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Abstract

Objective

Meta-analyses of behavior change (BC) interventions typically find large heterogeneity in effectiveness and small effects. This study aimed to assess the effectiveness of active BC interventions designed to promote physical activity and healthy eating and investigate whether theoretically-specified BC techniques improve outcome.

Design

Interventions, evaluated in experimental or quasi-experimental studies, using behavioral and/or cognitive techniques to increase physical activity and healthy eating in adults were systematically reviewed. Intervention content was reliably classified into 26 BC techniques and the effects of individual techniques, and of a theoretically-derived combination of self-regulation techniques, were assessed using meta-regression.

Main Outcome Measures

Valid outcomes of physical activity and healthy eating.

Results

The 122 evaluations (N = 44,747) produced an overall pooled effect size of 0.31 (95% CI 0.26 to 0.36) (I^2 = 69%). The technique, "self-monitoring", explained the greatest amount of among-study heterogeneity (13%). Interventions that combined self-monitoring with at least one other technique derived from control theory were significantly more effective than the other interventions (0.42 versus 0.26).

Conclusion

Classifying interventions according to component techniques and theoretically-derived technique combinations and conducting meta-regression enabled identification of effective components of interventions designed to increase physical activity and healthy eating.

Key words: physical activity, healthy eating, behavior change, self-regulation, meta-regression, meta-analysis, systematic review

Introduction

Interventions designed to change health-related behaviors generally include many components and typically produce small effects in meta-analyses, but with large heterogeneity in effectiveness (e.g. National Institute for Health and Clinical Excellence, 2007; Dishman & Buckworth, 1996; Grimshaw et al., 2004). This limits the potential for understanding *how* intervention content relates to effectiveness and, consequently, the inferences that can be drawn regarding optimal design and the content of future behavior change interventions. Recent guidance has called for new methods to evaluate the effects of “complex” interventions (Craig et al., 2008). This study aimed to assess the utility of classifying the content of behavior change interventions into component techniques and applying meta-regression to identify effective individual techniques and theoretically-derived combinations of techniques.

To address this aim, we focused on interventions designed to increase physical activity and healthy eating because these are key change targets in the context of the growing obesity epidemic, one of the most serious health risk factors in both the developed and developing world (World Health Organisation, 2002). We further focused on active interventions that engaged participants in the process of behavior change, rather than passive interventions such as simply providing information or advice. Self management approaches, involving people in their own change, have had considerable success among those with long term illnesses (e.g., Lorig, Ritter & Plant, 2005), can initiate change within other groups (Bandura, 2000; Gupta, 2005). Active interventions have also been found to be more effective than passive interventions in other areas (Albarracín, et al., 2005) and, because of the sustained behaviour changes necessary to translate dietary and physical activity into health benefits, self regulatory processes are likely to be central to health-enhancing change, recommending active engagement of participants. Yet, despite the potential of active, self management approaches, there is little guidance on which techniques are important to the effectiveness.

Two methodological advances have enhanced our capacity to learn from intervention evaluations. First, reliable methods of specifying component techniques (e.g., Abraham & Michie, 2008) and, second, use of meta-analysis and meta-regression to identify the effects of individual techniques, and combinations of techniques, across studies (e.g., Albaraccin et al., 2005). In the current study we combined these tools in an investigation of effective change techniques included in healthy eating and physical activity interventions.

Repeated calls have been made for precise specification of what makes one behavior change intervention more effective than another and how this can be understood theoretically (e.g., Rothman, 2004). In the current study, we used a reliable taxonomy of 26 techniques to identify intervention content. Reliability checks have shown that independent coders can reliably judge whether or not published intervention descriptions in papers or manuals indicated inclusion of each technique (Abraham & Michie, 2008).

If we are to understand, not only what works, but how interventions work, it is necessary to understand the causal mechanisms hypothesised to explain intervention effects (Michie & Abraham, 2004; Michie, Johnston, Francis, Hardeman & Eccles, 2008). Interventions have been found to be more effective if they involve techniques that behavior change theory predicts would act synergistically (Albaraccin et al., 2005). Carver and Scheier's (1981; 1982) control theory specifies action control processes underpinning behavioral regulation. The theory proposes that setting goals, monitoring behavior, receiving feedback and reviewing relevant goals in the light of feedback are central to self management and behavioral control. Therefore, while we examined which of 26 change techniques would be most strongly associated with intervention effectiveness, we hypothesized that interventions which included five self-regulation techniques derived from control theory would be more effective than other techniques. These were (1) prompt intention formation or goal setting, (2) specify goals in relation to particular contextualized actions, (3) self monitoring of behavior, (4) feedback on performance, and (5) review previously-set goals. These techniques may act additively or synergistically; the number of studies required to detect the latter is substantially greater than the former.

Previous studies have employed meta-analysis to assess whether the presence or absence of particular techniques is associated with effectiveness. For example, Albarracín et al. (2005) showed that 10 techniques (e.g., provision of factual information and attitudinal arguments) could be reliably identified in published descriptions of interventions designed to promote condom use, and that inclusion of some of these (e.g., provision of attitudinal arguments) was associated with greater effectiveness, while inclusion of others (e.g., threat-inducing arguments) was not. Noar, Benac and Harris (2007) showed that eight targeted theoretical constructs could be reliably identified in reports of tailored print interventions designed to promote health behaviors, and that inclusion of some of these constructs (e.g., attitudes, self-efficacy) was associated with greater effectiveness. Two (social norms and behavioral intentions) were not associated with effectiveness and one (perceived susceptibility) was associated with decreased effectiveness. Despite the impressive scope of these meta-analytic reviews, they have shortcomings. First, only 10 distinct techniques and eight constructs, respectively, were considered. The need for more comprehensive categorization of intervention content is evidenced from reviews of interventions in other behavioral domains (e.g., Webb & Sheeran, 2006). In addition, Albaraccín et al. (2005) used within-group change over time as the criterion of effectiveness as opposed to behavior change observed in an intervention group relative to changes observed in a matched no-intervention control. This allows inclusion of many more datasets but is a less rigorous criterion of effectiveness because the benefits of controlling for techniques within the control conditions are lost. In addition, both these reviews usedmeta-analysis and/or univariate regression rather than multivariate meta-regression to synthesize the evidence. While meta-analysis provides a technique for combining data from separate studies to arrive at pooled effect size estimates, meta-regression provides a means of assessing both single and multiple predictors of effect size from variables derived from individual studies, while weighting the regression so that precision of study results is properly accounted for (Sutton & Higgins, 2008).

The present systematic review applied a reliable taxonomy of behavior change techniques and meta-regression to analyse the effect of individual intervention techniques and the effect of combining five theoretically-derived self-regulation techniques.

Method

Search strategy and results

We searched MEDLINE, EMBASE, PsychINFO, the Cochrane library (Cochrane Central Controlled Trials Register and the Health Technology Assessment database), AMED (Allied and Complementary Medicine Database) and HMIC (Health Management Information Consortium) databases between 1990–2008 for peer-reviewed journal articles written in English. Three search filters were used, one for interventions targeting physical activity/healthy eating, one for study design and one to exclude those with chronic diseases. Studies were also sought from experts in the field, identified by the British Psychological Society's Division of Health Psychology experts list.

Inclusion criteria specified interventions which recruited adults' (18 years or over) in order to increase their levels of physical activity or healthy eating, used experimental or quasi-experimental designs (that is, controlled trials and interrupted time series designs) and outcome measures that were objective, standardised or validated self-report measures. Inclusion criteria also specified that interventions had to use cognitive or behavioral change strategies so that, for example, interventions consisting only of the provision of information were excluded. The following were excluded: interventions aimed at pregnant or recently post-natal women, amateur or professional athletes, those already engaged in a another intervention such as dietary, slimming or fitness programs, and interventions targeting those not living in the free-population or those exclusively targeting participants with physical or mental health problems. Studies targeting the general population, with a small proportion exhibiting physical or mental health problems, were included if members of that sub-set were assessed as being healthy enough to participate by a physician.

This strategy identified 34,769 references (physical activity [PA] = 13,870; healthy eating [HE] = 20,899). After excluding duplicates, 28,440 references remained (PA = 10,859 (including 22 papers recommended by experts in the field); HE = 17,581). In a sample of 300 titles screened independently by two reviewers, there was 100% agreement on inclusion/ exclusion. One thousand and forty one studies identified as potentially relevant were further screened by abstract to assess suitability for inclusion (PA = 472; HE = 569). One hundred abstracts were screened independently by two reviewers, with 85% agreement on inclusion. Disagreements were resolved through discussion and consulting a third reviewer and where uncertainly remained the full paper examined. After screening by abstract, full text papers were obtained for 270 articles (PA = 156; HE = 139). Where there was insufficient statistical or intervention information ($N = 17$), authors were contacted (35% responded). Detailed evaluation according to the inclusion criteria resulted in a final set of 139 studies. Of these, 38 were excluded from the meta-analysis (see supplementary material, Table S1), leaving 101 papers reporting 122 evaluations (PA = 69; HE = 53).

Data extraction

In evaluations of PA interventions reporting multiple outcome measures, the most general or comprehensive measure was selected (e.g., exercise level, energy expenditure). For studies of healthy eating, measures of good and/or poor diet were extracted. There was a significant correlation ($r = .91$, $p < .001$) between the "good diet" and "poor diet" measures[1], consequently, an average effect size from each study was used for the meta-analysis. For studies reporting more

[1] For an initial set of 18 studies that reported both good and poor diet measures.

than one measure of fat intake, total fat intake (grams per day or % energy from fat) was preferred over saturated fat intake or kcal consumption, since a certain kcal consumption may reflect a more or less healthy diet. For studies reporting the percentage of participants consuming five fruit or vegetable servings per day in addition to the number of fruit and vegetable servings per day, the latter was selected.

Effect sizes were indexed as the standardised mean difference (the difference between two means divided by their pooled standard deviation) with Hedge's correction for small sample size (Hedges & Olkin, 1985). For studies that reported continuous data, the effect size was computed from means and standard deviations (adjusted for baseline differences if reported), or, if these data were not reported, from the sample size and *p*-value from an appropriate between-groups t- or F-test. For studies that only reported dichotomous data, the log odds ratio was converted into a standardised mean difference using the meta-analysis software. For cluster RCTs, where the study had used an appropriate analysis to account for the effect of clustering, the results of the analysis were used to estimate the effect size. Where the analysis did not properly take account of clustering, we calculated an effective sample size using the following formula: *N* (effective) = (k x m) / (1+ (m - 1) * ICC, where k indicates the number of clusters; m, the number of observations per cluster; and ICC, the intracluster correlation coefficient (Shojania et al., 2006). We imputed unreported ICCs based on an empirically derived value of 0.05 (Elley, Kerse, Arroll & Robinson, 2003; Elley, Kerse, Chondros & Robinson, 2005). When results were reported only as significant, $p = .05$ was assumed, and when only as non-significant, $p = .50$ was assumed. Where data were reported from multiple time points, outcomes or evaluations, an average effect size was used (we explored the effect of doing this using a series of sub-group analyses, but found little difference between sub-groups; data not reported but available from the authors). Where there were two interventions compared in one study and both met the inclusion criteria, we chose the intervention with the greatest effect (because we were exploring determinants of effectiveness). Where a single study reported both PA and HE outcomes, both were entered into the analysis as if from separate evaluations, but group sample sizes were halved when calculating the standard error of the effect size. This avoids double counting participants and underestimating the variance associated with each effect size.

Coding of study characteristics

The following information was extracted from each study: (a) bibliographic information, (b) location (setting, country), (c) type of behavior targeted by intervention (physical activity, health eating or both), (d) participant information (general description, age, gender, sample size, whether sedentary/low active/obese/at risk of cardiovascular disease or not, whether disadvantaged/from a low income group or not), (e) intervention information (techniques used, use of multiple sessions, duration of intervention, format of delivery, source of delivery, theoretical background), methodological information (attrition, outcomes, how outcome was validated, length of follow up, study design), and (f) effect size information (mean, standard deviation, statistic type, value of statistic, *p*-value, direction of effect, number of responders).

In addition, each intervention was coded for inclusion (or not) of each of 26 behavior change techniques. These were (T1) provide information on behavior-health link, (T2) provide information on consequences, (T3) provide information about others' approval, (T4) prompt intention formation, (T5) prompt barrier identification, (T6) provide general encouragement, (T7) set graded tasks, (T8) provide instruction, (T9) model/ demonstrate the behavior, (T10) prompt specific goal setting, (T11) prompt review of behavioral goals, (T12) prompt self-monitoring of behavior, (T13) provide feedback on performance, (T14) provide contingent rewards, (T15) teach to use prompts/ cues, (T16) agree a behavioral contract, (T17) prompt practice, (T18) use of follow up prompts, (T19) provide opportunities for social comparison, (T20) plan social support/ social change, (T21) prompt identification as role model/ position advocate, (T22) prompt self talk, (T23) relapse prevention, (T24) stress management, (T25) motivational interviewing and

(T26) time management. Inter-rater reliability checks on identification of techniques was conducted by the first two authors on the first 29 papers reporting PA intervention evaluations and the first 22 papers reporting HE interventions (i.e., 51 of 71 included papers, 72%). Modal and mean kappa values and average percentage of disagreements were, respectively, 0.79, 0.80, and 8.2% for PA evaluations and 0.81, 0.82, and 6.7% for HE evaluations, suggesting high reliability. Disagreements were resolved through discussion. The coding manual is available from the first two authors (Abraham & Michie, 2008).

Data synthesis and analytic strategy

Analyses and computations were conducted using Comprehensive Meta Analysis software, Version 2.2.040 (Borenstein, Hedges, Higgins, & Rothstein, 2005) and Stata Version 9.2 (StataCorp, 2007). Using the revised metareg command in Stata, we conducted random effects meta-analysis and random effects meta-regression with restricted maximum likelihood estimation and the improved variance estimator of Knapp and Hartung (2003). Meta-regression is "...a combination of meta-analytic principles (of combining results from multiple studies with due attention to within-study precision and among-study variation) with regression ideas (of predicting study effects using study-level covariates)." (p.629) (Sutton & Higgins, 2008). In our analysis, the regression coefficients (β**)** are the estimated increase in the effect size per unit increase in the covariate(s). Positive effect sizes indicate that the intervention had a better outcome than the control group.

A random effects model (DerSimonian & Laird, 1986) was used in the analyses to incorporate the assumption that the different studies are estimating different, yet related, treatment effects. In addition, the random effects model was used to incorporate heterogeneity beyond that explained by the explanatory variable(s) included in the meta-regression. Where the meta-regression suggested the presence of a potentially important covariate, we used sub-group analyses to further investigate the data. To counter the high risk of false-positive results in the univariate meta-regressions because of among-study heterogeneity and the large number of covariates, we used the Higgins and Thompson (2004) Monte Carlo permutation test (10,000 permutations) to calculate *p*-values adjusted for multiple testing (implemented using the revised metareg command in Stata).

To examine statistical heterogeneity in the meta-analysis, both the *Q* statistic and I^2 (Higgins & Thompson, 2002) were used as well as a visual inspection of the forest plots. I^2 describes the "...percentage of total variation across studies that is due to heterogeneity rather than chance" (Higgins, Thompson, Deeks, & Altman, 2003). Based on suggestions made by Higgins et al. (2003), we interpreted an I^2 of over 75% as high heterogeneity and over 50% as moderate.

We used random effects univariate meta-regression models to examine whether any of the following intervention characteristics were associated with intervention effectiveness: target behavior (coded as physical activity or healthy eating); number of intervention techniques, duration of intervention (weeks); source of delivery (coded as medically trained health professional non-medically trained health professional or non-health professional); format of delivery (coded as individual, group, or mixed); country (coded as UK, other European, US or other); treatment setting (coded as community, primary care, or workplace); total number of techniques; use of multiple sessions (coded as yes or no); time of outcome measurement (coded as immediate or follow up); target population: disadvantaged/low income (yes, no); target population: sedentary/low active/obese/at risk of cardiovascular disease (yes, no); target population: women only (yes, no).

Random effects univariate meta-regression models were also used to examine the association between the 26 individual behavior change techniques and intervention effectiveness. To be included in the analysis, each technique was required to be evaluated by at least four separate studies. We then created a multivariate meta-regression model including all study characteristics and behavior change techniques that were shown in the univariate models to have a meaningful association (i.e., β >.10 for dichotomous variables) with effect size.

To examine how much of the heterogeneity was accounted for by the covariates(s) included in each model, we used the adjusted R^2 produced by the revised metareg command in Stata. The adjusted R^2 is calculated by comparing the baseline value of the heterogeneity variance (τ_a^2) obtained from the empty regression model with the heterogeneity variance from the meta-regression (τ_b^2) after the covariate(s) were added, using the following formula: 100% x ([τ_a^2 - τ_b^2]/τ_a^2).

Sensitivity analyses were used to explore the effect of removing: a) studies which were not randomised at the individual participant level; b) studies not randomised or for which assumptions about statistical significance were made, and c) studies with results classified as outliers, determined by the Sample-Adjusted Meta-Analytic Deviancy (SAMD) Statistic (Huffcut & Arthur, 1995).

We assessed the possibility of publication bias using the Stata metabias command. Where there was evidence of significant asymmetry in the funnel plot (as judged by the Begg and Mazumdar adjusted rank correlation test) (Begg & Mazumdar, 1994), we used the Stata metatrim command to perform the Duval and Tweedie nonparametric "trim and fill" method (Duval & Tweedie, 2000). This method was used to examine the impact of the missing studies by adjusting the meta-analysis to take into account the theoretically missing studies.

Analysis of theoretically-derived self-regulation techniques

The ideal comparison would be that of interventions that include all five self-regulation techniques without additional techniques compared with interventions that include none of the self-regulation techniques. In the absence of sufficient data for this, a comparison will be made that best approximates it, given the available data. In addition, we examined the additive (rather than synergistic) effects by conducting both univariate and multivariate meta-regressions. For the univariate meta-regression, the number of theoretically-derived self-regulation techniques used by each evaluation was entered into the model. For the multivariate meta-regression, we added all five individual techniques into the model to examine the unique association between each technique and intervention effectiveness.

Results

Description of interventions

One hundred and one papers reporting 122 evaluations were included in the meta-analysis (see Table 1 and online supplementary material, Table S2). Fifty-one evaluations targeted physical activity only, 35 targeted healthy eating only and 18 targeted both. Table 1, shows that the majority of studies evaluated a multifaceted intervention, using more than one behavior change technique. Of a possible 26 behavior change techniques, the overall average per intervention was 6.0 (*SD* = 3.1) (online supplementary, Table S3). Two techniques were used in less than four evaluations (‘provide information about others’ approval’ and ‘prompt identification as role model/ position advocate’). In most evaluations, the intervention was compared with a no treatment or treatment-as-usual control, while a small number of evaluations used an active control. Overall, the mean number of techniques in the control groups was 0.8 (*SD* = 1.3).

The duration of interventions varied greatly, ranging from receipt of a single session to two and a half years (*M* = 24.9 weeks, *SD* = 29.1) (online supplementary material, Table S3). Overall, in 16% of the evaluations the treatment was brief (< 1 day), in 9% it was less than one month, in 34% it was between 1 and 5 months, in 22% it was between 6 and 11 months, and in 20% it was 12 or more months long. Overall, in 84% of evaluations, multiple sessions were used to deliver the intervention, and the majority (59%) assessed the outcome at follow up, which ranged from one week to 36 months post baseline assessment. In 13% of evaluations, the intervention was delivered by a clinically trained health professional (defined as someone qualified to provide direct patient care), in 28% delivery was by a non-clinically trained health professional (e.g., health educators or exercise facilitators) and in 59% a non-professional delivered the intervention. Format of intervention delivery was 'individuals' in 62% of evaluations, 'groups' in 17% and both individuals and groups in 20%. In 55% of evaluations, the setting was the community, in 25% primary care and in 20% the workplace. Studies were conducted in Australasia (10%), Canada (2%), United Kingdom (11%), another European country (11%), the US (61%) or Japan (4%). In 7% of evaluations, the target population was disadvantaged/ low income groups, in 34% it was sedentary/low active, obese or individuals at risk of cardiovascular disease, and in 21% it was women.

Effect of the interventions (evaluations of physical activity and healthy eating combined)

Overall effect. Pooling the data across the 122 evaluations (N = 44,747) using a random-effects model produced an overall effect size of 0.31 (95% CI 0.26 to 0.36), indicating that participants receiving behavior change interventions reported significantly better outcomes than those in control conditions. Examination of the I^2 suggested moderate levels of heterogeneity (I^2 = 69%; Q=393, p<.001) (online supplementary material, Table S4, Model 0). Sensitivity analyses excluding studies defined as outliers[2], non-randomised studies or other studies for which assumptions were made had little effect on either the overall effect size or heterogeneity.

Moderating variables. To explore the reason for heterogeneity across evaluations, we used meta-regression to examine 10 intervention characteristics (e.g., target behavior, duration of intervention, target population) and the 26 behavior change techniques (see online supplementary material, Table S4 and S5, Models 1 to 33). Initially, potential moderators were entered into univariate models to determine the size of the association and the percentage of among-study heterogeneity (adjusted R^2) explained by the covariate. The results indicated that most variables explained very little of the heterogeneity, with 'prompt self-monitoring of behavior' (T12)

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[2] Havas et al. (1998); Insull et al. (1990); Vandelanotte et al. (2005)

explaining the greatest amount (13%) (see model 21). A sub-group analysis indicated that the 46 evaluations (N = 11,019) that used the technique produced a pooled effect size of 0.41 (95% CI 0.29 to 0.52) compared with the remaining 76 evaluations (N = 33,728), which produced a pooled effect size of 0.26 (95% CI 0.21 to 0.30). We then developed a multivariate model, entering only those covariates that had a meaningful association with effect size (see online supplementary material, Table S6). However, the model explained less heterogeneity (11%) than the single technique involving self-monitoring.

Separate effect of physical activity and healthy eating

Across all evaluations, there was no evidence from the univariate meta-regression that the target behavior (physical activity or healthy eating) accounted for any of the among-study heterogeneity (model 1). Sub-group analyses by behavior showed similar effect sizes; for the 69 PA evaluations (N = 18,330), the overall effect size was 0.32 (95% CI 0.26 to 0.38), while for the 53 HE evaluations (N = 26,417), the overall effect size was 0.31 (95% CI 0.23 to 0.39). Moreover, within each sub-group, there was notable heterogeneity, I^2 = 58% (PA), 73% (HE).

Theoretically-derived self-regulation techniques

Overall, 60% of the evaluations prompted intention formation, 50% provided feedback on performance, 38% prompted self-monitoring of behavior, 22% prompted specific goal setting, and 16% prompted review of behavioral goals. Only two evaluations used all five of the self-regulation techniques derived from control theory (PA = 1; HE = 1), nine evaluations used four of the techniques (PA = 7; HE = 2), 19 used three techniques (PA = 10; HE = 9), 41 used two techniques (PA = 25; HE = 16), 42 used one technique (PA = 21; HE = 21), and nine used none of the five self-regulation techniques (PA = 5; HE = 4).

Entering the number of theoretically-derived self-regulation techniques used by each evaluation into a univariate meta-regression model accounted for 9% of the among-study heterogeneity (Online supplementary material, Table S7, Model 35). Entering all five techniques into a multivariate model also accounted for 9% of the among-study heterogeneity (Online supplementary material, Table S7, Model 37), and indicated that the strongest covariate was ‘prompt self-monitoring of behavior’ (T12).

Given that in both the univariate and the multivariate model, self-monitoring was the most important technique, we dummy coded a new variable (self-monitoring plus) to examine the impact of combining self-monitoring with any of the other four self-regulatory techniques. The meta-regression indicated that 17% of the heterogeneity was accounted for by this covariate. A sub-group analysis showed that the 42 evaluations (*N* = 10,572) that used ‘self-monitoring plus’ produced a pooled effect size of 0.42 (95% CI 0.30 to 0.54) compared with the remaining 80 evaluations (*N* = 34,175) that produced a pooled effect size of 0.26 (95% CI 0.21 to 0.30) (online supplementary material, Table S7, Model 36). Sensitivity analyses suggested that these results were robust to the presence of outliers.

To evaluate whether the ‘self-monitoring plus’ effect was consistent in both PA and HE interventions, we repeated the analysis within each sub-group of studies. For the 29 PA evaluations (*N* = 5,108) that used ‘self-monitoring plus’ the overall effect size was 0.38 (95% CI 0.27 to 0.49) compared with the remaining 40 evaluations (*N* = 13,222) that produced a pooled effect size of 0.27 (95% CI 0.21 to 0.34). For the 13 HE evaluations (*N* = 5,464) that used ‘self-monitoring plus’ the overall effect size was 0.54 (95% CI 0.21 to 0.86), while the remaining 40 evaluations (*N* = 20,953) produced a pooled effect size of 0.24 (95% CI 0.18 to 0.29).

Discussion

This systematic review of interventions designed to promote physical activity and/or healthy eating used a novel approach to classifying intervention content according to change techniques and theoretically-derived technique combinations (Abraham & Michie, 2008). Use of meta-analysis and meta-regression showed that specification of intervention content clarified which interventions were most likely to be effective. Those including self-monitoring and at least one of four other self regulatory techniques derived from control theory (Carver & Scheier,1981; 1982) were significantly more effective than interventions not including these techniques, both in interventions designed to promote physical activity and healthy eating. Thus our hypothesis that inclusion of the five techniques derived from control theory (i.e., prompt goal setting, specify goals in relation to contextualized actions, self monitoring of behavior, feedback on performance, and review of previously-set goals) was partially supported.

We identified 122 evaluations of interventions which actively involve adults living in the community in cognition and behavior change sessions and were evaluated using an experimental or quasi experimental design. We found that such interventions are effective with effect sizes of 0.32 and 0.31 for physical activity and healthy eating interventions, respectively. These are small effect sizes (Cohen, 1992) in the typical range for psychological interventions (Hunter & Schmidt, 1990). Our results show that the behavioral target and many design characteristics (duration, person delivering the intervention, delivery format [e.g., individual versus group], setting [e.g., workplace or community settings], use of multiple sessions, time to follow up, target population did not distinguish between effective and ineffective interventions. Moreover, the number of behavior change techniques included did not increase effectiveness. This may be because intervention quality and fidelity of delivery may be compromised by a large number of techniques. By contrast, intervention content was associated with intervention effectiveness.

Moderator analysis, using both univariate and multivariate meta-regression, revealed that the number of theoretically-derived self-regulation techniques, and in particular, self-monitoring of behavior was associated with improved effectiveness. The interpretation of this effect is supported by the finding that combining self-monitoring with the other theoretically-predicted techniques enhances its effect. Interventions combining self-monitoring with one or more of four other hypothesized self-regulation techniques, namely, prompting intention formation or goal setting, specifying goals in relation to particular contextualized actions, providing feedback on performance and reviewing previously-set goals were significantly more effective than interventions not including self-monitoring and one other self-regulatory technique (pooled effect sizes for healthy eating: 0.54 versus 0.24; physical activity: 0.38 vs. 0.27; all interventions: 0.42 vs. 0.26). Unfortunately, we were unable to reliably compare interventions which combined all five of our hypothesized self-regulatory technique set with those that did not because only two studies included all five. Nonetheless, these data strongly suggest that inclusion of self-monitoring in combination with other self-regulation behavior change techniques is likely to enhance the effectiveness of interventions designed to promote healthy eating and physical activity.

It would be desirable to test our hypothesis on a larger set of intervention studies, since the model may be over-determined, given the ratio of techniques to studies. However, at present, this would mean relaxing the methodological rigour by which we selected evaluations, i.e., including only experimental or quasi-experimental designs. Sensitivity analysis suggests that our findings are robust. For example, it is possible that the magnitude of the intervention effects were over-estimated due to publication bias, indicated by asymmetry in the funnel plot (provided in the online supplementary materials). However, using the “trim and fill” method (Duval & Tweedie, 2000) to adjust the meta-analysis to incorporate the theoretically missing studies, the overall pooled effect size did not substantially change. In addition, excluding both non-randomised studies and studies for which we had to make assumptions when calculating effect sizes (for example, studies reporting non-significant effects were assumed to have an effect size of 0.50) did not substantially change the results. This suggests that our sample of intervention evaluations is representative of the population of such evaluations using rigorous evaluation methods.

Our analyses do not illuminate determinants of a large proportion of unaccounted variance in effect size heterogeneity but we have shown that a series of study characteristics that might be expected to affect effectiveness do not account for this heterogeneity. It is likely that combinations of characteristics and behavior change techniques may interact to account for this heterogeneity.

However, the number of studies in the available literature does not allow us to reliably explore these potential effects.

In conclusion, our analyses offer clear support for including self-monitoring of behavior as well as prompting intention formation or goal setting, specifying goals in relation to particular contextualized actions, providing feedback on performance and reviewing previously-set goals in interventions designed to promote healthy eating and physical activity. The implications of these analyses need to be tested experimentally with study designs of interventions which do, and do not include, sets of behavior change techniques theoretically predicted to effect change (e.g., the set of five intervention techniques based on Carver and Scheier's [1981; 1982] control theory). This will advance both the design of more effective interventions and theory development.

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*Tate, D.F., Wing, R.R., & Winett, R.A. (2001). Using internet technology to deliver a behavioral weight loss program. *Journal of the American Medical Association, 285*(9), 1172-1177.

*Tate, D. F., Jackvony, E. H., & Wing, R. R. (2006). A randomized trial comparing human e-mail counseling, computer-automated tailored counseling, and no counseling in an internet weight loss program. *Archives of Internal Medicine, 166,* 1620-1625.

*Tilley, B. C., Glanz, K., Kristal, A. R., Hirst, K., Li, S., Vernon, S. W. et al. (1999). Nutrition intervention for high-risk auto workers: results of the Next Step Trial. *Preventive Medicine*, *28*(3), 284-292.

*Vandelanotte, C., De Bourdeaudhuij, I., Sallis, J. F., Spittaels, H., & Brug, J. (2005). Efficacy of sequential or simultaneous interactive computer-tailored interventions for increasing physical activity and decreasing fat intake. *Annals of Behavioural Medicine, 29*(2), 138-146.

Webb, T. L., and Sheeran, P. (2006). Does changing behavioural intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychological Bulletin, 132*(2), 249-268.

*Winett, R. A., Anderson, E. S., Wojcik, J. R., Winett, S. G., & Bowden, T. (2007). Guide to health: nutrition and physical activity outcomes of a group-randomized trial of an internet-based intervention in churches. *Annals of Behavioral Medicine, 33*(3), 251-261.

*Wing, R. R., Tate, D. F., Gorin, A. A., Raynor, H. A., Fava, J. L. (2006). A self-regulation program for maintenance of weight loss. *New England Journal of Medicine, 355*(15), 1563-1571.

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*Writing Group for the Activity Counseling Trial Research Group. (2001). Effects of physical activity counseling in primary care: the Activity Counseling Trial: a randomized controlled trial. *Journal of the American Medical Association, 286*(6), 677-687.

Table 1

Effectiveness and Behavior Change Techniques by Target Behaviour and Study

Study[a]	***N***	***d***	**SE**	**Techniques**[b]
Physical Activity				
Aldana et al., 2005	337	0.61	0.16	1, 2, 4, 6, 8, 9, 18
Anderson et al., 2006	133	0.75	0.23	4, 10, 12
Arao et al., 2007	128	0.51	0.26	4, 11, 12, 13, 20
Ash et al. 2006	55	0.66	0.28	23
Babazono et al., 2007	87	0.89	0.32	4, 8, 11, 14
Baker et al., 2008	79	0.74	0.23	2, 5, 7, 8, 12, 13
Bennett et al., 2008	72	0.16	0.23	4, 5, 6, 8, 11, 12, 13, 25
Blissmer et al., 2002	78	0.40	0.23	2, 5, 8, 10, 14, 15, 20, 21, 23
Bolognesi et al., 2006	96	0.53	0.21	1, 2, 5, 6, 10, 12, 16, 18, 23
Bull et al., 1999	570	0.18	0.10	2, 5, 13
Calfas et al., 1996	212	0.19	0.14	2, 4, 5, 10, 13, 18, 20, 23
Calfas et al., 2000 (W)	177	0.00	0.15	2, 5, 6, 8, 9, 17, 18, 19, 20, 22, 23, 26
Calfas et al., 2000 (M)	144	-0.17	0.17	
Campbell et al., 2002	538	0.12	0.24	1, 2, 4, 8, 9, 13, 19, 20
De Cocker et al., 2008	82	-0.06	0.22	1, 7, 8, 12, 13
Dinger et al., 2007	56	0.54	0.27	2, 4, 5, 8, 10, 11, 12, 13, 14, 15
Dzator et al., 2004	90	0.19	0.30	1, 2, 4, 8
Elbel et al., 2003	118	0.15	0.22	2, 4, 5, 6, 8, 19, 23, 26
Elley et al., 2003	750	0.25	0.07	4, 6, 18, 25
Elliot et al., 2004	23	0.90	0.68	1, 2, 4, 6, 8, 11, 13, 14, 18, 20,

				23, 25
Elliot et al., 2007	315	0.44	0.25	1, 2, 4, 6, 8, 11, 13, 14, 18, 20, 23, 25
Fahrenwald et al., 2004	44	1.28	0.33	2, 5, 10, 11, 12, 15, 17, 18, 19, 20, 21
Green et al., 2002	181	0.41	0.16	4, 5, 8, 12, 20, 25
Halbert et al., 2000	299	0.23	0.12	2, 4, 5, 7, 10, 11, 12, 18, 20
Hardcastle et al., 2008	334	0.22	0.16	2, 4, 5, 25
Harland et al., 1999	309	0.49	0.16	2, 4, 11, 25
Hivert et al., 2007	115	0.22	0.26	2, 4, 5, 12
Huddy et al., 1995	111	0.50	0.26	1, 2, 4, 5, 10, 16
Hurling et al., 2007	77	0.36	0.25	4, 5, 6, 8, 12, 13
Hyman et al., 2007	185	0.03	0.23	12, 13, 25
Inoue et al., 2003	84	0.57	0.15	8, 10, 12, 14, 15, 16, 17, 18, 19, 20, 22, 23
King et al., 2008	37	0.98	0.17	1, 4, 5, 8, 12, 13
Kinmonth et al., 2008	218	0.02	0.34	2, 10, 11, 12, 13, 14, 18, 20, 23
Lawton et al., 2008	1089	0.30	0.12	2, 4, 5, 6, 13, 25
Little et al., 2004	72	0.52	0.07	1, 2, 4, 8, 10, 16
Loughlan et al., 1997	104	0.43	0.24	2, 4, 5, 8, 10, 18, 20
Marcus et al., 1997	44	0.20	0.20	2, 4, 8, 10, 14, 18
Marcus et al., 2007	159	0.54	0.15	4, 6, 8, 13, 19
Marshall et al., 2003	462	0.25	0.16	2, 5, 6, 8, 10, 14, 20
Marshall et al., 2004	719	-0.01	0.11	2, 5, 6, 8, 10, 14, 20

Martinson et al., 2008	986	0.17	0.09	2, 4, 5, 6, 12, 13, 15, 20, 23
Mayer et al., 1994	1548	0.17	0.07	2, 4, 8, 13, 14, 16, 18
McAuley et al., 1994	114	0.52	0.07	1, 2, 6, 7, 8, 9, 12, 13, 17, 19, 20
Merom et al., 2007	246	-0.01	0.19	4, 8, 11, 12, 13
Miller et al., 2002	390	0.31	0.13	2, 5, 18, 19, 20
Newton et al., 2004	18	0.46	0.17	12
Nichols et al., 2000	58	0.40	0.46	2, 4, 9, 17, 18, 19, 22, 23, 26
Nies et al., 2003	137	0.34	0.26	2, 5, 7, 10, 20, 23, 26
Nies et al., 2006	173	0.10	0.17	2, 4, 23
Norris et al., 2000	812	0.02	0.15	2, 4, 5, 6, 8, 10, 16, 18, 20, 23
Peterson et al., 1999	359	0.45	0.08	1, 4, 23
Peterson et al., 2005	42	0.18	0.11	8, 10, 12, 14, 20
Poston et al., 2001	237	0.02	0.36	1, 2, 6, 7, 8, 9, 12, 13, 17, 19, 20
Purath et al., 2004	271	0.45	0.05	1, 4, 16, 18
Resnicow et al., 2005	535	0.22	0.14	1, 2, 5, 6, 8, 15, 16, 25
Rodearmel et al., 2006	81	0.52	0.38	4, 7, 12, 15
Rosamond et al., 2000	515	-0.07	0.14	4, 6, 8, 14, 15, 18
Schneider et al., 2004	16	0.44	0.10	4, 5, 7, 8, 9, 12, 17, 18
Speck et al., 2001	49	0.45	0.48	12
Spittaels et al., 2007	257	-0.01	0.29	2, 8, 13
Stevens et al., 1998	714	0.59	0.12	1, 4, 11, 12, 13, 18
Stewart et al., 1997	89	0.59	0.09	1, 2, 4, 5, 12, 18
Tate et al., 2001	62	-0.14	0.25	4, 6, 12, 13, 14, 15, 20, 24
Tate et al., 2006	110	0.27	0.28	4, 5, 11, 12, 13

Vandelanotte et al., 2005	393	0.31	0.15	2, 8, 13
Writing Group for the ACT Research Group, 2001 (W)	228	0.40	0.14	
Writing Group for the ACT Research Group, 2001 (M)	297	0.08	0.19	1, 2, 4, 5, 6, 7, 8, 12, 13, 14, 18, 19
Winett et al., 2007	620	0.23	0.12	7, 8, 13, 14, 19
Wing et al., 2006	190	0.10	0.20	1, 12, 14, 17
Healthy Eating				
Ahluwalia et al., 2007	173	0.47	0.16	2, 8, 13
Aldana et al., 2005	331	0.46	0.16	1, 2, 4, 6, 8, 9, 18
Anderson et al., 2001	221	0.44	0.14	8, 10, 12, 13
Arao et al., 2007	135	0.05	0.25	4, 11, 12, 13, 20
Armitage, 2004	264	0.34	0.12	10
Armitage, 2007	82	0.40	0.22	10
Babazono et al, 2007	87	0.49	0.43	4, 8, 11, 14
Beresford et al., 1997	1853	0.15	0.05	4, 18
Brug et al., 1996	352	0.04	0.11	1, 2, 5, 6, 8, 13
Brug et al., 1998	435	0.33	0.10	1, 2, 5, 6, 8, 13
Burke et al., 2003	64	0.28	0.25	1, 2, 5, 6, 8, 9, 12, 13, 17, 19, 20, 23, 24, 26
Campbell et al., 1994	258	0.22	0.13	1, 2, 4, 5, 8, 13, 15, 23
Campbell et al., 1999	377	0.03	0.10	2, 4, 8, 13
Campbell et al., 2002	538	0.09	0.24	1, 2, 4, 8, 9, 13, 19, 20
Campbell et al., 2004	306	-0.08	0.12	1, 13

Carpenter et al., 2004	61	0.82	0.26	1, 2, 4, 5, 7, 12, 13, 14, 15, 20, 23, 24, 26
de Bourdeaudhuij et al., 2000 (W)	35	0.71	0.34	
de Bourdeaudhuij et al., 2000 (M)	35	0.24	0.33	4, 8, 13
de bourdeaudhuij et al., 2007	213	0.56	0.25	2, 8, 13
de Noojier et al., 2006	293	0.06	0.15	4, 10
Delichatsios et al., 20001a	298	0.28	0.12	2, 4, 8, 13
Delichatsios et al., 2001b	504	0.35	0.09	1, 4, 8, 10, 13, 25
Dzator et al., 2004	90	0.53	0.30	1, 2, 4, 8
Elder et al., 2005	214	0.14	0.14	4, 5, 8, 12, 15
Elliot et al., 2004	23	0.42	0.65	1, 2, 4, 6, 8, 11, 13, 14, 18, 20, 23, 25
Elliot et al., 2007	315	0.57	0.26	1, 2, 4, 6, 8, 11, 13, 14, 18, 20, 23, 25
Emmons et al., 1999	2054	0.13	0.04	6, 13, 19, 20
Fuller et al., 1998	50	1.28	0.32	4, 7, 8, 12, 14, 15, 16
Hardcastle et al., 2008	334	-0.12	0.16	2, 4, 5, 25
Havas et al., 1998	3122	0.11	0.18	4, 5, 8, 14, 15, 20
Hivert et al., 2007	115	0.01	0.04	2, 4, 5, 12
Iinsull et al., 1990	264	1.90	0.22	4, 8, 12, 13, 18
Kellar et al., 2005	218	0.34	0.15	4, 10
Kristal et al., 1992	1050	0.40	0.14	2, 8, 13, 18
Kristal et al., 2000	1205	0.28	0.07	2, 4, 6, 7, 8, 13
Kroeze et al., 2008	278	0.23	0.06	1, 5, 8, 13, 19

Mayer et al., 1994	1548	0.10	0.06	2, 4, 8, 13, 14, 16, 18
Oenema et al., 2005	301	0.13	0.07	4, 8, 10, 13, 19
Paineau et al., 2008	673	0.40	0.11	8, 13
Raats et al., 1999	113	0.22	0.12	12, 13
Resnicow et al., 2001	576	0.36	0.19	1, 2, 5, 6, 8, 15, 16, 25
Resnicow et al., 2005	535	0.25	0.18	1, 2, 5, 6, 8, 15, 16, 25
Reueter et al., 2008	115	0.51	0.18	10
Rodearmel et al., 2006	81	0.52	0.25	4, 7, 12, 15
Rosamond et al., 2000	515	0.34	0.14	4, 6, 8, 14, 15, 18
Steptoe et al., 2003	271	0.28	0.13	1, 2
Stevens et al., 2002	616	0.39	0.08	4, 5, 7, 8, 10, 11, 12, 13, 18, 23, 25
Tate et al., 2001	62	-0.12	0.26	4, 6, 12, 13, 14, 15, 20, 24
Tate et al., 2006	106	0.72	0.25	4, 5, 11, 12, 13
Tilley et al., 1999	3477	0.56	0.27	4, 6, 12, 13, 14, 15, 20
Vandelanotte et al., 2005	371	0.84	0.22	2, 8, 13
Winett et al., 2007	620	0.45	0.17	7, 8, 13, 14, 19
Wing et al., 2006	190	0.10	0.11	1, 12, 14, 17

Note. [a]18 studies (Aldana et al., 2005; Arao et al., 2007; Babazono et al., 2007; Campbell et al., 2002; Dzator et al., 2004; Elliot et al., 2004; Elliot et al., 2007; Hardcastle et al., 2008; Hivert et al., 2007; Mayer et al., 1994; Resnicow et al., 2005; Rodearmel et al., 2006; Rosamond et al., 2000; Tate et al., 2001; Tate, Jackvony, & Wing, 2006; Vandelanotte, De Bourdeaudhuij, Sallis, Spittaels, & Brug, 2005; Winett et al., 2007; Wing, Tate, Gorin, Raynor, Fava, 2006) reported both physical activity and healthy eating outcomes and so were entered into the meta-analysis as if they were separate evaluations. To avoid double counting participants (and underestimating the variance associated with each effect size), we calculated the standard error of each study effect size using half the sample size. In addition, three studies (Calfas et al., 2000;

Writing Group for the ACT Research Group, 2001; de Bourdeaudhuij et al., 2000) reported data for men and women separately, therefore were entered into the meta-analysis as if they were separate evaluations without adjustment of sample size, [b]Techniques: 1 = Provide information on behavior-health link, 2 = Provide information on consequences, 3 = Provide information about others' approval, 4 = Prompt intention formation, 5 = Prompt barrier identification, 6 = Provide general encouragement, 7 = Set graded tasks, 8 = Provide instruction, 9 = Model/ demonstrate the behavior, 10 = Prompt specific goal setting, 11 = Prompt review of behavioral goals, 12 = Prompt self-monitoring of behavior, 13 = Provide feedback on performance, 14 = Provide contingent rewards, 15 = Teach to use prompts/ cues, 16 = Agree behavioral contract, 17 = Prompt practice, 18 = Use of follow up prompts, 19 = Provide opportunities for social comparison, 20 = Plan social support/ social change, 21 = Prompt identification as role model/ position advocate, 22 = Prompt self talk, 23 = Relapse prevention, 24 = Stress management, 25 = Motivational interviewing, 26 = Time management, M = men, W = women.

Online supplementary materials

Table S1

Excluded Studies and Reason for Exclusion

Study	***Reason for exclusion***
Ackermann, R. T., Deyo, R. A., & LoGerfo, J. P. (2005). Prompting primary providers to increase community exercise referrals for older adults: a randomized trial. *Journal of the American Geriatric Society, 53*(2), 283-289.	Intervention did not meet the inclusion criteria
Aittasalo, M., Miilunpalo, S., & Suni, J. (2004). The effectiveness of physical activity counseling in a work-site setting. A randomized, controlled trial. *Patient Education and Counseling, 55*(2), 193-202.	Intervention did not meet the inclusion criteria
Aittasalo, M., Miilunpalo, S., Kukkonen-Harjula, K., & Pasanen, M. (2006). A randomized intervention of physical activity promotion and patient self-monitoring in primary health care. *Preventive Medicine, 42*(1), 40-46.	Included participants with physical illness
Armit, C. M., Brown, W. J., Ritchie, C. B., & Trost, S. G. (2005). Promoting physical activity to older adults: a preliminary evaluation of three general practice-based strategies. *Journal of Science and Medicine in Sport, 8*(4), 446-450.	No data from an appropriate outcome reported
Assema, P., Steenbakkers, M., Rademaker, C., & Brug, J. (2005). The impact of a nutrition education intervention on main meal quality and fruit intake in people with financial problems. *Journal of Human Nutrition & Dietetics, 18*(3), 205-212.	No appropriate outcome measure

Ball, K., Salmon, J., Leslie, E., Owen, N., King, A. C. (2005). Piloting the feasibility and effectiveness of print- and telephone-mediated interventions for promoting the adoption of physical activity in Australian adults. *Journal of Science and Medicine in Sport, 8*(2),134-142.	No appropriate control
Bradbury, J., Thomason, J. M., Jepson, N. J., Walls, A. W., Allen, P. F., & Moynihan, P. J. (2006). Nutrition counseling increases fruit and vegetable intake in the edentulous. *Journal of Dental Research*, *85*(5), 463-468.	Not general population
Brand, R., Schlicht, W., Grossman, K., & Duhnsen, R. (2006). Effects of a physical exercise intervention on employees'perceptions quality of life: a randomized controlled trial. *Soz Praventivmed, 51*(1), 14-23.	No appropriate intervention
Brug, J., Steenhuis, I., Van Assema, P., Glanz, K., & De Vries, H. (1999). Computer-tailored nutrition education: differences between two interventions. *Health Education Research, 14*(2), 249-256.	Comparison of two active interventions
Burke, L. E., Dunbar-Jacob, J., Orchard, T. J., & Sereika, S. M. (2005). Improving adherence to a cholesterol-lowering diet: a behavioral intervention study. *Patient Education and Counseling, 57*(1), 134-142.	Participants already engaged in a diet
Burke, V., Giangiulio, N., Gillam, H. F., Beilin, L. J., & Houghton, S. (2003). Physical activity and nutrition programs for couples: a randomized controlled trial. *Journal of Clinical Epidemiology*, *56*(5), 421-432.	Insufficient data reported to allow an effect size to be calculated (physical activity outcome only)
Calfas, K. J., Sallis, J. F., Zabinski, M. F., Wilfley, D. E., Rupp, J., Prochaska, J. J., et al. (2002).	Insufficient data reported to allow an effect size to be

Preliminary evaluation of a multicomponent program for nutrition and physical activity change in primary care: PACE+ for adults, *Preventive Medicine, 34*(2), 153-161.	calculated
Carels, R. A., Darby, L. A., Cacciapaglia, H. M., Douglass, O. M. (2004). Reducing cardiovascular risk factors in postmenopausal women through a lifestyle change intervention. Journal of Women's Health, *13*(4), 412-426.	No appropriate control
Castro, C. M., Sallis, J. F., Hickmann, S. A., Lee, R. E., & Chen, A. H. (1999). A prospective study of psychosocial correlates of physical activity for ethnic minority women. *Psychology and Health, 14* (2), 277-293.	Insufficient data reported to allow an effect size to be calculated
Castro, C. M., Wilcox, S., O'Sullivan, P., Baumann, K., King, A. C. (2002). An exercise program for women who are caring for relatives with dementia. *Psychosomatic Medicine*, *64*(3), 458-468.	No appropriate outcome data reported
Connell, C. M., Sharpe, L. A., & Gallant, M. P. (1995). Effect of health risk appraisal on health outcomes in a university worksite health promotion trial. *Health Education Research, 10*(2), 199-209.	Insufficient data reported to allow an effect size to be calculated
Courneya, K. S., Estabrooks, P. A., & Nigg, C. R. (1997). A simple reinforcement strategy for increasing attendance at a fitness facility. *Health Education and Behaviour*, *24*(6), 708-715.	Participants were already engaged in a fitness program & study only reports attendance at gym
Graham-Clarke, P., & Oldenburg, B. (1994). The effectiveness of a general-practice-based physical activity intervention on patient physical activity status. *Behaviour Change, 11*(3), 132-144.	Insufficient data reported to allow an effect size to be calculated
Greene, G.W., Rossi, S.R., Rossi, J.S., Fava, J.L., Prochaska, J.O., & Velicer, W.F. (1998). An expert system intervention for dietary fat reduction. Annals of Behavioral Medicine, 20 (supplement), S197.	Insufficient information about the intervention

Haber, D., & Lacy, M. G. (1993). Evaluation of a socio-behavioral intervention for changing health behaviors of older adults. *Behavior, Health and Aging, 3*(2), 73-85.	No data from an appropriate outcome reported
Hallam, J., & Petosa, R. (1998). A worksite intervention to enhance social cognitive theory constructs to promote exercise adherence. *American Journal of Health Promotion, 13*(1), 4-7.	No data from an appropriate outcome reported
Heneman, K., Block-Joy, A., Zidenberg-Cherr, S., Donohue, S., Garcia, L., Martin, A., Metz, et al. (2005). A "contract for change" increases produce consumption in low-income women: a pilot study. *Journal of the American Dietetic Association, 105*(11), 1793-1796.	More than 50% of control participants (86%) failed to complete the control lesson series
Hopman-Rock, M., & Westoff, M. H. (2002). Health education and exercise stimulation for older people: development and evaluation of the program “Healthy and Vital”, *Journal of Gerontology and Geriatrics, 33*(2), 56-63	Insufficient data reported to allow an effect size to be calculated
Jacobs, A.D., Ammerman, A.S., Ennett, S.T., Campbell, M.K., Tawney, K.W., Aytur, S. A., et al. (2004). Effects of a tailored follow-up intervention on health behaviors, beliefs, and attitudes. *Journal of Womens Health,13*(5), 557-568.	Insufficient data reported to allow an effect size to be calculated
King A. C., Toobert, D., Ahn, D., Resnicow, K., Coday, M., Riebe, D., Garber, C. E., Hurtz, S., Morton, J., Sallis, J. F,. (2006). Perceived environments as physical activity correlates and moderators of intervention in five studies. *American Journal of Health Promotion, 21*(1), 24-35	Insufficient information about the interventions
Kreuter, M. W., Chheda, S. G., Bull, F. C. (2000). How does physician advice influence patient behavior? Evidence for a priming effect. *Archives of Family Medicine, 9*(5), 426-433.	No data from an appropriate outcome reported

Levy, S. S., & Cardinal, B. J. (2004). Effects of a self-determination theory-based mail-mediated intervention on adults' exercise behavior. *American Journal of Health Promotion, 18*(5), 345-349.	No data from an appropriate outcome reported
Marshall, A. L., Bauman, A. E., Owen, N., Booth, M. L., Crawford, D., & Marcus, B. H. (2003). Population-based randomized controlled trial of a stage-targeted physical activity intervention. *Annals of Behavioral Medicine*, *25*(3), 194-202.	Insufficient information about the intervention
Mihalko, S. L., Wickley, K. L., Sharpe, B. L. (2006). Promoting physical activity in independent living communities. *Medicine and Science in Sports and Exercise, 38*(1), 112-115.	Participants needed walking aids (e.g. crutches)
Pfeffer, I., & Alfermann, D. (2008). Initiation of physical exercise: An intervention study based on the transtheoretical model. *International Journal of Sport Psychology*, *39*(1), 41-58.	Insufficient data reported to allow an effect size to be calculated
Plotnikoff, R. C., Brunet, S., Courneya, K. S., Spence, J. C., Birkett, N. J., Marcus, B.,et al. (2007). The Efficacy of Stage-Matched and Standard Public Health Materials for Promoting Physical Activity in the Workplace: The Physical Activity Workplace Study (PAWS*). American Journal of Health Promotion,* 21*(6)*, 501-509.	Insufficient information about the intervention
Prochaska, J. O., Velicer, W. F., Rossi, J. S., Redding, C. A., Greene, G. W., Rossi, S. R., et al. (2004). Multiple Risk Expert System Interventions: Impact of Simultaneous Stage-matched Expert System Interventions for Smoking, High Fat Diet and Sun Exposure in a Population of Parents. *Health Psychology*, *23*(5), 503-516.	Insufficient information about the intervention
Proper, K. I., de Bruyne, M. C., Hildebrandt, V. H., van der Beek, A. J., Meerding, W. J., van	No data from an appropriate outcome reported

Mechelen, W. (2004). Costs, benefits and effectiveness of worksite physical activity counseling from the employer's perspective. *Scandinavian Journal of Work, Environment and Health, 30*(1), 36-46.	
Ransdell, L. B., Detling, N. J., Taylor, A., Reel, J., & Shultz, B. (2004). Effects of home- and university-based programs on physical self-perception in mothers and daughters. *Women & Health*, *39*(2), 63-81.	No appropriate control
Rowley, K. G., Daniel, M., Skinner, K., Skinner, M., White, G. A., & O'Dea, K. (2000). Effectiveness of a community-directed 'healthy lifestyle' program in a remote Australian aboriginal community. *Australian and New Zealand Journal of Public Health, 24* (2), 136-144.	No appropriate control
Smeets, T., Brug, J., & de Vries, H. (2008). Effects of tailoring health messages on physical activity. *Health Education Research*, *23*(3), 402-413.	Insufficient data reported to allow an effect size to be calculated
van Assema, P., Steenbakkers, M., Rademaker, C., Brug, J. (2005). The impact of a nutrition education intervention on main meal quality and fruit intake in people with financial problems. *Journal of Human Nutrition and Dietetics, 18*(3), 205-212.	No data from an appropriate outcome reported

Table S2

Key Characteristics of Studies Included in the Meta-Analysis, by Target Behavior (Physical Activity/Health Eating)

Study	N	Study design	Duration of treatment (weeks)	Time of outcome assessment	Format of delivery	Source of delivery	Country/ Setting	Outcome	No. of behavior change techniques	Multiple sessions
Physical Activity										
Aldana et al., 2005	337	RCT	4	FU	IF & GF	HP (medic)	US/PC	EL	7	Yes
Anderson et al., 2006	133	RCT	12	I	IF & GF	HP (non-medic)	Aus/Com	EL	3	Yes
Arao et al., 2007	128	Quasi	26	FU	IF	Non-HP	Japan / WP	EE	5	Yes
Ash et al., 2006	55	RCT	26	FU	IF & GF	HP (non-medic)	Aus/Com	BMI	1	Yes
Babazono et al., 2007	87	RCT	20	FU	IF	HP (Non-medic)	Japan / PC	EL	4	Yes
Baker et al., 2008	79	RCT	12	I	IF	Non-HP	UK / Com	EL	6	Yes
Bennett et al., 2008	72	RCT	26	I	IF	Non-HP	US / Com	EE	8	Yes
Blissmer et al., 2002	78	RCT	12	FU	IF	Non-HP	US / WP	EL	9	Yes
Bolognesi et al., 2006	96	RCT	3	FU	IF	HP (medic)	US/Com	BMI	9	Yes
Bull et al., 1999	570	Quasi	0.29	FU	IF	HP (medic)	Aus/PC	% active	3	No
Calfas et al., 1996	212	Quasi	2	FU	IF	HP (medic)	US/PC	EL	8	Yes
Calfas et al., 2000	177 (W); 144 (M)	RCT	78	FU	IF & GF	Non-HP	US/WP	EE	12	Yes
Campbell et al., 2002	538	CRCT	78	I	GF	Non-HP	US/WP	EL	8	Yes
De Cocker et al., 2008	82	RCT	3	I	IF	Non-HP	Eur / Com	EL	5	Yes
Dinger et al., 2007	56	RCT	6	I	IF			EL	10	

Dzator et al., 2004	90	RCT	16	I	IF & GF	HP (non-medic)	Aus/Com	EL	4	Yes
Elbel et al., 2003	118	Quasi	3	FU	GF	Non-HP	US/WP	EE	8	Yes
Elley et al., 2003	750	CRCT	12	FU	IF	HP (medic)	Aus/PC	EE	4	Yes
Elliot et al., 2004	23	RCT	26	I	GF	HP (non-medic)	US/WP	EL	13	Yes
Elliot et al., 2007	315	CRCT	38	FU	GF	Non-HP	US / WP	EL	13	Yes
Fahrenwald et al., 2004	44	RCT	8	FU	IF	Non-HP	US/Com	EE	11	Yes
Green et al., 2002	181	RCT	12	FU	IF	Non-HP	US/PC	EL	6	Yes
Halbert et al., 2000	299	RCT	26	FU	IF	Non-HP	Aus/PC	EL	9	No
Hardcastle et al., 2008	334	RCT	26	I	IF	HP (Non-medic)	UK / PC	EL	4	Yes
Harland et al., 1999	309	RCT	12	FU	IF	HP (non-medic)	UK/PC	EL	4	Yes
Hivert et al., 2007	115	RCT	104	I	GF	HP (Medic) & Non-HP	Canada / Com	EL	4	Yes
Huddy et al., 1995	111	Quasi	2	FU	GF	Non-HP	US/WP	EL	6	Yes
Hurling et al., 2007	77	RCT	8	I	IF	Non-HP	UK / Com	EL	6	Yes
Hyman et al., 2007	185	RCT	78	I	IF	HP (Non-medic)	US / PC	EL	3	Yes
Inoue et al., 2003	84	RCT	8	FU	IF	HP (non-medic)	Aus/Com	EE	12	Yes
King et al., 2008	37	RCT	8	I	IF	Non-HP	US / Com	EL	6	Yes
Kinmonth et al., 2008	218	RCT	52	I	IF	HP (Non-medic)	UK / Com	EL	9	Yes
Lawton et al., 2008	1089	RCT	38	FU	IF	HP (Medic)	NZ / PC	% active	6	Yes
Little et al., 2004	72	RCT	0.14	FU	IF	HP (medic)	UK/PC	EL	6	No
Loughlan et al., 1997	104	RCT	0.14	FU	IF	Non-HP	UK/WP	EL	7	Yes
Marcus et al., 1997	44	Quasi	0.14	FU	IF	HP (medic)	US/PC	EL	6	Yes
Marcus et al., 2007	159	RCT	52	I	IF	HP (Non-medic)	US / Com	EL	5	Yes

Marshall et al., 2003	462	RCT	0.14	FU	IF	Non-HP	Aus / Com	% active	7	No
Marshall et al., 2004	719	RCT	0.14	FU	IF	Non-HP	Aus / Com	% active	7	No
Martinson et al., 2008	986	RCT	26	I	IF	HP (Non-medic)	US / Com	EE	9	Yes
Mayer et al., 1994	1548	RCT	52	I	IF & GF	Non-HP	US/Com	EL	7	Yes
McAuley et al., 1994	114	RCT	20	I	GF	Non-HP	US/Com	EL	11	Yes
Merom et al., 2007	246	RCT	10	FU	IF	Non-HP	Aus / Com	EL	5	Yes
Miller et al., 2002	390	CRCT	8	I	IF & GF	Non-HP	US/Com	EL	6	Yes
Newton et al., 2004	18	RCT	26	I	IF & GF	HP (non-medic)	US/Com	EL	1	Yes
Nichols et al., 2000	58	RCT	12	FU	GF	HP (non-medic)	US/WP	EE	9	Yes
Nies et al., 2003	137	RCT	26	I	IF	Non-HP	US/Com	EL	7	Yes
Nies et al., 2006	173	RCT	26	FU	IF	Non-HP	US/Com	EL	3	Yes
Norris et al., 2000	812	CRCT	4	FU	IF	HP (medic)	US/PC	EL	10	Yes
Peterson et al., 1999	359	RCT	0.14	FU	IF	Non-HP	US/WP	EL	3	No
Peterson et al., 2005	42	CRCT	12	I	IF & GF	Non-HP	US/Com	EL	5	Yes
Poston et al., 2001	237	RCT	52	FU	GF	HP (non-medic)	US/Com	EE	11	Yes
Purath et al., 2004	271	CRCT	0.14	FU	IF	HP (non-medic)	US/WP	EL	4	Yes
Resnicow et al., 2005	535	CRCT	52	I	IF	Non-HP	US/Com	EL	8	Yes
Rodearmel et al., 2006	81	RCT	13	I	GF	Non-HP	US/Com	EL	4	Yes
Rosamond et al., 2000	515	Quasi	26	FU	IF	HP (non-medic)	US/PC	EL	6	Yes
Schneider et al., 2004	16	Quasi	6	FU	IF	HP (non-medic)	US/Com	EL	8	Yes
Speck et al., 2001	49	CRCT	12	I	IF	Non-HP	US/Com	EL & EE	1	Yes

Spittaels et al., 2007	257	RCT	8	FU	IF	Non-HP	Eur / Com	EL	3	Yes
Stevens et al., 1998	714	RCT	10	FU	IF	Non-HP	UK/PC	EL	6	Yes
Stewart et al., 1997	89	Quasi	16	I	IF & GF	Non-HP	US/Com	% active	6	Yes
Tate et al., 2001	62	RCT	26	I	IF & GF	HP (non-medic)	US/Com	EL	8	Yes
Tate et al., 2006	110	RCT	26	I	IF	Non-HP	US/Com	EL	5	Yes
Vandelanotte et al., 2005	393	RCT	0.14	FU	IF	Non-HP	Eur/Com	EL	3	Yes
WG-ACT, 2001	228 (W); 297 (M)	RCT	104	I	IF & GF	HP (medic)	US/PC	EL	12	Yes
Winett et al., 2007	620	CRCT	12	FU	IF	Non-HP	US / Com	EL	5	Yes
Wing et al., 2006	190	RCT	78	FU	IF & GF	HP (non-medic)	US/Com	EL	4	Yes
Healthy Eating										
Ahluwalia et al., 2007	173	CRCT	20	FU	IF	Non-HP	US / Com	FV	3	Yes
Aldana et al., 2005	331	RCT	4	I	IF & GF	HP (medic)	US/PC	FV & Fat	7	Yes
Anderson et al., 2001	221	RCT	4	I	IF	Non-HP	US/Com	FV & Fat	4	Yes
Arao et al., 2007	135	Quasi	26	FU	IF	Non-HP	Japan / WP	FV	5	Yes
Armitage, 2004	264	RCT	4	I	IF	Non-HP	UK/WP	Fat	1	No
Armitage, 2007	82	RCT	0.14	FU	IF	Non-HP	UK / Com	Fruit	1	No
Babazono et al., 2007	87	RCT	20	FU	IF	HP (Non-medic)	Japan / PC	EL	4	Yes
Beresford et al., 1997	1853	CRCT	2	FU	IF	HP (medic)	US/PC	Fibre & Fat	2	Yes
Brug et al., 1996	352	RCT	3	FU	IF	HP (non-medic)	Eur/WP	FV & Fat	6	No
Brug et al., 1998	435	RCT	4	I	IF	HP (non-medic)	Eur/Com	FV & Fat	6	Yes
Burke et al., 2003	64	RCT	16	FU	IF & GF	Non-HP	Aus/Com	FV & Fat	14	Yes
Campbell et al., 1994	258	RCT	0.14	FU	IF	Non-HP	US/Com	FV & Fat	9	No

Campbell et al., 1999	377	RCT	0.14	FU	IF	Non-HP	US/Com	Fat	4	No
Campbell et al., 2002	538	CRCT	78	I	GF	Non-HP	US/WP	FV & Fat	8	Yes
Campbell et al., 2004	306	RCT	0.14	FU	IF	Non-HP	US/Com	FV & Fat	2	No
Carpenter et al., 2004	61	RCT	26	FU	GF	Non-HP	US/PC	Diet score	13	Yes
de Bourdeaudhuij et al., 2000	35 (W); 35 (M)	RCT	2	FU	IF	Non-HP	Eur/Com	Fat	4	No
De Bourdeaudhuij et al., 2007	213	CRCT	0.14	FU	IF	Non-HP	Eur / WP	Fat	3	No
de Noojier et al., 2006	293	RCT	0.14	FU	IF	Non-HP	Eur/Com	Fruit	2	No
Delichatsios et al., 20001a	298	RCT	26	I	IF	Non-HP	US/Com	FV	4	Yes
Delichatsios et al., 2001b	504	CRCT	8	I	IF	HP (medic)	US/PC	FV	6	Yes
Dzator et al., 2004	90	RCT	16	I	IF & GF	HP (non-medic)	Aus/Com	FV & Fat	4	Yes
Elder et al., 2005	214	RCT	12	I	GF	Non-HP	US/Com	Fibre & Fat	5	Yes
Elliot et al., 2004	23	RCT	26	I	GF	HP (non-medic)	US/WP	FV & Fat	13	Yes
Elliot et al., 2007	315	CRCT	38	FU	GF	Non-HP	US / WP	FV	13	Yes
Emmons et al., 1999	2054	CRCT	130	I	IF & GF	Non-HP	US/WP	FV & Fat	5	No
Fuller et al., 1998	50	RCT	26	FU	GF	HP (non-medic)	US/PC	Fat	7	Yes
Hardcastle et al., 2008	334	RCT	26	I	IF	HP (Non-medic)	UK / PC	FV & Fat	4	Yes
Havas et al., 1998	3122	RCT	26	FU	IF & GF	Non-HP	US/Com	FV	6	Yes
Hivert et al., 2007	115	RCT	104	I	GF	HP (Medic) & Non-HP	Canada / Com	Caloric intake	4	Yes
Insull et al., 1990	264	RCT	104	I	IF & GF	HP (non-medic)	US/Com	Fat	5	Yes

Kellar et al., 2005	218	RCT	0.14	FU	IF	Non-HP	UK/Com	FV	2	No
Kristal et al., 1992	1050	RCT	104	FU	GF	HP (non-medic)	US/PC	FV & Fat	4	Yes
Kristal et al., 2000	1205	RCT	52	FU	IF	Non-HP	US/PC	FV & Fat	6	Yes
Kroeze et al., 2008	278	RCT	0.14	FU	IF	Non-HP	Eur / Com	Fat	5	No
Mayer et al., 1994	1548	RCT	52	I	IF & GF	Non-HP	US/Com	FV & Fat	7	Yes
Oenema et al., 2005	301	RCT	3	I	IF	Non-HP	Eur/WP	FV & Fat	5	No
Paineau et al., 2008	673	CRCT	34	I	IF	Non-HP	Eur/Com	Fat	2	Yes
Raats et al., 1999	113	Quasi	18	FU	IF	Non-HP	UK/WP	Fat	2	Yes
Resnicow et al., 2001	576	CRCT	52	I	IF	Non-HP	US/Com	FV	8	Yes
Resnicow et al., 2005	535	CRCT	52	I	IF	Non-HP	US/Com	FV	8	Yes
Reuter et al., 2008	115	RCT	0.14	FU	IF	Non-HP	Eur / WP	FV	1	No
Rodearmel et al., 2006	81	RCT	13	I	GF	Non-HP	US/Com	Fibre	4	Yes
Rosamond et al., 2000	515	Quasi	26	FU	IF	HP (non-medic)	US/PC	Fat	6	Yes
Steptoe et al., 2003	271	RCT	0.14	FU	GF	HP (non-medic)	UK/PC	FV	2	Yes
Stevens et al., 2002	616	RCT	4	FU	IF	HP (non-medic)	US/PC	FV & Fat	11	Yes
Tate et al., 2001	62	RCT	26	I	IF & GF	HP (non-medic)	US/Com	Fat	8	Yes
Tate et al., 2006	106	RCT	26	I	IF	Non-HP	US/Com	Fat	5	Yes
Tilley et al., 1999	3477	CRCT	52	I	IF & GF	Non-HP	US/WP	FV & Fat	7	Yes
Vandelanotte et al., 2005	371	RCT	0.14	FU	IF	Non-HP	Eur/Com	Fat	3	Yes
Winett et al., 2007	620	CRCT	12	FU	IF	Non-HP	US / Com	Fruit, Fibre & Fat	5	Yes
Wing et al., 2006	190	RCT	78	FU	IF & GF	HP (non-medic)	US/Com	Fat	4	Yes

Note. Aus = Australia, BMI = Body Mass Index, Com = Community, Eur = European country other than UK, FU = Follow up, GF = Group format, HP =

healthcare professional, I = Immediate, IF = Individual format, NZ = New Zealand, PC = Primary care, Quasi = Quasi-experimental study, UK = United Kingdom, US = United States of America, WP = Workplace.

Table S3

Summary of Intervention Characteristics

Variable	PA	HE	Total
Target behaviour	69	53	122
Total number of techniques (intervention): mean (SD), range	6.6 (3.0), 1-12	5.2 (3.1), 1-14	6.0 (3.1), 1-14
Total number of techniques (control): mean (SD), range	0.9 (1.4), 0-6	0.7 (1.0), 0-5	0.8 (1.3), 0-6
Technique			
T1. Provide information on behavior-health link	20	17	37
T2. Provide information on consequences	42	22	64
T3. Provide information about others' approval	0	0	0
T4. Prompt intention formation	43	31	74
T5. Prompt barrier identification	32	13	45
T6. Provide general encouragement	23	13	36
T7. Set graded tasks	11	6	17
T8. Provide instruction	38	34	72
T9. Model/ demonstrate the behavior	8	3	11
T10. Prompt specific goal setting	18	9	27
T11. Prompt review of behavioral goals	13	6	19

T12. Prompt self-monitoring of behavior	32	14	46
T13. Provide feedback on performance	28	33	61
T14. Provide contingent rewards	18	12	30
T15. Teach to use prompts/ cues	9	11	20
T16. Agree behavioral contract	8	4	12
T17. Prompt practice	9	2	11
T18. Use of follow up prompts	25	9	34
T19. Provide opportunities for social comparison	14	6	20
T20. Plan social support/ social change	24	10	34
T21. Prompt identification as role model/ position advocate	2	0	2
T22. Prompt self talk	4	0	4
T23. Relapse prevention	17	6	23
T24. Stress management	1	3	4
T25. Motivational interviewing	10	7	17
T26. Time management	5	2	7
Duration of intervention: mean (SD) weeks	24.4 (27.3)	25.6 (31.6)	24.9 (29.1)
Brief (< 1 day)	8	11	19
Less than one month	6	5	11

1 – 5 months	27	14	41
6 – 11 months	15	12	27
12 months or more	13	11	24
Use of multiple sessions			
Yes	65	38	103
No	4	15	19
Time of outcome assessment			
Immediate	30	20	50
Follow up[a]	39	33	72
Delivery source			
Medically trained health professional[b]	12	4	16
Non-medically trained health professional	20	14	34
Non-health professional	37	35	72
Format of delivery			
Individual	43	33	76
Group	11	10	21
Mixed	15	10	25
Setting			

Community	38	29	67
Primary care	18	12	92
Workplace	13	12	25
Country			
Australasia	10	2	12
Canada	1	1	2
Japan	3	2	5
Other European	3	11	14
UK	8	6	14
USA	44	31	75
Target population			
Disadvantaged/low income	5	4	9
Sedentary/obese/at risk for CVD	35	7	42
Women only	16	10	26
Theoretically-derived self-regulation techniques			
Prompt intention formation (T4)	43	31	74
Prompt specific goal setting (T10)	18	9	27

Prompt review of behavioral goals (T11)	13	6	19
Prompt self-monitoring of behavior (T12)	32	14	46
Provide feedback on performance (T13)	28	33	61

Note. [a]Including evaluations where results were averaged across timepoints, [b]For the purposes of the review, we defined a health professional as someone with a professional qualification enabling them to contribute to direct patient care within health services, CVD = Cardiovascular disease, HE = Healthy eating, PA = Physical activity.

Table S4

Univariate Meta-regression Analyses for Selected Study and Intervention Characteristics

			Physical activity or healthy eating outcome					
Model	**Covariate**	**Classification**	***k (N)***	**Effect size (95% CI)**	***I^2***	**β (95% CI)**	**P-value[a]**	**Adjusted R^2**
0	**None**	Overall effect	122 (44747)	0.31 (0.26, 0.36)	69%	–	–	–
1	**Type of behaviour**	PA	69 (18330)	0.32 (0.26, 0.38)	58%	-.016 (-.114, 0.082)	1.000	0%
		HE	53 (26417)	0.31 (0.23, 0.39)	73%			
2	**Duration of intervention (weeks)**	Range: <1 day to 130 weeks	122 (44747)	–	–	-.001 (-.003, .001)	.998	2%
3	**Delivery source**	HP	50 (15794)	0.33 (0.23, 0.42)	78%	-.015 (-.114, .084)	1.000	0%
		Non-HP	72 (28953)	0.30 (0.24, 0.36)	59%			
3a	**Delivery source**	Medic	16 (7425)	0.27 (0.16, 0.37)	78%	.046 (-.086, .178)	1.000	0%
		Non-medic	106 (37322)	0.32 (0.26, 0.38)	66%			
3b	**Delivery source**	Non-medic HP	34 (8369)	0.36 (0.22, 0.50)	74%	-.052 (-.164, .060)	[b]	0%
		Medic or non-HP	88 (36378)	0.29 (0.24, 0.33)	65%			
4	**Format of delivery**	Individual	76 (25233)	0.30 (0.25, 0.35)	58%	.022 (-.081, .125)	1.000	0%
		Group or mixed	46 (19514)	0.34 (0.23, 0.44)	78%			
4a	**Format of delivery**	Group	21 (4512)	0.36 (0.23, 0.50)	75%	-.060 (-.204, .083)	[b]	0%
		Individual or Mixed	101 (40235)	0.30 (0.25, 0.36)	67%			

4c	**Format of delivery**	Mixed	25 (15002)	0.32 (0.15, 0.48)	65%	.012 (-.108, .132)	1.000	0%
		Individual or Group	97 (29745)	0.31 (0.26, 0.35)	64%			
5	**Country**	European	28 (7022)	0.31 (0.23, 0.40)	55%	-.006 (-.121, .109)	1.000	0%
		All others	94 (37725)	0.31 (0.25, 0.37)	72%			
5a	**Country**	UK	14 (3189)	0.36 (0.23, 0.48)	46%	-.047 (-.198, .103)	1.000	0%
		All others	108 (41558)	0.31 (0.25, 0.36)	70%			
5b	**Country**	US	75 (32407)	0.29 (0.23, 0.36)	66%	.018 (-.082, .119)	1.000	0%
		All others	47 (12340)	0.32 (0.25, 0.39)	71%			
6	**Setting**	Workplace	25 (10324)	0.27 (0.17, 0.37)	60%	.043 (-.083, .168)	[b]	0%
		PC or Community	97 (34423)	0.32 (0.26, 0.38)	71%			
6a	**Setting**	Community	67 (20511)	0.32 (0.25, 0.40)	74%	-.018 (-.115, .080)	1.000	0%
		PC or workplace	55 (24236)	0.30 (0.24, 0.35)	60%			
6b	**Setting**	PC	30 (13912)	0.31 (0.23, 0.40)	62%	-.010 (-.119, .099)	1.000	0%
		Community or workplace	92 (30835)	0.31 (0.25, 0.37)	71%			
7	**Use of multiple or single sessions**	Single	19 (6481)	0.24 (0.15, 0.33)	67%	.081 (-.042, .204)	.999	2%
		Multiple	103 (38266)	0.33 (0.27, 0.38)	70%			
8	**Time of follow up**	Immediate	50 (19312)	0.31 (0.22, 0.40)	76%	.012 (-.087, .112)	1.000	0%
		Follow up	72 (25435)	0.31 (0.25, 0.36)	58%			
9	**Target population (disadvantaged/ low**	Yes	9 (5415)	0.31 (0.26, 0.36)	68%	.022 (-.155, .199)	1.000	0%
		No	113 (39332)	0.34 (0.08, 0.60)	78%			

	income)							
9a	**Target population (sedentary/ obese or at risk for CVD)**	Yes	42 (8393)	0.28 (0.22, 0.34)	68%	.088 (-.016, .192)	.884	7%
		No	80 (36354)	0.37 (0.28, 0.46)	59%			
9b	**Target population (women only)**	Yes	26 (11970)	0.30 (0.26, 0.35)	64%	.012 (-.108, .132)	1.000	0%
		No	96 (32777)	0.34 (0.17, 0.51)	79%			
10	**Number of techniques (intervention)**	Range 1-14	122 (44747)	–	–	.003 (-.013, .020)	1.000	0%

Note. [a]From Monte Carlo permutation test for single covariate meta-regressions (models 1 to 34; 10,000 permutations), [b]Dropped from the Monte Carlo simulation due to collinearity, HE = Healthy eating, HP = Healthcare professsional, *N* = Total sample size, PA = Physical activity.

Table S5

Univariate Meta-Regression Analyses for the Individual Behavior Change Techniques

				Physical activity or healthy eating outcome				
						Univariate model		
Model	**Covariate**	**Classification**	***k (N)***	**Effect size (95% CI)**	**I^2**	**β (95% CI)**	**P-value[a]**	**Adjusted R^2**
11	T1. Provide information on behavior-health link	Yes	37 (9862)	0.35 (0.27, 0.43)	62%	0.06 (-0.044, 0.165)	.999	4%
		No	85 (34885)	0.29 (0.23, 0.36)	66%			
12	T2. Provide information on consequences	Yes	64 (22425)	0.29 (0.23, 0.34)	54%	-0.038 (-0.136, 0.059)	1.000	0%
		No	58 (22322)	0.34 (0.25, 0.42)	78%			
–	T3. Provide information about others' approval	Yes	0	–	–	–	–	–
		No	122 (44747)	–	–			
13	T4. Prompt intention formation	Yes	74 (29701)	0.34 (0.27, 0.41)	68%	0.058 (-0.04, 0.157)	.999	1%
		No	48 (15046)	0.27 (0.2, 0.34)	66%			
14	T5. Prompt barrier identification	Yes	45 (29022)	0.29 (0.21, 0.36)	57%	-0.033 (-0.133, 0.068)	1.000	0%
		No	77 (15725)	0.33 (0.26, 0.39)	74%			
15	T6. Provide general encouragement	Yes	38 (18268)	0.24 (0.17, 0.31)	52%	-0.1 (-0.205, 0.005)	.866	2%
		No	86 (26479)	0.34 (0.28, 0.41)	73%			
16	T7. Set graded tasks	Yes	17 (4823)	0.38 (0.27, 0.49)	48%	0.094 (-0.047, 0.235)	.997	2%
		No	105 (39924)	0.30 (0.25, 0.35)	70%			
17	T8. Provide instruction	Yes	72 (26282)	0.33 (0.26, 0.4)	67%	0.031 (-0.068, 0.13)	1.000	0%
		No	50 (18465)	0.29 (0.22, 0.35)	71%			
18	T9. Model/ demonstrate the behavior	Yes	11(2554)	0.28 (0.09, 0.48)	63%	-0.028 (-0.205, 0.149)	1.000	0%

		No	111 (42193)	0.31 (0.26, 0.36)	69%			
19	T10. Prompt specific goal setting	Yes	27 (6337)	0.32 (0.24, 0.41)	55%	0.029 (-0.087, 0.145)	1.000	0%
		No	95 (38410)	0.31 (0.25, 0.36)	72%			
20	T11. Prompt review of behavioral goals	Yes	19 (3903)	0.42 (0.28, 0.55)	33%	0.127 (-0.027, 0.281)	.960	3%
		No	103 (40844)	0.30 (0.24, 0.35)	71%			
21	T12. Prompt self-monitoring of behavior	Yes	46 (11019)	0.41 (0.29, 0.52)	71%	0.135 (0.036, 0.235)	.189	13%
		No	76 (33728)	0.26 (0.21, 0.3)	62%			
22	T13. Provide feedback on performance	Yes	61 (26656)	0.32 (0.24, 0.39)	69%	0.004 (-0.094, 0.101)	1.000	0%
		No	61 (18091)	0.30 (0.24, 0.37)	70%			
23	T14. Provide contingent rewards	Yes	30 (15658)	0.26 (0.16, 0.36)	50%	-0.052 (-0.171, 0.066)	1.000	1%
		No	92 (29089)	0.32 (0.27, 0.38)	73%			
24	T15. Teach to use prompts/ cues	Yes	20 (11392)	0.33 (0.18, 0.49)	59%	0.018 (-0.121, 0.157)	1.000	0%
		No	102 (33355)	0.31 (0.26, 0.36)	71%			
25	T16. Agree behavioral contract	Yes	12 (6238)	0.35 (0.19, 0.52)	77%	0.051 (-0.103, 0.205)	1.000	0%
		No	110 (38509)	0.31 (0.25, 0.36)	67%			
26	T17. Prompt practice	Yes	11 (1318)	0.30 (0.06, 0.54)	75%	-0.019 (-0.194, 0.156)	1.000	0%
		No	111 (43429)	0.31 (0.26, 0.36)	69%			
27	T18. Use of follow up prompts	Yes	34 (14300)	0.36 (0.24, 0.49)	78%	0.057 (-0.049, 0.164)	1.000	0%
		No	88 (30447)	0.29 (0.24, 0.34)	62%			
28	T19. Provide opportunities for social comparison	Yes	20 (7063)	0.27 (0.15, 0.39)	66%	-0.05 (-0.179, 0.08)	1.000	0%
		No	102 (37684)	0.32 (0.27, 0.37)	70%			
29	T20. Plan social support/ social change	Yes	34 (16357)	0.24 (0.15, 0.33)	54%	-0.082 (-0.195, 0.03)	.993	2%
		No	88 (28390)	0.33 (0.27, 0.39)	73%			
–	T21. Prompt identification as role	Yes	2 (122)	–	–	–	–	–

	model/ position advocate	No	120 (44625)	–	–			
30	T22. Prompt self talk	Yes	4 (463)	0.17 (0.44, 0.78)	77%	-0.151 (-0.439, 0.136)	1.000	0%
		No	118 (44284)	0.31 (0.27, 0.36)	69%			
31	T23. Relapse prevention	Yes	23 (5382)	0.29 (0.18, 0.4)	43%	-0.02 (-0.152, 0.113)	1.000	0%
		No	99 (39365)	0.32 (0.26, 0.37)	72%			
32	T24. Stress management	Yes	4 (249)	0.21 (0.51, 0.92)	67%	-0.109 (-0.444, 0.226)	1.000	0%
		No	118 (44498)	0.31 (0.26, 0.36)	70%			
33	T25. Motivational interviewing	Yes	17 (6696)	0.30 (0.23, 0.37)	0%	-0.019 (-0.162, 0.124)	1.000	0%
		No	105 (38051)	0.32 (0.26, 0.37)	72%			
34	T26. Time management	Yes	7 (759)	0.20 (0.11, 0.51)	51%	-0.128 (-0.368, 0.113)	1.000	1%
		No	115 (43988)	0.32 (0.27, 0.37)	70%			

Note. [a]From Monte Carlo permutation test for single covariate meta-regressions (models 1 to 34; 10,000 permutations), [b]Dropped from the Monte Carlo simulation due to collinearity, k = number of evaluations, N = number of participants.

Table S6

Multivariate Meta-Regression Analysis

			Physical activity or healthy eating outcome			
					Multivariate model	
Covariate	**Classification**	***k (N)***	**Effect size (95% CI)**	I^2	**β (95% CI)**	**P-value[a]**
Prompt review of behavioral goals (T11)	Yes	19 (3903)	0.42 (0.28, 0.55)	33%	.054 (-.107, .215)	.948
	No	103 (40844)	0.3 (0.24, 0.35)	71%		
Prompt self-monitoring of behaviour (T12)	Yes	46 (11019)	0.41 (0.29, 0.52)	71%	.137 (.028, .246)	.062
	No	76 (33728)	0.26 (0.21, 0.3)	62%		
Prompt self talk (T22)	Yes	4 (463)	0.17 (0.44, 0.78)	77%	-.152 (-.503, .199)	.870
	No	118 (44284)	0.31 (0.27, 0.36)	69%		
Stress management (T24)	Yes	4 (249)	0.21 (0.51, 0.92)	67%	-.203 (-.581, .174)	.746
	No	118 (44498)	0.31 (0.26, 0.36)	70%		
Time management (T26)	Yes	7 (759)	0.2 (0.11, 0.51)	51%	.008 (-.307, .323)	1.000
	No	115 (43988)	0.32 (0.27, 0.37)	70%		

Note. [a]Monte Carlo permutation test for multiple meta-regressions (10,000 permutations), *k* = number of evaluations, *N* = number of participants.

Table S7

Meta-Regression Analyses for the Theoretically-derived Self-Regulation Techniques

			Physical activity or healthy eating outcome					
Model	**Covariate**	**Classification**	***k (N)***	**Effect size (95% CI)**	I^2	**β (95% CI)**	**P-value**[a]	**Adjusted** R^2
35	**Number of self-regulation techniques (univariate model)**	0	9 (2798)	0.17 (0.01, 0.33)	66%	.053 (.009, .096)	.019	9%
		1	42 (19919)	0.26 (0.20, 0.32)				
		2	41 (11765)	0.33 (0.25, 0.40)				
		3	19 (7565)	0.50 (0.26, 0.75)				
		4	9 (2028)	0.30 (0.09, 0.51)				
		5	2 (672)	0.41 (0.26, 0.55)[c]				
36	**Self-monitoring plus**[b] **(univariate model)**	Yes	42 (10572)	0.42 (0.30, 0.54)	71%	.154 (.052, .255)	.003	17%
		No	80 (34175)	0.26 (0.21, 0.30)	61%			
37	**All self-regulation techniques (multivariate model)**	T4. Prompt intention formation	74 (29701)	–	–	.043 (-.057, .144)	.884	9%
		T10. Prompt specific goal setting	27 (6337)	–	–	.023 (-.094, .141)	.996	
		T11. Prompt review of behavioral goals	19 (3903)	–	–	.053 (-.116, .221)	.975	

	T12. Prompt self-monitoring of behavior	46 (11019)	–	–	.122 (.016, .228)	.075
	T13. Provide feedback on performance	61 (26656)	–	–	-.008 (-.108, .092)	1.000

Note. [a]From Monte Carlo permutation test for single covariate meta-regressions (models 35 and 36) or multiple meta-regressions (model 37) (10,000 permutations), [b]Studies were categorised as 'yes' if they used self-monitoring plus any other technique from the self-regulation group of techniques, [c]Insufficient data to calculate the effect size using restricted maximum likelihood estimation, therefore calculated with the Stata meta command using a random effects model, k = number of evaluations, N = number of participants.

Table S8

Sensitivity analyses

				Physical activity or healthy eating outcome			
Model	**Covariate**	**Classification**	***k (N)***	**Effect size (95% CI)**	I^2	**β (95% CI)**	**Adjusted R^2**
Excluding outliers as defined by the SAMD statistic							
0a	None	Overall effect	119 (40990)	0.29 (0.25, 0.34)	64%	–	–
21a	T12. Prompt self-monitoring of behavior	Yes	45 (10755)	0.37 (0.28, 0.46)	59%	.114 (.027, .201)	13%
		No	74 (30235)	0.25 (0.21, 0.30)	62%		
Excluding studies not randomised at the patient level							
0b	None	Overall effect	86 (26282)	0.33 (0.26, 0.39)	73%	–	–
21b	T12. Prompt self-monitoring of behavior	Yes	38 (6970)	0.42 (0.28, 0.55)	73%	.145 (.011, .278)	10%
		No	48 (19312)	0.26 (0.19, 0.32)	67%		
Excluding quasi-experimental studies and those for which assumptions were made to calculate the effect size or we had concerns about the validity of the data							
0c	None	Overall effect	106 (41187)	0.33 (0.27, 0.38)	71%	–	–
21c	T12. Prompt self-monitoring of behavior	Yes	38 (9921)	0.44 (0.31, 0.57)	72%	.150 (.037, .263)	13%
		No	68 (31266)	0.27 (0.22, 0.32)	65%		

Note. k = number of evaluations, N = number of participants.

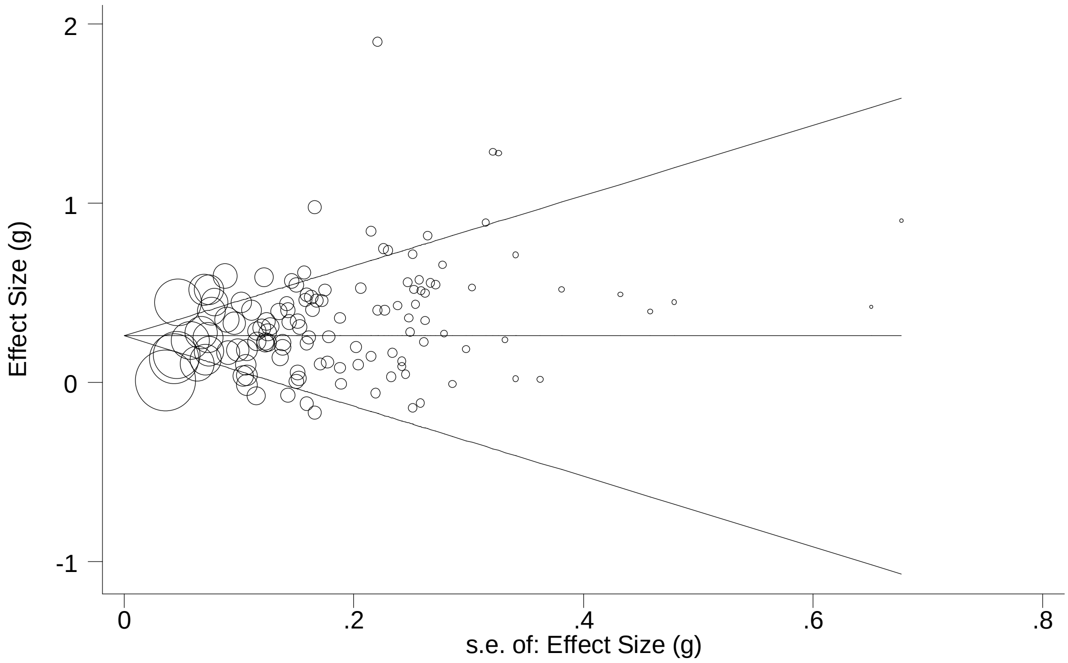

Figure 1. Begg’s funnel plot (with pseudo 95% CI) showing the effect size versus the standard error of the effect size for 122 physical activity and healthy eating evaluations (Kendall's Score [corrected for ties, if any] was 913 [SD 451.87], 2-tailed P-value = 0.04).