Behavior change techniques used to promote walking and cycling: a systematic review

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Abstract

Objective: Evidence on the effectiveness of walking and cycling interventions is mixed. This may be partly attributable to differences in intervention content, such as the cognitive and behavioral techniques (BCTs) utilized. Adopting a taxonomy of BCTs, this systematic review addressed two questions: 1) What are the behavior change techniques used in walking and cycling interventions targeted at adults? 2) What characterizes interventions that appear to be associated with changes in walking and cycling in adults? **Methods:** Previous systematic reviews and updated database searches were used to identify controlled studies of individual-level walking and cycling interventions involving adults. Characteristics of intervention design, context and methods were extracted in addition to outcomes. Intervention content was independently coded according to a 26-item taxonomy of BCTs. **Results:** Studies of forty six interventions met the inclusion criteria. Twenty-one reported a statistically significant effect on walking and cycling outcomes. Analysis revealed substantial heterogeneity in the vocabulary used to describe intervention content and the number of BCTs coded. 'Prompt self-monitoring of behavior' and 'prompt intention formation' were the most frequently coded BCTs. **Conclusions:** Future walking and cycling intervention studies should ensure that all aspects of the intervention are reported in detail. The findings lend support to the inclusion of self-monitoring and intention formation techniques in future walking and cycling intervention design, although further exploration of these and other BCTs is required. Further investigation of the interaction between BCTs and study design characteristics would also be desirable.

Keywords: walking, cycling, intervention, review, behavior change

Introduction

Regular physical activity is associated with a reduced risk of mortality, the prevention of several chronic diseases (Bull et al., 2010; Lee et al., 2012), and an improvement in quality of life (Blair & Morris, 2009). Self-reported data suggest that fewer than half of UK adults meet current physical activity guidelines (Department of Health, 2011); while objectively measured data imply that the actual proportion is less than 10% (NHS Information Centre for Health and Social Care, 2009).

In contrast to many other forms of physical activity, it has been suggested that walking and cycling (in particular for transport purposes) may be easily incorporated into a daily routine, increasing the potential for adoption and maintenance of these behaviors over time (Ogilvie et al., 2007; Yang, Sahlqvist, McMinn, Griffin, & Ogilvie, 2010). As well as providing health benefits, the promotion of walking and cycling for transport could have positive environmental implications (Woodcock et al., 2009). However, between 1995 and 2009, the mean annual number of walking trips made by UK adults fell by 22 per cent (Department for Transport, 2009). It has been estimated that cycling accounts for only 2 per cent of all trips in the UK (Department for Transport, 2009), a proportion much lower than that for many surrounding European countries (Ministry of Transport, Public Works and Water Management, 2009).

A systematic review investigating the effectiveness of interventions to promote walking found modest evidence that such interventions had the potential to increase levels of walking (Ogilvie et al., 2007). The review concluded that specific intervention characteristics (e.g. using tailored intervention content targeted at motivated individuals or groups) may be associated with more favorable outcomes. A similar systematic review investigating the effectiveness of cycling interventions found some support for those based on individualized approaches or on community-wide approaches including changes to the built environment

(Yang et al., 2010). However, many of the studies included in those reviews did not demonstrate, or did not report, statistically significant changes in walking or cycling outcomes, resulting in somewhat mixed overall findings (Ogilvie et al., 2007; Yang et al., 2010).

Inconsistent evidence of effectiveness is not a problem unique to the promotion of walking and cycling; it has also been observed in other public health intervention programs, for example those designed to prevent childhood obesity (Brown & Summerbell, 2009). The mixed evidence is potentially attributable to differences in study design and methodological quality (such as varying outcome measures and evaluation criteria or lack of controlled comparisons) but also to differences in intervention content and program theory such as the cognitive and behavioral techniques reported (Grimshaw et al., 2004). The categorization of intervention techniques has, until recently, been problematic due to a failure to standardize the vocabulary used to describe the content of interventions (Abraham & Michie, 2008). When positive outcomes have been demonstrated in studies, it has often been unclear which specific behavior change techniques (BCTs) were being applied (Michie, Fixsen, Grimshaw & Eccles, 2009b). This has limited our understanding of how intervention content is related to intervention effectiveness, and has reduced our ability to accurately replicate intervention material and identify the most valuable intervention techniques that should be incorporated into future intervention design (Marcus et al., 2000; Michie, Abraham, Whittington, McAteer, & Gupta, 2009a).

In an attempt to address this problem, Abraham and Michie (2008) developed a taxonomy of 26 BCTs and assessed the inter-rater reliability of the identification of each technique. The taxonomy was derived from an extensive review of physical activity and dietary intervention studies. The taxonomy highlighted the feasibility of using a standardized vocabulary framework to describe the content of behavior change interventions for

implementation and in reporting studies. Since its inception, the taxonomy has been used to assess interventions designed to promote or maintain physical activity and healthy eating (Fjeldsoe, Neuhaus, Winkler, & Eakin, 2011; Michie, et al. 2009a; Webb, Joseph, Yardley, & Michie, 2010), reduce alcohol consumption or increase smoking abstinence (Webb et al., 2010).

Although previous applications of the taxonomy (Abraham & Michie, 2008) have focused on the BCTs used in interventions that aimed to promote physical activity in general (Fjeldsoe et al., 2011; Michie et al., 2009a; Webb et al., 2010), to date the taxonomy has not been used to investigate BCTs used in interventions to promote walking and cycling specifically. The ability to differentiate between the specific BCTs that should be utilized for the promotion of different forms of physical activity is important as these are influenced by a different set of individual, social and environmental-level determinants (Alfonzo, 2005; Krizek, Handy, & Forsyth, 2009; Saelens, Sallis, & Frank, 2003). For example, results from a systematic review exploring the relationship between physical activity and the built environment revealed that the presence of a supportive environment was more strongly associated with walking and cycling than with general physical activity (McCormack & Sheill, 2011). Further, there is evidence to suggest that walking and cycling, and their determinants, may also differ from each other. In the same review, an increase in neighborhood parks and open space was associated with walking, but not cycling trips (McCormack & Sheill, 2011). Therefore the BCTs applied in the design of walking and cycling interventions, and their impact upon behavior, may differ from those applied in interventions designed to promote physical activity in general.

Present study

Adopting the 26 item taxonomy (Abraham & Michie, 2008), this systematic review addressed two questions:

1. What are the behavior change techniques used in walking and cycling interventions targeted at adults?
2. What characterizes interventions that appear to be associated with changes in walking and cycling in adults?

Method

Search strategy

All walking and cycling intervention studies identified from two high-quality reviews were compiled. These included walking studies published between 1990 and 2007 (Ogilvie et al., 2007), and cycling studies with no date restriction imposed (Yang et al., 2010). Studies published subsequent to those reviews were also eligible for inclusion: for walking, studies published between January 2007 and March 2011, and for cycling, studies published between January 2010 and March 2011. Two structured systematic searches of Medline, PsycARTICLES, PsycINFO, the Cochrane Library, AMED, the Campbell Collaboration, EMBASE and HMIC were conducted during March 2011. Adopting the same search terminology used in previous reviews (Ogilvie et al., 2007; Yang et al., 2010), one search was limited to terms for walking and interventions, while the other search was limited to terms for cycling and interventions (search terms are provided in Table S1 of the online supplementary material). Searches were limited to English language publications and adult study populations. Duplicate references were removed.

Study selection and inclusion

Studies delivering individually targeted intervention materials were eligible for inclusion; while interventions delivered at a population-level were excluded (e.g. mass-media campaigns). All published randomized and non-randomized studies of the effect of any relevant intervention were eligible for inclusion. Studies were required to have a "no intervention" or "standard-care" control or comparison group. Studies that were cross-

sectional or did not include a control condition were excluded. Studies were also excluded if the "control" condition involved an alternative intervention providing more than a "standard-care" approach. Although before-and-after measures of walking or cycling were necessary, promoting walking or cycling did not have to be the primary objective of the intervention. No search filters were set for country of origin.

Data extraction and critical appraisal

Eligible studies were examined following a review of the titles and abstracts. Where multiple interventions were compared in one study, each intervention was included separately in analyses. If a study reported changes in walking and cycling separately, outcomes were treated separately in analyses. For each intervention study, data regarding context (author, country of origin, year of publication), sample characteristics (sample size at baseline, age and sex of participants, group characteristics), methods (study design, process evaluation information, outcome measurement tool(s) applied, length of follow-up period), and results (net changes in walking and cycling, statistical significance) were extracted (online supplementary material, Tables S2, S3 and S4). The reviewer (EB) was not blinded to journal names, authors, institutions, or outcomes during data extraction.

Intervention content.

Following instruction from the 26 item taxonomy coding manual (Abraham & Michie, 2008), the BCTs identified from each intervention were independently coded by the first and second reviewers (EB and GB). The kappa and percentage disagreement were computed separately for each intervention and then averaged. The mean kappa value for inter-rater reliability was 0.58 and the average percentage of disagreement was 16%, indicating moderate-to-good agreement on the coding of BCTs (Peat, 2001). Reviewers discussed and resolved any discrepancies. Four studies referred to five additional publications providing further information on methods. These were obtained via internet searches or

through contact with the corresponding author (Fisher, Pickering, & Li, 2002; Fitzsimons et al., 2008; Kriska et al., 1986; Long et al., 1996; Pender, Sallis, Long, & Calfas, 1994). One publication reporting additional findings of one study could not be obtained and was therefore not included in analyses. Newly identified BCTs were added to the BCTs coded from the original interventions where appropriate. Quality control of coding was implemented with 20% of the included studies being randomly selected and coded by two additional reviewers (NM and JP). The final coding of BCTs for each intervention was discussed and agreed by several authors (EB, GB, NM and JP).

Study quality.

Studies were critically appraised according to a seven-item appraisal tool adapted from previous reviews (Ogilvie et al., 2007; Yang et al., 2010) (online supplementary material, Table S5). For each of the seven items, studies were scored using a binary variable (0/1). Studies scoring 6-7 were deemed 'higher' quality, 4-5 as 'medium', and 0-3 as 'lower' quality.

Data synthesis.

As the reporting of statistical changes in walking and cycling varied greatly across studies and was absent in many cases, neither meta-analysis nor meta-regression were appropriate. Instead, data pertaining to all interventions (regardless of statistical outcomes) were synthesized using a systematic semi-quantitative method (online supplementary material, Tables S2, S3 and S4). Reviewers considered ranking studies by effect size; however, only a limited number of studies reported this information, or provided adequate outcome data that would enable calculation of a common effect size, meaning that an alternative approach was required. Included studies (disaggregated by intervention where appropriate) were therefore grouped into one of three categories: 'Interventions reported to have a statistically significant effect', 'Interventions reported to have a statistically

insignificant effect', and 'Interventions for which the statistical significance of the effect was not reported'. This categorization enabled reviewers to examine and compare which BCTs were associated with studies in these categories. Study characteristics and outcomes were tabulated according to these categories, with each category ranked by quality and then by sample size.

One-way between-groups ANOVAs with planned comparisons were conducted to compare: the frequency of BCTs coded for each category; the frequency of BCTs coded according to study quality; and finally, a comparison of study quality with each category.

Results

Seventy three studies from previous systematic reviews (Ogilvie et al., 2007; Yang et al., 2010) and 29,438 studies identified from the comprehensive database search were compiled (online supplementary material, Figure S1). Forty one studies met the inclusion criteria: 37 studies compiled from previous systematic reviews (Ogilvie et al., 2007; Yang et al., 2010), and 4 identified from the subsequent database search. Three studies evaluated two interventions and one study evaluated three interventions, which meant that 46 distinct interventions were reviewed. Twenty-one interventions were reported to have a statistically significant effect on walking and/or cycling outcomes; 12 were reported to have a statistically insignificant effect on walking and/or cycling outcomes; and studies of 13 interventions did not report the statistical significance of their effects on walking and/or cycling outcomes. Thirty (65%) interventions promoted walking only; 16 (35%) promoted both walking and cycling. Twenty six interventions (56%) assessed total walking and/or cycling; seventeen interventions (37%) assessed walking and/or cycling for transport purposes; three interventions (7%) assessed walking for recreational purposes alone (online supplementary material, Table S2, S3 and S4). Critical appraisal revealed that study quality was generally

good, with the majority of studies rated as of medium (56%) or higher (37%) quality overall (37%) (Table S5).

Characteristics of included studies

Interventions reported to have a statistically significant effect.

Sample characteristics. Of the studies which reported a statistically significant change in walking or cycling, eight (38%) were conducted in the United States, eight (38%) in Australia, two (9.5%) in Scotland, two (9.5%) in England and one (5%) in Sweden. Sample size ranged from 30 to 1694 participants. Interventions targeted a variety of populations. Seven (33%) were designed for sedentary adults; five (23%) targeted the general adult population; four (19%) targeted elderly adults; two (10%) targeted overweight adults; two (10%) targeted patients in clinical setting; one study (5%) targeted adults motivated to increase their physical activity levels. Sixteen (76%) interventions were community-based and five (24%) were delivered in the workplace.

Study and intervention design characteristics. Nineteen studies (90%) were randomized controlled trials, one (5%) was a quasi-experimental trial and one (5%) was a controlled-repeat cross-sectional study. Seven interventions (33%) involved one-to-one communication; four interventions (18%) delivered print-based materials; three (14%) were delivered via the internet; two interventions (10%) consisted of group counseling; two (10%) were delivered by telephone; one intervention (5%) used financial incentives; one (5%) provided group exercise sessions; and one (5%) involved a combination of group counseling and group exercise. Eleven interventions (52%) were reportedly based on a theoretical framework: five (24%) on the Transtheoretical Model (Prochaska & DiClemente, 1982), five (24%) on Social Cognitive Theory (Bandura, 1989) and one (4%) on a Client-Centered approach (Rogers, 1970). Intervention duration ranged from one week to three years.

Study outcomes. The evaluation of sixteen interventions (76%) relied on self-reported walking and/or cycling data while five studies (24%) collected objective data using pedometers. The reporting of intervention outcomes varied greatly. Eleven interventions (52%) were evaluated in terms of the change in weekly minutes walked, ranging from 30 to 87 min/week; five (24%) were evaluated in terms of changes in weekly step counts, ranging from 6,482 to 24,227 steps/week; two (10%) were evaluated in terms of the number of days walked each week; and one (5%) was reportedly associated with an increase of 7 miles walked per week. Of the interventions that assessed walking and cycling for transport, one was reported to be associated with an increase in walking of 64 min/week but no increase in cycling; the other with a 1.1% increase in trips made on foot or by bicycle. Studies of eight interventions (38%) reported Cohen's *d* effect sizes and confidence intervals. For those that measured total walking, effect sizes ranged from small (d = 0.14, 95% CI -0.26 to 0.53) to large (d = 0.75, 95% CI 0.29 to 1.20). A medium effect size was reported for the only study that specifically assessed walking for recreation (d = 0.35, 95% CI 0.15 to 0.54).

Interventions reported to have a statistically insignificant effect.

Sample characteristics. Of the studies of interventions found to have a statistically insignificant effect on walking or cycling outcomes, nine (75%) were conducted in the United States and three (25%) in Brazil. Sample size ranged from 15 to 1531 participants. Interventions targeted a variety of populations; three (25%) targeted patients in clinical settings; three (25%) targeted the already physically active; two (18%) targeted rural dwellers; one (8%) targeted employees recruited from three public sector organizations; one (8%) targeted members of a car share scheme; one (8%) targeted post-menopausal women; and one (8%) targeted residents of an assisted living facility. All interventions (100%) were community-based.

Study and intervention design characteristics. Nine studies (75%) were randomized controlled trials, two (17%) were quasi-experimental and one (8%) was a controlled repeat cross-sectional study. Six interventions (52%) provided group counseling; one (8%) was telephone-based; one (8%) used print-based materials; one (8%) combined group counseling with print-based materials; one (8%) combined group exercise, print-based materials, and one-to-one communication; one (8%) combined group exercise with print-based materials; one (8%) was a car share scheme. Three interventions (25%) were reportedly based on a theoretical framework; two (17%) on the Transtheoretical Model (Prochaska & DiClemente, 1982); and one (8%) on Social Cognitive Theory (Bandura, 1989). Intervention duration ranged from four weeks to two years.

Study outcomes. The evaluation of nine interventions (75%) relied on self-report data; the other three (25%) were evaluated using both pedometer and self-report data. The reporting of intervention outcomes varied greatly. All studies of interventions in this category reported a statistically insignificant change in walking and/or cycling outcomes.

Interventions for which the statistical significance of the effect was not reported.

Sample characteristics. Of the studies of interventions where statistical data was not reported, eight interventions (62%) were conducted in England, three (22%) in Australia, one (8%) in the Netherlands and one (8%) in Germany. Sample size ranged from 242 participants to 3090. Eleven interventions (84%) targeted households; one (8%) targeted city residents; and one (8%) targeted adults. All interventions were community-based.

Study and intervention design characteristics. All studies in this category were controlled repeat cross-sectional studies. Twelve interventions (92%) promoted walking and cycling through individualized marketing and one (8%) altered the physical environment, the latter being reportedly based on Choice Theory (Glasser, 1998). Intervention duration ranged from four weeks to three years.

Study outcomes. All evaluations relied on self-reported data. The reporting of intervention outcomes varied greatly. No studies of interventions in this category reported statistical tests of the significance of the reported effects.

Behavior change techniques

Table S6 of the online supplementary material specifies the BCTs coded from each study. Figure S2 of the online supplementary material displays the number of BCTs against the study appraisal rating. The vocabulary used to describe intervention techniques was found to differ greatly across studies. For example, 'provide general encouragement' was coded from one study where it was reported that "...the physician...offers enthusiastic praise..." (Calfas et al., 1996). In comparison, 'provide general encouragement' was also coded from a study where "...the intervention included the use of verbal reinforcement..." (Butler, Furber, Phongsavan, Mark, & Bauman, 2009). For the majority of studies, multiple BCTs were coded.

Interventions reported to have a statistically significant effect.

The highest number of BCTs coded for a single intervention was 12; for one intervention, no BCTs were coded. Overall, the mean number of BCTs coded per study was 6.43 (*SD* = 3.92). The two most frequently identified BCTs were 'prompt self-monitoring of behavior' and 'prompt intention formation', both coded from thirteen interventions (68%). Two other BCTs were coded from over half of interventions: 'provide instruction' and 'prompt specific goal setting'. Seven BCTs were not coded for any intervention ('provide information on others' approval'; 'model/demonstrate the behavior'; 'prompt identification as role model/position advocate'; 'prompt self-talk'; 'stress management'; 'motivational interviewing'; 'time management').

Interventions reported to have a statistically insignificant effect.

The highest number of BCTs coded for a single intervention was 12; for two interventions, no BCTs were coded. Overall, the mean number of BCTs coded per study was 4.42 (*SD* = 3.29). The most frequently identified BCT was 'provide opportunities for social comparison', coded from seven interventions (58%). Nine BCTs were not coded for any intervention study ('provide information on others' approval'; 'model/demonstrate the behavior'; 'prompt practice'; 'prompt identification as role model/position advocate'; 'prompt self-talk'; 'stress management'; 'motivational interviewing'; 'time management').

Interventions for which the statistical significance of the effect was not reported.

The majority of interventions in this category were based on the same intervention framework (individualized marketing). However, despite following a similar approach, different BCTs were coded for each of those interventions. For example, in two interventions participants were asked to pledge that they would use environmentally friendly options more regularly, resulting in the coding of 'agree behavioral contract'. This BCT was not coded from any other study that applied an individualized marketing approach. For this reason, coding was completed for each individual intervention.

The highest number of BCTs coded for a single intervention was five; for one intervention, no BCTs were coded. Overall, the mean number of BCTs coded per study was 1.69 (*SD* = 1.32). The most commonly identified BCT was 'provide general encouragement', coded from twelve interventions (92%). Seventeen BCTs were not coded for any intervention study ('prompt intention formation'; 'prompt barrier identification'; 'set graded tasks'; 'prompt specific goal setting'; 'prompt review of behavioral goals'; 'prompt self-monitoring of behavior'; 'provide feedback on performance'; 'teach to use prompts/cues'; 'prompt practice'; 'provide opportunities for social comparison'; 'plan social support/social change'; 'prompt identification as role model/position advocate'; 'prompt self-talk'; 'relapse prevention'; 'stress management'; 'motivational interviewing'; 'time management').

Further comparisons.

To compare the frequency of BCTs coded across each of the outcome categories ('Interventions reported to have a statistically significant effect', 'Interventions reported to have a statistically insignificant effect', 'Interventions for which the statistical significance of the effect was not reported'), a one-way between-groups ANOVA with planned comparisons was conducted. Analysis revealed that there was a statistically significant difference between outcome categories in the number of BCTs coded, $F(1, 41) = 8.56$, $p = .003$, $\eta^2 = 0.29$. Planned comparisons revealed that a significantly higher frequency of BCTs were coded for interventions reported to have a statistically significant effect ($M = 6.43$, $SD = 3.92$) than for interventions for which the statistical significance of the effect was not reported, ($M = 1.69$, $SD = 1.32$, $t(32) = 4.19$, $p = .001$). However, there was no significant difference between the frequency of BCTs coded for interventions reported to have a statistically significant effect ($M = 6.43$, $SD = 3.92$) and the frequency for interventions reported to have an insignificant effect, *(*$M = 4.42$, $SD = 3.29$, $t(31) = 1.50$, $p = .14$).

To assess the association between BCT coding and study quality, a one-way between-groups ANOVA with planned comparisons was conducted. Analysis revealed a statistically significant difference in the number of BCTs coded per intervention and study quality, $F(1,43) = 5.01$, $p = .03$, $\eta^2 = 0.12$. Planned comparisons revealed that a significantly greater number of BCTs were coded for studies with a 'higher' quality rating, (M = 6.18, SD = 4.41) than for those categorized as of 'medium' quality, ($M = 3.77$, $SD = 3.02$, $t(41) = 2.24$, $p = .03$). However, planned comparisons revealed that the number of BCTs coded for studies of a 'higher' quality ($M = 6.18$ $SD = 4.41$) was not statistically different from the number coded for those of a 'lower' quality rating ($M = 2.33$, $SD = 2.52$ $t(43) = 1.71$, $p = .09$).

Finally, to compare study quality by outcome category ('Interventions reported to have a statistically significant effect', 'Interventions reported to have a statistically

insignificant effect', 'Interventions for which the statistical significance of the effect was not reported'), a one-way between-groups ANOVA with planned comparisons was conducted. The ANOVA identified a statistically significant difference in study quality rating and outcome categories, $F(1, 38) = 17.41$, $p = .001$, $\eta^2 = 0.41$. Planned comparisons revealed a significantly higher quality rating for interventions reporting a statistically significant effect ($M = 5.67$, $SD = 0.77$) compared with interventions for which the statistical significance of the effect was not reported, ($M = 3.85$, $SD = 0.99$, $t(29) = 5.78$, $p = .001$). However, planned comparisons revealed no significant difference in the methodological quality of interventions which reported a statistically significant change in walking or cycling ($M = 5.67$, $SD = 0.77$) compared with interventions which reported a statistically insignificant change ($M = 4.90$, $SD = 1.29$, $t(26) = 1.99$, $p = .06$).

Discussion

Principal findings

This review aimed to identify the BCTs used by walking and cycling interventions targeted at adults using a reliable classification system. Studies which met the inclusion criteria revealed substantial heterogeneity in the vocabulary used to describe intervention content as well as differences in the number of BCTs coded per intervention. For interventions that reported statistically significant changes in walking and cycling, 'prompt self-monitoring of behavior', and 'prompt intention formation' were coded in more than half of the intervention studies. 'Prompt intention formation' was also among the most commonly coded BCTs for interventions that reported a statistically insignificant change in walking and cycling. For interventions where the statistical significance of the effect was not reported, 'provide general encouragement' was the most frequently coded BCT; however, the majority of interventions in this category were based on the same intervention approach. There was no

evidence that any particular combination of BCTs was associated with statistically significant changes in walking and cycling.

The role of behavior change techniques

Our findings support a previous application of the taxonomy for physical activity and dietary interventions in which the combination of self-monitoring with other self-regulation techniques (e.g. intention formation) was associated with greater intervention effectiveness (Michie et al., 2009). Given the evidence to suggest that the individual, social and environmental determinants of walking and cycling differ from those of physical activity in general (Krizek et al., 2009; McCormack & Sheill, 2011); the similarity in BCTs coded is perhaps surprising. However, as neither meta-analysis nor meta-regression were possible in the current review, the influence of each BCT upon walking and cycling outcomes remains unclear. Despite this, the frequent coding of 'prompt self-monitoring of behavior' and 'prompt intention formation' from studies which reported a statistically significant change in walking and cycling lends support to the inclusion of these techniques in the design of future interventions to promote walking and cycling.

Self-monitoring has shown particular promise when used in interventions that target walking as it can increase self-efficacy (Du et al., 2011) and reduce perceived barriers (Wilbur, Miller, Chandler, & McDevitt, 2003); a finding supported by this review. In contrast, 'prompt self-monitoring of behavior' was only coded from one of the sixteen interventions assessed for their effects on cycling behavior. Overall, the relatively small number of intervention studies to assess cycling limits our understanding of the relationship between such BCTs and cycling outcomes. However, given the positive association identified between self-monitoring and walking, future studies of cycling interventions should investigate the effectiveness of self-monitoring as a specific BCT. For example, walking behavior can be monitored using a pedometer, or by mobile phone application (Baker et al.,

2008; Merom et al., 2007); perhaps similar techniques (e.g. using a cycle computer or Global Positioning System (GPS) receiver in place of a pedometer) could be promoted for self-monitoring of cycling.

The BCTs coded for interventions reported to have statistically insignificant effects, and for those for which statistical significance was not reported, also merit further consideration. Interestingly, many of the interventions reported to have a statistically insignificant effect focused on ego-orientation rather than task orientation (Duda & Nicholls, 1992), as shown by the frequent coding of 'provide opportunities for social comparison'. For example, two studies encouraged individuals to attend group sessions with a significant other, thus increasing the opportunity for praise when completing a task, as opposed to mastering a task for its own sake. 'Provide general encouragement' was frequently identified from interventions for which statistical significance was not reported. Given the evidence that a pre-specified short-term goal is more likely to be achieved than a vague long-term goal (Locke & Latham, 2002), the frequent provision of general encouragement may not have had the desired effect. However, the lack of statistical reporting in studies of interventions in this category means that the effect of this BCT upon walking and cycling outcomes remain unclear.

It is unclear whether the number of BCTs incorporated into walking and cycling intervention design was positively associated with intervention outcomes. Findings reported from previous applications of the taxonomy are also inconclusive. One study identified a clear relationship between the number of coded BCTs and intervention effectiveness (Webb et al., 2010); however, another study found no relationship (Michie et al., 2009a). Notably, ten of the interventions reported to have statistically significant outcomes in this review were coded as involving eight or fewer BCTs, suggesting that simpler interventions can also be

effective. The association between the number of BCTs and intervention outcomes requires further investigation.

Many intervention studies incorporated BCTs into the design of both the experimental and control condition. This implies that when a singular BCT was coded from both conditions, it may have been insufficient to facilitate behavior change. However, when that BCT was combined with other BCTs in the experimental condition, it may have resulted in significant behavior change. Unfortunately however, due to the heterogeneity of the data, we were unable to empirically determine the contribution made by each individual technique, and in turn were unable to identify any particular combination of BCTs associated with the greatest evidence of intervention effectiveness.

The role of other intervention characteristics

While our findings add to the evidence that BCTs may contribute towards intervention effectiveness, the impact of other characteristics previously shown to influence effectiveness (such as theoretical framework, target population, etc.,) varied greatly between interventions and cannot be disregarded (Abraham & Michie, 2008). In line with the findings of a previous systematic review (Ogilvie et al., 2007), the targeting of interventions at sedentary individuals appeared to be associated with intervention effectiveness. However, a recent systematic review of intervention components identified from dietary and physical activity interventions found no association between intervention characteristics and intervention effectiveness (Greaves et al., 2011). Unfortunately, just as the quality of BCT reporting varied, the description of other intervention characteristics was also diverse and insufficient in many cases. Our understanding of the interplay between the BCTs and study design characteristics therefore remains in its early stages.

Evaluation of the taxonomy tool

Given the evidence that the correlates of walking and cycling may differ from those of other forms of physical activity, and from each other (Saelens et al., 2003), it is possible that BCTs incorporated into the design of interventions in the current review were not captured by the 26 item taxonomy designed for general physical activity and dietary interventions (Abraham and Michie, 2008). In response to the limitations of the 26 item taxonomy, more comprehensive iterations have since been developed (Michie et al., 2011a; Michie et al., 2011b). However, these newer tools were unpublished and therefore unavailable at the time this review was conducted.

Strengths and weaknesses of the review

Details of intervention content were obtained from a diverse range of interventions. However, the relatively focused inclusion criteria resulted in a limited overall sample of walking and cycling interventions. Categorizing interventions according to the statistical significance of the reported outcomes allowed reviewers to identify and compare intervention characteristics across each category. While this decision was justified for reasons of scientific rigor, additional evidence of effectiveness from a wider range of methods might have been overlooked.

Statistical analyses suggest that the methodological quality of each study may have been associated with the coding of BCTs and intervention effectiveness. Studies of a 'lower' or 'medium' quality might have utilized or reported the use of more BCTs and reported significant outcomes, had they been conducted or reported more rigorously. Studies of a 'higher' quality are more likely to reflect awareness of the importance of transparent reporting and may therefore have provided more detail on intervention content, enabling easier identification of BCTs. However, as a limited number of studies were included within this review, the potential impact of study quality requires further investigation.

The decision to include studies that reported walking and cycling outcomes was based on the fact that walking and cycling can be incorporated into activities of daily living coupled with evidence that these behaviors are distinct from many other forms of physical activity (Saelens et al., 2003). However, as previously acknowledged, the determinants of walking and cycling also differ from each other and in terms of their individual, behavioral (e.g. transport, recreation, etc.) or environmental contexts (Giles-Corti, Timperio, Bull, & Pikora, 2005). Together with the small sample size of intervention studies, this makes it difficult to disentangle which BCTs and design characteristics are most strongly associated with the optimal outcomes for behavior- and context-specific interventions.

Strengths and weaknesses of the available evidence

As observed in previous reviews of walking and cycling (Ogilvie et al., 2007; Yang et al., 2010), differences in sample characteristics, study and intervention design and study outcomes meant that neither meta-analysis nor meta-regression were possible for this review. Reported outcome data should be treated with caution as many studies relied on a small sample and self-reported data. The long-term behavioral outcomes also remain unclear, with varying follow-up periods reported.

As many studies of interventions included within this review were conducted in the United States and Australia, it is unclear whether the effects associated with them can be generalized to other populations. While some studies recruited a range of more sedentary and more active individuals, the majority of studies were conducted among sedentary middle-aged or older adults. Women were over-represented in many studies, which limits our understanding of the effects of the interventions upon men. However, almost half of the studies achieved a response rate of at least 60%, or recruited a sample that was otherwise shown to be broadly representative of the study population.

The large variation in vocabulary observed across intervention text resulted in difficulty matching content to the BCT definitions provided (Abraham & Michie, 2008). For example, in one study which evaluated an intervention for the elderly, no BCTs were coded. In this case, the intervention description referred to the role requirements of the facilitator, rather than providing information on the BCTs utilized (Kerse, Flicker, Jolley, Arroll, & Young, 1999).

Although BCT definitions were provided by the coding manual (Abraham & Michie, 2008), in some cases it was not possible to code certain BCTs because the technique was not explicitly stated in the intervention text. For example, while several interventions reported that goal setting was utilized, 'prompt specific goal setting' could not be coded because the definition required that frequency, intensity, or duration, along with context were explicitly stated in the text. If the text referred to "goal setting" alone, it had to be coded as 'prompt intention formation'. Given that many journals often impose a word limit, it is perhaps unsurprising that authors did not provide in-depth descriptions of BCTs such as goal setting, even if the technique was in fact included within the design of an intervention.

Implications for future research

This review is the first to use a reliable classification system to classify the intervention content of walking and cycling interventions into distinct behavior change techniques. The findings of the review suggest a number of implications:

1) Future studies of walking and cycling interventions should ensure that all aspects of intervention design are reported in detail, using standardized vocabulary and guidelines where possible (Abraham & Michie, 2008). More specifically, researchers are encouraged to publish details of methods or intervention development, in addition to a manuscript reporting on study outcomes. This may help to overcome the word limit restrictions imposed by many journals.

2) Further exploration of the BCTs used in walking and cycling interventions (particularly 'prompt self-monitoring of behavior' and 'prompt intention formation') would be desirable. This may help to identify the most effective individual BCTs and combinations of BCTs and thereby help guide development of future interventions.
3) Finally, the nature of associations between the incorporation and reporting of BCT content and study design characteristics remains unclear; further exploration of this interaction is therefore desirable.

Authors' Contributions

The analysis plan was conceived by EB, GB, NM and JP. Coding of intervention content was performed by EB, GB, NM and JP. EB drafted the first version of the manuscript. All authors provided critical edits and revisions to the paper and have reviewed and approved the final version of the paper.

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Table S1
Search syntax for electronic databases

Walking interventions	Cycling interventions
walk* OR stair use OR activ* commut* OR activ* travel* OR green* commut* OR green* transport* OR green* travel* OR ecological commut* OR ecological transport* OR ecological travel* OR non-motorised OR non-motorized OR physical* activ* OR exercis*	bicycl* OR bike* OR biking* OR cycle hire OR cycling OR cyclist* OR active* OR green* OR transport* OR travel*OR ecological commut* OR ecological travel* OR non-motorised OR non-motorized OR non-auto
AND	**AND**
campaign* OR encourag* OR habit* OR impact* OR increase* OR intervention* OR pattern* OR policy OR policies OR program* OR program* OR project* OR promot* OR scheme* OR shift* OR start* OR Health behaviour* OR Health education* OR Health promotion* OR Patient education	campaign* OR encourag* OR habit* OR impact* OR increase* OR intervention* OR pattern* OR policy OR policies OR program* OR program* OR project* OR promot* OR scheme* OR shift* OR start* OR Health behaviour* OR Health education* OR Health promotion* OR Patient education

Note. * = Truncation wildcard.

Table S2
Sample characteristics of studies of walking and cycling interventions

Study (a)	N (b)	Setting	Year	Age (M)	Country	Gender M / F	Population (c)	Target behavior (d)
Interventions reported to have a statistically significant effect								
Hemmingsson	120	Community	2009	48.2	Sweden	0 / 120	Overweight women	Total W/C
Butler	110	Community	2009	63.75	Australia	83 / 27	CVD patients $	Total W
Coull	319	Community	2004	67.6	USA	191 / 128	IHD patients *	Total W
Halbert (2000)	299	Community	2000	67.6	Australia	155 / 144	Sedentary adults	Total W
Mutrie	295	Workplace	2002	38	Scotland	109 / 186	Motivated adults	W/C for T
Kerse	267	Community	1999	73.55	Australia	123 / 144	Elderly adults	Total W
Calfas	255	Community	1996	39	USA	41 / 214	Sedentary adults	Total W
Prestwich*	149	Community	2010	23.44	England	54 / 95	Adults	Total W
Baker	79	Community	2008	49.2	Scotland	16 / 63	Sedentary adults	Total W
Gilson *	70	Workplace	2006	42.2	Australia	7 / 63	Adults	Total W
Napolitano	65	Workplace	2003	42.8	USA	9 / 56	Sedentary adults	Total W
Fisher	582	Community	2004	74	USA	182 / 400	Elderly adults	W for R
Merom*	369	Community	2007	49.1	Australia	284 / 170	Sedentary adults	W for R
Kriska	229	Community	1988	57.6	USA	0 / 229	Elderly women	Total W
Nies	197	Community	2003	44.4	USA	0 / 197	Sedentary women	Total W
Jarvis	85	Community	1997	66.9	USA	0 / 85	Elderly women	Total W
Pal	30	Community	2009	43	Australia	0 / 30	Overweight women	Total W
Shoup	1694	Workplace	1997	N/R	USA	N/R	Adults	W/C for T
Interventions reported to have a statistically insignificant effect								
Norris	847	Community	2000	54	USA	407 / 440	Workplace HMO employees	Total W
Pereira	229	Community	1998	70	USA	0 / 229	Post-menopausal	Total W
Halbert (2001)	69	Community	2001	69	USA	28 / 41	Sedentary with osteoarthritis	Total W
Talbot	36	Community	2003	70	USA	9 / 27	Osteoarthritis	Total W
Ferreira *	64	Community	2005	61.9	Brazil	0 / 64	Physically active	Total W
Tudor-Locke	47	Community	2004	52.7	USA	26 / 21	Overweight, sedentary with type II diabetes	Total W
Croteau	15	Community	2004	80	USA	1 / 14	Assisted living facility	Total W
Brownson (2005)	1531	Community	2005	45-64	USA	360 / 1171	Rural residents	Total W
Brownson (2004)	1232	Community	2004	45-64	USA	303 / 929	Rural residents	Total W
Cervero	298	Community	2002	30-39	USA	N/R	City CarShare members	W for T
Interventions for which the statistical significance of the effect was not reported								
Marinelli	N/R	Community	2002	N/R	Australia	N/R	Households	W/C for T
Socialdata (Perth)	2578	Community	2004	N/R	Australia	N/R	Households	W/C for T
Socialdata (Melville)	3090	Community	2001	N/R	Australia	N/R	Households	W/C for T
Sustrans (Lancashire)	2262	Community	2006	N/R	England	N/R	Households	W/C for T

Sustrans (Nottingham)	2057	Community	2004	N/R	England	N/R	Households	W/C for T
Sustrans (Sheffield)	1517	Community	2004	N/R	England	N/R	Households	W/C for T
Sustrans (Gloucester)	1367	Community	2004	N/R	England	N/R	Households	W/C for T
Sustrans (Bristol)	1360	Community	2004	N/R	England	N/R	Households	W/C for T
Sustrans (Cramlington)	1061	Community	2004	N/R	England	N/R	Households	W/C for T
Sustrans (Doncaster)	977	Community	2004	N/R	England	N/R	Households	W/C for T
Wilmink	2000	Community	1987	N/R	Netherlands	N/R	Adults	W/C for T
TAPESTRY	1299	Community	2003	N/R	Germany	N/R	City residents	W/C for T
Haq	242	Community	2004	N/R	England	115 / 127	Households	W/C for T

Note. N/R = not reported, (a) * = study incorporating two or more interventions, (b) N = at baseline, (c) $ = Cardiovascular disease, * = ischemic heart disease, (d) Total W = total walking, Total W/C = total walking and cycling, W for R = walking for recreation, W for T = walking for transport, W for R/T = walking for recreation or transport, W/C for R/T = walking or cycling for recreation or transport, W/C for T = walking or cycling for transport.

Table S3
Study and intervention design components

Study (a)	Design (b)	Theoretical framework (c)	Delivery (d)	Number / frequency (e)	Intervention duration (weeks)	Follow- up (f)	Process evaluation (g)
Interventions reported to have a statistically significant effect							
Hemmingsson	RCT	TTM	Group counseling	5 / various	52	18 months	N/A
Butler	RCT	N/A	One-to-one	4 / various	6	6 months	N/A
Coull	RCT	CC	One-to-one	12 / monthly	52	-	N/A
Halbert (2000)	RCT	SCT	Group counseling	1 / N/A	24	12 months	N/A
Mutrie	RCT	TTM	Print-based	N/A	52	12 months	N/A
Kerse	RCT	N/A	One-to-one	5 / various	8-12	-	N/A
Calfas	Q	TTM	One-to-one	1 / N/A	1	6 weeks	Long et al. and Pender et al.
Prestwich (Plan)	RCT	N/A	Telephone-based	1 / N/A	4	-	N/A
Prestwich (Goal)	RCT	N/A	Telephone-based	1 / N/A	4	-	N/A
Baker	RCT	TTM	One-to-one	12 / weekly	12	-	Fitzsimmons et al
Gilson (Routes)	RCT	N/A	Internet-based	10 / weekly	10	-	N/A
Gilson (Tasks))	RCT	N/A	Internet-based	10 / weekly	10	-	N/A
Napolitano	RCT	SCT	Internet-based	12 / weekly	12	3 months	N/A
Fisher	RCT	N/A	Group exercise	192 / 3x weekly	24	-	Fisher et al.
Merom (WPP)	RCT	SCT	Print-based	6 / weekly	6	-	N/A
Merom (WP)	RCT	SCT	Print-based	6 / weekly	6	-	N/A
Kriska	RCT	N/A	Group counseling and exercise	16 / biweekly	32	24 months	N/A
Nies	RCT	SCT	One-to-one	16 / various	24	-	N/A
Jarvis	RCT	TTM	One-to-one	12 / weekly	12	-	U/K
Pal	RCT	N/A	Print-based	12 / weekly	12	-	N/A
Shoup	CR-CS	N/A	Financial incentive	N/A	52-156	-	N/A
Interventions reported to have a statistically insignificant effect							
Norris	RCT	N/A	Group counseling	2 / monthly	4	6 months	N/A
Pereira	RCT	N/A	Telephone-based	N/R	104	10 years	Kriska et al.
Halbert (2001)	RCT	N/A	Group counseling	72 / (3 x weekly)	24	12 months	N/A
Talbot	RCT	N/A	Print-based	12 / weekly	12	6 months	N/A
Ferreira (N)	RCT	N/A	Group counseling	12 / weekly	12	-	N/A
Ferreira (N/PA)	RCT	N/A	Group counseling	12 / weekly	12	-	N/A
Ferreira (PA)	RCT	N/A	Group counseling	12 / weekly	12	-	N/A
Tudor-Locke	RCT	N/A	Group counseling / print-based	4 / weekly	6	6 months	N/A

Croteau	RCT	SCT	Group counseling	4 / weekly	4	-	N/A
Brownson (2005)	Q	TTM	Group exercise / print-based / one-to-one	6 / monthly	4	-	N/A
Brownson (2004)	Q	TTM	Group exercise / print-based	6 / monthly	4	-	N/A
Cervero	CR-CS	N/A	Car share scheme	N/A	12 - 16	-	N/A
Interventions for which the statistical significance of the effect was not reported							
Marinelli	CR-CS	N/A	'Indi-mark'	N/A	24	6 months	N/A
Socialdata (Perth)	CR-CS	N/A	'Indi-mark'	N/A	36	8 months	N/A
Socialdata (Melville)	CR-CS	N/A	'Indi-mark'	N/A	40	6 months	N/A
Sustrans (Lancashire)	CR-CS	N/A	'Indi-mark'	N/A	52	9 months	N/A
Sustrans (Nottingham)	CR-CS	N/A	'Indi-mark'	N/A	4	6 months	N/A
Sustrans (Sheffield)	CR-CS	N/A	'Indi-mark'	N/A	52	9 months	N/A
Sustrans (Gloucester)	CR-CS	N/A	'Indi-mark'	N/A	54	9 months	N/A
Sustrans (Bristol)	CR-CS	N/A	'Indi-mark'	N/A	12	9 months	N/A
Sustrans (Cramlington)	CR-CS	N/A	'Indi-mark'	N/A	36	9 months	N/A
Sustrans (Doncaster)	CR-CS	N/A	'Indi-mark'	N/A	12	6 months	N/A
Wilmink	CR-CS	CT	Infrastructure change	N/A	156	-	N/A
TAPESTRY	CR-CS	N/A	'Indi-mark'	N/A	52	12 months	N/A
Haq	CR-CS	N/A	'Indi-mark'	N/A	24	6 months	N/A

Note. (a) (WP) = walking program, (WPP) = walking with pedometer, (Routes) = walking in routes, (Tasks) = walking in tasks, (N) = nutrition, (N/PA) = nutrition and physical activity, (PA) = physical activity, (b) RCT = Randomized controlled trial, CR-CS = Controlled repeat cross-sectional, Q = Quasi-experimental, C-C = Controlled-cohort, N/A – not applicable (c) Theoretical Framework: TTM = Transtheoretical Model, SCT = Social Cognitive Theory, CC =Client-Centered Approach, CT = Choice Theory, N/A = not applicable, (d) 'Indi-mark' = individualized marketing approach, (e) number and frequency of sessions, (f) Follow-up: - = follow-up measure taken immediately following the end of the intervention, (g) Process evaluation: references for intervention studies which provided additional information on intervention methods or content, N/A = not applicable.

Table S4
Post-intervention walking and cycling outcomes

Study (a)	Measurement	Outcome (b)	Effect size (*CI*) (c)
Interventions reported to have a statistically significant effect			
Hemmingsson	Self-report	Walking target of 10,000 steps/day (NS) Cycling target of >2km/day ($p < .001$)	N/R
Butler	Pedometer	+ 87 minutes/week	0.14 (95% *CI* -0.26 to 0.53)
Coull	Self-report	+ 73 minutes/week (95% *CI* 1 to 137)	N/R
Halbert (2000)	Self-report	+ 30minutes/week ($p < .05$)	N/R
Mutrie	Self-report	+ 64 walking minutes/week ($p < .05$)~ + 0 cycling minutes/week ($p < .05$)~	N/R
Kerse	Self-report	+ 44 minutes/week (95% *CI* 8-168)	N/R
Calfas	Self-report	+ 34 minutes/week ($p < .025$)	N/R
Prestwich (Plan)	Self-report	+1.38 days W/week	0.49 (95% *CI* 0.05 to 0.94)
Prestwich (Goal)	Self-report	+1.42 days W/week	0.45 (95% *CI* 0.04 to 0.88)
Baker	Pedometer	+ 22,225 steps/week ($p < .001$)	0.75 (95% *CI* 0.29 to 1.20)
Gilson (Routes)	Pedometer	+ 6482 steps/week ($p < .002$)	N/R
Gilson (Tasks)	Pedometer	+6979 steps/week ($p < .005$)	N/R
Napolitano	Self-report	+ 62 minutes/week ($p < .05$)	0.41 (95% *CI* 0.15 to 0.97)
Fisher	Self-report	ES = 0.35 (95% *CI* 0.15 to 0.54)	0.35 (95% *CI* 0.15 to 0.54)
Merom (WPP)	Self-report	+ 66 minutes/week ($p < .001$)	N/R
Merom (WP)	Self-report	+ 64 minutes/week ($p < .001$)	N/R
Kriska	Self-report	+ 7 miles per week ($p < .05$)	0.73 (95% *CI* 0.46 to 0.99)
Nies	Self-report	+ 32 minutes/week ($p < .01$)	0.30 (95% *CI* 0 to 0.59)
Jarvis	Self-report	+ 50 minutes/week ($p < .02$)	N/R
Pal	Pedometer	+ 24,227 steps/week ($p < .04$)	N/R
Shoup	Self-report	+ 1.1% walking trips ($p < .01$) + 1.1% cycling trips (SSNR)	N/R
Interventions reported to have a statistically insignificant effect			
Norris	Self-report	+1 minutes/week (NS)	N/R
Pereira	Self-report	+7.3 miles/week (NS)	N/R

Halbert (2001)	Self-report	+0 sessions/week (NS)	N/R
Talbot	Self-report / pedometer	+687 steps/day (NS)	N/R
Ferreira (N)	Self-report	+0 change in minutes/week (NS)	N/R
Ferreira (N/PA)	Self-report	+0 change in minutes/week (NS)	N/R
Ferreira (PA)	Self-report	+0 change in minutes/week (NS)	N/R
Tudor-Locke	Self-report / pedometer	+1367 steps/day (NS)	N/R
Croteau	Self-report / pedometer	-1124 steps/week (NS)	N/R
Brownson (2005)	Self-report	+5.2 minutes/week (NS)	N/R
Brownson (2004)	Self-report	-1.4 minutes/week (NS)	N/R
Cervero	Self-report	-3.4% walking trips (NS)	N/R
Interventions for which the statistical significance of the effect was not reported			
Marinelli	Self-report	+18 trips/year (SSNR)	N/R
Socialdata (Perth)	Self-report	+3 minutes/day (SSNR)	N/R
Socialdata (Melville)	Self-report	+5 minutes/day (SSNR)	N/R
Sustrans (Lancashire)	Self-report	+1 minute/day (SSNR)	N/R
Sustrans (Nottingham)	Self-report	+2 minutes/day in one area, +3 minutes/day in another (SSNR)	N/R
Sustrans (Sheffield)	Self-report	+2 minutes/day (SSNR)	N/R
Sustrans (Gloucester)	Self-report	+25 trips/year (SSNR)	N/R
Sustrans (Bristol)	Self-report	+2 minutes/day (SSNR)	N/R
Sustrans (Cramlington)	Self-report	+1 minute/day (SSNR)	N/R
Sustrans (Doncaster)	Self-report	+0 minutes/day (SSNR)	N/R
Wilmink	Self-report	+2 trips/year (SSNR)	N/R
TAPESTRY	Self-report	+16 trips/year (SSNR)	N/R
Haq	Self-report	+0.1 km/wk (SSNR)	N/R

Note. (a) (WP) = walking program, (WPP) = walking with pedometer, (Routes) = walking in routes, (Tasks) = walking in tasks, (N) = nutrition, (N/PA) = nutrition and physical activity, (PA) = physical activity, (b) Outcome: ~ = tabulated effect size is that observed in most sedentary subgroup, not across whole study population, NS = Interventions reported to have a statistically insignificant effect, SSNR = statistical significance not reported, ES = effect size, days W/week = days walked, per week. (c) Effect size (if more than one follow-up result, effect size calculated from data reported furthest from baseline data), N/R = not reported.

Table S5
Study quality assessment

Study (a)	Pre- and post-data (b)	Comparability (c)	Randomization (d)	Response rate (e)	Attrition rate (f)	Statistics (g)	Follow-up (h)	Total
Interventions reported to have a statistically significant effect								
Hemmingsson	YES	YES	YES	YES	YES	YES	YES	7
Butler	YES	YES	YES	YES	YES	YES	YES	7
Coull	YES	YES	YES	YES	YES	YES	-	6
Halbert (2000)	YES	YES	YES	YES	YES	YES	-	6
Mutrie	YES	YES	YES	YES	-	YES	YES	6
Kerse	YES	YES	YES	YES	YES	YES	-	6
Calfas	YES	YES	-	YES	YES	YES	YES	6
Prestwich*	YES	YES	YES	YES	YES	YES	-	6
Baker	YES	YES	YES	YES	YES	YES	-	6
Gilson *	YES	YES	YES	YES	YES	YES	-	6
Napolitano	YES	YES	YES	-	YES	YES	YES	6
Fisher	YES	YES	YES	YES	-	YES	-	5
Merom*	YES	YES	YES	-	YES	YES	-	5
Kriska	YES	YES	YES	-	YES	YES	-	5
Nies	YES	YES	YES	-	YES	YES	-	5
Jarvis	YES	YES	YES	-	YES	YES	-	5
Pal	YES	YES	YES	-	YES	YES	-	5
Shoup	YES	YES	-	-	YES	YES	-	4
Interventions reported to have a statistically insignificant effect								
Norris	YES	YES	YES	-	YES	YES	YES	6
Pereira	YES	YES	YES	-	YES	YES	YES	6
Halbert (2001)	YES	YES	YES	-	YES	YES	YES	6
Talbot	YES	YES	YES	YES	YES	YES	-	6
Ferreira *	YES	YES	-	YES	YES	YES	-	5
Tudor-Locke	YES	YES	YES	-	-	YES	YES	5
Croteau	YES	YES	YES	-	YES	YES	-	5
Brownson (2005)	YES	YES	-	-	-	YES	YES	4
Brownson (2004)	YES	YES	-	-	-	YES	YES	4
Cervero	YES	-	-	-	-	YES	-	2
Interventions for which the statistical significance of the effect was not reported								
Marinelli	YES	YES	-	YES	YES	-	YES	5
Socialdata (Perth)	YES	YES	-	YES	YES	-	YES	5
Socialdata (Melville)	YES	YES	-	-	YES	-	YES	4
Sustrans (Lancashire)	YES	-	-	YES	YES	-	YES	4
Sustrans (Nottingham)	YES	-	-	YES	YES	-	YES	4
Sustrans (Sheffield)	YES	-	-	YES	YES	-	YES	4
Sustrans (Gloucester)	YES	-	-	YES	YES	-	YES	4
Sustrans (Bristol)	YES	-	-	YES	YES	-	YES	4
Sustrans (Cramlington)	YES	-	-	YES	YES	-	YES	4
Sustrans (Doncaster)	YES	-	-	YES	YES	-	YES	4
Wilmink	YES	YES	-	YES	-	-	YES	4
TAPESTRY	YES	-	-	YES	-	-	YES	3
Haq	YES	-	-	-	-	-	-	1

Note. (a) * = study incorporating two or more interventions, (b) were data collected at baseline and post-intervention?, (c) were baseline characteristics of intervention and control groups, populations, or areas comparable, or, if there were important differences in potential confounders at baseline, were these appropriately adjusted for in analysis?, (d) were participants,

groups, or areas randomly allocated to intervention and control groups?, (e) were study samples randomly recruited from study population with response rate of at least 60%, or were they otherwise shown to be representative of study population? (f) were outcomes studied in cohort or panel of respondents with attrition rate of less than 30%, or were results based on repeated cross sectional design with minimum achieved sample of at least 100 participants in each wave in both intervention and control groups?, (g) was a test of statistical significance applied specifically to the observed net change in walking and/or cycling behavior?, (h) was there a follow-up?

Table S6
BCTs coded from walking and cycling interventions

Study (a)	Study quality (b)	Behavior change technique (c)												
		Health-behavior	Consequences	Others' approval	Intention formation	Barrier identification	General encouragement	Graded tasks	Instruction	Model/demonstrate behavior	Goal setting	Review behavioral goals	Self-monitoring	Feedback
Interventions reported to have a statistically significant effect														
Hemmingsson	7	YES	-	-	YES	YES	-	-	YES	_	-	-	YES	YES
Butler	7	YES	YES	_	YES	YES	YES	-	YES	_	-	-	YES	YES
Coull	6	YES	-	_	YES	-	-	-	-	_	-	-	-	-
Halbert (2000)	6	-	YES	_	_	YES	YES	YES	YES	_	YES	YES	YES	YES
Mutrie	6	_	YES	_	_	-	YES	-	-	_	-	-	YES	-
Kerse	6	-	-	_	_	-	-	-	-	_	-	-	-	-
Calfas	6	-	YES	_	YES	YES	YES	-	-	_	YES	-	YES	YES
Prestwich (Plan)	6	-	YES	_	YES	-	YES	-	-	_	YES	-	-	-
Prestwich (Goal)	6	-	YES	_	YES	-	YES	-	-	_	YES	-	-	-
Baker	6	-	YES	_	YES	YES	YES	YES	YES	_	YES	YES	YES	YES
Gilson (Routes)	6	-	-	_	_	-	-	_	-	_	YES	-	-	-
Gilson (Tasks)	6	-	-	_	-	-	-	-	-	_	-	-	-	-
Napolitano	6	YES	YES	_	YES	YES	-	_	YES	_	-	-	YES	-
Fisher	5	YES	YES	_	-	-	-	-	YES	_	-	-	YES	-
Merom (WPP)	5	YES	-	_	YES	-	YES	YES	YES	_	YES	-	YES	-
Merom (WP)	5	YES	_	_	YES	-	YES	YES	YES	_	YES	-	YES	-
Kriska	5	-	-	_	-	YES	YES	YES	YES	_	YES	-	YES	YES
Nies	5	-	YES	_	YES	YES	YES	YES	-	_	-	YES	-	-
Jarvis	5	-	YES	_	YES	-	-	-	YES	_	_	-	YES	-
Pal	5	YES	-	_	YES	-	-	YES	-	_	YES	-	YES	YES
Shoup	4	-	-	_	-	-	-	-	-	_	-	-	-	-
Total		8	11	0	13	8	11	7	10	0	10	3	13	7
Interventions reported to have a statistically insignificant effect														
Norris	6	-	YES	-	YES	YES	YES	-	-	-	-	-	YES	-

Pereira	6	-	-	-	YES	YES	YES	YES	YES	-	YES	-	YES	YES
Halbert (2001)	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Talbot	6	-	-	-	-	-	-	YES	YES	-	YES	-	YES	YES
Ferreira (N)	6	YES	-	-	-	-	-	-	-	-	-	-	-	-
Ferreira (N/PA)	6	YES	YES	-	-	YES	-	-	-	-	-	-	-	-
Ferreira (PA)	5	-	YES	-	-	YES	-	-	-	-	-	-	-	-
Tudor-Locke	5	-	-	-	YES	YES	YES	-	-	-	-	-	-	YES
Croteau	5	-	-	-	YES	-	-	YES	-	-	YES	YES	-	-
Brownson (2005)	5	-	-	-	-	-	YES	-	-	-	-	-	-	YES
Brownson (2004)	5	-	-	-	YES	-	YES	-	-	-	-	-	-	YES
Cervero	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		2	3	0	5	5	5	3	2	0	3	1	3	5
Interventions for which the statistical significance of the effect was not reported														
Marinelli	5	YES	-	-	-	-	YES	-	-	-	-	-	-	-
Socialdata (Perth)	5	-	-	-	-	-	YES	-	-	-	-	-	-	-
Socialdata (Melville)	4	-	-	-	-	-	YES	-	-	-	-	-	-	-
Sustrans (Lancashire)	4	-	-	-	-	-	YES	-	-	-	-	-	-	-
Sustrans (Nottingham)	4	-	-	-	-	-	YES	-	-	-	-	-	-	-
Sustrans (Sheffield)	4	-	-	-	-	-	YES	-	-	-	-	-	-	-
Sustrans (Gloucester)	4	-	-	-	-	-	YES	-	-	-	-	-	-	-
Sustrans (Bristol)	4	-	-	-	-	-	YES	-	-	-	-	-	-	-
Sustrans (Cramlington)	4	-	-	-	-	-	YES	-	-	-	-	-	-	-
Sustrans (Doncaster)	4	-	-	YES	-	-	YES	-	-	-	-	-	-	-
Wilmink	4	-	-	-	-	-	-	-	-	-	-	-	-	-
TAPESTRY	3	-	-	-	-	-	YES	-	-	YES	-	-	-	-
Haq	1	YES	YES	-	-	-	YES	-	YES	-	-	-	-	-
Total		2	1	1	0	0	12	0	1	1	0	0	0	0

Table S6 (continued)

BCTs coded from walking and cycling interventions

Study (a)	Study quality (b)	Behavior change technique (c)												
		Contingent rewards	Use prompts/cues	Behavioral contract	Practice	Follow-up	Social comparison	Social support	Role model	Self-talk	Relapse prevention	Stress management	Motivational interviewing	Time management
Interventions reported to have a statistically significant effect														
Hemmingsson	7	-	YES	-	-	-	YES	YES	-	-	YES	-	-	-
Butler	7	-	-	-	-	YES	YES	-	-	-	-	-	-	-
Coull	6	-	-	-	-	-	YES	-	-	-	-	-	-	-
Halbert (2000)	6	-	-	-	-	-	YES	YES	-	-	-	-	-	-
Mutrie	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Kerse	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Calfas	6	-	-	YES	-	YES	-	YES	-	-	YES	-	-	-
Prestwich (Plan)	6	-	YES	-	-	-	-	-	-	-	-	-	-	-
Prestwich (Goal)	6	-	YES	-	-	-	-	-	-	-	-	-	-	-
Baker	6	-	YES	-	-	-	-	YES	-	-	-	-	-	-
Gilson (Routes)	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Gilson (Tasks)	6	-	YES	-	-	-	-	-	-	-	-	-	-	-
Napolitano	6	-	-	-	-	-	-	YES	-	-	YES	-	-	-
Fisher	5	-	-	-	YES	-	YES	-	-	-	-	-	-	-
Merom (WPP)	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Merom (WP)	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Kriska	5	YES	-	-	-	YES	YES	YES	-	-	-	-	-	-
Nies	5	YES	-	-	-	-	-	YES	-	-	YES	-	-	-
Jarvis	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Pal	5	-	YES	-	-	-	-	-	-	-	-	-	-	-
Shoup	4	YES	-	-	-	-	-	-	-	-	-	-	-	-
Total		3	6	1	1	3	6	7	0	0	4	0	0	0
Interventions reported to have a statistically insignificant effect														

Norris	6	-	-	YES	-	-	-	YES	-	-	-	-	-	-
Pereira	6	YES	-	-	-	YES	YES	YES	-	-	-	-	-	-
Halbert (2001)	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Talbot	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Ferreira (N)	6	-	-	-	-	-	YES	-	-	-	-	-	-	-
Ferreira (N/PA)	6	-	-	-	-	-	YES	-	-	-	-	-	-	-
Ferreira (PA)	5	-	-	-	-	-	YES	-	-	-	-	-	-	-
Tudor-Locke	5	-	-	-	-	-	YES	YES	-	-	-	-	-	-
Croteau	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Brownson (2005)	5	-	-	-	-	-	YES	YES	-	-	-	-	-	-
Brownson (2004)	5	-	-	-	-	-	YES	YES	-	-	-	-	-	-
Cervero	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		1	0	1	0	1	7	5	0	0	0	0	0	0
Interventions for which the statistical significance of the effect was not reported														
Marinelli	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Socialdata (Perth)	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Socialdata (Melville)	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustrans (Lancashire)	4	-	YES	-	YES	-	-	-	-	-	-	-	-	-
Sustrans (Nottingham)	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustrans (Sheffield)	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustrans (Gloucester)	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustrans (Bristol)	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustrans (Cramlington)	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustrans (Doncaster)	4	-	-	-	YES	-	-	-	-	-	-	-	-	-
Wilmink	4	-	-	-	-	-	-	-	-	-	-	-	-	-
TAPESTRY	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Haq	1	-	-	-	-	-	YES	-	-	-	-	-	-	-
Total		0	1	0	2	0	1	0	0	0	0	0	0	0

Note. (a) (WP) = walking program, (WPP) = walking with pedometer, (Routes) = walking in routes, (Tasks) = walking in tasks, (N) = nutrition, (N/PA) = nutrition and physical activity, (PA) = physical activity, (b) Study quality = studies scoring 6-7 were deemed 'higher' quality, 4-5 as 'medium', and 0-3 as 'lower' quality, (c) 1 = Provide information on the health-behavior 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 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/posit

Figure S1
Systematic review flowchart