Digital Behaviour Change Interventions to Facilitate Physical Activity in Osteoarthritis: A Systematic Review

Introduction

Physical activity is recommended as a core treatment for osteoarthritis (OA), irrespective of disease severity, age, and pain levels (1,2), yet 44% of people with OA report doing no activity at all (3). Low-cost, effective, and accessible interventions are needed to provide information, support and encouragement to stay active (4). Digital Behaviour Change Interventions (DBCIs) employ digital technologies (such as websites, apps, or wearable devices) to promote and maintain health (5), and have the potential to overcome many barriers associated with face-to-face programmes, by offering cost-effective and widely accessible information, that can be tailored to the individual (6–8). A number of systematic reviews have reported small to moderate positive effect sizes of DBCIs for increasing physical activity in healthy adults, adults with a chronic condition, and older adults (4,6,9–11). To the authors' knowledge, no systematic reviews have been published on the effectiveness of DBCIs at increasing levels of physical activity specifically for people with OA. Given OA affects 8.75 million people in the UK (12), even small positive effects could have significant public health consequences (6).

Previous reviews in similar populations describe how a wide range of behaviour change techniques (BCTs) have been used (9), making it difficult to ascertain which are the effective components. BCTs are observable, and replicable components of an intervention proposed to be the 'active ingredients' (13). There are also a lack of reviews which have examined how behavioural theory has been used to develop interventions (14). This makes it difficult to draw conclusions as to whether findings (positive or negative) are due to a lack of theoretical fidelity, or other factors such as inappropriate intervention content (7). Further exploration is needed to learn more about which BCTs and behavioural theories are linked to effectiveness, over the long term (6), so that future interventions can be more focused and streamlined. Website usage, such as number and duration of log-ins, has also been insufficiently reported (4,9–11). Further exploration of intervention usage is needed, not only to see how usage of a DBCI might be linked to levels of PA, but also to learn more about how people choose to use DBCIs in everyday life, and over longer periods of time.

This review addresses the areas that have been poorly explored and reported in previous studies in this area. Specifically, the aims of this study are to explore; the effectiveness of existing DCBIs in increasing levels of physical activity in people with osteoarthritis; which behavioural theory and BCTs have been used in existing DCBIs; and how physical activity, website usage and attrition have been measured and reported.

Methods

Criteria for considering studies for this review

Details of the inclusion criteria are detailed below:

- Randomised or quasi-experimental studies of interventions for adults with OA. This was purposively not limited to RCTs to provide a more comprehensive picture of published research in this evolving area (Note: It was recognised that interventions existed which were aimed at people with a range of different chronic conditions. Where possible, results of the OA participants (only) were used in this review (Clarification of the sample analysed is provided in the 'sample size' column, in tables 5 and 6 – results)).
- Primary or secondary aim to increase levels of physical activity. Studies focusing on general self-management (for OA) were only included if they had a physical activity element.
- Whole, or part of an intervention delivered via a digital platform (e.g. website, app, telehealth).
- Level of physical activity reported, as primary or secondary outcome measure. Any studies which failed to measure actual physical activity levels were excluded.
- Any country of origin, but English language papers only.

Study Identification

The search strategy (Supplement 1) was established after reviewing search terms in literature reviews in the area of physical activity interventions (digital and non-digital) for arthritis, musculoskeletal pain and other chronic diseases. The following databases were searched from inception to July 2017: AMED, CINAHL Plus, Cochrane Library, Embase, Medline, PsycINFO, Pubmed, SPORTDiscus and Web of Science.

Data collection and analysis

Selection of studies

All abstracts were independently screened by two members of the research team (AB and either NW, CM, SM). Full-texts of remaining articles were independently assessed by two members of the research team (AB and either NW, CM, SM). Any disagreements were discussed with a third team member until consensus was reached. Reference lists of the included studies were checked for other potentially eligible papers. Data from conference abstracts were not included unless corresponding full-text articles were available. Abstract authors were contacted to request further details when necessary.

Data extraction and measurement

All data were extracted using a pre-defined data extraction form. This was based on previous systematic reviews of digital interventions (6,8,10,15), with focus given to the specific information required to meet the objectives of this review.

The Behaviour Change Technique Taxonomy (v1) (16) was used to identify which BCTs had been used. Each intervention was coded by evaluating all descriptions of the interventions, including any other development papers identified.

Quality Assessment

The quality of studies were evaluated using the critical appraisal skills programme (CASP) tools for RCTs and Cohort studies (17). Each article was independently reviewed by two members of the team (AB and NW). Any disagreements were resolved through discussion.

Risk of bias

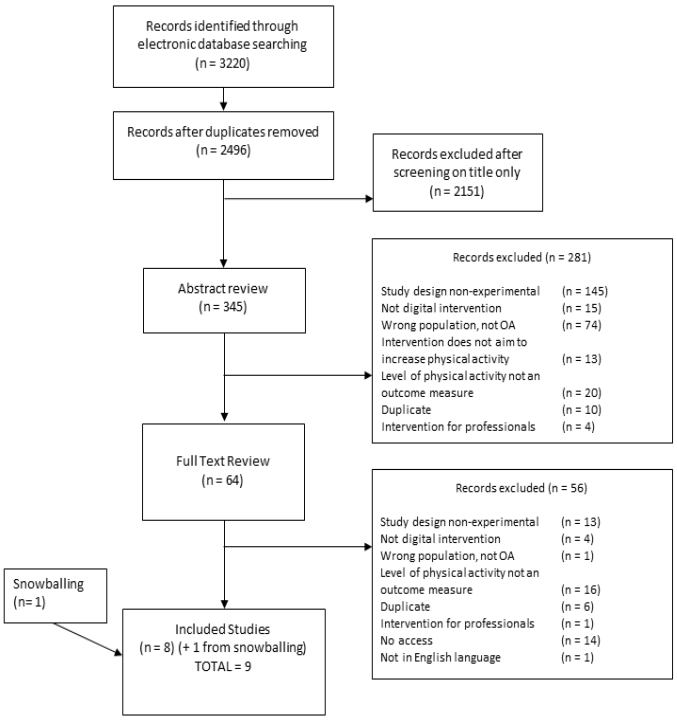
Included papers were assessed using the Cochrane Collaboration's tool for assessing risk of bias (18). A full assessment was carried out for those studies which adopted a randomised design; studies adopting other designs were assessed for attrition bias, reporting bias, and for any other observed source of bias. Studies were assessed independently by two members of the research team (AB and either NW or SM) to ensure consistency.

Results

Results of the search

Figure 1 shows the results of the study selection process. A total of nine studies were eligible for review. Eight of these were obtained from the original search and one additional study was found through a review of reference lists.

Figure 1. Study selection and screening procedures



Characteristics of Studies and populations

The included studies were carried out in Australia, Canada, the Netherlands, UK and USA. Sample size varied greatly from 20 to 958 participants, and females made up the majority of the study samples. Tables 1 and 2 (RCTs and Non-randomised respectively) show details of the main characteristics of the studies.

Five studies focused on people with 'arthritis' (rheumatoid arthritis, osteoarthritis or fibromyalgia) or analysed the proportion of the sample with arthritis separately (19–23). The four remaining studies included participants with a number of different chronic conditions such as diabetes, heart disease, and arthritis (24–27). These studies did not split the results into sub-groups, therefore all outcomes reported are for the whole cohort.

Table 1 - Characteristics of Included Studies - (Randomised Controlled Trials – RCTs)

Author, year	Location of Study	Study Design	Name of Intervention	Study Aim	Sample Size	Population	Gender	Age range of participants
Bossen et al, 2013 (RCT) (19)	Netherlands	RCT	Join2move	Short (3 months) and long-term (12 months) effectiveness of the intervention in patients with knee and/or hip OA in physical activity , physical function, and self-perceived effect	199	Self-reported knee and/or hip OA	Intervention – 40% male, 60% female Control – 30% male, 70% female	Intervention mean = 61 Control group mean = 63
Lorig et al, 2006 (25)	USA	RCT	Internet-based Chronic Disease Self-Management Program (I-CDSMP)	1-year outcomes (health status, health behaviour and health care utilisation)	958	Arthritis: 24.9% (usual care), 24.9% (online intervention) Other: diabetes, hypertension,	Female 71.6% usual care, 71.2% online intervention Male 28.4% usual care, 28.8%	Range 22 to 89) Control: 57.6 (SD ± 11.3) Intervention: 57.4 (SD ± 10.5)

						lung disease, heart disease.	online intervention	
Lorig et al, 2008 (21)	USA	RCT	Internet-based Arthritis Self-Management Programme (I-ASMP)	6-month and 1-year outcomes (health status, health behaviour, self-efficacy, and health care utilisation).	855	546 (63.9%) had OA. Usual care: 26.6% RA, 64.9% OA, 51.3% Fibromyalgia Intervention: 28.3% RA, 62.3% OA, 49.2% Fibromyalgia	Usual care: 9.5% male 90.5% female Intervention: 10.2% male 89.8% female	Usual Care: 52.5 (SD ± 12.2) Intervention: 52.2 (SD ± 10.9)
Skrepnik et al, 2017 (22)	USA	RCT	OA GO	To evaluate the impact of a mobile app, plus wearable activity monitor/pedometer (Jawbone UP 24) used for 90 days on the mobility	211	Adults with OA	Intervention: male = 45%, females = 55% Control:	Total sample: mean 62.6 (SD = 9.4) Intervention: 61.6 (SD ± 9.5)

				of patients with knee OA treated with hylan G-F 20			male = 55%, females = 45%	Control: 63.6 (SD ± 9.3)
Trudeau et al, 2015 (23)	USA	RCT	painACTION.com	To assess the efficacy (outcomes included: arthritis self-efficacy, pain catastrophizing, pain awareness, exercise behaviours, symptoms mngt, communication with physicians, and pain levels) of the intervention, at 1, 3, and 6 months.	228	OA only (59%), RA or other arthritic condition (41%)	Female = 68.4% Male = 31.6%	49.9 (SD ± 11.6)

Table 2 – Characteristics of Included Studies – (Non-Randomised/Cohort Studies)

Author, year	Location of Study	Study Design	Name of Intervention	Study Aim	Sample Size	Population	Gender	Age range of participants
Bossen et al, 2013 (20)	Netherlands	Pre-post test	Join2move	Preliminary effectiveness (physical activity, physical function and self-perceived effect), feasibility and acceptability of join2move in patients with knee and/or hip OA?	20	Self-reported knee and/or hip OA	Female – 75% Male – 25%	Mean = 64 (SD ± 6.6)
Jaglal et al, 2012 (24)	Canada	Two-group, pre-post test	Telehealth version of Chronic Disease Self-management	Does access to tele-CDSMP in rural and remote communities improve self-efficacy, health behaviours, and	213	Arthritis (76.5%). Other conditions	Female: 158, Male: 52 (3 unknown)	45-88, median = 67

			Programme (Tele-CDSMP)	health status and whether there are differences in outcomes between the two delivery models (single/multiple site).		included: Heart, lung, diabetes, other MSK, and stroke		
Lorig et al, 2008 (21)	UK	Implementation study	Expert Patients Programme Online (EPP Online) (version of I-CDSMP)	6 and 12 month outcomes (health distress, self-rated health, illness intrusiveness, disability, fatigue, pain and shortness of breath), four behaviours (aerobic exercise, stretching exercise, stress mngt and communications with physician), and five utilization measures (GP visits, pharmacy visits, PT/OT visits, emergency	593	Arthritis (30.5%). Other: Diabetes, hypertension, lung disease, heart disease, mental health conditions, ME, MS, back problems	Female = 77.9% Male = 22.1%	median age = 45

				visits and hospitalisations)				
Lorig et al, 2013 (27)	Australia	Implementation study		1: Could the ICDSMP be successfully implemented in South Australia? 2: Could the ICDSMP reach rural and aboriginal people less served by CDSMP? 3: Effect on health behaviours, health status, health care utilisation, reduction in lost workdays?	254	Arthritis (40.1%) Other: Asthma, cancer, COPD, diabetes, heart disease, lung disease, mental health condition, Other chronic condition	Female = 68.5% Male = 31.5%	Median age = 45

Description of Digital Interventions

Across the nine included studies, five different interventions were evaluated. Details about how each of the interventions was delivered, is given below.

- Join2Move (19,20) – A fully-automated, web-based intervention containing automatic (tailored) functions (text messaging and e-mails) without human support; self-paced; nine week programme.
- Internet-based Arthritis Self-Management Programme (I-ASMP) (21) – A six week internet-based course; peer moderators; email reminders to encourage participation; tailored information to participants.
- Internet-based Chronic Disease Self-Management Programme (I-CDSMP) (25–27) - A six week internet-based course; peer moderators; email reminders to encourage participation; tailored information to participants. (Note: (26) This study evaluated the Expert Patients Programme – an intervention based on the I-CDSMP).
- Telehealth-CDSMP (24) – Same content as CDSMP programme described above, course ran via live video and audio communications between the participants and moderators.
- OA GO App (22) – Mobile phone app providing motivational messages; goal setting (daily steps); linked to wearable activity monitor; self-monitoring (pain and mood); No moderator.
- PainACTION (23) - Web-based patient education, self-management intervention. Modular; No moderator.

Quality Appraisal

Tables 3 and 4 (attached as supplement file 2) present a summary of the results.
In summary, the quality of RCTs was moderate to strong. Strengths included; adequate reporting of all patient outcomes at conclusion (4/5), similarities between control and intervention groups at baseline (5/5), the measurement of clinically important outcomes (5/5), and results that can be applied to people with osteoarthritis (5/5). Details of randomisation, blinding procedures, and confidence limits, were not always reported.

The cohort studies were found to be of moderate quality. Strengths included: acceptable recruitment procedures (4/4), accurate measurement of outcomes (self-reported, but validated instruments used) (4/4), and sufficient fit of results in line with similar studies (4/4).

Risk of Bias

Tables 5 and 6 show the overall risk of bias for the included studies. (Attached as supplement file 3).

Risk of bias for RCTs:

Three studies were considered to have a predominantly low risk of bias (19,22,23) , by adequately describing how group allocation was concealed, how incomplete data was dealt with (such as using intent-to-treat analysis), and reported all *a priori* analyses. Two RCTs (21,25) failed to provide detailed information about random sequence generation, allocation concealment, and blinding, therefore were judged to be at a higher risk of bias. Sources of other bias, such as an inappropriate study design, or extreme baseline imbalance, were also explored. One study (23) provided a financial incentive to participants of $250, and therefore was judged to be of high risk.

Risk of bias for Implementation and pre-post-test studies

Risk of bias assessments for incomplete outcome data, selective reporting, and other sources of bias were carried out for these studies. Two were judged to sufficiently report outcome data (19,26). One study reported a data collection error, resulting in incomplete outcome data, therefore was considered to have a high risk of bias (27). All studies reported outcome measures that were initially described, and were therefore considered to have a low risk of bias for selective reporting.

Effectiveness of Digital Behaviour Change Interventions

A statistically significant difference between intervention and control groups were seen at post-intervention in three of the RCT studies (Table 7) (19,22,25). Three of the non-randomised studies (Table 8) also found levels of physical activity were significantly improved post-intervention (24,26,27). Furthermore, the studies which reported non-significant improvements in levels of physical activity, noted a trend towards increased participation (20,21,23)

Table 7 - Effectiveness of Interventions evaluated by RCTs

Author (year)	Sample Size	Physical activity outcome measures	Endpoints	PA Change (difference between gps) (mean)	P Value
Bossen, 2013 (19)	199 (All OA)	Physical Activity Scale for the Elderly (PASE)	3 months 12 months	-1.6 (-16.6 to 13.5) 21.2 (3.6 to 38.9)	0.84 0.02*
		Accelerometer	3 months 12 months	3 (-26 to 32) 24 (0.5 to 46.8) (Mean (95% confidence interval))	0.83 0.045*
Lorig, 2006 (25)	958 (not split) 24.9% of sample had arthritis	Stretching/strengthening (minutes per week)	12 months	10.75	0.024*
		Aerobic exercise (minutes per week)	12 months	4.11	0.701

Lorig, 2008 (21)	Total sample: 855 (OA sample reported here = 292)	Stretching/strengthening (minutes per week) Aerobic exercise (minutes per week)	12 months 12 months	-1.97 22.28	0.999 0.260
Skrepnik et al 2017 (22)	Total = 211 Group A = 107 Group B = 104 (All OA)	Least squares (LS) mean number of steps per day – change from baseline to 3 months	3 months	732	0.03*
Trudeau 2015 (23)	228 (Not split – arthritis – OA,RA, or other arthritic condition)	Stretching/strengthening (minutes per week) Aerobic exercise (minutes per week)	6 month 6 month	2.58 3.53	NSD NSD

*significance at p<0.05, NSD = No significant difference

Table 8 - Effectiveness of interventions evaluated by Implementation/cohort studies

Author (Non-RCTs)	Sample Size	Outcome measures	Endpoints	PA Change between baseline and endpoint (mean/SD)	P Value
Bossen 2013 (20)	20 (All OA)	Total PA (mins per week)	3 months	347	0.3
		Moderate PA (mins per week)	3 months	230	0.43
Jaglal 2013 (24)	213 (not split) 76.5% of sample had arthritis	Stretching/strengthening (minutes per week)	4 months	17.9 (67.1)	<0.001*
		Aerobic exercise (minutes per week)	4 months	39.8 (133.1)	<0.001*
Lorig 2008 (26)	593 (not split) 30.5% of sample had arthritis	Stretching/strengthening (minutes per week)	6 months 12 months	10.7 (54.4) 6.62 (52.2)	<0.001* 0.009*
		Aerobic exercise (minutes per week)	6 months 12 months	9.40 (76.2) 14.6 (83.3)	0.008* <0.001*

Lorig 2013 (27)	254 (not split) 40.1% of sample had arthritis	Stretching/strengthening (minutes per week)	6 months	7.08 (55.7)	0.131
			12 months	21.0 (84.0)	<0.001*
		Aerobic exercise (minutes per week)	6 months	22.1 (89.8)	0.004*
			12 months	32.2 (130)	<0.001*

*significance at $p<0.05$

Behavioural Theory

Social cognitive theory (SCT) (28), or the key construct of SCT 'self-efficacy', was described as guiding the development of the majority of interventions (n=6). However, further details of which aspects of each intervention were intended to improve levels of self-efficacy were not reported.

Three studies did not report the use of any theoretical concept (19,20,22), however they did provide information about behaviour change techniques employed within the interventions.

Behaviour Change Techniques (BCTs)

The use of BCTs was described in different ways, making it difficult to ascertain which were present. Figure 2 shows the BCTs most commonly used, these included; goals and planning, feedback and monitoring, and social support.

The Join2Move intervention (19,20) contained a range of different BCTs. Key areas included goal setting, action planning, and reviewing the behaviour. This was done by self-monitoring; no external human support was given. Performance charts were built into the programme.

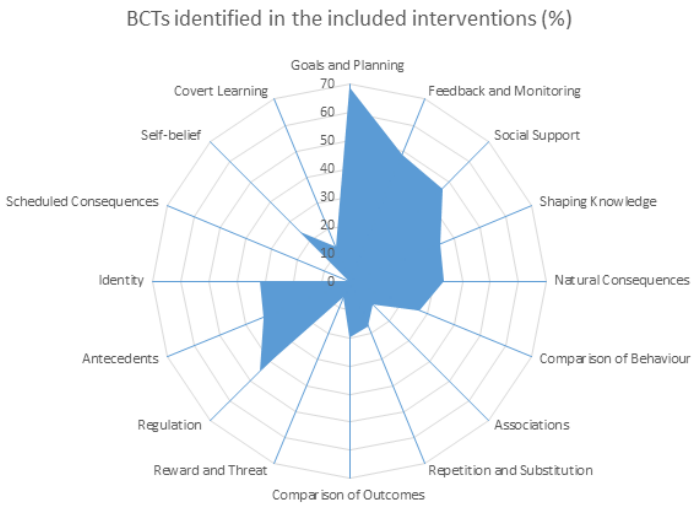
The Arthritis Self-Management Programme (ASMP) (21) and the Chronic Disease Self-Management Programme (CDSMP) (25) had similar content, and a large number of BCTs including: goal setting, action planning and feedback on behaviour, information about health consequences and information about how to perform physical activity, emotional support, distraction, framing/re-framing, valued self-identity, and self-talk. These interventions were human-supported, with feedback provided by trained moderators. They had interactive bulletin boards and an internal messaging centre where participants and facilitators could leave private messages for other users.

The OA GO app (22) focused on goal setting, action planning, self-monitoring of goals, emotional and physical forms of social support, and information about health

consequences. This intervention was self-guided, with personalised feedback, and made use of a wearable monitor, so participants could see if personal step goals had been achieved.

The PainACTION intervention (23) made use of similar BCTs, with goal setting, action planning, information about health and emotional consequences, body changes, framing/re-framing, and discussion about incompatible beliefs, included. This intervention was largely self-guided, though did provide automated email reminders to log-on to the website.

Figure 2 – BCTs identified in the included interventions



Interventions which focused specifically on arthritis were more likely to report improvements in physical activity. Significant outcomes were also found for interventions which focused on setting goals, and monitoring behaviours (either peer, or self-monitoring). A key feature of one intervention (19) was the positive reinforcement of gradual physical activity (such as walking or cycling), despite the presence of pain.

Studies which found non-significant changes in physical activity, reported heterogeneous populations (21), and lack of peer interaction (23) as possible reasons for the lack of positive outcomes.

Physical Activity Outcome Measures

The majority of interventions used self-report questionnaires to measure physical activity. Self-reported aerobic exercise (minutes over the last 7 days), and strengthening and stretching exercises (minutes over the last 7 days) were the most common measures. These measures were developed and validated by the Stanford Patient Education Research Centre and have been used in a number of previous studies at Stanford University (29).

Other measures included the Physical Activity Scale for the Elderly (PASE) and the Short Questionnaire to Assess Health-enhancing Physical Activity (SQUASH) (20).

The PASE questionnaire asked participants to report on activity over the last 7 days, the SQUASH questionnaire asked participants to think about an average week over the last few months.

Two studies utilised wearable physical activity monitors (19,22). One study (22) provided participants with Jawbone UP 24 activity monitors, in both control and intervention groups. Another (19) gave accelerometers to a random sub-sample of participants.

Uptake and usage of digital interventions

A clear picture of how many participants completed each online session was often not provided, with only one study giving full details of the number of participants to complete each session (19). Other studies described information such as the average

number of log-ins (25), number of posts generated on discussion boards (26), number of minutes using the intervention (23) and most frequently visited pages (23). One study (22) reported the percentage of participants who were ‘compliant’ (used the app 80% of the time).

The percentage of people reported to participate in all sessions ranged widely from 31.5% to 79%. One study (23) reported that levels of user engagement were significantly correlated with an improvement in outcome measures, whilst another (19) reported that level of participation had no influence on outcomes. Other studies did not explore how usage was related to any change in levels of PA. The rate of use declined over time in all of the intervention studies, at varying rates. One study (22) reported high adherence with the use of their app, with 96% of the intervention group using the app 80% of the time. This study also reported significant improvements in levels of PA.

Discussion

The aim of this review was to explore the effectiveness of existing DBCIs for increasing levels of physical activity (PA), in those with OA. Included studies provided evidence that people with OA can significantly increase their levels of physical activity (for up to one year post-intervention) using a digital programme. Complexity of interventions varied, and a range of BCTs were used, however, all interventions included a form of goal setting, action planning, provided feedback, and ways of self-monitoring behaviour. Most of the interventions were based on Social Cognitive Theory, or 'self-efficacy' (28).

In particular, two RCT studies with positive outcomes (19,22), focused primarily on increasing PA levels and mobility, as opposed to the general self-management of arthritis (21,25). Bossen et al (19) tested a web-based intervention (Join2Move) which focused on gradually increasing levels of physical activity (determined by participant), over of 8 weeks, and had no human support. Factors that potentially contributed to this success include: 1) focus on gradually increasing chosen activity, despite the presence of pain, 2) users were encouraged to select day-to-day activities that were easy to integrate into a daily routine, 3) intervention was systematically developed and evaluated by potential end-users, prior to testing (19). Skrepnik et al (22) tested a mobile app (OA GO App) linked to an activity monitor, and a daily step goal was set up by the trial coordinator. This support may have been an important factor in the success of the trial. A high percentage of the sample used the app for 80% of the trial (3 months). However, despite the majority choosing to continue using the intervention after the initial 90 days, compliance between 90 – 180 days dropped to just 35.6%. This highlights the issue of long-term engagement both with interventions, and the behaviour they are attempting to influence.

Two RCTs (21,25) evaluated a programme which was previously shown to be effective in small group settings. Both studies aimed to change multiple health indicators and behaviours. One (21) focused on patients with arthritis or fibromyalgia, but failed to significantly increase physical activity. Conversely, the trial which included patients with a range of chronic conditions (25) did report a significant increase for stretching and strengthening exercises, but not aerobic exercise.

Three of the four cohort studies reported significant improvements in PA. Once again, these were based on the chronic disease self-management programme evaluated in two of the RCTs (21,25). Significant findings were reported at 12 months post-intervention, however, results for those with OA were not reported separately. The interventions all had peer moderators, and one was a telehealth version of the self-management programme, so included live interaction via video link between groups and moderators etc. This element of additional moderator support is potentially an important aspect of the success of the programmes.

Despite the majority of studies being based on the concept of 'self-efficacy', none explicitly reported which elements were intended to improve this**.** Improved descriptions of how self-efficacy has been used to guide content, during the development stages are needed.

Levels of physical activity and use of interventions were measured in a variety of different ways. This heterogeneity amongst outcome measures made comparison difficult, and excluded a meta-analysis. Previous systematic reviews evaluating the effectiveness of digital interventions in non-OA specific populations report similar heterogeneity of outcome measures (4,6,10).

Coding of the elements of each intervention against the behaviour change taxonomy (16) was difficult, due to a lack of detailed reporting on how various elements were attempting behaviour change. MRC guidance (30) calls for improved methods of specifying and reporting intervention content, to address this problem of lack of consistency and consensus.

The findings in this review are in-line with previous reviews. One review (31), explored factors affecting adherence to exercise in people with chronic musculoskeletal pain. They reported effectiveness of trials which targeted exercise adherence specifically, as well as those which studied broader self-management programmes. They also reported on one study which found a positive relationship between graded activity, and exercise adherence, similar to a study included in this review (19). Another review (10) examining internet-delivered interventions for increasing PA levels, found

that the inclusion of educational components significantly increased intervention effectiveness. All studies in the present review did include an element of education (coded as 'shaping knowledge'), though techniques such as goals and planning, feedback and monitoring, and social support, were considered to have a more prominent role. Finally, a review which examined the effectiveness of non-face-to-face physical activity interventions for older adults (32), found the majority of interventions were based on Social Cognitive Theory, individual tailoring was found in most studies, and also reported that intervention dosage varied greatly.

Limitations

Design and population heterogeneity was present across studies making it difficult for comparisons (or meta-analysis) to be made across the whole sample. In particular, the studies evaluating the chronic disease self-management programme were heterogeneous for disease, age, education and symptom distribution (25).

Conclusion

Results of this review show that DBCIs can have a positive effect on levels of physical activity in this population, for up to 12 months post-intervention. Key findings from this review show that interventions with a focused primary aim, which do not try to change multiple behaviours simultaneously, resulted in more effective clinical outcomes, for this population. Importantly, a focus on realistic, and autonomous goals that can be easily integrated into everyday life seemed to produce stronger outcomes.

Both interventions with, and without human support were associated with improved outcomes, making it difficult to judge which is optimal.

In-depth development and evaluation (with potential end-users) prior to full trial, was seen as necessary, and recognised as a strong point for any intervention.

Optimal intervention dosage needs further exploration, as it remains unclear how use of an intervention is associated with long-term engagement with physical activity. Future exploration of intervention burden, optimal frequency of prompts and moderator interaction would provide new evidence in this area.

Future interventions should clearly document which theories, and BCTs were used during the development stage, and use accepted taxonomies to record this. Up-to-

date guidelines on the most accepted and valid measure of physical activity adherence should be used, and the uptake and usage of interventions reported in detail.

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