Table 1. Annotated summary of empirical studies and study protocols evaluating smartphone apps and web-based interventions for chronic pain. [*Available as supplementary electronic material*]

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| **Smartphone apps** | | | |
| **Empirical studies** | | | |
| **Study** | **Participants** | **Methods** | **Results** |
| Zia, J., Schroeder, J., Munson, S., Fogarty, J., Nguyen, L., Barney, P., . . . Ladabaum, U. (2016). Feasibility and Usability Pilot Study of a Novel Irritable Bowel Syndrome Food and Gastrointestinal Symptom Journal Smartphone App. *Clin Transl Gastroenterol, 7*(3), e147. | N=10 patients with bowel distress. | Symptom diary including measures for pain and bowel distress. | 7/10 participants found at least one trigger for their bowel distress but no change in the rates of this distress.  Participant feedback suggested addition of a behaviour change component to the intervention. |
| Guillory, J., Chang, P., Henderson Jr, C. R., Shengelia, R., Lama, S., Warmington, M., . . . Reid, M. C. (2015). Piloting a text message based social support intervention for patients with chronic pain: Establishing feasibility and preliminary efficacy. *Clin J Pain, 31*(6), 548-556. | N=68 (17 men, 51 women) referred from two pain clinics | Social support (network support, emotional support, esteem support and informational support) to chronic pain patients via SMS. The smartphone app component was not the primary focus; it was used as a means to collect the data on the efficacy of the SMS intervention used.  Patients recorded pain interference and affect via the app. | Showed weak overall results for improvement on pain scores and some improvements on anxiety. |
| Kristjánsdóttir, Ó. B., Fors, E. A., Eide, E., Finset, A., Stensrud, T.L., van Dulmen, S., . . . Eide, H. (2013). A smartphone-based intervention with diaries and therapist-feedback to reduce catastrophizing and increase functioning in women with chronic widespread pain: randomized controlled trial. *J Med Internet Res,*  *15*(1), e5. | N=140 women with chronic widespread pain (mostly fibromyalgia) who had already undergone a 4 week inpatient treatment. Only112 completed. | A post-treatment RCT including one face-to-face session with a nurse and a smartphone app intervention  The app contained web-based diaries, written situational feedback (based on the diaries) and audio files with guided mindfulness. The aim was to reduce catastrophizing, emotional distress and increase acceptance, values-based behaviour and functioning and symptom level. | Outcomes were measured 5 months from the end of the smartphone intervention.  Dropout rate from the treatment arm was large. Hard to tease out how much of the effect is based on the previous four week inpatient intervention for chronic pain and how much is based on this app, but significant effects were found for catastrophizing, functioning, symptom level and acceptance. |
| Kristjánsdóttir, Ó. B., Fors, E. A., Eide, E., Finset, A., Stensrud, T. L., van Dulmen, S., . . . Eide, H. (2013). A smartphone-based intervention with diaries and therapist feedback to reduce catastrophizing and increase functioning in women with chronic widespread pain. Part 2: 11-month follow-up results of a randomized trial. *J Med Internet Res, 15*(3), e72. | N=84 | As above but repeating the measures at 11 months. | Results were “ambiguous” but essentially only catastrophizing and acceptance were significant at 11 months. |
| **Study protocols** | | | |
| Barr C, Marois M, Sim I, Schmid CH, Wilsey B, Ward D, Duan N, Hays RD, Selsky J, Servadio J, Schwartz M, Dsouza C, Dhammi N, Holt Z, Baquero V, MacDonald S, Jerant A, Sprinkle R, Servadio J. (2015). The PREEMPT study-evaluating smartphone-assisted n-of-1 trials in patients with chronic pain: study protocol for a randomized controlled trial. Trials 2015; 16(1): 67. | Patients with chronic pain | Protocol for an app called trialist which can be used within the patient/physician relationship to tailor the intervention to the dyad, thus creating a series of n=1 trials of interventions.  The trial is physician led with patient input. It is a 52 week study.  This app really combines all possibilities for treatment that would be required for a pain patient and is totally at the discretion of a physician to prescribe [the only study in the pool to be quite so flexible]. | None as yet. The hypotheses are:   * + Patients randomised to trialist will experience less interference at 26 weeks follow up.   + Compared to usual care patients randomised to trialist will experience less pain interference, less pain intensity, better general health-related quality of life, improved participant decision making, greater satisfaction with pain treatment, better adherence to prescribed therapy and better patient experience with care at 52 weeks. |
| Blödt, S., Pach, D., Roll, S., & Witt, C. M. (2014). Effectiveness of app-based relaxation for patients with chronic low back pain (Relaxback) and chronic neck pain (Relaxneck): study protocol for two randomized pragmatic trials. *Trials, 15*(1), 490. | Patients with neck pain or lower back pain. | Protocol for a relaxation intervention delivered via mobile app  App collects outcome data and provides the relaxation intervention in the form of audio content to the participant of the intervention group.  Data will also be collected on patient expectations, adherence to the app, self-reported general changes in back pain and neck pain, suspected adverse reactions and serious adverse events. | Outcome measures are pain intensity at 3 months and pain acceptance, pain intensity, sick leave days and pain medication intake at 6 months. |
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| **Web-based Interventions\*** | | | |
| **Study** | **Participants** | **Methods** | **Results** |
| **Empirical studies** | | | |
| Palermo TM, Law EF, Fales J, Bromberg MH, Jessen-Fiddick T, Tai G. (2016). Internet-delivered cognitive-behavioral treatment for adolescents with chronic pain and their parents: a randomized controlled multicenter trial. Pain 2016; 157:174-185. | N=273 adolescents (205 females and 68 males) with chronic pain and their parents | This study describes results of an RCT for Web-MAP2, an online intervention containing behavioural and cognitive skills training over 8 modules with an online coach.  It assessed outcomes of the trial at 6 months. | A significant effect was found for reduction in daily activity limitation at 6 months, but this was not significant immediately post-treatment. Beneficial effects were also found for sleep, emotion, and parental scores. |
| Dear BF, Gandy M, Karin E, Staples LG, Johnston L, Fogliati VJ, Wootton BM, Terides MD, Kayrouz R, Nicholson Perry K, Sharpe L, Nicholas MK, Titov N. (2015). The Pain Course: A randomised controlled trial examining an internet-delivered pain management program when provided with different levels of clinician support. *Pain*, *156*, 1920-1935. | N=490 participants with chronic pain conditions who self-referred to participant | This study evaluated an internet-delivered 5 session CBT pain management program over 8 weeks (*Pain Course*).  Participants were randomized to (1) Regular Contact (n=143), (2) Optional Contact (n=141), (3) No Contact (n =131), and (4) treatment as usual Waitlist Control Group (n=75). | The treatment groups all reported significant improvements in disability, anxiety, depression and average pain which were maintained or improved to 3-month follow-up.  Therapist support did not influence treatment completion or satisfaction with the intervention. |
| Trompetter HR, Bohlmeijer ET, Fox JP,Schreurs KM. Psychological flexibility and catastrophizing as associated change mechanisms during online Acceptance & Commitment Therapy for chronic pain.  Behav Res Ther 2015; 74:50-59. | N=238 participants who self-identified as having chronic pain and self-referred to the study. | Only study to examine the theory behind these interventions.  Participants randomised to 1 of 3 groups: wait list control, expressive writing control or a 9 session intervention (two sessions of psycho-education and 7 sessions of ACT treatment). | Found that pain catastrophizing and psychological flexibility mediated changes in pain interference and psychological stress at 3 months. Psychological flexibility seemed to be the only variable which had a direct mechanism for change. |
| Law, E. F., Beals‐Erickson, S. E., Noel, M., Claar, R., & Palermo, T.  M. (2015). Pilot randomized controlled trial of internet‐delivered  Cognitive‐Behavioral Treatment for pediatric headache. Headache 2015; 55(10): 1410-1425. | n=83 adolescent headache patients. Controls (n=39) waited until after the three month assessment to access the intervention and so were included in the n=83. | An online intervention for paediatric headache sufferers and their parents called Web-MAP, a tailored programme of medication management, psychological therapy and physical therapy. | Significant effects for time were found across both groups on the main outcome variable - headache frequency. Improvements were also found in depressive symptoms, headache pain intensity, activity limitations and parent protective behaviours. Anxiety and sleep were not significant and no differences were found between groups on any measure –both improved. |
| Armbrust, W., Bos, J. J., Cappon, J., van Rossum, M. A., Sauer, P. J.,  Wulffraat, N., . . . Lelieveld, O. T. (2015). Design and acceptance of  Rheumates@ Work, a combined internet-based and in-person  instruction model, an interactive, educational, and cognitive  behavioral program for children with juvenile idiopathic arthritis.  *Pediatric Rheumatology, 13*(1), 1-13. | N= 64 juvenile arthritis patients. | Feasibility study for a CBT intervention to promote exercise in adolescents with juvenile arthritis. | No efficacy results reported. All participants completed measures of satisfaction with the study, reported on any technical issues and some cost analysis was also conducted. |
| Dowd, H., Hogan, M. J., McGuire, B. E., Davis, M. C., Sarma, K. M., Fish, R. A., & Zautra, A. J. (2015). Comparison of an online mindfulness-based cognitive therapy intervention with online pain management psychoeducation: a randomized controlled study. *Clin J* *Pain, 31*(6), 517-527. | N=124 chronic pain patients. | Computerized mindfulness-based cognitive therapy (Mindfulness in Action) or pain management psychoeducation programs, both of which were in twelve sessions, twice per week, over six weeks. | Both groups had an improvement in pain interference, pain acceptance and catastrophizing which remained stable at follow-up but there was no effect for time or group on psychological distress.  Participants in the mindfulness group also reported an increase in their ability to manage emotions and manage stress that was maintained at follow-up (one of the few studies reviewed here that showed maintenance of change). |
| Nieto, R., Hernández, E., Boixadós, M., Huguet, A., Beneitez, I., & McGrath, P. Testing the feasibility of DARWeb: An online intervention for children with functional abdominal pain and their parents. Clin J Pain 2015; 31(6): 493-503. | N=15 families recruited, n=9 nine families completed the entire programme. | Mixed qualitative/quantitative design to evaluate children with functional abdominal pain and their parents’ perceptions of an online intervention called DARWeb.  The intervention was made up of seven units for parents and seven for children containing multimedia, text and graphics, covering five sections within each unit: objectives, introduction, training, exercises, and summary all based on a cognitive behavioural perspective. | Analysis was based around patient satisfaction with the intervention and time to complete rather than efficacy of the intervention. |
| Irvine AB, Russell H, Manocchia M, Mino DE, Glassen TC, Morgan R, Gau JM, Birnie AJ, Ary DV. Mobile-Web app to self-manage low back pain: randomized controlled trial. J Med Internet Res 2015;  17(1):e1. | N=597 participants with low back pain. | FitBack is an online program (accessible across multiple devices and platforms including mobile apps and desktop computers) designed to provide adults with education and behavioral strategies to manage low back pain and prevent future pain episodes. It uses a self-tailored cognitive-behavioral approach. Participants were randomised to three groups: control, FitBack and “alternative care”. | Two months post intervention there was no change on current back pain; however, participants in FitBack did significantly better at 4 months and were also significantly less likely to be experiencing other indicators of back pain (frequency, intensity, and duration of back pain). FitBack group had better functionality, quality of life, and well-being at 2- and 4- month follow-up and more likely to be engaging in adaptive behaviors intended to help or prevent back pain. |
| Hausmann, L. R., Parks, A., Youk, A. O., & Kwoh, C. K. Reduction of bodily pain in response to an online positive activities intervention. J Pain 2014; 15(5): 560-567. | N=417 patients from a larger study of positive psychology chosen for this analysis on the basis of reporting in the upper third of the larger sample on pain score. | Feasibility study based on data taken from a larger study of an online positive activities intervention.  This portion of the study aimed to test whether the number of “positive” activities offered (0, 2, 4, or 6) affected adherence and pain. | Pain improved for the study groups (those 2, 4 or 6 activities) but not for the 0 activities group, however, effect sizes are not reported. |
| Davis MC, Zautra AJ. An online mindfulness intervention targeting socioemotional regulation in fibromyalgia: results of a randomized controlled trial. Ann Behav Med 2013; 46(3): 273-284. | N=79 patients with fibromyalgia. | Participants in the experimental group were compared to a simple psychoeducation condition.  This intervention uses text, audio and animated graphics as well as homework assignments. | The mindfulness group had a greater improvement in efficacy for coping with pain and stress, positive and negative affect, positive social engagement, and decreased loneliness and family stress.  Pain remained unchanged over time for both groups. |
| Shigaki CL, Smarr KL, Siva C, Ge B, Musser D, Johnson R. RAHelp: an online intervention for individuals with rheumatoid arthritis. Arthrit Care Res 2013; 65(10): 1573-1581. | N=106 rheumatoid arthritis patients. | RAHelp.org is a secure website providing educational modules for improving self-efficacy in self-management of rheumatoid arthritis. Reminded to participate by weekly telephone call which has the dual purpose of encouraging use of program tools and reminding participates to apply skills taught as part of the programme.  The intervention takes a Social Learning Theory and a cognitive behavioural stance. | Self-efficacy and quality of life improved over time in the experimental group, no other differences were found. |
| Buhrman M, Fredriksson A, Edström G, Shafiei D, Tärnqvist C, Ljótsson B, Hursti T, Gordh T, Andersson G. (2013). Guided Internet‐delivered cognitive behavioural therapy for chronic pain patients who have residual symptoms after rehabilitation treatment: Randomized controlled trial. Eur J Pain 2013; 17(5): 753-765. | N=72 chronic pain patients who have residual pain after rehabilitation treatment. | Control group was randomised to participate in an online discussion forum.  This is a text-based intervention with an online therapist given over 8 weeks to patients who had previously undergone CBT treatment (almost a “post-treatment top-up” for those patients who were not doing well on follow up). | There was a main effective for time for pain catastrophizing but not time x group interaction and the effect size was small. Anxiety and depression was also reduced, favouring the treatment group. |
| Buhrman M, Skoglund A, Husell J, Bergström K, Gordh T, Hursti T, Bendelin N, Furmark T, Andersson G. Guided internet-delivered acceptance and commitment therapy for chronic pain patients: A randomized controlled trial. Behav Res Ther 2013, 51(6): 307-315. | N=76 chronic pain patients | Participants were randomized to either acceptance and commitment therapy (ACT) treatment or a moderated online discussion forum group (which served as a control group) for 7 weeks. | Intent to treat analyses showed significant increases regarding pain acceptance (activity engagement and pain willingness) and reductions in pain-related distress, anxiety and depressive symptoms which favoured the treatment group, although the effect sizes were small.  Benefits were maintained at 6 month follow-up – a notable treatment effect given that the group had long duration of pain and much co-morbidity. |
| Rini, C., Porter, L. S., Somers, T. J., McKee, D. C., DeVellis, R. F., Smith, M., . . . Stiller, J. L. (2015). Automated, internet-based pain coping skills training to manage osteoarthritis pain: A randomized controlled trial. Pain, 156(5), 837. | N=113 patients with pain and radiographic confirmation of osteoarthritis in the same joint (91 female and 22 male) | 8 week, self-directed intervention called PainCOACH.  The programme was underpinned by theoretically based methods including social cognitive theory, adult learning theory and principles of multimedia instruction and was tailored to be responsive to service user patterns of engagement with therapy (e.g. more prompts for those who suggest that they have not practiced their exercises).  Outcome data at baseline, midway through the intervention and post intervention.  The primary outcome was pain and the secondary outcomes were self-efficacy, pain related interference and functioning, pain related anxiety, and positive and negative affect. | Results showed that women in PainCOACH had significant reductions in pain from baseline, to midpoint which continued to post-intervention compared to controls.  Participants in PainCOACH also had higher levels of pain related self-efficacy compared to controls in all but the baseline timepoint, with self-efficacy remaining statistically stable in the control condition compared to an overall increase in the PainCOACH condition.  No other outcomes were significant.  Adherence was reported as a proxy for acceptability and all participants randomised to PainCOACH completed the programme. |
| **Study protocols** | | | |
| Hayes S, Hogan M, O’Higgins S, Doherty E, Nic Gabhainn S, MacNeela P, Murphy AW, Kropmans T, Dowd H, O’Neill C, McGuire BE. (2014). Comparing the clinical- and cost-effectiveness of an internet-delivered Acceptance and Commitment Therapy (ACT) intervention with a waiting list control group among adults with chronic pain: Study protocol for a randomized controlled trial. BMJ Open, 4(7). Doi:10.1136/bmjopen-2014-005092. | Participants with non-malignant pain that persists for at least 3 months. | The study will compare the clinical-effectiveness and cost effectiveness of the management of pain-related functional interference among people with chronic pain.  The experimental group will undergo an eight-session internet-delivered ACT programme over an 8-week period.  The control group will be a waiting list group and will be offered the ACT intervention after the 3-month follow-up period. | This is one of the few studies looking at cost effectiveness. |
| Fu, M., Axelrod, D., Guth, A., Scagliola, J., Rampertaap, K., El-Shammaa, N., . . . Schnabel, F. (2015). A Web-and Mobile-Based Intervention for Women Treated for Breast Cancer to Manage Chronic Pain and Symptoms Related to Lymphedema: Randomized Clinical Trial Rationale and Protocol. *JMIR Res Protoc, 5*(1), e7-e7. | Breast cancer survivors at risk of Lymphedema | Protocol for a 12 week web and mobile based intervention called The- Optimal-Lymph-Flow system. Designed for managing chronic pain, aching, soreness, and tenderness among breast cancer survivors.  The intervention group, in addition to the informational component have access to Avatar videos demonstrating exercises to promote lymph flow and optimize shoulder and limb mobility. | Primary outcomes measures are pain reduction and secondary are other symptom relief, BMI and quality of life related to pain. All outcomes measures are at the 12 week point in the study. |
| \*Note: some website based interventions had both a desktop and smartphone enabled access route, but the primary platform was web-based. | | | |