A Meta-Analysis of Physical Activity Interventions in People with Physical Disabilities: Content, Characteristics, and Effects on Behaviour

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Abstract

Objectives: Among samples of people with physical disabilities, the effects of physical activity (PA) interventions and the factors that influence intervention success are unknown. The purpose of this meta-analysis was to i) evaluate the overall effect of interventions on PA behaviour and ii) examine the influence of intervention characteristics, theory, and behaviour change techniques (BCTs) on PA intervention effects in persons with physical disability. **Design**: Meta-analysis. **Method**: Medline, Embase, PsychINFO, and AMED databases were searched for randomized controlled trials that evaluated the effects of a PA intervention in people with physical disability. Data were extracted regarding study and intervention characteristics and use of theory. Intervention descriptions were coded using the BCT Taxonomy version 1. **Results**: A total of 24 articles met the inclusion criteria. Overall, interventions had a small to medium-sized effect on PA behaviour (g=0.35, k=22, 95% CI [0.21, 0.48]). Interventions that used theory (g=0.53, k=12, 95% CI [0.38, 0.68]) had larger effects than interventions that did not, p<0.001. Interventions that included self-monitoring of behaviour produced larger effects (g=0.45 k=12, 95% CI [0.28, 0.63], p=.04) and interventions with monitoring of behaviour by others without feedback produced smaller effects (g=0.05, k=3, 95% CI [-0.22, 0.32], p=.02) than studies without these BCTs. **Conclusion**: Interventions to increase PA behaviour in people with physical disability are effective, especially when theory is used to guide their development. Research is needed to examine a wider range of BCTs and the moderating effects of intervention characteristics on PA behaviour.

Keywords

Physical disability, Physical activity, Interventions, Theory, Intervention characteristics, Behavior change techniques

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Among people with physical disabilities, physical activity (PA) participation rates are even lower than the sub-optimal levels reported in the general population. For instance, in a British national survey (Sport England, 2016), just 17% of adults with a disability reported at least one session of exercise or sport per week, compared to 40% of able-bodied adults. Furthermore, a Dutch study found that daily accelerometry counts were up to 60% lower in people with various disabilities and chronic conditions than in an able-bodied reference sample (Van Den Berg-Emons, Bussmann, & Stam, 2010). Given the tremendous personal, environmental and systemic PA barriers faced by people with disability (Martin Ginis, Ma, Latimer-Cheung, & Rimmer, 2016), these statistics are not particularly surprising. Nevertheless, the data do speak to the need for targeted PA behaviour change interventions for populations with disability.

Several meta-analyses have demonstrated the effectiveness of PA behaviour change interventions in the general population (e.g. Conn, Hafdahl, & Mehr, 2011; Michie, Abraham, Whittington, & McAteer, 2009; Webb, Yardley, & Michie, 2010). For instance, Conn and colleagues (2011) reported an average effect size of $d = .19$ across 206 studies of healthy adults that compared an intervention to a control condition. Exploratory moderator analyses revealed that interventions were more effective when delivered by research staff than by people trained by researchers (e.g., health care providers), and when delivered face-to-face, rather than through mediated channels (e.g., telephone, internet). There was no association between the magnitude of behaviour change and either the number of intervention strategies used or the amount of time devoted to the intervention. However, intervention content did seem to matter. Interventions that

used only behavioural strategies (e.g., goal setting, self-monitoring) were more effective than interventions that used educational/informational strategies.

Physical activity intervention content has been addressed in several meta-analyses (e.g., Michie et al., 2009; Olander et al., 2013; Webb et al., 2010), with a particular focus on behaviour change techniques (BCTs). Behaviour change techniques are "observable, replicable, and irreducible" mechanisms of change within a behavioural intervention (Michie, Johnson, & Johnston, 2015; Michie et al., 2011). Development of reliable methods for coding and classifying BCTs has helped advance knowledge regarding the most effective 'ingredients' of PA interventions for various populations (Michie et al., 2011; Michie et al., 2013).

For instance, Michie *et al.* (2009) coded the characteristics and content of PA and healthy eating behaviour change interventions in healthy adults. Across 69 PA studies, the overall effect on behaviour was $d = 0.32$. Interestingly, only intervention content was associated with intervention effectiveness. Specifically, interventions that included the BCT of self-monitoring plus one of four other self-regulation BCTs (intention formation, prompting specific goal setting, providing feedback on performance, and prompting review of behavioural goals) produced significantly larger effects ($d = .38$) than interventions that did not include these BCTs ($d = .27$). Other intervention characteristics--such as intervention duration, setting, delivery format (e.g., group versus individual), person delivering the intervention, or number of BCTs used--were unrelated to intervention effects.

The effectiveness of self-regulation BCTs in changing PA behaviour has also been supported in a systematic review of reviews and meta-analyses of studies of adults at risk for developing type II diabetes (Greaves et al., 2011). High quality randomized controlled trial (RCT) evidence showed overall medium-sized changes in self-reported PA (standardized mean

difference = 0.30). Similar to Michie et *al.*'s (2009) findings, the use of self-regulation BCTs (goal setting, prompting self-monitoring, providing feedback on performance, goal review) was associated with larger effects. No associations were found between effect sizes and intervention delivery format, provider, mode, or intensity. Taken together, these reviews suggest that delivery characteristics of an intervention are not nearly as important as whether the intervention employs BCTs targeting an individual's ability to self-regulate.

It is not known, however, if these findings generalize to populations with disability. Because people living with physical disability experience unique barriers to PA (e.g., limitations in functional ability, inaccessible facilities, negative attitudes from others; Martin Ginis, et al., 2016), they may have unique needs for intervention content and delivery. For instance, given the lack of good quality, basic information on PA for people with disabilities (Shaw, Mallory, Arkell, & Martin Ginis, 2017), provision of information/education may be an important aspect of intervention effectiveness. Furthermore, because of transportation and architectural barriers to accessing intervention settings (e.g., clinics, universities), mediated forms of intervention delivery (e.g., telephone, internet) may be more effective than face-to-face delivery. Although these issues have not yet been addressed in a meta-analysis of the disability literature, a recent meta-synthesis provides support for the unique intervention needs of people with disabilities.

Specifically, Williams and colleagues (2017) conducted a meta-synthesis of 10 qualitative studies that explored experiences of adults with physical impairments who had participated in PA-enhancing interventions. Thematic analysis revealed five intervention components that participants considered important for intervention success. The components included: giving consideration to how the intervention is communicated and delivered (e.g., by whom and through what medium); providing information on PA and the self-management of

impairments and related symptoms; teaching behavioural strategies for initiating and maintaining PA (e.g., action planning, goal-setting, obtaining feedback); and addressing participants' need for social support, particularly from health professionals. The authors recommended that these intervention characteristics and content be taken into consideration when developing PA-enhancing interventions for people with disabilities.

A recent scoping review catalogued 24 studies that used behaviour change strategies aimed at increasing community-based PA in adults with physical or cognitive disabilities (Lai, Young, Bickel, Motl, & Rimmer, 2017). The authors defined behaviour change strategies as the theoretical frameworks used in the studies, rather than as BCTs. Sixteen studies mentioned a theoretical framework, with two studies 'informed by theory', 10 'applying theory' and four 'testing theory'. Bandura's (1997) social cognitive theory was the most often-cited framework (14 studies). All but one study reported a significant increase in PA. These findings suggest that interventions that are theory-based or 'theory-inspired' (Michie et al., 2016) are generally effective for increasing PA in people with disabilities. It is not known, however, which specific content and characteristics of the interventions account for their effectiveness. A meta-analysis was undertaken to address these knowledge gaps.

Specifically, we conducted a meta-analysis of RCTs of PA behaviour change interventions involving persons with physical disability, in order to identify intervention characteristics and BCTs that produce the greatest behaviour change. Based on previous reviews, it was hypothesized that: 1) overall, interventions would result in significant increases in behaviour; 2) the largest effects would be produced by interventions that used theory and by interventions employing BCTs related to self-regulation; 3) intervention effectiveness would be unrelated to delivery setting (group versus individual), intervention intensity, or number of BCTs

used. No hypotheses were formulated regarding the effects of intervention provider or mode of delivery; while there is a rationale for the importance of these characteristics in populations with disability (Williams et al., 2007), evidence is mixed regarding their importance in the general population (Conn et al., 2011; Michie et al., 2009).

Methods

Search strategy and study selection criteria

PRISMA guidelines were followed in the conduct of this review (Supplementary Figure 1). The first author (XX) and a research assistant conducted independent searches of electronic databases for relevant articles. Reference lists of selected reviews were also searched and experts in the field were consulted to search their personal libraries to identify any other relevant articles. The original search included articles published until April 2015 and was updated in April 2017. AMED (1985-present), Embase (1974-present), ERIC (1966-present), Medline (1946-present), PsychINFO (1987-present), and PubMed (1950-present) databases were searched using the following keywords (for a sample search strategy see Supplementary File 1): (1) Terms for interventions: 'intervention stud*' OR 'program' OR 'curriculum' OR 'physical education' OR 'promotion' OR 'initiative' OR 'behaviour change' OR 'strateg*' (2) Terms for physical activity: 'physical activity' OR 'exercise' OR 'physical fitness' OR 'sports' (3) Terms for disability: 'disabled persons' OR 'stroke' OR 'cerebral palsy' OR 'amputee' OR 'spinal cord injur*' OR 'multiple sclerosis' OR 'osteoarthritis' OR 'Parkinson disease'.

Limits were set to include only articles written or translated in English. Terms for disability were based on our experience with similar reviews indicating the need to include these terms to maximize coverage of the literature (e.g. Martin Ginis et al., 2016; Williams et al., 2017).

Conditions that do not necessarily result in physical disability (e.g., traumatic brain injury, rheumatic conditions) were not included.

Study inclusion criteria were: (a) original reports of RCTs published in peer-reviewed journals; (b) articles that reported quantitative data from interventions designed to increase PA performed in home and/or community settings; (c) participants were youth or adults who had a physical disability, which was defined as mobility, stamina, or dexterity impairments. Exclusion criteria were: (a) studies without a PA intervention, (i.e. studies that did not include an informational, behavioural, social or environmental approach to increasing activity; see Kahn et al., 2002); (b) included rehabilitation exercise only and (c) interventions targeting multiple health behaviours.

Screening of articles

After removal of duplicate abstracts, relevant titles were screened. Abstracts of relevant titles were then screened for inclusion/exclusion criteria. Twenty-six articles met the criteria; however, two articles were subsequently excluded because they did not provide adequate data to calculate effect sizes. Authors were emailed with a request to provide additional data but they did not respond. The first author and a research assistant worked independently throughout all of the screening steps and had no discrepancies. Figure 1 is a PRISMA diagram of the screening process leading to the final sample of 24 articles.

Data extraction

Supplementary Table 1 shows the full data extraction table and includes: *Study details*: author, year, study design, objective, number of participants in intervention and control groups, dropouts, PA measure used, and theoretical framework. *Participant information:* age, disability type, gender, PA behaviour pre- and post-intervention. *Intervention details:* intervention

description, intensity, duration, provider, provider training, format, setting, type, exercise prescription (frequency, intensity, time, type), delivery method, and materials (cf. Davidson et al., 2003). Data were extracted by XX and checked by a research assistant.

Appraisal of the evidence

The Cochrane Risk of Bias Assessment (ROB) for RCTs was used to assess study quality. Evidence for its reliability and validity has been reported (Hartling et al., 2009; Hartling et al., 2011). This tool is based on narrative descriptions of evidence-based methodological features known to increase the risk of bias in RCTs. Six domains of potential bias were assessed: sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other sources of bias (Higgins et al., 2011). A summary of the studies' overall risk of bias was assessed based on the domains most relevant within the context of the review: participant randomization, incomplete outcome data, and blinding of outcome assessments. Assessments were conducted (unblinded) by the first author (XX) and a research assistant. Two discrepancies were resolved through discussion. In addition to the ROB, visual examination of the funnel plot and an Egger's test was conducted to assess for publication bias.

Coding for intervention intensity

Intervention intensity was assessed using a scale that takes into account intervention duration, frequency of contact, type of contact, and reach (Hendrie, Brindal, Baird, & Gardner, 2013; see Table 2 Notes). Scores were summed to provide an overall intensity score out of 20. Higher scores indicate higher intensity or more rigorous intervention requirements.

Coding moderator variables

Coding for study and intervention characteristics. Studies were coded by disability type. Studies that included more than one type of disability were coded as *mixed.* Physical

activity behaviour sample time point was categorized as the longest sample time point falling within <3 months, 3-6 months, and >6 months. Intervention providers were classified as *health care providers* (physiotherapists, occupational therapists, social workers, nurses), *researcher*, or *other* (exercise specialists, strictly online delivery, and a combination of researcher and peer deliverers). Delivery format was coded as *group, individual, or individual and group*. Mode of delivery was grouped into *in-person, technology* (computer, online video, email), *telephone,* and *in-person and technology/telephone.*

Coding for use of theory. Studies were coded for use of theory as follows: 0 = *no mention of theory* (including interventions that measured theoretical constructs but did not explicitly identify a theory); 1 = *informed by theory*, when a theory was identified but there was no clear application in the intervention; 2 = *applied theory*, when a theory was identified and between one and half of the theoretical constructs were applied in components of the intervention; 3 = *testing theory*, when a theory was identified and more than half of its theoretical constructs were measured and tested, or when two or more theories were compared to one another; and *4 = building or creating theory,* when theory was revised or expanded upon (Painter, Borba, Hynes, Mays, & Glanz, 2008).

Coding for behaviour change techniques (BCTs). Each intervention was coded for BCTs using the 93 Behaviour Change Technique Taxonomy version 1 (BCTTv1) (Michie et al., 2013). The first author and a research assistant independently coded each study after completing a BCTTv1 online training program (http://www.bct-taxonomy.com). A study testing the BCTTv1 produced evidence of good inter-coder and test-retest reliability (Michie et al., 2015). In the present study, inter-coder agreement was 88% ($\kappa = 0.93$, prevalence-adjusted and bias-adjusted kappa [KAPPA]= 0.98). Kappa values > 0.81 are considered 'almost perfect' strength

of agreement (Viera & Garrett, 2005). When coding discrepancies arose, the coders discussed until agreement was reached. When this was not possible, the second author was consulted to make a final decision. For the purpose of conducting moderator analyses, a binary coding scheme was used. Studies that employed a given BCT were coded as "1" and those that did not were coded "0". BCTs that were used in both the intervention and control conditions of a particular study were not included in the BCT coding analysis and results. Results from the BCT coding are presented in Supplementary Table 2.

Meta-analysis strategy

Effect sizes were computed using the Comprehensive Meta-Analysis software program (Borenstein & Rothstein, 2014) and expressed as Hedge's *g* which provides a conservative estimate of effects (Cheung, Ho, Lim, & Mak, 2012). Effect sizes were interpreted according to Cohen's (1988) conventions (0.2=small, 0.5=medium, 0.8=large). The mean ES across studies was calculated using a random effects model which yields a more conservative estimate than a fixed effects model. Random effects assume the effect size is a combination of the study-specific effect as well as random between study effects (Cheung et al., 2012). When calculating the overall effect, if more than one measure of PA was used, the average effect size was calculated. If there was more than one measurement time-point, the measure immediately post-intervention was used because it likely reflects the largest intervention effect. To test for homogeneity of variance among the effect sizes, an overall Q value and I^2 were calculated. A significant Q value indicates the data are heterogeneous and warrant examination of moderator variables. I^2 can be interpreted as the percentage of total variation across studies that is due to heterogeneity rather than due to chance. I^2 values of 25%, 50%, and 75% represent low, medium and high heterogeneity, respectively (Higgins et al., 2003). Sensitivity analyses were conducted to

examine whether the effect of interventions on physical activity behaviour remained when a) either the subjective versus objective measure of PA was used to calculate overall effect size for studies that employed both types of measures and b) the longest time point within each study was used to calculate the overall effect size.

Moderator Analyses

Study and Intervention characteristics. Table 3 shows average effect sizes as a function of the categorical moderators. Heterogeneity within each category of moderators was evaluated using the between-study Q statistic (Q_b) (Borenstein, Hedges, Higgins, & Rothstein, 2009). When the Q_b statistic was significant, planned comparisons were calculated to test the strength of the evidence for differences between levels of the moderating variable. To reduce the risk of type I errors, significance was set at 0.05/number of comparisons within the moderating variable. Intervention intensity was treated as a continuous, rather than categorical variable; effect sizes were regressed on intervention intensity in a simple regression model.

Behaviour change techniques. The small number of studies precluded the use of meta-regression to examine the relative effectiveness of BCTs. Instead, when at least three studies used a given BCT, the average effect size for studies that did not employ that BCT was subtracted from the average effect size for studies that did employ the BCT (Olander et al., 2013). The Q_b statistic was calculated to test the difference (Borenstein et al., 2009). To test the relationship between number of BCTs used in a study and the magnitude of behaviour change, effects sizes were regressed on the number of BCTs used in each study.

Results

Two of the 24 articles did not use a control group that would constitute usual care (Arbour-Nicitopoulos et al., 2009; Bennell et al., 2017) and were included only in the BCT

analysis. Thus, 22 articles were included in the meta-analysis of intervention effectiveness (total N = 1670; see Table 2). The most frequently studied disabilities were MS, SCI, and osteoarthritis, whereas people with Parkinson's Disease and cerebral palsy were included only in one and two studies, respectively. Study sample sizes ranged from 12 (Rice, Rice, & Motl, 2015) to 540 (Nimwegen et al., 2013) with a sample size of 92 participants on average. Most interventions were delivered in-person or over the phone, in a one-on-one setting, and ranged from 4 weeks (Kosma, Cardinal, & McCubbin, 2005; Latimer, Martin Ginis, & Arbour, 2006) to 2 years (Nimwegen et al., 2013) in duration.

Risk of bias

Using the Cochrane Risk of Bias tool, most studies were categorized as low risk of bias for random sequence generation (n=18). The remaining six studies were classified as unclear as their method of randomization was not clearly stated. Half of the studies were at low risk of bias for blinding of outcome assessment (n=12). Lastly, more than half of the studies used methods to account for missing data (n=16). Overall, 13 studies were identified as high risk of bias when examining our a priori-identified important domains. It should be noted that less than half were categorized as low risk of bias for allocation concealment (n=9). Selective reporting was difficult to evaluate as almost no studies listed their trial registry to compare a priori listing of outcomes and most studies were categorized to have some other bias (n=20). Visual inspection of the funnel plot showed relatively even distribution between the effect and estimated precision of studies. Egger's test revealed no evidence of publication bias (t=0.42, CI [-2.29, 1.52], p=0.68).

Overall effects of interventions on physical activity behaviour

Immediately following intervention, the overall effect size was 0.35 (*k*=22, 95% CI [0.21, 0.48]), indicating that interventions had a small to medium-sized effect on PA behaviour when

compared to usual care or no intervention. A forest plot showing the effect size for each study is presented in Figure 2.

Sensitivity analyses revealed the overall effect was virtually identical for studies that used both a subjective and objective measure of physical activity, when data from the objective measures (g=0.35, k=22, 95% CI [0.24, 0.47]) were analyzed separately from the subjective measures (g=0.35, k=22, 95% CI [0.19, 0.50]). Likewise, when the longest time point sampled was used instead of the time point immediately following intervention, the effect size remained small to medium (g=0.41, k=22, 95% CI [0.30, 0.52]). Although the test of heterogeneity was not significant ($Q(21)$=29.85, p=0.095, I^2=29.65%), moderator analyses were conducted as outlined a priori (Geyskens, Krishnan, Steenkamp, & Cunha, 2009).

Moderators

Study and intervention characteristics. None of the Q_b values were significant for any of the study or intervention characteristic moderators. The greatest effects were observed in studies of people with multiple sclerosis (MS; g=0.50, k=7, 95% CI [0.26, 0.73]), spinal cord injury (SCI; g=0.54, k=4, 95% CI [0.21, 0.87]), and Parkinson's Disease (g=0.52, k=1, 95% CI [0.06, 0.97]); all had medium-sized effects, although the estimate for Parkinson's Disease was somewhat less precise than for SCI and MS. When analyses were conducted using data from the last measurement time-point in each study, a small to medium-sized effect was found at ≤3 months (g=0.38, k=8, 95% CI [0.17, 0.58]) and >6 months (g=0.32, k=9, 95% CI [0.13, 0.51]), whereas studies with a time point at 3-6 months showed a medium-sized effect (g=0.52, k=8, 95% CI [0.34, 0.70]).

For the *intervention provider* variable, interventions delivered by researchers produced a medium-sized effect (g=0.48, k=10, 95% CI [0.27, 0.68]), health care providers produced a small

to medium-sized effect (g=0.31, k=7, 95% CI [0.05, 0.56]), and 'others' produced a small effect with confidence intervals that included zero, suggesting weak evidence for the small effects (g=0.22, k=5, 95% CI [-0.02, 0.47]). For delivery setting, interventions delivered in group settings had medium to large effects (g=0.61, k=3, 95% CI [0.22, 1.01]), individual settings had small to medium effect sizes (g=0.35, k=15, 95% CI [0.18, 0.48]) while there was weak evidence that combined group and individual delivery was effective (g=0.20, k=4, 95% CI [-0.13, 0.53]). Regarding *mode of delivery*, all modes produced medium-sized effects except for the combination of in-person plus technology/phone which produced a small to medium-sized effect (g=0.27, k=8, 95% CI [0.07, 0.47]). Intervention intensity was unrelated to intervention effectiveness (R^2=0.02, B=.14, p=.55, $t(21)$=0.62)

Use of theory. The following frameworks were used: Social cognitive theory, the transtheoretical model, theory of planned behaviour, health action process approach model, and the relapse prevention model. Overall, interventions developed using theory (g=0.53, k=12, 95% CI [0.38, 0.68]) had medium-sized effects, whereas interventions developed without theory had small effects with confidence intervals including zero (g=0.13, k=10, 95% CI [-0.04, 0.29]), p<0.001. More specifically, studies with no mention of theory showed small effects with confidence intervals including zero (g=0.13, k=10, 95% CI [-0.04, 0.29]); studies that identified theory with no clear application showed a small to medium-sized effect with confidence intervals including zero (g=0.35, k=3, 95% CI [0.00, 0.69]). There were no significant differences between these two theory-use categories (p=1.00). However, studies that applied theory (g=0.62, k=7, 95% CI [0.44, 0.81]) or tested theory (g=0.38, k=2, 95% CI [0.03, 0.72]) showed the largest effects and when combined showed strong evidence that they yielded larger effects than studies with "no mention of theory", p=.002.

Use of behaviour change techniques (BCTs). The most commonly used BCTs were goal setting (behaviour) (k=15), problem solving (k=19), self-monitoring of behaviour (k=12), social support (practical) (k=16), instructions on how to perform the behaviour (k=12), and graded tasks (k=11). Difference scores comparing effect sizes of studies that did versus did not employ a particular BCT showed strong evidence for the effectiveness of two BCTs ('self-monitoring of the behaviour' and 'monitoring of behaviour by others without feedback') and moderate evidence for one BCT ('feedback on behaviour'). Specifically, interventions that incorporated self-monitoring (g=0.45, k=12, 95% CI [0.28, 0.63]) showed larger effects than interventions that did not employ this technique (g=0.21, k=12, 95% CI [0.05, 0.35]), Δg=0.24, p=.04. Interventions that used monitoring by others without feedback (g=0.05, k=3, 95% CI [-0.22, 0.32) resulted in smaller effects than interventions without this BCT (g=0.40, k=21, 95% CI [0.28, 0.52]), (Δg=-0.35, p=.02). Interventions that provided feedback on behaviour (g=0.52, k=8, 95% CI [0.28, 0.77]) tended to have larger effects than those that did not (g=0.26, k=16, 95% CI [0.14, 0.38]), Δg=0.26, p = .06. Studies that provided instructions on how to perform the behaviour (g=0.44, k=11, 95% CI [0.24, 0.64]) or used problem solving (g=0.40, k=19, 95% CI [0.25, 0.54]) showed the next largest difference in effect sizes compared to interventions that did not employ these techniques ($g_{\text{instructions on how to perform the behaviour}}$=0.26, k=13, 95% CI [0.12, 0.40]; $g_{\text{problem solving}}$=0.22, k=6, 95% CI [-0.01, 0.45]), $\Delta g_{\text{instructions on how to perform the behaviour}}$ =0.18, p=0.16; $\Delta g_{\text{problem solving}}$=0.17, p=0.22. Although Δg for these techniques were not significant, studies using these techniques showed small to moderate effects with relatively tight confidence intervals. There was a medium-sized (f^2=0.16) positive relationship between number of BCTs employed and intervention effectiveness that was not statistically significant (B=.37, p=.09).

Discussion

385 This paper reports on the first meta-analysis of RCTs testing PA behaviour change
386 interventions among people with physical disabilities. Consistent with our hypotheses, overall,
387 the interventions had small to medium-sized effects on behaviour and yielded significantly larger
388 effects when theory was used. Interventions incorporating 'self-monitoring of behaviour' as a
389 BCT had significantly larger effects, and interventions with 'monitoring of behaviour by others
390 without feedback' had significantly smaller effects. Although none of the intervention
391 characteristics were significant moderators, some interesting patterns emerged. Together, these
392 findings have important implications for guiding the design of future RCTs and for developing
393 more effective PA-enhancing interventions for people with physical disabilities.
394 On average, the RCTs reported a significant effect size of .35. This finding was robust
395 regardless of PA measurement time-point (i.e., <3 months, 3-6 months, or > 6 months post-
396 intervention) or whether a subjective or objective measure of PA was employed. The magnitude
397 of the effects is consistent with meta-analyses conducted in other populations showing that,
398 overall, PA behaviour change interventions produce small- to medium-sized effects (e.g., Conn
399 et al., 2011; Michie et al., 2009). Our findings also align with meta-analyses showing that these
400 interventions are more effective when guided by theory (Taylor et al., 2016; Webb et al., 2010).
401 We found that RCTs that merely mentioned a theory, with no clear application of it, were no
402 more effective than RCTs that did not mention theory whatsoever. This finding speaks to the
403 need for the explicit application of theory in intervention design and testing. As Michie and
404 Prestwich (2010) have noted, theory-based interventions are ideal because: (1) targeting
405 constructs that are theorized to change behaviour can lead to greater intervention effects; (2)
406 measuring the effects of interventions within a theoretical framework allows for the
407 accumulation of evidence to be compared against different contexts, populations, and

behaviours; and (3) using theory can help to identify mechanisms of change, facilitating the refinement of theories and interventions. Coding schemes are available to evaluate the extent to which an intervention has used theory (e.g. Michie & Prestwich, 2010; Painter et al. 2008). These schemes could also be used to guide researchers in how to implement theory when developing interventions.

Most theories currently being used to guide PA interventions in the general population are also being used with populations with disability (cf., Lai et al., 2017). We did note, however, that while self-determination theory (SDT; Deci & Ryan, 1985) is being used increasingly in PA interventions (Silva, Marques, & Teixeira, 2014) it was not used in any of the reviewed RCTs. SDT has shown utility for explaining variance in PA among people with other types of chronic health conditions (e.g., heart disease, Russell & Bray, 2009) but research is needed to test its applicability as an intervention framework in populations with disability. The knowledge to action cycle (KTAC) may also be a useful framework for guiding intervention design (Graham et al., 2006). The KTAC is a dynamic and iterative process involving knowledge creation and action phases, and collaboration between researchers and end-users to identify barriers and develop interventions relevant to the end-user's context. Given that people with disabilities face varied and unique barriers to participation (Martin Ginis et al. 2016), their involvement in the design of PA-enhancing interventions can help ensure these needs are met (cf. Williams et al., 2017).

Regarding intervention content, consistent with other meta-analyses (Michie et al., 2009; Abraham & Michie, 2008; Webb et al., 2010), we found that interventions with self-monitoring produced significantly greater effects than interventions without this BCT. Interestingly, interventions that provided feedback on behaviour (another form of monitoring) tended to

produce greater effects, while interventions that used monitoring by others without feedback resulted in significantly smaller effects. Monitoring is a key construct of control theory (Carver & Scheier, 1981). Without feedback or knowledge of progress, people cannot evaluate whether they are approaching their desired goals and cannot make necessary behavioural modifications to achieve their goals. Thus, it is not surprising that monitoring--by one's self or by others--was part of the most effective interventions.

Although to a lesser extent than self-monitoring, interventions that included problem solving and instructions on how to perform the behaviour tended to produce larger effects than those that did not. Studies that included these techniques produced effect sizes in the small-medium range. Problem solving involves both the identification of barriers and the development of solutions to address them. The able bodied literature consistently supports the use of monitoring and feedback (Greaves et al., 2011; Michie , 2009). It makes sense that problem solving and instructions on how to perform the behaviour are two techniques unique to the disability population. Over 200 barriers to PA participation have been identified for people with physical disabilities (Martin Ginis et al., 2016). The sheer number of barriers highlights the need to problem solve in order to overcome obstacles. Furthermore, a lack of PA information/knowledge is an often-cited barrier (Martin Ginis et al., 2016; Williams et al., 2017), and many online resources for people with disability are of questionable quality (Shaw et al., 2017). Our results suggest that BCTs that address these disability-specific issues may be beneficial.

Regarding intervention characteristics, consistent with previous findings (e.g., Hobbs et al., 2013; Michie et al., 2009), we found that neither differences in intervention provider, delivery mode, nor setting moderated intervention effectiveness. From these results, one might

conclude that how an intervention is delivered is inconsequential. However, this conclusion may be premature given limitations of the meta-analysis and the included studies. Specifically, most of the moderator analysis categories included less than ten studies, thus undermining confidence in the results. For instance, only one RCT employed a peer as part of the intervention team (Froehlich-Grobe et al., 2014). This study had an effect size of g=.44 but had to be included in the "other" intervention provider category (see Table 3). Given that people with disabilities identify peers as one of the most important providers of PA information (Faulkner et al., 2010; Letts, Martin Ginis, et al., 2011; Williams et al., 2017), we encourage further investigation of peers as intervention delivery agents. Likewise, all studies in the HCP category were delivered by physiotherapists or occupational therapists with the exception of two studies delivered by a nurse and social worker. Interventions delivered by rehab professionals resulted in small to large effect sizes while the two studies delivered by a nurse and a social worker were the only studies in this category to produce negative effect sizes. Further to the role of health care providers, it is unknown whether the training they received to deliver the intervention influenced effectiveness. Only two studies (Bennell et al., 2012; Nooijen et al., 2016) reported the training provided to HCPs. This is concerning considering lack of knowledge in working with people with physical disability is a commonly cited barrier to PA participation (Martin Ginis et al., 2016). More research is needed to better understand the role of the intervention provider and the training they receive.

Moreover, the relatively small number of studies meant that we could only look at the overall effects of each intervention characteristic without controlling for interactions with other characteristics or with BCT content (Dombrowski, O'Carroll, & Williams, 2016). When content is controlled, intervention characteristics may make a difference. For instance, Wing et al. (2006)

showed that the same intervention was more effective when delivered face to face versus over the internet. Given that the act of getting to an interventionist often can be thwarted by transportation, accessibility, and weather barriers, alternative forms of intervention delivery are needed to ensure access and inclusion (Williams et al., 2017). In order to develop evidence-based best-practices, it will be important for researchers to conduct comparisons of different intervention delivery characteristics while controlling for intervention content.

Consistent with previous findings (Greaves et al., 2011; Taylor et al., 2016; Webb et al., 2010), we found that the number of BCTs used and intervention intensity were unrelated to behaviour change. Intuitively, complex and resource-intensive interventions might be expected to yield the biggest effects; this was not the case. For instance, Latimer *et al.* (2006)'s theory-based intervention employed one BCT, had the lowest intensity score, and produced medium-sized effects. Brosseau *et al.'s* (2012) atheoretical intervention included 10 BCTs, had the highest intensity score, and had negative effects. In fact, it is possible the greater time required for the more intensive interventions posed as challenging for participants to sustain. The finding that 'more isn't necessarily better' has important implications for resource allocation. Resources may be better spent *developing* an intervention that is rich in theory and selective BCT content, rather than *delivering* a complex intervention in a high intensity manner (e.g., long duration, several BCTs).

In addition to the previously mentioned limitations of the moderator analyses, a few other limitations warrant mention. First, over half of the RCTs were identified as having a high risk of bias. Future studies should address the issues of small sample size and neglecting trial registration. Although we acknowledge the challenges in collecting data in these populations, including adequately powered sample sizes is especially pertinent given the heterogeneity of

participant function and subsequently physical activity participation in physical disability. Trial registry is an integral step to improving transparency and ensuring results are not selectively reported (Higgins et al., 2011). Despite these limitations, the authors suggest the effects of interventions on physical activity in physical disability remain robust. Most studies were conservative and performed intention to treat analyses, no publication bias was found, and the small to medium overall effect of interventions on physical activity was consistent regardless of measure used or time point sampled. Second, two-thirds of BCTs included in Michie et al. (2013)'s taxonomy have not yet been tested in studies of people with disability. Thus, conclusions regarding the most effective BCTs are restricted to comparisons involving a small subset of possible BCTs. Similarly, the limited number of studies testing BCTs precluded the use of meta-regression to look at the relative effectiveness of BCTs. Third, it was impossible to tease out the effectiveness of individual BCTs within a given study. With the exception of two studies (Arbour-Nicitopoulos, Martin Ginis, & Latimer, 2009; Latimer, Martin Ginis, & Arbour, 2006), all RCTs used more than one BCT. Fourth, we only reported presence or absence of BCTs, not frequency or intensity of use; these delivery factors might moderate the impact of BCTs. Further, the identification of BCTs does not account for differences in *how* the BCT is delivered. Intrapersonal, interpersonal, and external factors can influence the effect of intervention beyond simply *what* is done to them (Ogden, 2016). Fifth, because of concerns about including studies that had not been vetted through peer review, unpublished studies were excluded from the meta-analysis. While this decision may raise concerns about publication bias, results of the Egger's test indicate otherwise. Finally, analyses combined studies of people with different types of physical disabilities. People with disabilities are heterogeneous and the needs and preferences of one group may not necessarily be the same for all.

Some key strengths of this meta-analysis also warrant mention. First, our focus on RCTs allowed us to estimate intervention effects relative to control groups, rather than relying on within-subjects studies which can over-estimate the true effects of an intervention. Second, we coded for multiple intervention characteristics. Because it is unlikely that just one characteristic will dictate whether an intervention is effective, it is important to examine multiple factors. Third, we coded for BCTs. Coding BCTs improves intervention replication accuracy, faithful intervention implementation, reliable systematic review extraction methodology, and intervention reporting (Michie et al., 2013). Furthermore, analyses of BCTs help identify the techniques to be used in future interventions and provide a link to theory, thus facilitating an understanding of mechanisms and an evaluation of intervention success (Abraham & Michie, 2008; Michie, Fixsen, Grimshaw, & Eccles, 2009).

In summary, the results of this meta-analysis indicate that overall, PA-enhancing interventions are effective for increasing PA in adults with physical disabilities. The most effective interventions are theory-based and utilize BCTs that incorporate monitoring or address unique challenges experienced by people with disabilities. Although the moderating effects of intervention characteristics require further investigation, it is clear that more is not necessarily better; simply increasing the number of BCTs and intervention intensity does not translate into greater increases in behaviour. Moving forward, we urge researchers and practitioners to involve end-users in the design, testing and implementation of interventions. An integrated knowledge translation approach (e.g. guided by the KTAC) will help to develop novel interventions that address the unique barriers and challenges to PA faced by people with physical disabilities.

Table 1. Study characteristics

First Author, year^	Disability/Health Condition*	Total sample size	Sample time points	Theory[#]	Use of behaviour change theory[‡]	PA Measure[$]
Arbour-Nicitopoulos, 2009	SCI	44	Week 5 and 10	HAPA	Theory applied	PARA-SCI (short version)
Bennell, 2017	Knee OA	168	Month 6, 12, 18	N/A	None	PASE, accelerometer, adherence
Bossen, 2013	Knee/ Hip OA	199	Month 3 and 12	N/A	None	PASE Accelerometer (sub group)
Brosseau, 2012	Knee OA	222	Month 3, 6, 9, 12 and 6 month follow-up	N/A	None	Participant log books and site-reported program adherence
Froelich-Grobe, 2004	Arthritis, SCI, MS, MD, Fibromyalgia, Orthopedic problems, Spina Bifida, CP, TBI, lupus, stroke/amputation/post polio (mobility limitations)	75 (women only)	Weekly for 25 weeks	N/A	None	Self-report physical activity log
Froelich-Grobe, 2014	SCI, CP, Spina bifida, MS, amputation, polio, fibromyalgia, lupus, stroke, TBI	128	Weekly for 52 weeks	SCT Relapse Prevention Theory	Theory applied	Self-reported minutes of weekly physical activity
Hughes, 2006	OA	215	2, 6, 12 months	SCT	Theory applied	6-item recall measure (type, duration, frequency)
Kosma, 2005	Amputation, CP, MS, MD, SCI, other	75	4 weeks	TTM	Theory tested	PASIPD LTPA sub scores only
Latimer, 2006	SCI	37	8 weeks	TPB	Theory applied	PARA-SCI and # of days the participant engaged in >30 min of PA
Learmonth, 2017	MS	53	Weekly up to 16 weeks	SCT	Theory tested	GLTEQ Accelerometer
Maher, 2010	CP	41	10, 20 weeks	SCT	Theory identified	Accelerometer (7 days) MARCA (4 day self-report)
McAuley, 2007	MS	15	12 weeks	SCT	Theory applied	Daily attendance logs
Nooijen, 2015	SCI	39	6-7 weeks, 8 months, 14 months		None	Body fixed 3-axis accelerometers PASIPD
O'Brien, 2013	Lower Limb OA	15	12 weeks	N/A	None	Adherence: Self- report, Class- based Adherence: SIRAS

Pilutti, 2014	MS	76	6 months	SCT	Theory applied	GLTEQ ActiGraph accelerometers
Plow, 2014	MS	40	12, 24 weeks	SCT and TTM	Theory applied	GLTEQ PADS
Rice, 2015	MS	12	3 months	SCT	Theory identified	Accelerometer
Rimmer, 2013	SCI, MS, Spina Bifida , CP, Stroke, Lupus	64	9 months		None	PADS
Slaman, 2014	CP	36	6 months	N/A	None	PASIPD VotaMove system
Smith, 2012	MS	13	8 weeks		None	Exercise adherence reported by research staff
Suh, 2015	MS	68	6 weeks	SCT	Theory applied	GLTEQ and pedometers
Talbot, 2003	Knee Osteoarthritis	34	24 weeks	N/A	None	Tritrac-R3D accelerometer Digi-walker pedometer
van Nimwegan, 2013	PD	540	6, 12, 18, 24 months	SCT TTM	Theory identified	LAPAQ 7-day diary Ambulatory activity monitor
Wise et al., 2009	SCI	21	3 months, 6 months	N/A	None	Self-reported personal physical activity log

Note: ^References for studies included in the meta-analysis are found in Supplementary File 2.

*CP=cerebral palsy, MD=muscular dystrophy, MS=multiple sclerosis, OA=osteoarthritis, PD=Parkinson's disease, SCI=spinal cord injury, TBI=traumatic brain injury

#HAPA=Health Action Process Approach, SCT=social cognitive theory, TPB=theory of planned behaviour, TTM=transtheoretical model

$GLTEQ= Godin Leisure Time Exercise Questionnaire, LAPAQ= LASA Physical Activity Questionnaire, LTPA=leisure time physical activity, MARCA= Multimedia Activity Recall for Children and Adolescents, PARA-SCI=Physical Activity Recall Assessment for People with Spinal Cord Injury, PASE= Physical Activity Scale for the Elderly, PASIPD= Physical Activity Scale for Individuals with Physical Disabilities, SIRAS= Sport Injury Rehabilitation Adherence Scale

Table 2. Intervention characteristics

First author, year	Mode of delivery	Provider	Group or individual	Setting	Contact duration	Intensity score[#]	Contact details	Effect size
Arbour-Nicitopoulos, 2009	Telephone	Researcher	Individual	Home	10 weeks	11	Baseline: 20-30 min telephone interview Sent calendar	0.70*
Bennell, 2017	In-person Telephone	Physiotherapists, nurses, occupational therapist, health psychologist	Individual	Home and clinic	6 months	15	5 x 30 minute individual PT/educational sessions 6-12 telephone coaching sessions	0.23*
Bossen, 2013	Technology (Telephone/ email/ text/ computer module training)	Online	Individual	Home	9 weeks	10	Weekly modules	0.01
Brosseau, 2012	In-person Telephone	Physical activity specialist	Individual and group	Walking clubs Classes	12 Months	17	Baseline: intro information session Weekly walking sessions (65 mins) with PA specialist present for ≥3x /wk 20x2 hour weekly group sessions months 0-6: Monthly face-to-face meetings (first 6 months) Months 7-12: Telephone counselling (unspecified frequency)	-0.10
Froelich-Grobe, 2004	In-person Telephone	Exercise physiologist	Individual and group	Home and/or commu-nity fitness centre	25 weeks	16	Baseline: Day-long educational workshop 1x30-45 minute individualized PA counselling phone call Paired with program partner for weekly telephone support Self- reward encouraged weekly	0.45
Froelich-Grobe, 2014	In-person Telephone Mail	Professional patient educator/peer Researcher	Individual and group	Particip-ant choice	26 weeks	15	Day-long educational workshop Months 1-2: weekly phone calls Months 3-4: biweekly phone calls Months 5-6: monthly phone calls Monthly newsletters by mail	.46
Hughes, 2006	In-person	Physiotherapists Researchers	Group	Senior's centres	8 weeks	11	90 minutes supervised training and educational coaching 3x/wk	0.89
Kosma, 2005	Technology (Website,	Computer	Group	Home	4 weeks	10	Weekly email for link to lesson plan	0.35

	E-mail)							
Latimer, 2006	Telephone	Researcher	Individual	Home	4 weeks	10	Baseline: Interview, emailed calendar Week 4: Update goals, emailed calendar	0.59
Learmonth, 2017	Technology (Skype and newsletter)	Researcher	Individual	Home	16 weeks	13	Month 1: skype calls=1-4, newsletters=1-2 Month 2: skype calls=5, Newsletters=3-4 Month 3: skype calls=6-7, Newsletters=6 Month 4: skype calls=8, Newsletters=6	0.42
Maher, 2010	In-person Technology (Text, e-mail, website)	Researcher	Individual	Home	8 weeks	13	One intro session Weekly emails or text messages to use the site	0.44
McAuley, 2007	In-person	Researcher	Group	Health and wellness centre	12 weeks	11	Bi-weekly workshops Buddy groups formed	0.44
Nooijen, 2015	In-person Telephone	Physiotherapist or occupational therapist	Individual	Rehab centre	8 months	12	Bimonthly coaching	0.60
O'Brien, 2013	In-person	Researcher	Individual	Research setting	12 weeks	10	1 intro session	-0.04
Pilutti, 2014	Technology (Website and video)	Researchers	Individual	Home	6 months	14	15 web-based video coaching sessions (7 in 1st two months, 6 in second 2 months, 2 in final 2 months) Website (new content available 7 times in first 2 months, 4 in second 2 months, twice in final 2 months)	0.82
Plow, 2014	In-person Pamphlet	Researcher	Individual	Home	12 weeks	14	2 in-person home exercise prescription sessions Customized pamphlets mailed every 3 weeks for 24 weeks (first time in person)	0.72
Rice, 2015	In-person Telephone	Occupational therapists Physiotherapists	Individual	Home	3 months	13	Weekly phone calls	0.22
Rimmer, 2013	Telephone	Researcher	Individual	Home	9 months	14	Months 1-4: Weekly telephone coaching Months 5-7: biweekly coaching Months 8-9: monthly coaching Monthly newsletter and individualized feedback	0.19
Slaman,	In-person	Physiotherapists	Individual	Home	6	15	Months 1-6: monthly counselling 30	0.32

2014		Movement therapist		Rehabilita-tion centre	Months		minute sessions + 2-4 sports participation counselling sessions Optional sports-specific training	
Smith, 2012	In-person	Social worker Physiotherapist (supervised exercise)	Individual	Interview space	8 weeks	10	3 x 30-60 minute sessions of motivational interviewing	-0.15
Suh, 2015	Telephone	Researcher	Individual	Home	6 weeks	11	Weekly newsletters and phone calls	0.33
Talbot, 2003	In-person	Registered nurse	Individual and group	Class	24 weeks	11	Brief individual counselling session once every 4 weeks	-0.10
van Nimwegan, 2013	In-person	Physiotherapists	Individual	Community hospitals	2 years	15	Baseline: information brochure Year 1: 16 coaching sessions + maximum of 18 physical therapy sessions Year 2: 12 coaching sessions + maximum of 23 physical therapy sessions	0.52
Wise et al., 2009	In-person Telephone	Physiotherapists	Individual	Home	3 months	13	Baseline: individualized instructions on in-home PA program Month 1: Telephone calls 1x/wk Month 2: 2 telephone calls Month 3: 1 telephone call	0.08

Note: If provider was unspecified researcher was assumed. POWERS group was used from Rimmer et al. (2010). The walking and behavioural intervention group was used from Brosseau et al. (2012).

[#]Intervention intensity scale scoring: *Intervention duration*: 1 = <6 weeks, 2= 6 to 11 weeks, 3= 12 weeks to 5 months, 4 = 6 to 12 months and 5 = >12 months; *frequency of contact*: 1 = annually, 2 = bimonthly to quarterly, 3 = monthly, 4 = weekly and 5 = daily; *type of contact*: 1 = environmental (physical, policy or legislative level), 2 = environmental with a small group/ education component, 3 = group, 4 = group with an individual component (goal setting, homework task) and 5 = individual (one-on-one); *reach (number of settings used to reach the target audience)*: 1 = one setting, 3 = two settings and 5 = three settings.

*Not included in the overall effect size calculation.

Table 3. Moderating variables for the effect of intervention on physical activity behaviour

Category	df	Qb	Level	k	ES	SE	Lower CI	Upper CI	i^2
Overall	21	29.85* (Q)		22	**0.35**	0.07	0.21	0.48	29.65
Disability Type	5	3.08	CP	2	0.20	0.22	-0.24	0.64	0
			Mixed	4	0.37	0.10	0.17	0.58	0
			MS	7	0.50	0.12	0.26	0.73	0
			OA	6	0.18	0.17	-0.16	0.51	71.00
			PD	1	0.52	0.23	0.06	0.97	0
			SCI	4	0.54	0.17	0.21	0.87	0
Sample Time Point	4	1.61	<3 months	8	0.38	0.11	0.17	0.58	0
			3-6 months	7	0.52	0.09	0.34	0.70	24.51
			>6 months	9	0.32	0.10	0.13	0.51	0
Theory	1	12.90*	Yes	12	**0.53**	0.08	0.38	0.68	0
			No	10	0.13	0.08	-0.04	0.29	0
Theory intensity	3	15.64*	0	10	0.13	0.08	-0.04	0.29	0
			1	3	0.35	0.18	0.00	0.69	0
			2[a]	7	**0.62**	0.09	0.44	0.81	0
			3[a]	2	**0.38**	0.18	0.03	0.72	0
Provider	5	9.41	HCP	7	0.31	0.13	0.05	0.56	0
			Researcher	10	0.49	0.08	0.32	0.66	27.6
			Other	5	0.21	0.08	0.03	0.38	49.6
Group/individual delivery	2	2.49	Group	3	0.61	0.20	0.22	1.01	38.23
			Individual	15	0.35	0.08	0.20	0.49	0
			Individual and group	4	0.20	0.17	-0.13	0.53	60.42
Mode of delivery	4	0.98	In-person	8	0.41	0.15	0.12	0.70	37.15
			In-person and Technology/Telephone	8	0.27	0.10	0.07	0.47	19.84
			Technology	3	0.39	0.24	0.05	0.73	53.12
			Telephone	3	0.32	0.14	0.04	0.60	0

Note. CI=confidence interval, CP=cerebral palsy, df= degrees of freedom, ES=effect size, HCP=health care provider, k=number of studies, MS=multiple sclerosis, OA=osteoarthritis, OT=occupational therapist, PD=Parkinson's disease, Qb= measure of homogeneity, SCI=spinal cord injury, SE=standard error, *$p<0.05$, [a]=significantly different from theory intensity of 0 ($p<0.0125$; adjusted for number of comparisons)

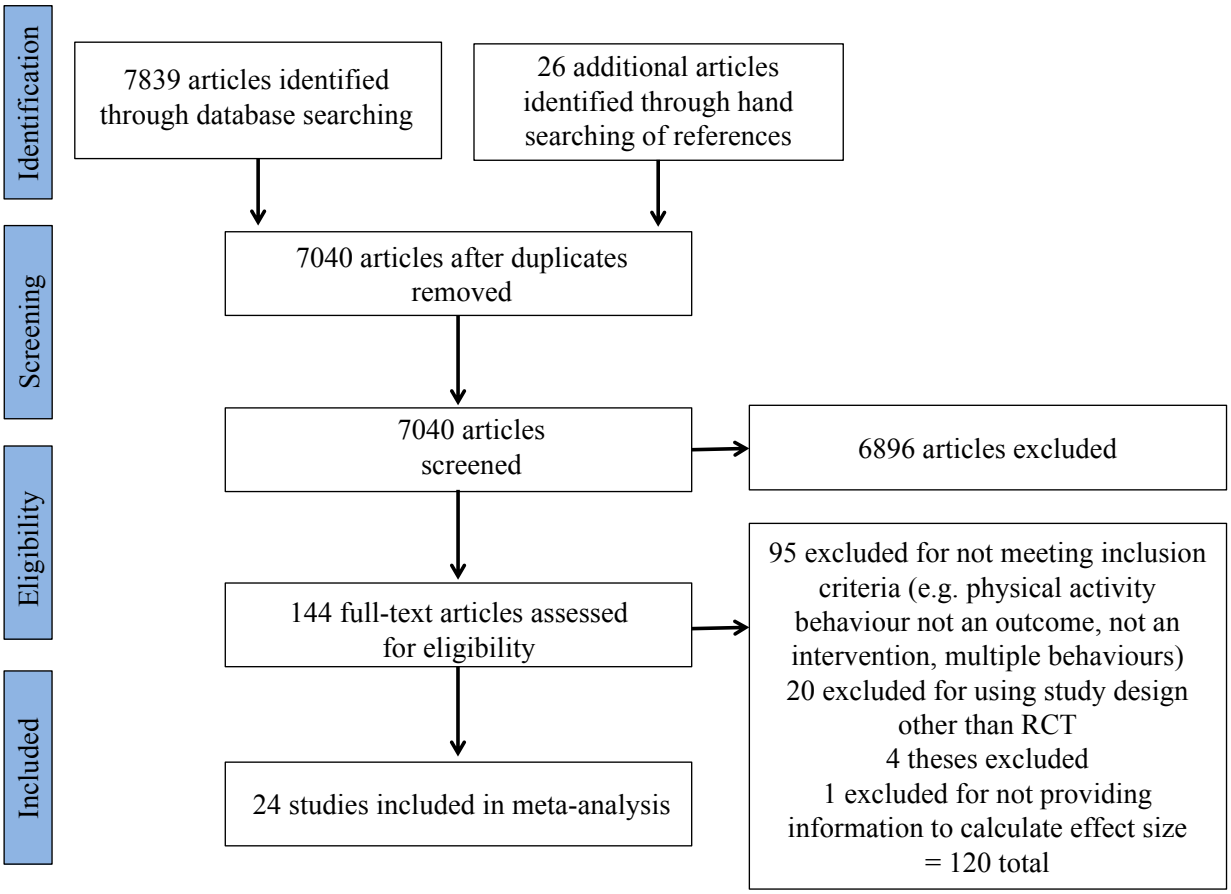

Figure 1. Systematic literature search and exclusion of papers.

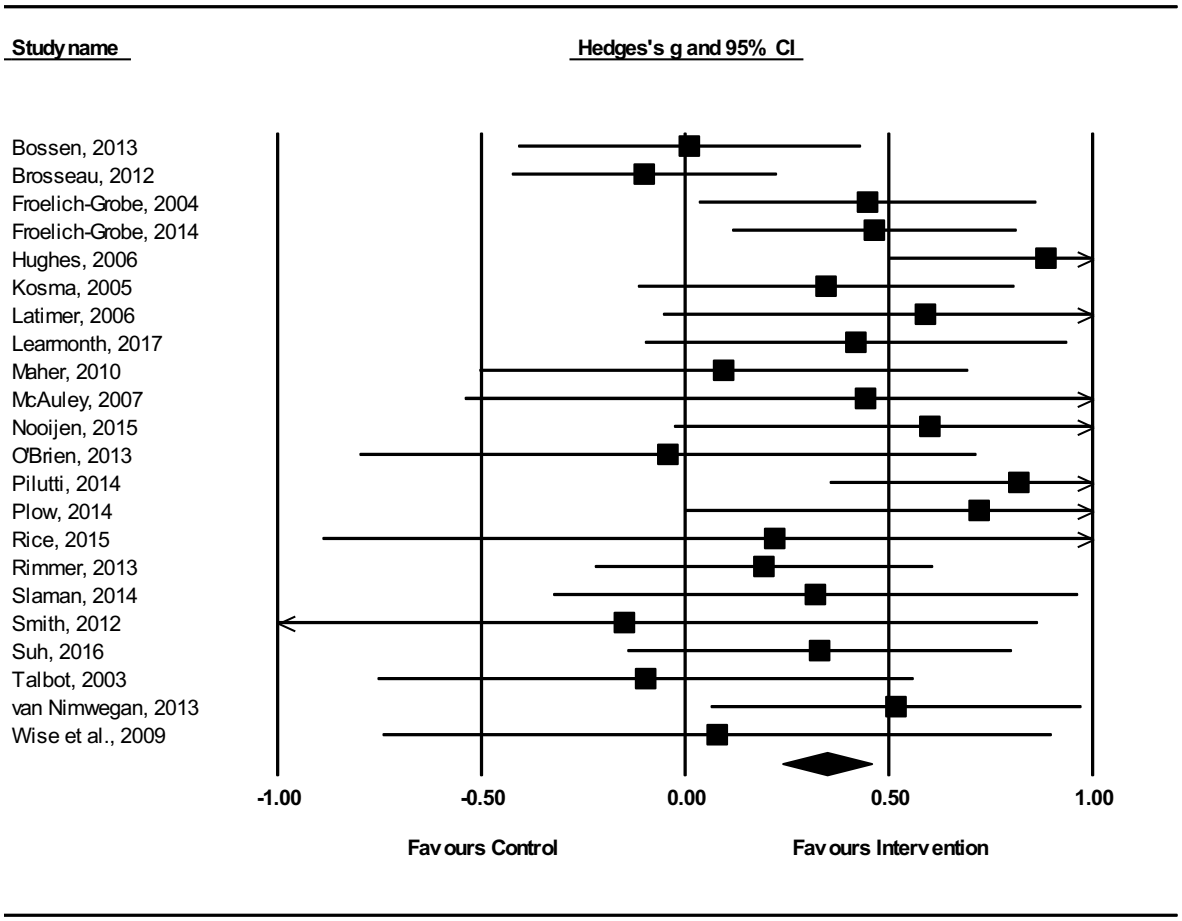

Figure 2. Forest plot of study effect sizes

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Supplementary File 1: Sample Search Strategy

Medline:

1. exp Intervention Studies/
2. exp Program Evaluation/ or program*.mp. or exp Program Development/
3. exp Curriculum/
4. "Physical Education and Training"/
5. promotion.mp.
6. initiative.mp.
7. behavio$r change.mp.
8. strateg*.mp.
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. exp Sports/
11. exercise/ or circuit-based exercise/ or plyometric exercise/ or resistance training/ or running/ or swimming/ or walking/
12. exp Physical Fitness/
13. exp Exercise Therapy/
14. physical activ*.mp.
15. 10 or 11 or 12 or 13 or 14
16. exp Osteoarthritis/
17. exp Parkinson Disease/
18. exp Multiple Sclerosis/
19. exp Spinal Cord Injuries/
20. exp Amputees/
21. exp Cerebral Palsy/
22. exp Stroke/
23. exp Disabled Persons/
24. 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23
25. 9 and 15 and 24

Supplementary File 2: References for studies included in the meta-analysis

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Supplementary Table 1. Data Extraction

Available upon request (file format not able to download to submission system).

Supplementary Table 2. Summary of individual studies and the behaviour change techniques employed

BCTs Identified	Arbour-Nicitopoulos, 2009	Bennell, 2017	Bossen, 2013	Brosseau, 2012	Froelich-Groebe, 2004	Froelich-Groebe, 2014	Hughes, 2006	Kosma, 2005	Latimer, 2006	Learmonth, 2017	Maher, 2010	McAuley, 2007	Nooijen, 2015	O'Brien, 2013	Pilutti, 2014	Plow, 2014	Rice, 2015	Rimmer, 2013	Slaman, 2014	Smith, 2012	Suh, 2015	Talbot, 2003	Van Nimwegen, 2013	Wise, 2009	Total	Studies using BCT ES	ES difference between studies that did and did not use BCT	Q_b
Goal setting (behaviour) (1.1)			■	■		■		■		■	■		■	■	■		■	■			■		■	■	15	.29	-.15	1.41
Problem Solving (1.2)	■	■		■	■	■	■	■		■		■	■	■	■	■	■	■	■		■		■	■	19	.40	.17	1.533
Goal Setting (outcome) (1.3)								■																	1			
Action planning (1.4)		■				■			■				■	■		■		■							7	.35	.01	0.01
Review behaviour goal(s) (1.5)						■																			2			
Behavioural contract (1.8)							■																■		2			
Commitment (1.9)														■											2			
Monitoring of behaviour by others without feedback (2.1)				■																	■			■	3	.05	-35*	5.31*
Feedback on behaviour (2.2)							■			■		■	■		■	■		■				■			8	.52	.26[a]	3.52[a]
Self-monitoring of behaviour (2.3)			■		■	■	■			■			■		■	■	■	■				■	■		12	.45	.24*	4.34*
Self-monitoring of outcome of behaviour (2.4)						■																			1			
Monitoring of outcome of behaviour by others without feedback (2.5)				■																					1			
Social support (unspecified) (3.1)					■	■						■	■		■			■		■		■			8	.41	.08	0.39
Social support (practical) (3.2)		■		■	■	■	■	■				■	■	■	■		■	■	■		■		■	■	16	.34	-.02	0.02
Social support (emotional) (3.3)		■	■	■		■																	■	■	6	.28	-.12	0.46
Instruction on how to perform the behaviour (4.1)			■		■	■	■			■		■			■	■	■	■				■	■		12	.34	.18	1.99
Information about health consequences (5.1)				■	■	■		■		■			■		■		■				■				9	.38	.05	0.12
Salience of consequences (5.2)			■																						1			
Demonstration of the behaviour (6.1)						■				■							■								3	.38	.04	0.81
Prompts/cues (7.1)								■																	1			
Behavioural practice/rehearsal (8.1)						■													■	■			■		4	.42	.08	0.29
Graded tasks (8.7)			■	■		■	■			■			■			■		■	■			■			11	.31	-.08	0.38
Credible source (9.1)				■	■	■	■						■				■		■			■	■		9	.38	.06	0.19

Material reward (behaviour) (10.2)				■			■																	2			
Social reward (10.4)							■																	1			
Self-reward (10.9)					■			■																2			
Restructuring the physical environment (12.1)													■											1			
Adding objects to the environment (12.5)						■				■						■							■	4	.45	.11	0.58
Identification of self as role model (13.1)											■													2			
Verbal persuasion about capability (15.1)																				■				2			
Focus on past success (15.3)																				■				1			
Vicarious consequences (16.3)								■		■														2			
Total BCTs/ paper	1	4	6	10	8	16	11	8	1	10	2	6	11	5	8	8	8	9	5	3	7	6	9	6			

Note: ES=effect size, Q_b=measure of homogeneity, *significantly different ($p<0.05$), [a]Approaching significance.

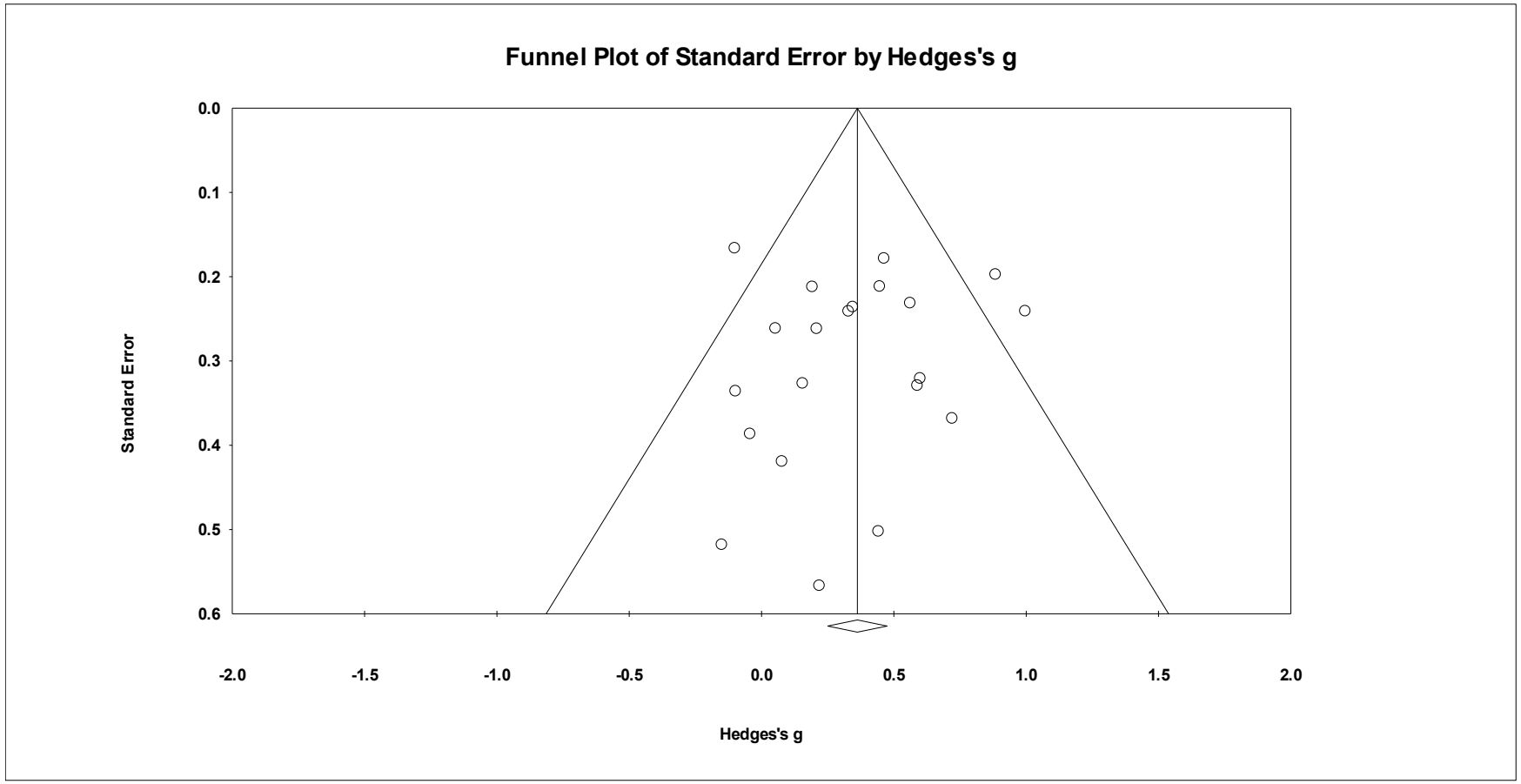
Supplementary Table 3. Cochrane risk of bias table for randomized controlled trials

First author, year	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Arbour-Nicitopoulos, 2009	+	−	−	−	+	?	+
Bennell, 2017	+	+	−	+	+	−	−
Bossen, 2013	?	+	−	−	+	?	−
Brosseau, 2012	+	+	−	+	+	?	−
Froelich-Grobe, 2004	?	?	−	−	−	?	−
Froelich-Grobe, 2014	+	?	−	+	+	+	−
Hughes, 2006	+	−	−	?	+	?	−
Kosma, 2005	?	?	−	?	−	?	−
Latimer, 2006	+	?	−	+	+	?	−
Learmonth, 2017	+	+	−	−	+	?	−
Maher, 2010	+	?	−	+	−	?	−
McAuley, 2007	?	−	−	−	+	?	−
Nooijen, 2015	+	+	−	+	+	?	−
O'Brien, 2013	+	?	−	+	+	?	−
Pilutti, 2014	+	+	−	−	−	?	−
Plow, 2014	+	+	−	−	+	+	+

Rice, 2015	?	?	−	?	−	?	−
Rimmer, 2013	+	−	−	+	+	?	−
Slaman, 2014	+	?	−	+	−	?	−
Smith, 2012	?	−	−	+	+	?	−
Suh, 2015	+	+	−	+	+	?	+
Talbot, 2003	+	−	−	−	−	?	+
van Nimwegan, 2013	+	+	−	+	+	?	−
Wise et al., 2009	+	?	−	?	−	?	−

Note. + = low risk of bias − =high risk of bias ? =unclear

Supplementary Figure 1. Funnel Plot



Supplementary Figure 2. PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract online
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	1-3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4-5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5-6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5, (SF1)
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7-9
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7-9
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	9-10
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	9-10

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	8
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	10-11
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10, Fig. 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 1, SF2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	11, ST3
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Table 2, 3, ST2, Fig 2
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	11-14
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	11
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	12
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	14-21
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	19-20
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	20-21
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Title Page

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