* Generalized Anxiety Disorder, *IPAQ* International physical Activity Questionnaire, *WPAI* Work Productivity and Activity Impairment Questionnaire

Table 4 Quality assessment for the included studies

Pedro Scale Domains	Item 1	Item2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total
Irvine [53]	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	6/11
Chhabra [51]	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	8/11
Mbada [49]	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes	5/11
Toelle [47]	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	5/11
Suman [50]	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	9/11
Priebe [48]	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes	5/11
Fatoye [26]	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes	Yes	6/11
Sandal [52]	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	8/11
Weise [37]	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	6/11
Koppenaal [38]	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	7/11
Özden [40]	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	8/11
Itoh [39]	Yes	Yes	No	No	No	No	No	Yes	No	Yes	Yes	5/11
Villatoro-Luque [42]	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	8/11
Cui [41]	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	8/11
Shi 2024 [43]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	9/11

The summary of the results of the included study is described in Table 3. Fourteen RCTs and one quasi-experimental study [49] employed smartphone app intervention in physiotherapy rehabilitation of low back pain. Eight studies compared smartphone-based intervention to the face-to-face physiotherapy control group [26, 37, 38, 41–43, 47, 49]. Four studies compared to the usual medical care [39, 48, 51, 52]. Two studies compared the education control group [41, 50], and one employed home exercises with an information sheet [40].

Pain

A total of 13 studies reported pain outcome measures [37–43, 47–49, 51–53]. The clinical outcomes measured were pain on lumbar movements and special test [42], NRS [38, 39, 48, 52], NRPS [41, 43, 51], current back pain [53], pain self-efficacy questionnaire [52], QVAS [49], VNRS [37], and VAS [40]. All these studies found that smartphone-based support improved the pain in patients with LBP. Seven studies had face-to-face (in-person) physiotherapy in the control group [37, 38, 41–43, 47, 49], four studies had usual care as the control group [39, 48, 51, 52], one study had an educational approach [53], and one study had home exercises sheet in the comparator group [40].

Seven studies found that the app group was superior to the control group in managing pain in LBP patients [37–40, 48, 52, 53]. One study found that the app group reduced the pain intensity score but found no between-group difference [47]. Four studies [41, 43, 49, 51] found that pain improved in both groups, but there were no superior groups across pain outcome measures. One study found that exercise through telerehabilitation reduced pain during the knee extension test ($p = 0.043$) immediately after the 8-week intervention [42].

Four studies [38, 39, 43, 48] involving 1606 patients employed similar pain rating scales (NRS or NRPS), and follow-up periods were included in the meta-analysis. The results showed that smartphone-based apps did not significantly reduce pain in patients with chronic LBP (SMD = − 0.597; 95% CI −1.342 to 0.148; $p = 0.116$; $\tau^2 = 0.000$; p-heterogeneity = 0.116) (Fig. 2). A sensitive test (leave-one-out analysis) showed that the removal of Itoh et al. [39] did not substantially change the results (SMD = − 0.076; 95% CI −0.395 to 0.243; $p = 0.639$; $\tau^2 = 0.000$; p-heterogeneity = 0.639) (Supplementary figure).

Disability

A total of 13 studies employed disability-related outcome measures [37–43, 47–49, 51–53]. These studies used the Tampa Scale of Kinesiophobia [39, 41, 42], Graded Chronic Pain Scale [47], Roland Morris Disability Questionnaires [39, 40, 49, 50, 52], Pain self-efficacy questionnaire [52], fear-avoidance beliefs questionnaire [41, 52], Oswestry Disability Index [26, 38, 40, 43, 49], Modified Oswestry Disability Index [51], Hannover Functional Ability Questionnaire [48], Back Beliefs Questionnaire [50].

Five studies noted that there was a significant improvement in within-group analyses with p-value ($p \leq 0.001$), but no superior group emerged during the between-group analyses [26, 41, 43, 47, 49]. One study found that e-health intervention was ineffective in improving disability in low back pain patients [50]. One study observed that telerehabilitation improves kinesiophobia with a medium effect size ($d = 0.509$) [42]. Similarly, another

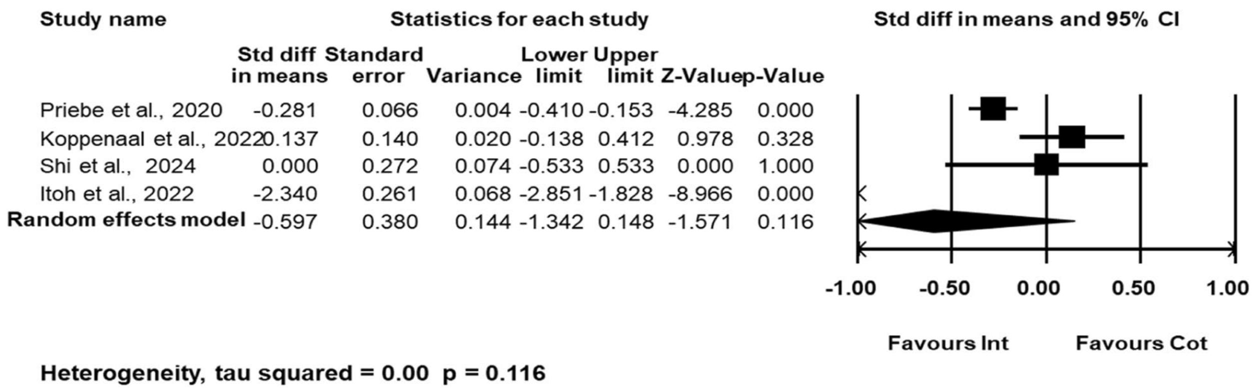

Fig. 2 Forest plot for the effect of smartphone-based applications on pain outcomes in low-back pain patients

study found that the app group showed significant improvement in kinesiophobia ($p = 0.04$) but did not find the superior group in other disability-related outcome measures (RDQ-24) [39]. One study demonstrated that app delivered home exercise program along with medications compared to usual care is effective ($p < 0.001$) [51], while another study demonstrated that telerehabilitation accompanied by therapist communication is more effective in improving disability, compared to only exercise sheet ($p < 0.05$) [40].

One study compared the app groups with the usual care group that employed more than one disability-related outcome measure and found different results across the outcome measures [52]. The study found the app group superior across the RMDQ ($p = 0.003$) and pain self-efficacy questionnaire ($p = 0.001$), but there was no significant difference in the Fear-avoidance beliefs questionnaire. Conversely, one study noted that the app group outperformed the usual care group in disability-related outcome measures ($p < 0.001$) [48]. Another study compared the app group with face-to-face physiotherapy sessions and found no superior group across ODI, but the app group was superior in the fear avoidance belief questionnaire (< 0.001). The same study reported that, in patients with a high risk of developing persistent pain, the app group was noted as superior in the ODI ($p = 0.01$) and fear avoidance belief questionnaire ($p = 0.04$) [38].

Three studies [39, 49, 50] with 925 patients utilized Roland Morris Disability Questionnaires and had measures of variability were included in the meta-analysis. The meta-analysis showed that the included studies were homogenous but revealed that smartphone-based apps did not significantly reduce disability among patients with LBP (SMD = − 0.846; 95% CI −2.071 to 0.379; $p = 0.176$; $\tau^2 = 0.000$; $p = 0.176$) (Fig. 3). However, sensitive analysis of two studies [49, 50] (826 patients) showed a significant effect of smartphone-based apps on disability (SMD = − 0.141; 95% CI −0.279 to −0.003; $p = 0.045$) with a small heterogeneity ($\tau^2 = 0.000$; $p = 0.045$) (Supplementary figure).

Quality of life

A total of 12 studies employed quality-of-life measures [38–41, 43, 47–53]. These studies used Veterans RAND 12-item Health Survey (VR-12) [47, 48], Functionality, Quality of life and well-being [53], Dartmouth CO-OP [53], work productivity [53], presenteeism [53], EQ-5D-3L [38, 39, 50], EuroQol-5 Dimension questionnaire

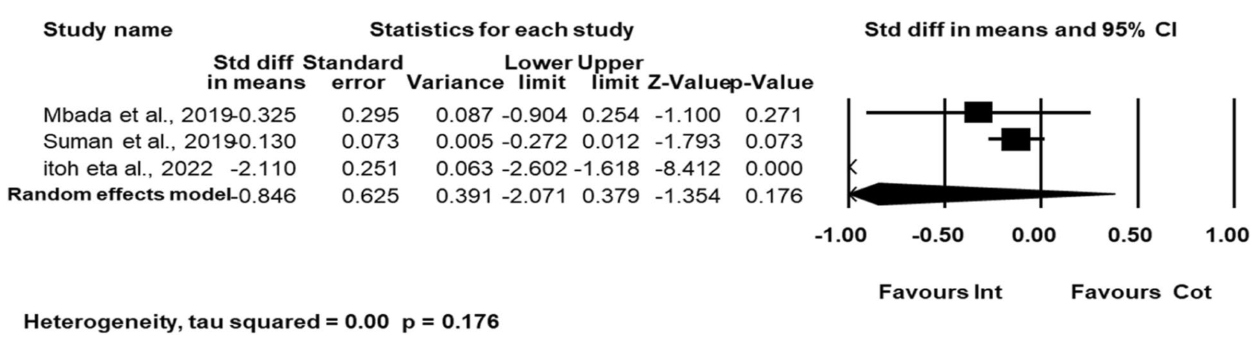

Fig. 3 Forest plot for the effect of smartphone-based applications on disability (Roland Morris Disability) outcomes in low-back pain patients

[52], EuroQol visual analogue scale [52], SF-12 (GHS, HRQoL) [49], Current Symptom Score (CSS) [51], SF-36 [40, 43], GAD-7 [41], WPAI [41], and WPAI-GH [39].

Four studies found that intervention groups significantly improved patients' quality of life ($P < 0.05$) [39, 40, 48, 51]. One study noted telerehabilitation-based McKenzie group improved the vitality domain of the SF-12 ($P = 0.001$), while no superior group emerged in the general health status domain of the same scale [49]. Three studies that used app-based exercises compared to face-to-face physiotherapy intervention found no superior group across quality-of-life measures [41, 43, 47]. Similar results were found in a study that compared the e-health strategy to the control group [50]. Two studies found no significant difference in between-group analysis across quality-of-life measures [38, 52]. One study compared app-based intervention with two groups (alternative care and control), and the app group showed a significant improvement in only one of the quality of life measures when compared to the control group ($P < 0.005$) at both points of follow-up [53].

Only 2 studies [39, 50] using EQ-5D-3L to assess QoL and had measures of variability were included in the meta-analysis. The pooled results of 878 patients with LBP showed no significant difference in QoL between smartphone-based apps and usual care interventions (SMD = 1.359; 95% CI −0.798 to 3.516; $p = 0.217$) (Fig. 4). The results showed that the pooled studies were homogenous ($\tau^2 = 0.000$; $p = 0.217$).

Discussion

This systematic review and meta-analysis aimed to investigate the effectiveness of smartphone app-delivered rehabilitation in improving pain, diminishing disability, and enhancing quality of life in patients with LBP. Based on the findings from the included studies, this review suggests that smartphone apps could be effective in physiotherapy rehabilitation in patients with LBP. Our meta-analysis, based on a limited number of studies, found that smartphone app-based interventions did not significantly reduce pain (1606 patients), disability (925 patients), and quality of life (878 patients) in individuals with LBP compared to usual care, suggesting that digital interventions may offer similar benefits to usual care in these domains. Previously, one systematic review attempted to measure the effect of mobile health applications and concluded that mHealth in combination with usual care is better than usual care alone in managing pain and disability in patients with LBP [30]. Also, emphasized the importance of telephone calls and feedback intervention may improve the positive effects. Similar findings were noted in this review. Video-based telerehabilitation, along with means of communication with clinicians, found improvements in disability in patients [40, 42].

The increase in mobile device penetration has led to growth in the development of medical software applications for communications and consulting, disease assessment, and information gathering; clinical diagnosis or decision-making; and management and monitoring of patients [56]. The benefits obtained or ascribed to these applications may be a result of patients' empowerment resulting from having an active role in their health care that these applications provide [57]. In maximizing these applications based on the prescriptions of clinicians, there is the chance of having improved patient outcomes [58]. A qualitative study [59] explored the experience of patients with LBP with internet-based intervention, and one of the themes that emerged was "feeling supported by physiotherapists," which was through the addition of telecommunication along with digital intervention and was described as motivating and encouraging. Similarly, one study [48] found that patients who received teleconsultation and app intervention showed a significant decrease in pain compared to guidelines-led standard care. However, it is important to note the limitations of the study that impact the results, such as there was a lack of blinding between patients, therapists, and assessors which may have led to bias [60]. A comparison of

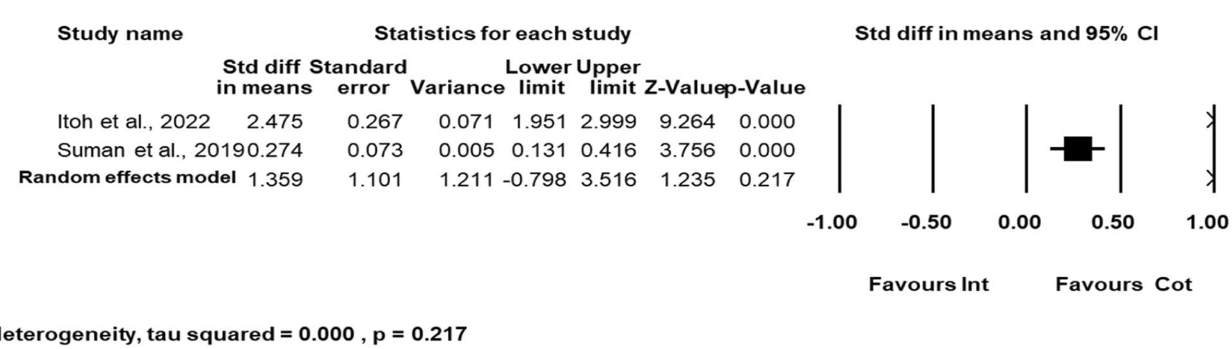

Fig. 4 Forest plot for the effect of smartphone-based applications on health-related quality of life outcomes in low-back pain patients

clinician-prescribed and non-prescribed (commercially available) mobile applications may help prove these assertions.

On the contrary, two studies administered telerehabilitation-based McKenzie therapy through smartphone apps but with no specific communication with therapist option, and one found significant differences in only one domain of the quality-of-life measure [49], whereas another study [26], found no superior group across the disability measure. This could be due to the significant difference in baseline characteristics in both studies. Both studies had differences in BMI between the two groups and may have an impact on fatigue/vitality, due to which the difference was only in that domain of quality of life but not in other domains. Another study [26] showed significant differences in both groups' age range and pain duration, due to which the baseline disability between the groups differed, and the impact of intervention might have differed for participants and reflected in the results. Also, the sample size was relatively small ($n=$ 46), which may have skewed the results further. The study had undertaken only 4 and 8 weeks of follow-up, which may not be enough to observe the intervention's effect.

In this review, PEDro was employed to measure the quality assessment. According to the quality assessment, most of the included studies revealed a high [39, 47–49] to moderate risk of bias [26, 37, 38, 40–42, 51–53] whereas only two were found to have a low risk of bias [43, 50]. The findings are similar to a recent systematic review [32–34, 36] that measured the effect of eHealth on patients with chronic LBP and found moderate quality evidence that e-health interventions that emphasise self-maintenance and education can improve back-specific functional status and pain in patients with chronic LBP just as much as other in-person or home-based interventions. Several other reviews [16, 30, 61] found similar findings in terms of evidence quality, which suggests that in general, the literature on digital support in LBP rehabilitation lacks high-quality evidence.

It is also essential to emphasize that in this review, there is significant heterogeneity among the included studies regarding apps used for the intervention, control group interventions, duration of the administered intervention, follow-up duration, and the outcome measures employed. Despite all studies administering interventions via smartphone applications, the user elements of the app exhibited differences across the studies. Additionally, each app intervention had its unique framework, exercise program, educational material, tracking options, prompting mechanism, and motivating components. Several variations among the interventions were noted; choosing the best application or treatment program is difficult. However, it was evident that post-intervention benefits were noted in the app interventions that were tailored to each patient's specific conditions and needs, provided flexibility, and featured interactive user interfaces [37, 40, 42, 43, 52, 53]. On the contrary, one study [50] that employed app intervention that lacked a structure and despite providing the communication tools did not show any significant results. Additionally, the control group of the study had more participants in general compared to the intervention group and had patients doing more physical work and higher absenteeism, which suggests that there seems to be more disability in the control group and may have skewed the results.

Some studies that compared app group intervention with face-to-face intervention found that both interventions effectively improve pain, disability, and quality of life in low back pain patients. One study [47] did not find a statistically significant difference between the groups across pain, disability, and quality of life outcome measures, but the mean difference was noted after 12 weeks in pain outcome measure; the potential reason for that could be that the study was underpowered. The study calculated more than 200 patients per group per protocol analysis but had only included 101 in total, which might not be enough to see the difference in the results. Similarly, a study [41] compared face-to-face intervention to self-tailored app intervention and found significant within-group differences but no group differences in pain and disability measures. The study follow-up was 8 weeks only, which may be insufficient to measure the effect completely. Additionally, it was conducted during the pandemic, which may have impacted exercise adherence and motivation and, hence, the results. On the contrary, in another study, the app group significantly improved pain compared to face-to-face interventions with significant statistical differences [37]; the main difference between the two groups was the number of sessions administered. The app group received 12 weeks of intervention, while the control group received between 6 and 12 weeks, which may impact pain intensity. Also, the exercises were progressed by an algorithm according to the feedback given by the patients in the app group. Additionally, the follow-up was taken through different means; for the app group, it was accessed through the app while the control group follow-up was done through interviews and there was a lack of blinding in the study. All these factors may have influenced the results. Another study [36] compared stratified blended physiotherapy via app to face-to-face physiotherapy intervention and found disability improved in both groups and in some measures, the app group showed a statistically significant difference. The study employed multiple outcome measures and the majority of them were patient-reported outcomes, which may have different domains and parametric properties due to which there could be differences in results. Another aspect is the lack of blinding in the study as it might have caused bias in the results [62]. Also, 3 months follow-up may be insufficient to measure the long-term effects. All these factors may have impacted the results.

Two studies compared app group intervention with pharmacotherapy [39, 51]. While both studies employed different outcome measures having different constructs, one study developed some of the quality of life measures specifically for the study [51], which may have different parametric properties compared to the original version and may not have fully captured the effect of the interventions and further, may have overestimated the results. Additionally, both groups did not have similar baseline characteristics. The dosage and type of medicine itself may influence patients' symptoms, which is not discussed in detail about the results and may have affected the findings of the study. Overall, app group intervention seems to be superior to pharmacotherapy and improves pain, disability, and quality of life in LBP patients.

This review also noted that except for one [50], all studies could not determine the interventions' long-term effects or adverse effects. Studies that compared app intervention to face-to-face physiotherapy had follow-up periods between 2 and 12 weeks. A similar range of follow-up was seen in studies of the usual care and education approach as a control group. Only one study had 12 months of follow-up [50]. While all studies employed appropriate outcome measures, heterogenicity was observed in selecting the outcome measures across the studies. Due to the differences in the parametric properties of the measures, the reporting of the results might have differed. A study [63] measured the psychometric properties of fear avoidance measures and found that commonly used measures may be reliable but suggested using a pain catastrophizing scale and fear avoidance belief questionnaire together due to different construct redundancy. This could be the potential reason for differences in the results found in one of the studies [36]. Additionally, across the studies, only a few mentioned the repetition of exercises [26, 49], which could pose a problem when applying these interventions in clinical practice.

Some of the included studies are conducted at different places [48, 50, 52], and a few studies adopted a multi-centre design [38, 39], which may increase the generalizability of the results of these studies. However, most studies included patients who were familiar with technology and could access the app independently [26, 37–39, 41, 43, 47, 48, 51–53] which may reduce the potential participant pool. Except for two studies out of 15 [37, 41], all studies have slightly younger age groups. It suggests that smartphone apps may not be feasible for those unfamiliar with or unable to operate technology. While the inclusion criteria of the studies are similar, only six studies had similar patient baseline characteristics [40–43, 47, 52]. There were differences in baseline pain intensity, duration of the back pain, age groups, and number of participants in the group. Also, one study failed to report the age group of the included participants [53], while another study [51] did not report the gender distribution among the included patients. All these factors affect the generalizability of the results.

Few of the included studies monitored adherence and follow-up through app activity data [40, 43, 48, 51], while few did it through calls, emails, or interviews [38, 40, 49, 50, 52, 64]. Also, only a few have mentioned the reasons behind the dropouts, but all studies have reported the number of dropouts. The number of dropouts differed across all the studies. In general, app tracking or activity for adherence seems to be a better option when considering feasibility in clinical practice. A recent systematic review [65] found that incorporating mobile application-based therapy interventions into clinical practice can enhance therapeutic adherence which is an important factor to consider for clinical application. Similar findings were found in one study [41]. The presentation of results was appropriate in all the included studies and was easy to interpret. However, few studies could have provided more information about the protocol [36, 38]. Also, the sample size was calculated in all studies except for one [53], and seven of the included studies did not analyse all the patients they allocated in the group [26, 40, 41, 43, 49, 50, 52], which may have affected the results [66, 67].

In general, smartphone app interventions seem to be equally effective as other face-to-face interventions in improving pain, disability, and quality of life which may be superior to usual or educational care. Several methodological limitations and strengths were found in the studies. All studies defined the eligibility criteria which may ensure that suitable patients were included in the study and may have strengthened the generalizability [68]. All studies randomised the participants which may have reduced the potential bias arising [69]. Only two studies blinded the participants [43, 50], lack of blinding between participants in other studies may have led to bias and further impacted the results. Additionally, the allocation was not concealed in some studies [37, 39, 47, 53], which may have been affected by selection bias [70]. Hence, the results should be considered with these limitations in mind. Lastly, limited studies measured the effect on quality of life in patients with LBP [38–41, 47–53]; future research studies should focus on measuring the effect of smartphone application intervention on the quality of life of LBP patients.

This review presents several limitations and strengths. The strength of this review is that compared to the previous published systematic reviews, and this review included the results of a meta-analysis of some included results and attempted to employ rigorous methodology by excluding pilot, feasibility, or protocol studies. Additionally, this review explored databases that were not addressed previously with a refined search strategy. Also, the previous reviews included a wide range of digital technologies such as computer-based and activity tracker watches and found heterogeneous results and could not provide a definite conclusion. This review only focused on one type of digital support, smartphone-based applications, and excluded studies that used computers or devices other than smartphones.

The limitations of this review are that the included studies seem to have a moderate to high risk of bias, which may skew the results. Additionally, all studies lack blinding. Moreover, language preference for records was limited to English so this review might have missed potential good-quality articles published in other languages. Also, unpublished, or grey literature was not searched in the review, which introduces a publication bias. In the included studies, there seems to be an imbalance in number of male and female participants. The long-term effect of smartphone app intervention cannot be determined due to the lack of long-term follow-up across the included studies. Additionally, limited studies were there to draw comparisons to the findings of the included studies. Furthermore, meta-analysis was not conducted for all the studies that were eligible for the systematic review, as only studies that used the same tools to assess pain, disability, and QoL were pooled for meta-analysis.

Clinical implication and future recommendations

Based on the results of this review, across the studies, the results may have shown app group intervention favourable compared to the control group. However, the studies that did not find the superior group suggest that both groups are effective. In general, it seems that smartphone applications can be a valuable tool for rehabilitating low back pain patients. Nevertheless, by upgrading and integrating a structured, interactive, and user-friendly element in the application, the effectiveness of the smartphone app intervention may be maximised to its full potential in the rehabilitation of LBP. In addition, digital interventions cannot simply replace face-to-face sessions as discussed above; incorporating therapist communication in smartphone application interventions might have other advantages. It is also essential to consider the individual patient's compatibility with technology, and whether they can access the applications independently or not should be a factor to be checked before administering it to the patients. Digital health interventions are rising to new horizons. Hence, future studies should focus on measuring the impact of smartphone application interventions on quality of life and further explore the long-term effects by taking appropriate, longer follow-ups to carry out high-quality studies.

Conclusion

Smartphone-based application interventions have the potential to effectively reduce pain, improve disability, and enhance the quality of life as a viable alternative to other interventions for patients with LBP. This review also emphasizes the benefits of therapist communication in conjunction with a smartphone app and highlights the necessity of considering patient compatibility with technology in clinical practice.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43161-025-00288-w.

Additional file 1: Forest Plot without Itoh et al., 2022. S1. Forest plot for the effect of smartphone-based applications on pain outcomes in low-back pain patients. Fig. S2. Forest plot for the effect of smartphone-based applications on disability (Roland Morris Disability) outcomes in low-back pain patients.

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All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References

1. The global epidemic of low back pain. The Lancet. Rheumatology. 2023;5(6):e305. https://doi.org/10.1016/S2665-9913(23)00133-9.
2. Casiano VE, Sarwan G, Dydyk AM, Varacallo M. Back pain. [Updated 2023 Dec 11] In: StatPearls [Internet]. Treasure Island [FL]: StatPears Publishing;

2025 Jan-, Available from: https://www.ncbi.nlm.nih.gov/books/NBK538173/.
3. Balagué F, Mannion AF, Pellisé F, Cedraschi C. Clinical update: low back pain. Lancet. 2007;369(9563):726–8. https://doi.org/10.1016/S0140-6736(07)60340-7.
4. Manchikanti L, Singh V, Falco FJE, Benyamin RM, Hirsch J. Epidemiology of low back pain in adults. Neuromodulation. 2014;17(Suppl 2):3–10.
5. Driscoll T, Jacklyn G, Orchard J, et al. The global burden of occupationally related low back pain: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis. 2014;73(6):975–81. https://doi.org/10.1136/annrheumdis-2013-204631.
6. Hicks GE, Sions JM, Velasco TO, Manal TJ. Trunk muscle training augmented with neuromuscular electrical stimulation appears to improve function in older adults with chronic low back pain: a randomized preliminary trial. Clin J Pain. 2016;32(10):898–906. https://doi.org/10.1097/ajp.0000000000000348.
7. Reid MC, Williams CS, Gill TM. Back pain and decline in lower extremity physical function among community-dwelling older persons. J Gerontol A Biol Sci Med Sci. 2005;60(6):793–7. https://doi.org/10.1093/gerona/60.6.793.
8. Maniadakis N, Gray A. The economic burden of back pain in the UK. Pain. 2000;84(1):95–103. https://doi.org/10.1016/s0304-3959(99)00187-6.
9. Nolet PS, Kristman VL, Côté P, Carroll LJ, Cassidy JD. Is low back pain associated with worse health-related quality of life 6 months later? Eur Spine J. 2015;24(3):458–66. https://doi.org/10.1007/s00586-014-3649-4.
10. Knezevic NN, Candido KD, Vlaeyen JWS, Van Zundert J, Cohen SP. Low back pain. Lancet. 2021;398(10294):78–92. https://doi.org/10.1016/S0140-6736(21)00733-9.
11. National Institute for Health and Care Excellence. Low back pain and sciatica in over 16s: assessment and management (NICE guideline 59); 2018.
12. Zhang SK, Gu ML, Zhang T, Xu H, Mao SJ, Zhou WS. Effects of exercise therapy on disability, mobility, and quality of life in the elderly with chronic low back pain: a systematic review and meta-analysis of randomized controlled trials. J Orthop Surg Res. 2023;18(1)513.https://doi.org/10.1186/s13018-023-03988-y.
13. Moseley L. Combined physiotherapy and education is efficacious for chronic low back pain. Aust J Physiother. 2002;48(4):297–302. https://doi.org/10.1016/S0004-9514(14)60169-0.
14. Quentin C, Bagheri R, Ugbolue UC, et al. Effect of home exercise training in patients with nonspecific low-back pain: a systematic review and meta-analysis. Int J Environ Res Public Health. 2021;18(16).https://doi.org/10.3390/ijerph18168430.
15. Lewis JS, Stokes EK, Gojanovic B, et al. Reframing how we care for people with persistent non-traumatic musculoskeletal pain. Suggestions for the rehabilitation community. Physiotherapy. 2021;112:143–9. https://doi.org/10.1016/j.physio.2021.04.002.
16. Nicholl BI, Sandal LF, Stochkendahl MJ, et al. Digital support interventions for the self-management of low back pain: a systematic review. J Med Internet Res. 2017;19(5). https://doi.org/10.2196/jmir.7290.
17. Areias AC, Costa F, Janela D, et al. Impact on productivity impairment of a digital care program for chronic low back pain: a prospective longitudinal cohort study. Musculoskelet Sci Pract. 2023;63:102709. https://doi.org/10.1016/j.msksp.2022.102709.
18. Fatoye F, Gebrye T, Mbada C, Useh U. Economic evaluations of digital health interventions for the management of musculoskeletal disorders: systematic review and meta-analysis. J Med Internet Res. 2023;25:e41113. https://doi.org/10.2196/41113.
19. Mallow JA, Theeke LA, Theeke E, Mallow BK. The effectiveness of mI SMART: a nurse practitioner led technology intervention for multiple chronic conditions in primary care. Int J Nurs Sci. 2018;5(2):131–7. https://doi.org/10.1016/j.ijnss.2018.03.009.
20. Abimbola S, Keelan S, Everett M, et al. The medium, the message and the measure: a theory-driven review on the value of telehealth as a patient-facing digital health innovation. Health Econ Rev. 2019;9(1):21. https://doi.org/10.1186/s13561-019-0239-5.
21. Fioratti I, Fernandes LG, Reis FJ, Saragiotto BT. Strategies for a safe and assertive telerehabilitation practice. Braz J Phys Ther. 2021;25(2):113–6. https://doi.org/10.1016/j.bjpt.2020.07.009.
22. Fisk M, Livingstone A, Pit SW. Telehealth in the context of COVID-19: changing perspectives in Australia, the United Kingdom, and the United States. J Med Internet Res. 2020;22(6):e19264. https://doi.org/10.2196/19264.
23. Dantas LO, Barreto RPG, Ferreira CHJ. Digital physical therapy in the COVID-19 pandemic. Braz J Phys Ther. 2020;24(5):381–3. https://doi.org/10.1016/j.bjpt.2020.04.006.
24. Vieira AGdS, Pinto ACPN, Garcia BMSP, Eid RAC, Mól CG, Nawa RK. Telerehabilitation improves physical function and reduces dyspnoea in people with COVID-19 and post-COVID-19 conditions: a systematic review. J Physiother. 2022;68(2):90–98.https://doi.org/10.1016/j.jphys.2022.03.011.
25. Costa F, Janela D, Molinos M, et al. Digital rehabilitation for acute low back pain: a prospective longitudinal cohort study. J Pain Res. 2022;15:1873–87. https://doi.org/10.2147/jpr.s369926.
26. Fatoye F, Gebrye T, Fatoye C, et al. The clinical and cost-effectiveness of telerehabilitation for people with nonspecific chronic low back pain: randomized controlled trial. JMIR Mhealth Uhealth. 2020;8(6):e15375. https://doi.org/10.2196/15375.
27. Law L, Kelly JT, Savill H, et al. Cost-effectiveness of telehealth-delivered diet and exercise interventions: a systematic review. J Telemed Telecare. 2022:1357633x211070721. https://doi.org/10.1177/1357633x211070721.
28. Priori Data. Global smartphone statistics. 2024. Available from:https://prioridata.com/data/smartphone-stats. Cited 2025 Mar 9.
29. Vashist SK, Schneider EM, Luong JH. Commercial smartphone-based devices and smart applications for personalized healthcare monitoring and management. Diagnostics (Basel). 2014;4(3):104–28. https://doi.org/10.3390/diagnostics4030104.
30. Chen M, Wu T, Lv M, et al. Efficacy of mobile health in patients with low back pain: systematic review and meta-analysis of randomized controlled trials. JMIR Mhealth Uhealth. 2021;9(6):e26095. https://doi.org/10.2196/26095.
31. Abbott JH. The distinction between randomized clinical trials (RCTs) and preliminary feasibility and pilot studies: what they are and are not. J Orthop Sports Phys Ther. 2014;44(8):555–8. https://doi.org/10.2519/jospt.2014.0110.
32. Lara-Palomo IC, Gil-Martínez E, Ramírez-García JD, et al. Efficacy of e-health interventions in patients with chronic low-back pain: a systematic review with meta-analysis. Telemed J E Health. 2022;28(12):1734–52. https://doi.org/10.1089/tmj.2021.0599.
33. Mitchaï PM, Mapinduzi J, Verbrugghe J, Michiels S, Janssens L, Kossi O, Bonnechère B, Timmermans A. Mobile technologies for rehabilitation in non-specific spinal disorders: a systematic review of the efficacy and potential for implementation in low- and middle-income countries. Eur Spine J. 2023;32(12):4077–100. https://doi.org/10.1007/s00586-023-07964-2. (Epub 2023 Oct 4 PMID: 37794182).
34. Stark C, Cunningham J, Turner P, Johnson MA, Bäcker HC. App-based rehabilitation in back pain, a systematic review. J Pers Med. 2022;12(10):1558. https://doi.org/10.3390/jpm12101558.PMID:36294697;PMCID:PMC9604788.
35. Scala L, Giglioni G, Bertazzoni L, Bonetti F. The efficacy of the smartphone app for the self-management of low back pain: a systematic review and assessment of their quality through the Mobile Application Rating Scale (MARS) in Italy. Life (Basel). 2024;14(6):760. https://doi.org/10.3390/life14060760.PMID:38929744;PMCID:PMC11204566.
36. Didyk C, Lewis LK, Lange B. Effectiveness of smartphone apps for the self-management of low back pain in adults: a systematic review. Disabil Rehabil. 2022;44(25):7781–90. https://doi.org/10.1080/09638288.2021.2005161. (Epub 2021 Dec 2 PMID: 34854335).
37. Weise H, Zenner B, Schmiedchen B, et al. The effect of an app-based home exercise program on self-reported pain intensity in unspecific and degenerative back pain: pragmatic open-label randomized controlled trial. J Med Internet Res. 2022;24(10):e41899. https://doi.org/10.2196/41899.
38. Koppenaal T, Pisters MF, Kloek CJ, Arensman RM, Ostelo RW, Veenhof C. The 3-month effectiveness of a stratified blended physiotherapy intervention in patients with nonspecific low back pain: cluster randomized controlled trial. J Med Internet Res. 2022;24(2):e31675. https://doi.org/10.2196/31675.
39. Itoh N, Mishima H, Yoshida Y, Yoshida M, Oka H, Matsudaira K. Evaluation of the effect of patient education and strengthening exercise therapy using a mobile messaging app on work productivity in japanese patients with chronic low back pain: open-label, randomized, parallel-group trial. JMIR mHealth uHealth. 2022;10(5):e35867. https://doi.org/10.2196/35867.

40. Özden F, Sari Z, Karaman Ö, Aydogmus H. The effect of video exercise-based telerehabilitation on clinical outcomes, expectation, satisfaction, and motivation in patients with chronic low back pain. Ir J Med Sci. 2022;191(3):1229–39. https://doi.org/10.1007/s11845-021-02727-8.
41. Cui D, Janela D, Costa F, et al. Randomized-controlled trial assessing a digital care program versus conventional physiotherapy for chronic low back pain. NPJ Digit Med. 2023;6(1):1–10. https://doi.org/10.1038/s41746-023-00870-3.
42. Villatoro-Luque FJ, Rodríguez-Almagro D, Aibar-Almazán A, et al. Telerehabilitation for the treatment in chronic low back pain: a randomized controlled trial. J Telemed Telecare. 2023. https://doi.org/10.1177/1357633X231195091.
43. Shi W, Zhang Y, Bian Y, Chen L, Yuan W, Zhang H, Feng Q, Zhang H, Liu D, Lin Y. The physical and psychological effects of telerehabilitation-based exercise for patients with nonspecific low back pain: prospective randomized controlled trial. JMIR Mhealth Uhealth. 2024;12:e56580.
44. PEDro. PEDro scale. Sydney: The George Institute for Global Health; 1999. Available from:https://pedro.org.au/english/resources/pedro-scale. Cited 2025 Mar 9.
45. Foley NC, Teasell RW, Bhogal SK, Speechley MR. Stroke rehabilitation evidence-based review: methodology. Rev Top Stroke Rehabil. 2003;10(1):1–7. https://doi.org/10.1310/Y6TG-1KQ9-LEDQ-64L8.
46. Gonzalez GZ, Moseley AM, Maher CG, Nascimento DP, Costa LdCM, Costa LO. Methodologic quality and statistical reporting of physical therapy randomized controlled trials relevant to musculoskeletal conditions. Arch Phys Med Rehabil. 2018;99(1):129–136.https://doi.org/10.1016/j.apmr.2017.08.485.
47. Toelle TR, Utpadel-Fischler DA, Haas KK, Priebe JA. App-based multidisciplinary back pain treatment versus combined physiotherapy plus online education: a randomized controlled trial. npj Digit Med. 2019;2(1)34.https://doi.org/10.1038/s41746-019-0109-x.
48. Priebe JA, Haas KK, Sanchez LFM, et al. Digital treatment of back pain versus standard of care: the cluster-randomized controlled trial, rise-up. J Pain Res. 2020;13:1823–38. https://doi.org/10.2147/JPR.S260761.
49. Mbada CE, Olaoye MI, Dada OO, et al. Comparative efficacy of clinic-based and telerehabilitation application of mckenzie therapy in chronic low-back pain. Int J Telerehabil SPR. 2019;11(1):41–57. https://doi.org/10.5195/ijt.2019.6260.
50. Suman A, Schaafsma FG, Van Dongen JM, et al. Effectiveness and cost-utility of a multifaceted eHealth strategy to improve back pain beliefs of patients with non-specific low back pain: a cluster randomised trial. BMJ Open. 2019;9(12):e030879. https://doi.org/10.1136/bmjopen-2019-030879.
51. Chhabra HS, Sharma S, Verma S. Smartphone app in self-management of chronic low back pain: a randomized controlled trial. Eur Spine J. 2018;27(11):2862–74. https://doi.org/10.1007/s00586-018-5788-5.
52. Sandal LF, Bach K, Øverås CK, et al. Effectiveness of app-delivered, tailored self-management support for adults with lower back pain-related disability: a selfBACK randomized clinical trial. JAMA Intern Med. 2021;181(10):1288–96. https://doi.org/10.1001/jamainternmed.2021.4097.
53. Irvine AB, Russell H, Manocchia M, et al. Mobile-Web app to self-manage low back pain: randomized controlled trial. J Med Internet Res. 2015;17(1):e1–e1. https://doi.org/10.2196/jmir.3130.
54. de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. Aust J Physiother. 2009;55(2):129–33. https://doi.org/10.1016/S0004-9514(09)70043-1.
55. Cashin AG, McAuley JH. Clinimetrics: Physiotherapy Evidence Database (PEDro) Scale. J Physiother. 2020;66(1):59. https://doi.org/10.1016/j.jphys.2019.08.005.
56. Aungst TD. Medical applications for pharmacists using mobile devices. Ann Pharmacother. 2013;47(7–8):1088–95. https://doi.org/10.1345/aph.1S035.
57. Wallace S, Clark M, White J. 'It's on my iPhone': attitudes to the use of mobile computing devices in medical education, a mixed-methods study. BMJ Open. 2012;2(4). https://doi.org/10.1136/bmjopen-2012-001099.
58. Kiser K. 25 ways to use your smartphone. Physicians share their favorite uses and apps. Minn Med. 2011;94(4):22–9.
59. Geraghty AWA, Roberts LC, Stanford R, et al. Exploring patients' experiences of internet-based self-management support for low back pain in primary care. Pain Med. 2019;21(9):1806–17. https://doi.org/10.1093/pm/pnz312.
60. Renjith V. Blinding in randomized controlled trials: what researchers need to know? Manipal J Nurs Health Sci. 2017;3:45–50.
61. Valentijn PP, Tymchenko L, Jacobson T, et al. Digital health interventions for musculoskeletal pain conditions: systematic review and meta-analysis of randomized controlled trials. J Med Internet Res. 2022;24(9):e37869. https://doi.org/10.2196/37869.
62. Hróbjartsson A, Thomsen AS, Emanuelsson F, et al. Observer bias in randomized clinical trials with measurement scale outcomes: a systematic review of trials with both blinded and nonblinded assessors. CMAJ. 2013;185(4):E201–11. https://doi.org/10.1503/cmaj.120744.
63. George SZ, Valencia C, Beneciuk JM. A psychometric investigation of fear-avoidance model measures in patients with chronic low back pain. J Orthop Sports Phys Ther. 2010;40(4):197–205. https://doi.org/10.2519/jospt.2010.3298.
64. Rughani G, Nilsen TIL, Wood K, et al. The selfBACK artificial intelligence-based smartphone app can improve low back pain outcome even in patients with high levels of depression or stress. Eur J Pain (London, England). 2023;27(5):568–79. https://doi.org/10.1002/ejp.2080.
65. Jiménez-Chala EA, Durantez-Fernández C, Martín-Conty JL, Mohedano-Moriano A, Martín-Rodríguez F, Polonio-López B. Use of mobile applications to increase therapeutic adherence in adults: a systematic review. J Med Syst. 2022;46(12):87. https://doi.org/10.1007/s10916-022-01876-2.
66. Andrade C. Sample size and its importance in research. Indian J Psychol Med. 2020;42(1):102–3. https://doi.org/10.4103/ijpsym.Ijpsym_504_19.
67. McCoy CE. Understanding the intention-to-treat principle in randomized controlled trials. West J Emerg Med. 2017;18(6):1075–8. https://doi.org/10.5811/westjem.2017.8.35985.
68. Hornberger B, Rangu S. Designing inclusion and exclusion criteria. 2020:2020.
69. Suresh K. An overview of randomization techniques: an unbiased assessment of outcome in clinical research. J Hum Reprod Sci. 2011;4(1):8–11. https://doi.org/10.4103/0974-1208.82352.
70. Altman DG, Schulz KF. Statistics notes: concealing treatment allocation in randomised trials. BMJ. 2001;323(7310):446–7. https://doi.org/10.1136/bmj.323.7310.446.

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