

Behavior Change Techniques Used to Promote Walking and Cycling: A Systematic Review

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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) used. Adopting a taxonomy of BCTs, this systematic review addressed two questions: (a) What are the behavior change techniques used in walking and cycling interventions targeted at adults? (b) What characterizes interventions that appear to be associated with changes in walking and cycling in adults? **Method:** 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 46 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. **Conclusion:** 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

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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 adults in the United Kingdom meet current physical activity guidelines (Department of Health, Physical Activity, Health Improvement and Protection, 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 U.K. adults fell by 22% (Department for Transport, 2009). It has been estimated that cycling accounts for only 2% of all trips in the U.K. (Department for Transport, 2009), a proportion much lower than that for many surrounding European countries (Ministry of Transport, Public Works & 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) as well as 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, 2009). 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 to identify the most valuable intervention techniques that should be incorporated into

future intervention design (Marcus et al., 2000; Michie, Abraham, Whittington, McAteer, & Gupta, 2009).

In an attempt to address this problem, Abraham and Michie (2008) developed a taxonomy of 26 BCTs, and assessed the interrater 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, Abraham, et al., 2009; Webb, Joseph, Yardley, & Michie, 2010), to reduce alcohol consumption, and to 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, Abraham, et al., 2009; 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 used to promote different forms of physical activity is important because they 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 on 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 supplemental materials). 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; interventions delivered at a population-level were excluded (e.g., mass-media campaigns). All published randomized and nonrandomized studies on 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 after 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 about context (i.e., author, country of origin, and year of publication), sample characteristics (i.e., sample size at baseline, age and sex of participants, and group characteristics), methods (i.e., study design, process evaluation information, outcome measurement tool[s] applied, and length of follow-up period), and results (i.e., net changes in walking and cycling, and statistical significance) were extracted (see online supplemental materials, Tables S2–S4). The reviewer (ELB) 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 (ELB and GB). The kappa and percentage disagreement were computed separately for each intervention and then averaged. The mean kappa value for interrater 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. They 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 to by several authors (ELB, GB, NM, and JP).

Study Quality

Studies were critically appraised according to a 7-item appraisal tool adapted from previous reviews (Ogilvie et al., 2007; Yang et al., 2010) (see online supplemental materials, 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

Because 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 semiquantitative method (online supplemental materials, Tables S2–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 have enabled 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: (a) interventions reported to have a statistically significant effect, (b) interventions reported to have a statistically insignificant effect, and (c) 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 analyses of variance (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 supplemental materials, 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 four 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; 17 interventions (37%) assessed walking and/or cycling for transport purposes; three interventions (7%) assessed walking for recreational purposes alone (see online supplemental materials, Table S2–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 (see online supplemental materials, Table S5).

Interventions Reported to Have a Statistically Significant Effect

Sample characteristics. Of the studies that 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 30–1,694 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 & Di Clemente, 1982), five (24%) on social cognitive theory (Bandura, 1989), and one (4%) on a client-centered approach (Rogers, 1970). Intervention duration ranged from 1 week to 3 years.

Study outcomes. The evaluation of 16 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 30–87 min/week; five (24%) were evaluated in terms of changes in weekly step counts, ranging from 6,482–24,227 steps/week; two (10%) were evaluated in terms of the number of days walked each week; and one (5%) was report-

edly 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 was associated with a 1.1% increase in trips made on foot or by bicycle per year. Studies of eight interventions (38%) reported Cohen's *d* effect sizes and confidence intervals (CIs). For those that measured total walking, effect sizes ranged from small, $d = 0.14$, 95% CI [–0.26, 0.53], to large, $d = 0.75$, 95% CI [0.29, 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, 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 15–1,531 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 postmenopausal 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; and one (8%) was a car share scheme. Three interventions (25%) were reportedly based on a theoretical framework: two (17%) on the transtheoretical model (Prochaska & Di Clemente, 1982), and one (8%) on social cognitive theory (Bandura, 1989). Intervention duration ranged from 4 weeks to 2 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 for which 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 242–3,090 participants. 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 4 weeks to 3 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 supplemental materials specifies the BCTs coded from each study. Figure S2 of the online supplemental materials 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). By comparison, “provide general encouragement” was also coded from a study in which “. . . 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 13 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 (i.e., “provide information on others’ approval”; “model/demonstrate the behavior”; “prompt identification as role model/position advocate”; “prompt self-talk”; “stress management”; “motivational interviewing”; and “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 (i.e., “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”; and “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). How-

ever, 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 12 interventions (92%). Seventeen BCTs were not coded for any intervention study (i.e., “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”; and “time management”).

Further Comparisons

To compare the frequency of BCTs coded across each of the outcome categories (i.e., “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”), 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 ($M = 6.18, SD = 4.41$) did not differ statistically 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 (i.e., “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”), 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 that reported a statistically significant change in walking or cycling ($M = 5.67, SD = 0.77$) compared with interventions that 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 that 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 that did not report the statistical significance of the effect, “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, Abraham, 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 (Krzek et al., 2009; McCormack & Sheill, 2011), the similarity in BCTs coded is perhaps surprising. However, because neither meta-analysis nor meta-regression were possible in the current review, the influence of each BCT on walking and cycling outcomes remains unclear. Despite this, the frequent coding of “prompt self-monitoring of behavior” and “prompt intention formation” from studies that 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 because 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 16 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 a mobile phone application (Baker et al., 2008; Merom et al., 2007); perhaps similar techniques (e.g., using a cycle computer or global positioning system 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 prespecified 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 on walking and cycling outcomes remain uncertain.

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 have also been 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, Abraham, et al., 2009). Notably, 10 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 the 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

Although our findings add to the evidence that BCTs may contribute to 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 & Michie, 2008). In response to the limitations of the 26-item taxonomy, more comprehensive iterations have since been developed (Michie, Abraham, et al., 2011; Michie, Ashford, et al., 2011). However, these newer tools were unpublished, and therefore were 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. Although 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 used 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, because 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 evi-

dence 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) 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 because 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.

Because many studies of interventions included in 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. Although 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 overrepresented in many studies, which limits our understanding of the effects of the interventions on 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 that 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 used (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, although several interventions reported that goal setting was used, “prompt specific goal setting” could not be coded because the definition required that frequency, intensity, or duration, along with context be explicitly stated in the text. If the text referred to “goal setting” alone, it had to be coded as “prompt intention formation.” Because many journals 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 when possible (Abraham & Michie, 2008). More specifically, researchers are encouraged to publish the details of methods or intervention development, in addition to an article 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.

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