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Behavior change techniques associated with changes in post-intervention and maintained changes in self-efficacy for physical activity: systematic review with meta-analysis

Abstract

Background: Self-efficacy is an important determinant of physical activity but it is unclear how best to increase self-efficacy for physical activity and to maintain these changes.

Purpose: This systematic review aimed to identify which specific behavior change techniques (BCTs), BCT clusters, and number of BCTs were associated with changes in post-intervention and maintained changes in self-efficacy for physical activity across all adult populations.

Methods: A systematic search yielded 180 randomized trials (204 comparisons) which reported changes in self-efficacy. BCTs were coded using the BCT Taxonomy v1. Hierarchical cluster analysis explored the clustering of BCTs. Meta-analyses and moderator analyses examined whether the presence and absence of individual BCTs in interventions were associated with effect size changes for self-efficacy.

Results: Small intervention effects were found for post-intervention self-efficacy for physical activity (d=0.26; 95% CI: [0.21, 0.31]; I^2=75.8%). 'Information about social, environmental, and emotional consequences' was associated with higher effect sizes, whereas 'social support (practical)' was associated with lower effect sizes. Small, and non-significant effects were found for maintained changes in self-efficacy for physical activity (d=0.08; CI: [-0.05, 0.21]; I^2=83.8%). Lack of meaningful clustering of BCTs was found. A significant positive relationship was found between number of BCTs and effect sizes for maintained changes in self-efficacy for physical activity.

Conclusions: There does not appear to be a single effective approach to change self-efficacy for physical activity in all adults: different approaches are required for different populations.

Interventions with more BCTs seem more effective at maintaining changes in self-efficacy for physical activity.

248/250 words, **keywords**: self-efficacy, physical activity, behavior change, systematic review, meta-analysis, meta-regression, cluster analysis

Introduction

Benefits of physical activity for health

Physical inactivity and poor diet has been identified as the second leading behavioral cause of mortality in the United States (US) [1]. It was estimated that 400,000 deaths in the US each year are attributable to the effects of overweight, as a result of poor diet and physical inactivity [1]. Physical activity can play an important role in the prevention of disease.

Self-efficacy as a target for physical activity interventions

Self-efficacy is a core construct in many health behavior theories such as the Social Cognitive Theory [2] and the Health Action Process Approach (HAPA) [3]. Self-efficacy has been defined as the perceived capability to perform a specific behavior [2]. The conceptualisation of self-efficacy changed over time to be about control over outcomes [4]. Whilst many definitions of the control construct exist [5], the present review defines self-efficacy in line with the earlier writings of Bandura which focusses on control over behavior. The stronger an individual's sense of self-efficacy, the more effort they are likely to devote to an activity [6].

Self-efficacy has been identified as a correlate of physical activity [7] and a predictor of future physical activity behavior [8] in many studies. The role of self-efficacy in mediating the effect of physical activity is also supported by a review of behavioral mediators of physical activity which concluded that, while the evidence is far from compelling, there is some support

for self-efficacy as a mediator of physical changes due to interventions [9]. For example, an experimental study showed that participants who participated in a single intervention session aimed at increasing perceived behavioural control showed larger increases in walking behavior, as objectively measured by a pedometer, than participants allocated to the control group [10]. Mediation analyses showed that the effects of the intervention on walking behavior were mediated by perceived behavioural control. Those who showed the largest increases in perceived behavioural control also showed the largest increases in walking behaviour.

There is also some evidence that self-efficacy plays a key role in the maintenance of physical activity. A recent systematic review found 'prompting self-monitoring of behavioral outcome' and 'use of follow-up prompts' to be effective at achieving maintenance of physical activity at six to nine months [11]. Some theorists have proposed that there are phase-specific self-efficacy beliefs [3]. A prospective cohort study, for example, has found that individuals high in recovery self-efficacy, the belief that one can continue an action following a relapse, may be more likely to maintain objectively assessed walking in groups [12]. Maintenance self-efficacy, the belief that one can maintain behavior regardless of obstacles encountered, was not found to be predictive of attendance at the walking groups.

However, progress in understanding maintenance has been hampered by a lack of a consistent definition [13]. Distinctions between the phases of behavioral initiation and maintenance tend to be based on the time frame in which the behavior has been performed [14]. For example, physical activity change is generally considered to have been successfully maintained when individuals continue to engage in regular physical activity for at least six months following the end of an intervention [15]. Conceptualising maintenance in terms of time suggests that there is a discrete moment in time where people shift from attempting to initiate a behavior to trying to maintain it [14]. Whilst phase-specific self-efficacy beliefs have been proposed, time has been used as a criterion for distinguishing between initiation and

maintenance (labelled as post-intervention self-efficacy and maintained changes in self-efficacy in the present paper, respectively) as few physical activity studies use measures of phase-specific self-efficacy beliefs.

Behavior Change Techniques and delivery features associated with self-efficacy for physical activity

Given its importance, we need to understand how best to increase self-efficacy to initiate and maintain physical activity. From a theoretical perspective, it has been proposed that self-efficacy beliefs are constructed from four main sources: enactive mastery experience, vicarious experiences, verbal persuasion, and physiological and emotional arousal [2]. In light of advances in behavioral science, recent systematic reviews have aimed to empirically identify which behavior change techniques (BCTs) are associated with changes in self-efficacy. A BCT is "a technique…proposed to be an 'active ingredient'" [16, p.2] of an intervention that contributes to its effectiveness. Previous reviews have coded BCTs using standardised taxonomies, calculated effect sizes, and conducted meta-analyses with moderator analyses by comparing the effect size estimates for groups of studies characterised by the presence or absence of individual BCTs [17-19].

The existing reviews using these methods have covered a range of populations. A systematic review with non-obese adults without a clinical condition [17] found interventions had a small significant effect on change in physical activity self-efficacy (d=0.16). Interventions that included 'action planning', 'reinforcing effort or progress towards behavior', and 'provide instruction' produced larger self-efficacy effect sizes than interventions which did not contain these BCTs.

Another systematic review and meta-analysis investigated which specific BCTs are associated with self-efficacy and physical activity behavior in obese adults [18]. The

interventions had a small significant effect on change in self-efficacy (d=0.23). Interventions that contained 'action planning', 'prompt self-monitoring of behavioral outcome', 'plan social support/social change', 'time management' produced larger effect sizes for self-efficacy compared to when these techniques were absent. Lower effect sizes for self-efficacy were produced when interventions included 'set graded tasks' and 'prompting generalisation of a target behavior'.

In addition to healthy and obese adults, a further review examined which BCTs are associated with increases in self-efficacy and physical activity behavior in non-clinical community-dwelling adults of 60 years or over [19]. The interventions had a significant small to medium sized effect on self-efficacy (d=0.37). Self-regulatory techniques, such as 'prompting self-monitoring of behavioral outcome', were found to be associated with lower effect sizes in self-efficacy. This differs to the findings of previous reviews on healthy and obese adults [17, 18]. The contrasting results across the three reviews suggest that different BCTs may be needed for changing self-efficacy for physical activity across different adult populations.

In all three previous reviews of which BCTs were associated with self-efficacy for physical activity, no analyses were conducted to investigate if delivery features of the interventions were associated with changes in self-efficacy for physical activity. It has been suggested that form of delivery is an 'active ingredient' in behavior change interventions and can impact on effectiveness [20]. Self-efficacy could be enhanced by observing a model similar to oneself successfully perform a behavior, or through verbal persuasion [2]. Therefore, it is possible that interventions delivered in person may be more effective at increasing self-efficacy than those which do not involve any human contact.

Behavior Change Techniques associated with maintaining changes in self-efficacy for physical activity

These three reviews just described have only focused on post-intervention changes in self-efficacy for physical activity. To date, the BCTs which are effective at maintaining changes in self-efficacy for physical activity have yet to be identified. A systematic review of maintaining changes in physical activity and dietary behavior found that interventions that included more than six BCTs were more successful at maintaining change than those that did not [21].

Association between number of Behavior Change Techniques and intervention effectiveness

The previous reviews cited have all examined BCTs individually. Most behavior change interventions however contain multiple interacting components. Yet, whether the number of BCTs present in interventions influences intervention effectiveness has received less empirical attention. The review conducted by Fjeldsoe and colleagues (2011) [21] implies that using more BCTs is associated with better maintenance of physical activity. However, this was based on dichotomising intervention characteristics (i.e. did the intervention consist of more than six BCTs), rather than a continuous count of BCTs. A positive association has also been found between the number of BCTs present in physical activity interventions and effect sizes for intention and stage of change [22]. Thus, it is possible that the number of BCTs contained in interventions can affect intervention outcomes.

Clustering of Behavior Change Techniques

Where multiple BCTs are present within an intervention, the effects of the BCTs can be: 1) additive, 2) cancelled out, or 3) synergistic [23]. One systematic review and meta-regression found physical activity and healthy eating interventions were more likely to be

effective if they include self-monitoring and at least one other self-regulatory technique from Control Theory [24]. This suggests that physical activity and diet interventions which contain this specific 'cluster' of techniques may be more effective than those which do not. A re-analysis of the Michie et al. [24] data was performed using the methodology of applying Classification and Regression Trees (CART) to meta-analytic data [23]. Two combinations of BCTs were identified that were associated with more change in behavior: 1) 'provide information about behavior-health link' with 'prompt intention formation', and 2) 'provide information about behavior-health link', 'provide information on consequences', and 'use of follow-up prompts.' These findings highlight that the combined effects of BCTs need to be explored.

Another review on the long-term effectiveness of physical activity interventions in older adults examined the co-occurrence of intervention features (such as delivery and BCTs) [25]. In this review, interventions which used 'feedback' also used at least one other self-regulatory technique, possibly indicating that BCTs were clustered, although this was not tested directly. Further, the co-occurrence data in this review was not linked to outcome effectiveness.

There are limitations with the approaches that have been used to consider combined effects of BCTs to date. For example, Meta-CART focused on applying regression techniques to effect sizes but still examined the BCTs individually, albeit sequentially. Further, meta-CART appears to be more suitable for when BCTs are already known to be clustered, as it aims to identify effects attributable to collections of individual BCTs rather than directly detect such clusters. Hence, these approaches do not directly assess whether unique associations of individual BCTs with outcomes may be due to those BCTs being associated with the presence of other BCTs. Hierarchical cluster analysis directly identifies the overall pattern of BCT clustering and provides an estimate of such clustering derived to identify which BCTs are more likely to occur together within a set of intervention descriptions. Such estimation is carried out

inductively, rather than based on pre-defined (theoretical) assumptions of how BCTs would cluster.

Aims of Present Review

The present systematic review with meta-analysis aimed to identify which specific BCTs, clusters of BCTs, and number of BCTs were associated with changes in self-efficacy for physical activity in randomized trials across all adult populations. The specific objectives were to use systematic review methods:

1) To explore the extent of clustering for BCTs present in interventions.
2) To quantify the overall intervention effects on post-intervention self-efficacy for physical activity and maintained changes in self-efficacy for physical activity.
3) To examine the relationship between the number of BCTs present in interventions to change physical activity and effect sizes for post-intervention self-efficacy for physical activity and maintained changes in self-efficacy for physical activity.
4) To identify which specific BCTs are associated with post-intervention self-efficacy for physical activity and maintained changes in self-efficacy for physical activity in adults.
5) To identify which delivery features of the interventions are associated with post-intervention self-efficacy for physical activity and maintained changes in self-efficacy for physical activity in adults.
6) To assess risk of bias of all included trials, and to conduct sensitivity analyses to assess whether overall estimated effects are affected by:
    a) Study quality
    b) Whether studies targeted physical activity or multiple behaviors
    c) Self-efficacy measures used in the studies

Method

The review followed the stages outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [26].

Eligibility criteria

Eligible studies were required to include samples of community-dwelling adults, who were 18 years or older. Only randomized trials were eligible, with at least one intervention group and a control group which either received no intervention/usual care (including waiting list conditions), or another active intervention (such as receiving a leaflet about the benefits of physical activity) with different BCTs to the comparator intervention group(s). Interventions that targeted increasing amount of physical activity, or which targeted multiple behaviors including physical activity, e.g. physical activity combined with healthy eating, were included.

Interventions should have targeted physical activity change, and measured changes in physical activity self-efficacy, at least once post-intervention. The interventions did not have to specifically state a change in self-efficacy as the intervention goal. Specific physical activity measures, such as walking self-efficacy, were included. Perceived behavioral control in relation to physical activity was considered as physical activity self-efficacy in the present review as discriminant analyses have shown that measures of perceived behavioral control and self-efficacy overlap considerably [27]. Following published guidance that self-efficacy scales should be specific to the domain/activity of interest (i.e. physical activity), measures of general self-efficacy, along with constructs such as competence, were excluded [28]. Perceived control was not included given that it does not take into account one's confidence in performing specific tasks within a particular context [29].

Search strategy

Studies were identified through electronic database searching, backward and forward-citation searching of the included studies and relevant review papers [17-19]. The search terms and string outlined in Appendix 1 (see Supplementary Materials 1) were first used to search in MEDLINE, PsycINFO, and Web of Science on 20 July 2013 and was last updated early 2016. Authors were contacted for additional information if data needed to calculate effect sizes were not adequately reported in the paper.

Study selection

Database searching generated 6806 citations relevant to the review for title and abstract screening, of which data was extracted for 180 studies (204 comparisons). A randomly selected 20% of the titles and abstracts from the first search were screened by two researchers (XX and XX). Inter-rater reliability was assessed by computing the chance-corrected kappa statistic, κ=0.61. Ten per cent of randomly selected full-text articles were also screened by two researchers (XX and XX), κ=0.73.

BCT coding process and data extraction

For all the included studies, information relating to intervention delivery characteristics were extracted: by whom (e.g. researcher), the mode (e.g. in-person session), and the delivery setting (e.g. community; see Table 1 for full list of items coded). BCTs were independently coded using the BCT Taxonomy version 1 (BCTTv1) [16] by at least two trained researchers (XX, XX, and XX) with good agreement (κ=0.70). Any disagreements were resolved through discussion and, where required, another researcher (XX) moderated. Effect sizes, obtained as Cohen's *d* (standardised mean difference), were calculated separately for post-intervention and maintained changes in self-efficacy for physical activity (where available). Where authors could not provide additional information for the calculation of Cohen's *d*, *p*-values and

confidence intervals were used to calculate effect sizes. In cases of null findings, the assumption of no effect was the best estimate so a value of zero was imputed, in line with recommended practice [30]. A random 10% of the included studies had data reliably extracted by two researchers (XX and XX), regarding by whom (κ=0.72), the mode (κ=0.90), and where the interventions took place (κ=0.74).

If data was reported for several time-points, data reported immediately post-intervention was used to calculate effect sizes for post-intervention self-efficacy as this would be when the largest effects attributable to the intervention would be expected. A period of six months post-intervention was considered as indicating maintained changes in self-efficacy [15]. If time-points beyond six months (e.g. 12 months) were also available, effect sizes were calculated for the first maintenance time-point (i.e. six months).

Post-intervention self-efficacy for physical activity refers to self-efficacy beliefs up to six months from the end of the intervention, in relation to baseline values. Maintained changes in self-efficacy for physical activity refers to self-efficacy beliefs six months after the end of the intervention, in relation to baseline values. This contrasts to other uses of 'maintenance self-efficacy' in the literature which, for example, has been conceptualised as the optimistic beliefs that one has for overcoming barriers and challenges during attempts to sustain the behavior change [31].

Where available, intention-to-treat data was used for the calculation of effect sizes. For studies where there were two or more experimental groups with the same BCTs, these groups were combined to create a single intervention group [30], resulting in a single sample size, mean, and standard deviation for the combined intervention group. For studies where there were two or more experimental groups, where each group contained different BCTs; each experimental group was compared to the control group so that each was treated as a separate comparison (i.e. a separate effect size was calculated for each comparison). In these cases, the

sample size of the 'shared group' (i.e. the control group) was split per the number of experimental groups [30].

The included studies were quality assessed using The Cochrane Collaboration tool for assessing risk of bias [30].

Synthesis of results and additional analyses

Hierarchical cluster analyses to examine the patterns of clustering amongst BCTs within individual trials were performed in IBM SPSS Statistics v22 using Ward's method, employing the Squared Euclidean distance for binary data as the measure of dissimilarity. In line with previous reviews, only BCTs which were present in at least two interventions were included in the analysis [19].

Meta-analyses for post-intervention self-efficacy for physical activity and maintained changes in self-efficacy for physical activity were performed using StataIC 12 using random-effects models. Heterogeneity was assessed using Higgins I-square (I^2), whereby 50% to 90% was considered as representing substantial heterogeneity [30].

Two-way Spearman's rho correlations were performed to correlate the number of BCTs present in the intervention groups of randomized trials with effect sizes for post-intervention self-efficacy for physical activity and maintained changes in self-efficacy for physical activity.

Univariate meta-regression analyses were conducted to explore sources of heterogeneity according to the presence and absence of specific BCTs and intervention characteristics. These analyses were conducted twice in relation to post-intervention self-efficacy for physical activity and maintained changes in self-efficacy for physical activity. Multivariate meta-regression models were then created 1) for BCTs only, 2) for intervention characteristics only, and 3) intervention characteristics and BCTs. Only variables which showed a potential association with the effect size (p <.2) in the univariate analyses were

included into these models. Correlations between variables were examined by calculating Cramer's V. This allowed us to identify variables that were potentially collinear (i.e. $V \geq .6$). Where Cramer's V was $\geq .6$, only one of the variables was entered into the multivariate models. Monte Carlo permutation tests (20,000) were conducted to calculate p values adjusted for multiple testing.

Sensitivity analyses employed meta-regression to explore whether results differed according to sources of bias identified from the risk of bias assessment, whether the studies targeted physical activity or multiple behaviors, and type of self-efficacy measures. However, analyses were not performed on the 'blinding of participants and personnel' criterion since this is difficult to achieve given the nature of physical activity interventions. In line with Cochrane's recommendations, results of studies of low risk were compared to those identified as high or unclear risk [30]. Egger's test was conducted to formally assess for the presence of publication bias.

Results

Study and intervention characteristics

A total of 180 studies (see Appendix 2, Supplementary Materials 1) were included into the review which allowed k=204 and k=27 comparisons for the test of the interventions on post-intervention self-efficacy for physical activity and maintained changes in self-efficacy for physical activity, respectively. Key characteristics of the studies are presented in Appendix 3 (see Supplementary Materials 1). A completed PRISMA flow diagram of studies screened, excluded (with reasons) and included is shown in Figure 1.

<Figure 1 – PRISMA flowchart here>

The majority of the interventions for post-intervention self-efficacy for physical activity focused on increasing general physical activity (n=129; see Table 1). Interventions were most

commonly delivered by a healthcare professional (*n*=74), researcher (*n*=71) or self-administered (*n*=65); through in-person sessions (*n*=130), or written/postal materials (*n*=118) and in the home setting (*n*=69; see Table 1).

<Table 1 here>

The frequencies with which all BCTs were included in interventions are presented in Supplementary Materials 2. The most commonly used BCTs included 'goal setting (behavior)' (*n*=115), 'problem solving' (*n*=114), 'information about health consequences' (*n*=88), 'social support (unspecified)' (*n*=86) and 'action planning' (*n*=81).

Cluster analysis

For post-intervention self-efficacy for physical activity, hierarchical cluster analyses suggested three potential clusters. The first consisted of 'goal setting (behavior)', 'action planning', 'review behavior goal(s)', 'feedback on behavior', 'problem solving', 'social support (unspecified)', 'self-monitoring of behavior', and 'information about health consequences'. This cluster seems to be mainly produced due to the high frequencies of these BCTs. The second consisted of 'instruction on how to perform the behavior', 'demonstration of the behavior', 'behavioral practice/rehearsal', and 'graded tasks'. The formation of this cluster appeared to reflect recommendations for coding using the BCTTv1, which suggests that all three BCTs should be coded together if the person attends a physical activity class. The rest of the BCTs (*n*=35) included in the analysis then formed the third cluster.

Post-intervention self-efficacy for physical activity

Meta-analysis results

Overall, the interventions had small but significant effects on post-intervention self-efficacy for physical activity (d=0.26, 95% CI: [0.21, 0.31], k=204). There was considerable heterogeneity for post-intervention self-efficacy for physical activity (I^2=75.8%).

Comparison of BCTs in intervention and control groups

For post-intervention self-efficacy for physical activity, interventions employed a mean of 7.12 (*SD* = 3.65) BCTs and control conditions employed a mean of 1.55 (*SD* = 2.72) BCTs. The association between the number of BCTs included in the intervention groups and the effect size for post-intervention self-efficacy for physical activity was not statistically significant (Spearman's rho=.078, k=204, p=.270).

Moderator analyses – univariate meta-regression results

<Table 2 here>

Moderator analyses were conducted to explore differences in post-intervention self-efficacy for physical activity, according to the presence and absence of 49 specific BCTs (see Table 2 for summary of significant moderators and Supplementary Materials 2 for full results). Three BCTs were found to be significantly associated with larger post-intervention self-efficacy for physical activity effect sizes when present: 'information about social and environmental consequences' (d=0.71, p=.001), 'commitment' (d=0.81, p=.009), and 'information about emotional consequences' (d=0.49, p=.033). One BCT, 'social support (practical)' (d=0.08, p=.029) was found to be significantly associated with lower effect sizes when present.

Moderator analyses also examined whether there were differences on post-intervention self-efficacy for physical activity according to the presence and absence of specific intervention delivery characteristics (see Table 2). Results showed that interventions delivered in person

were significantly associated with larger effect sizes (d=0.33, p=.006). Similarly, interventions delivered within church/community settings (d=0.47, p=.013) and by a researcher (d=0.36, p=.022) were found to be significantly associated with larger effect sizes for post-intervention self-efficacy for physical activity. By contrast, web-based interventions (d=0.13, p=.041) were found to be associated with lower effect sizes for post-intervention self-efficacy for physical activity.

Moderator analyses - multivariate meta-regression results

The first multivariate meta-regression model for post-intervention self-efficacy for physical activity included the BCTs only. No significant BCTs emerged from this model after adjusting for multiple testing which included only the significant (i.e. p=<.2) BCTs from the univariate analyses. The second model included intervention characteristics only. Multicollinearity was high between web-based delivery mode and computer delivery setting (V = .84). Therefore, computer delivery setting was omitted from the second model and only web-based delivery mode was fitted into the models given that it was more frequent and some interventions were explicitly testing the effectiveness of web-based delivery. Interventions which were delivered by a researcher were associated with larger effect sizes (p (adjusted) = .019). However, delivery by a researcher was no longer significant when entered into a multivariate meta-regression model which included both the BCTs and intervention characteristics – there were no significant associations between any of these and effect sizes in this final model.

Maintained changes in self-efficacy for physical activity

Meta-analysis results

A trivial pooled effect size was found for maintained changes in self-efficacy for physical activity (d=0.08, 95% CI: [-0.05, 0.21], k=27) but this was statistically non-significant. There was high study heterogeneity for maintained changes in self-efficacy for physical activity (I^2=83.8%).

Comparison of BCTs in intervention and control groups

For maintained changes in self-efficacy for physical activity, interventions had a mean of 7.00 (*SD* = 3.82) BCTs and control conditions had a mean of 0.52 (*SD* = 1.74) BCTs. There was a significant medium size positive relationship between the number of BCTs present in the intervention groups and the effect size for maintained changes in self-efficacy for physical activity (Spearman's rho=0.504, k=27, p=.007).

Moderator analyses – univariate meta-regression results

<Table 2 here>

For the 23 moderator analyses that were conducted for maintained changes in self-efficacy for physical activity (see Table 2), three BCTs were found to be significantly associated with changes in effect sizes. The presence of 'demonstration of the behavior' (d=0.47, p=.018) and 'behavioral practice/rehearsal' (d=0.41, p=.046) was associated with larger effect sizes, whilst the presence of 'social support (practical)' (d=-0.40, p=.034) was found to be associated with lower effect sizes, as it was for post-intervention self-efficacy for physical activity.

For maintained changes in self-efficacy for physical activity (see Table 2), moderator analyses suggest that interventions delivered by a health and fitness professional (d=0.67, p=.026), in person (p=.034), and within church/community settings (d=0.62, p=.015) were associated with larger effect sizes. Interventions delivered in college/university/laboratory (d=-

0.47, p=.004) were significantly associated with lower effect sizes for maintained changes in self-efficacy for physical activity.

Moderator analyses - multivariate meta-regression results

For maintained changes in self-efficacy for physical activity, the first model which included BCTs only showed that interventions which included 'social support (practical)' were associated with lower effect sizes (p (adjusted) = .021). The second multivariate meta-regression model which included intervention characteristics only did not reveal any significant variables. 'Social support (practical)' was no longer significant in the final model which included both the intervention characteristics and the BCTs.

Risk of Bias

Most studies were identified as high/unclear risk across all the risk of assessment criteria that were assessed (see Appendix 4, Supplementary Materials 1, for full table): random sequence generation (n=117), allocation concealment (n=184), blinding of outcome assessment (n=177), and incomplete outcome data (n=65), and selective reporting (n= 198).

Sensitivity Analyses

There were no differences in self-efficacy outcome for the risk of bias assessment criteria relating to random sequence generation, allocation concealment, incomplete outcome data, and selected reporting. However, there were differences for the risk of bias criterion on blinding of outcome assessment. For studies which were identified as high or unclear risk for the blinding of outcome assessment (see Appendix 5, Supplementary Materials 1, for full results), higher effect sizes were found for maintained changes in self-efficacy for physical activity (d=0.18) than for studies considered as low risk (d=-0.51). There were no differences

found for post-intervention self-efficacy for physical activity according to whether the studies targeted physical activity (d = 0.29) or multiple behaviors (d = 0.17). There were also no differences found for post-intervention self-efficacy for physical activity according to the type of self-efficacy measure (p = .323). Egger's test indicated that publication bias existed in the trials that were included into the analysis, with evidence of skew in the funnel plot (see Appendix 6, Supplementary Materials 1, p = .002).

Discussion

BCTs did appear to cluster within interventions, albeit not meaningfully (i.e. clusters identified appeared to reflect the hierarchical structure of coding recommended for the BCTTv1). Meta-analysis showed that the interventions had small but significant effects on post-intervention self-efficacy for physical activity (d=0.26). Results for maintained changes in self-efficacy for physical activity showed a trivial pooled effect size (d=0.08) but that was statistically non-significant. A significant positive relationship was found between the number of intervention BCTs and effect sizes for post-intervention self-efficacy for physical activity but not for maintained changes in self-efficacy for physical activity. Univariate meta-regressions identified three BCTs associated with larger effect sizes for post-intervention self-efficacy for physical activity: 'information about social and environmental consequences', 'commitment', and 'information about emotional consequences'. For maintained changes in self-efficacy for physical activity, moderator analyses showed that 'behavioral practice' was associated with larger effect sizes. 'Social support (practical)' was associated with lower effect sizes for post-intervention and maintained changes in self-efficacy for physical activity. Interventions delivered in person and within the church/community setting produced higher effect sizes for post-intervention and maintained changes in self-efficacy for physical activity.

Strengths and limitations

Although several previous reviews have explored how best to increase self-efficacy for physical activity in adults, this review has been the most comprehensive to date by examining all adult populations and including 180 randomized trials (204 comparisons). The present review has used the BCTTv1 which has been recommended to allow for standardisation of coding. Previous reviews of self-efficacy have coded intervention descriptions using the Coventry, Aberdeen & London – Refined (CALO-RE) taxonomy for physical activity and healthy eating interventions [32]. The use of the BCTTv1 in the present study has enabled the coding of techniques which would not have been captured using the less comprehensive CALO-RE taxonomy. The present review also adds to the literature by systematically comparing post-intervention and maintained changes in self-efficacy for physical activity. Further, risk of bias assessment and sensitivity analyses for the present review highlighted that there is generally little evidence of bias affecting outcomes in these studies.

The review also has several limitations. Firstly, BCTs were only coded using published reports and, where possible, published protocols. Without access to intervention manuals and unpublished protocols/materials, this could have increased the risk of publication bias. It is possible that some BCTs were not captured given that interventions are often poorly described in published reports [33]. A comparison of intervention descriptions in 13 article-manual pairs which described the intervention found 73% mismatches, whereby some techniques were only found in intervention manuals [34]. On average, 6.07 were coded in articles whereas 9.07 techniques were coded in intervention manuals. From published reports alone, it is difficult to ascertain other possible confounding factors such as the fidelity and quality of delivery of the intervention which could impact on outcomes [35]. Similarly, it is not possible to ascertain the impact of BCTs that were offered without knowing recipients' level of engagement with the

BCTs. Conclusions regarding effectiveness can only be drawn if we know that the BCTs were actively used. Secondly, though in line with recommended practice, considering null findings as a lack of effect may have led to Type I error. Further, multiple moderator analyses were conducted to examine whether certain BCTs were associated with post-intervention and maintained changes in self-efficacy for physical activity, with some consisting of a low number of studies using certain BCTs. This may have led to Type II error. Apparent effects of BCTs may be due to confounding effects of other BCTs or mode of delivery features that are also present in the arm with the BCT present [36]. However, this is unlikely to be a problem due to the absence of clustering. Meta-regression also examines all BCTs at the same time, so should therefore control for this, whereas univariate analyses do not. The associative nature of the analyses also suggests that cause and effect of the findings cannot be determined.

In the present review, a post-intervention period of six months was considered as indicating maintained changes, in relation to baseline values. However, this distinction could be considered arbitrary, and may have failed to fully capture true 'maintenance'. For example, on one hand, if there are large increases in self-efficacy for physical activity in the early stages post-intervention but then this gradually disappears off at six months to a lower but still significant level, this would have been considered as indicating maintenance, in line with the definitions used in the present review. On the other hand, if a small increase is achieved post-intervention but remains sustained beyond six months then this would have also been considered as maintained changes in self-efficacy for physical activity. Therefore, results could differ according to the point at which the changes are made, the level of change, the time-point at which measurements are taken, and at what point one considers maintenance in relation to.

Comparison with previous reviews

Whilst BCTs and delivery features were found to be associated with self-efficacy, there were few significant associations present. For post-intervention self-efficacy, three BCTs were found to be associated with larger effect sizes when present and one BCT was found to be significantly associated with lower effect sizes when present. A higher frequency of significant associations between BCTs and effect sizes for self-efficacy have been found in previous similar reviews. For example, in the review with older adults, six BCTs were found to be significantly associated with effect sizes when present and eleven BCTs were also found to be associated with lower effect sizes when present [19]. Further, there appeared to be a clearer pattern of results in the review with older adults whereby techniques based on self-regulatory or planning principles seemed less effective for older adults. This pattern was in opposition to previous reviews which found other self-regulatory techniques such as 'action planning' and 'prompting self-monitoring of outcome' to be associated with increased self-efficacy [17-18]. However, the present review found these techniques to be neither more nor less effective for self-efficacy for post-intervention and maintained changes in self-efficacy for physical activity. This may be because self-regulation is important for healthy and obese adults, but less so for older adults, which leads to an unclear pattern of results when data are combined across populations. This may suggest that different BCTs are indeed required to change self-efficacy in different populations. As we included more studies with therefore a larger sample and a wider range of BCTs employed, we should have more statistical power to detect such associations than previous studies, but instead we detected fewer. The results of the present review suggest that a single approach to increasing self-efficacy for all types of physical activity behavior across all adult populations may not be feasible.

In terms of specific BCTs, 'social support (practical)' was associated with decreased post-intervention self-efficacy for physical activity. This echoes the findings of both the reviews with younger adults [17] and older adults [19] which found 'plan social support/social

change' to be associated with lower effect sizes for self-efficacy when present. This BCT involves receiving advice or arrangement of practical help (e.g. from friends, family, or 'buddies') for the performance of the behavior (i.e. physical activity). Therefore, this BCT was coded in cases where, for example, people had a physical activity 'buddy'. It is likely that people will enlist the social support of those within their social circles, such as friends who will be similar to themselves [37]. People make judgements of their own capabilities through vicarious experiences in relation to the successes and failures of similar others [2]. Self-efficacy can be enhanced or lowered by seeing a similar other succeed or fail at performing the behavior [2]. Therefore, an individual's sense of self-efficacy may be reduced if they witness their 'running buddy' fail at the activity in question (e.g. running). Whilst having someone doing something, i.e. 'social support (practical)' for an individual may reduce their feelings of competence, social influence may still be important, especially in terms of the perceived impact that one's behavior can have on others.

Another source of self-efficacy, verbal persuasion, is concerned with others expressing confidence in the individual's abilities to successfully perform the behavior [2]. One's 'running buddy' may offer them encouragement but this may not necessarily be helpful which subsequently leads to decreased self-efficacy. As Bandura (1997, p.106) emphasises, "social persuasion involves much more than fleeting pep talks" [2]. Without insight into the dynamics and quality of people's interactions with their source of support, the explanation for this finding is unclear. It is possible that certain types of social interactions increases self-efficacy whilst others undermine it. Social support elements within interventions need to be better defined and reported to determine if the intended social support is experienced as helpful or a type of social pressure that impairs change. 'Social support (practical)' could be further examined through dyadic interviews or methods for observing and reporting interaction quality, such as motivational interviewing [38].

The present review found that 'information about emotional consequences' was associated with larger effect sizes for post-intervention and maintained changes in self-efficacy for physical activity. This BCT involves providing information about the emotional consequences of performing the behavior, and can include states of mind such as low mood and stress. For example, informing one that being physically active can increase happiness and satisfaction. The BCTTv1 taxonomy taps into the nuances of information provision: distinctions are made between information on health, social and environmental, and emotional consequences. It would not have been possible to code 'information about emotional consequences' using the CALO-RE taxonomy, which could explain why this BCT did not emerge in the findings of the previous reviews. Self-efficacy beliefs can be developed through physiological and somatic information [2]. Feelings of wellbeing and satisfaction that are achieved from physical activity could possibly explain why providing information about emotional consequences was associated with larger effect sizes for self-efficacy.

Implications and future directions

The lack of meaningful clustering of BCTs suggests that it was sensible to look at the effects of BCTs on outcomes in isolation in the present review. However, the method of clustering adopted in the present review has looked at empirically derived clusters, so further research could examine the association between effect sizes and clusters derived from expert consensus or theoretically derived clusters to ascertain the utility of univariate analyses in reviews of this type.

Significant positive relationships were found between the number of BCTs present in the interventions groups and the effect sizes for maintained changes in self-efficacy for physical activity. This suggests interventions consisting of more BCTs may be more effective for maintaining changes in self-efficacy for physical activity, supporting the use of interventions

which have numerous interacting components. However, multiple component interventions are likely to be more costly and require more resources than simple interventions, and standardisation and fidelity needs to be ensured [39]. A balance between effectiveness and costs needs to be achieved in accordance with the context of implementation.

Previous reviews have shown much clearer results, such as stronger associations between BCTs and effect sizes. However, having included all populations in the present review, there have been fewer clear associations with self-efficacy. This suggests it is important to better consider the nature of populations in behavioral medicine, and to not assume that interventions are equally effective across all populations. The importance of populations has not adequately examined and theorised in models of health behavior, aside from a few exceptions [e.g. 40]. There is an over-reliance on student populations in studies of behavior change, such as studies on implementation intentions which are mostly conducted on students. There is a need to consider factors such as socioeconomic status, illness, age (e.g. cognitive decline), acceptability, and the environment. The importance of populations could be examined by delivering the same BCTs to different populations and contrasting effects. It could also be explored using methodologies such as n-of-1 methods to test the effectiveness of BCTs in subgroups [41]. These factors may help to explain for self-efficacy differences in mastery or vicarious experiences between populations.

There are certain individual BCTs that are frequently included in physical activity interventions, such as 'goal setting (behavior)', which may not be the most effective techniques to initiate and maintain changes in self-efficacy for physical activity. By contrast, some less frequently used BCTs, such as 'information about emotional consequences', have emerged as effective for post-intervention changes in self-efficacy for physical activity. A recent study found that people might focus too much on the temporary perceived barriers of undertaking physical activity and underestimate the beneficial influence of movement on their future mood

[42]. This could account for why providing people with information about emotional consequences could help to increase perceived capabilities about performing physical activity by addressing this oversight. Therefore, future physical activity interventions could explore the partial benefits of shifting from the common focus on self-regulation onto emotional determinants of physical activity.

Interestingly, other emotion-related BCTs such as 'monitoring of emotional consequences', 'body changes', and 'reduce negative emotions' were not found to be effective in the present review. It seems that more focussed methods of dealing with physiological/emotion states are not as useful as merely providing information about emotional consequences. Therefore, the role of emotion and its different facets in changing self-efficacy beliefs for physical activity warrants further investigation. For example, there is evidence to suggest that emotion can be affected by the intensity of physical activity, whereby high intensity physical activity may lead to reduced positive valence [43]. It is possible that intervention effectiveness could be influenced by the synergistic effects of BCTs, dosage of BCTs, intensity of BCTs, and delivery characteristics [44].

'Demonstration of the behavior' and 'behavioral practice/rehearsal' were found to be associated with larger effect sizes for maintained changes in self-efficacy for physical activity. These findings are in line with a recent review which also found 'demonstration of the behavior' and 'behavioral practice/rehearsal' to increase motivation; suggesting that there seems to be similarities in effective predictors of motivation and self-efficacy [22]. There are several possible routes through which these BCTs could have an effect on maintained changes in self-efficacy for physical activity. For example, there may be a direct route from rehearsing the behavior to beliefs of capability to maintain the behavior; rather than through problem solving, using prompts/cues or through habit formation which were not significant moderators of self-efficacy.

According to the Health Action Process Approach [3], once a behavior has been initiated, maintenance self-efficacy and recovery self-efficacy, along with other volitional constructs, such as planning, enables the behavior to be maintained. Maintenance self-efficacy is concerned with optimistic beliefs that one can sustain the new behavior, even if they encounter any barriers during the maintenance period. In line with this, perhaps reminders of how to act the behavior and practising/rehearsing it helps to reinforce dexterity which could help to increase perceived coping skills for anticipated barriers. However, the present review did not look at specific types of self-efficacy so this could be explored in further work. In general, the present review highlights that current interventions are not effective at maintaining physical activity, so a better understanding of how to sustain changes is required. To achieve this, more studies with longer follow-ups are required and interventions focused on maintenance could measure self-efficacy that is specific to maintenance or relapse.

The present review identified BCTs associated with increased self-efficacy, for both post-intervention and maintained changes in self-efficacy for physical activity, across all adult populations. However, due to high heterogeneity, future analyses could be conducted based on more highly defined population groups so that these can be systematically compared. Heterogeneity was lower in the review with obese adults (I^2 = 53.59%) [18] compared to the present review (I^2 = 75.8%). Further work could investigate how best to increase self-efficacy for physical activity in less heterogeneous targeted narrower populations, such as in clinical samples, e.g. people with cardiovascular disease and hypertension.

Univariate moderator analyses showed that interventions which were delivered in person were associated with larger effect sizes for post-intervention and maintained changes in self-efficacy for physical activity. Delivery by a researcher and a health and fitness professional were identified as being associated with larger effect sizes for post-intervention changes in self-efficacy for physical activity and maintained changes in self-efficacy for physical activity,

respectively. Delivery in church/community settings were also associated with larger effect sizes for post-intervention and maintained changes in self-efficacy for physical activity. By contrast, web-based interventions were associated with lower effect sizes for post-intervention changes in self-efficacy for physical activity. This once again highlights the potential importance of emotion, particularly at the early stages of behavior change where web-based interventions devoid of human contact seem to be less effective. This could be due to user engagement being one of the biggest challenges with digital interventions [45]. Given the potential importance of human contact, it would be useful to examine how the style of delivery may impact on intervention outcomes; such as the communication style, communication technique, visual style, and complexity [20]. However, these results should be considered as tentative given that these variables were no longer significant in the multivariate models which also included the BCTs.

Results to the risk of bias assessment and sensitivity analyses also highlighted that the lack of blinding of outcome assessment can bias results. Future research should aim to use objective measures of physical activity where researchers are blind to the condition and participants also cannot read physical activity assessments either to avoid measurement reactivity [46].

Conclusion

To summarise, the present review with meta-analysis found a lack of meaningful clustering of techniques within interventions. For maintained changes in self-efficacy for physical activity, interventions consisting of more BCTs appeared to be more effective than those which contain less. BCTs that are associated with post-intervention and maintained changes in self-efficacy for physical activity have been identified. The unclear pattern of results found for self-efficacy suggests that a universal approach for increasing self-efficacy across all

adult populations is not practical, and that tailoring of BCTs and intervention content to different populations is necessary. The present review has also flagged the dearth of studies on maintenance suggesting that randomized trials with longer follow-ups are warranted.

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Figure 1: PRISMA flowchart: inclusion process

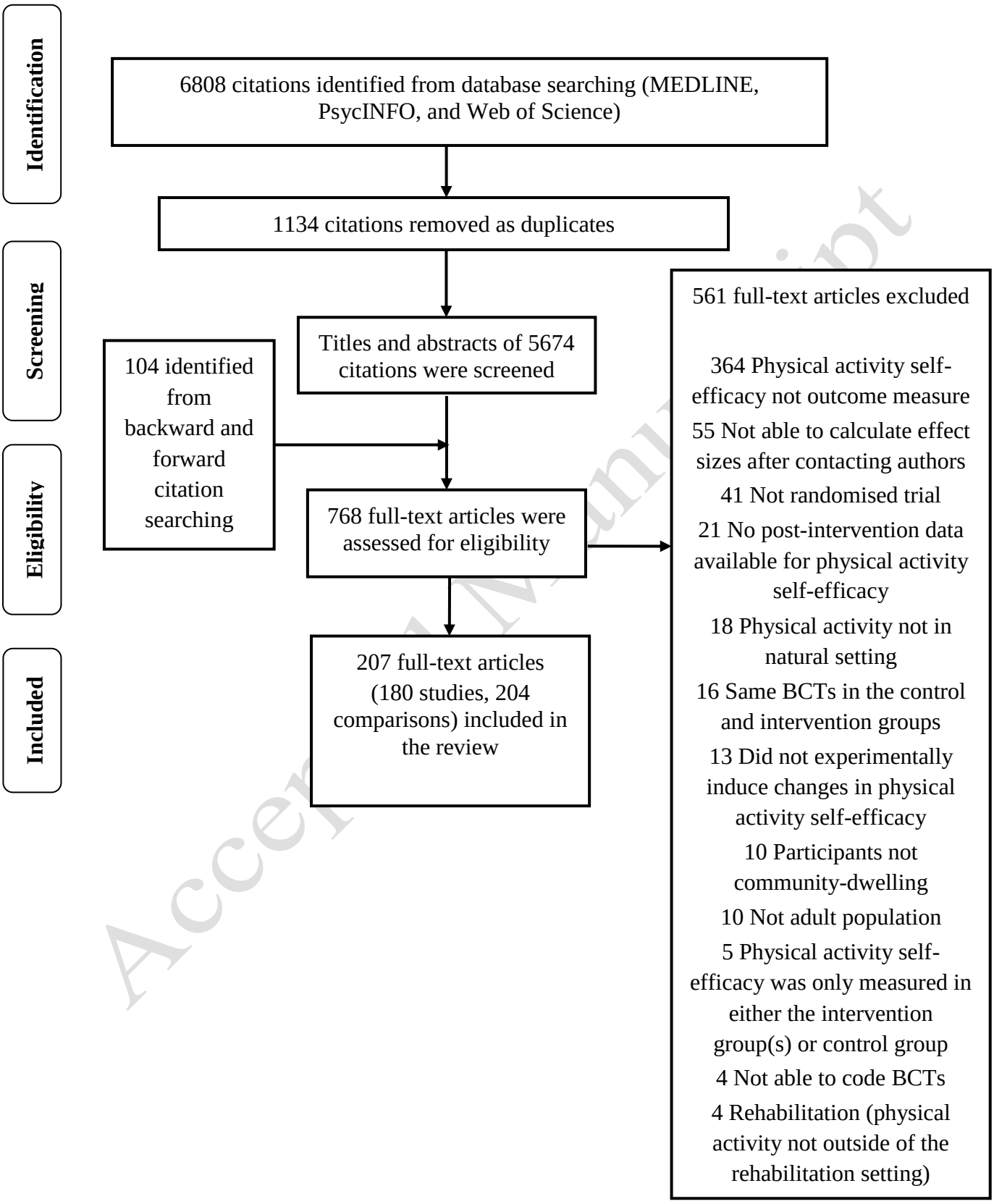

Table 1: Summary of intervention characteristics of included studies

Intervention characteristics	Post-intervention changes in self-efficacy for physical activity (*k*=204)*	Maintained changes in self-efficacy for physical activity (*k*=27)
Single or multiple behavior		
Single	153	
Multiple	51	
Type of self-efficacy measure		
General physical activity self-efficacy barrier	122	
Activity specific barrier	7	
General physical activity self-efficacy rating	45	
Activity specific rating	11	
Perceived behavioral control	19	
Focus of intervention†		
General physical activity	129	21
Lifestyle physical activity (e.g. gardening, walking)	59	5
Muscle-strengthening activities (e.g. tai chi, yoga)	26	4
Recreational physical activity (e.g. aerobics class, gym, jogging)	22	2
Delivered by whom†		
Healthcare professional	74	9
Researcher	71	10
Self-administered	65	10
Health and fitness professional	38	3
Peers/lay expert	10	2
Not stated	8	2
Delivery mode†		
In person	130	16
Written/postal materials	118	20
Mobile/telephone	68	11
Group	59	8
Web-based	40	5
Mass media	15	1
Delivery setting†		
Home	69	9
College/university/laboratory	39	7
General practice/hospital	35	6
Computer	34	5
Church/community	22	4
Workplace	5	1
Not stated	30	1

All presented as frequencies unless stated otherwise

*Based on comparisons

†Some were based on more than one focus/theory; could be delivered by more than one person/mode/setting

Table 2: Statistically significant* comparisons between mean effect sizes for post-intervention and maintained changes in self-efficacy for physical activity, for all populations, according to whether specific BCTs and intervention characteristics were present or absent in interventions

Behavior change techniques (BCTs) and Interventions Characteristics	**Post-intervention changes in self-efficacy for physical activity (*k*=204)**						**Maintained changes in self-efficacy for physical activity (*k*=27)**					
	Present		**Absent**		**Confidence Intervals**	**Sig**	**Present**		**Absent**		**Confidence Intervals**	**Sig**
	n	***d***	***n***	***d***			***n***	***d***	***n***	***d***		
BCTs												
1.9 Commitment	**4**	**0.81**	**200**	**0.25**	**0.14, 0.98**	**0.009****	Only present once					
3.2 Social support (practical)	**23**	**0.08**	**181**	**0.28**	**-0.40, 0.02**	**0.029***	**6**	**-0.40**	**21**	**0.17**	**-1.09, -0.05**	**0.034***
5.3 Information about social and environmental consequences	**8**	**0.71**	**196**	**0.24**	**0.20, 0.79**	**0.001****	Only present once					
5.6 Information about emotional consequences	**13**	**0.49**	**191**	**0.24**	**0.02, 0.52**	**0.033***	Only present once					
6.1 Demonstration of the behavior	47	0.22	157	0.25	-0.18, 0.11	0.621	**8**	**0.47**	**19**	**-0.04**	**0.10, 1.01**	**0.018***
8.1 Behavioral practice/rehearsal	52	0.32	152	0.23	-0.05, 0.23	0.232	**8**	**0.41**	**19**	**-0.02**	**0.01, 0.95**	**0.046***
Intervention characteristics[†]												
Researcher	**71**	**0.36**	**133**	**0.21**	**0.02, 0.26**	**0.022***	10	-0.04	17	0.08	-0.58, 0.30	0.538
Health and fitness professional	38	0.33	166	0.25	-0.08, 0.22	0.354	**3**	**0.67**	**24**	**0.02**	**0.08, 1.27**	**0.026***
In person	**130**	**0.33**	**74**	**0.16**	**0.05, 0.28**	**0.006****	**16**	**0.23**	**11**	**-0.13**	**0.03, 0.83**	**0.034***
College/university/laboratory	39	0.16	165	0.28	-0.27, 0.03	0.122	**7**	**-0.47**	**20**	**0.18**	**-1.08, -0.20**	**0.004****
Web-based	**40**	**0.13**	**164**	**0.29**	**-0.29, -0.01**	**0.041***	5	-0.04	22	0.09	-0.60, 0.47	0.815
Church/community	**22**	**0.47**	**182**	**0.24**	**0.05, 0.41**	**0.013***	**4**	**0.62**	**23**	**0.00**	**0.12, 1.16**	**0.015***

n=frequencies, *k*=number of tests of relationships, *d*=mean effect size, [†]could be delivered by more than one person/mode/setting
**p* < 0.05; ***p*< 0.01; ****p* < 0.001