doi: 10.1111/j.1467-789X.2010.00729.x

Obesity Prevention

The effect of theory-based interventions on physical activity participation among overweight/obese individuals: a systematic review

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Received 12 November 2009; revised 21 December 2009; accepted 7 January 2010

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Summary

Little attention has been paid to the evaluation of the long-term impact of theory-based interventions on physical activity participation among overweight/obese individuals after the interventions have ended. The primary aim of this systematic review was to investigate the long-term effectiveness of theory-based interventions increasing physical activity and identify the most effective techniques for behaviour change among overweight/obese individuals. The secondary aim was to investigate the effect of these interventions on theoretical variables. Eighteen studies were reviewed. Among these studies, three reported significant short-term and two long-term effects of interventions on physical activity participation. Most of the studies observed a significant short- or long-term effect of time on this behaviour. Theoretical frameworks most often applied included the Behavioural Model and the Social Learning/Cognitive Theory. However, few of the studies reported any impact on theoretical variables. The most prevalent techniques consisted of providing opportunities for social comparison and instruction as well as self-monitoring. Leading techniques differentiating the experimental group from the control group included prompting practice and intentions formation and barriers identification. Although the combination of these three techniques appears successful, the long-term impact of theory-based interventions remains ambiguous.

Keywords: Obesity, physical activity, systematic review, theory-based intervention.

obesity reviews (2011) **12**, 430–439

Introduction

Both obesity and physical inactivity contribute to the development of several chronic diseases and generate important healthcare costs (1). Consequently, lifestyle interventions for weight loss and maintenance are an important public health priority (2,3). In recent decades, significant efforts have been invested in the development of more effective behavioural approaches to the treatment of obesity. As such, some systematic reviews and meta-analyses have been published about the efficacy of interventions on weight loss (4,5). However, scant attention has been paid to the evaluation of the long-term effect of such interventions on physical activity after the interruption of contact with participants (6,7). This observation is quite surprising, given that exercise represents one of the major components of behavioural treatment of obesity (8). In a systematic review of this topic, mixed results about changes in physical activity have been reported (9). Moreover, although individually adapted programmes or behaviour

modification is effective in increasing physical activity on the short term (10,11), the long-term effect of such programmes is less conclusive (12).

The development of more effective interventions would benefit from health behaviour theory research and, more importantly, from the identification of the psychological processes whereby these interventions have an impact on behaviour (i.e. the 'active ingredients') (7,12–16). In the literature, little attention has been paid to the identification of the 'active ingredients' of theory-based interventions on physical activity among overweight/obese adults using validated taxonomy (9). Thus, the primary aim of this systematic review was to investigate the long-term effectiveness of theory-based interventions to increase physical activity participation among overweight/obese adults and identify potential intervention components that might prove most effective. A secondary aim involved investigating the effect of these interventions on modifying key theoretical variables (i.e. mediators).

Methods

Literature search

A literature search and data extraction were performed between April and October 2008. We searched for studies published in English in psycINFO, MEDLINE, EMBASE, CIHNAL, Sport Discuss, Cochrane library (Cochrane Central Trials Register) and PROQUEST dissertations & theses. The search strategy in MEDLINE involved (type of behavior) AND (targeted population) AND (intervention) AND adult (Table A1). The reference lists of all relevant articles were checked manually and additional searches were performed for articles published by important authors in the field of obesity treatment (e.g. Wing, Perri, Jeffery, etc.).

Inclusion and exclusion criteria

The mean age and body mass index was established as being between 18 and 64 years of age and 25.0 and 39.9 kg m^{-2}, respectively. Because the definition of obesity has changed over time, the last criterion was adjusted for studies that classified body weight according to other criteria such as the criterion developed by the Metropolitan Life Insurance Company (17).

Studies that included participants with known mental disorders, physical diseases or targeted specific populations were excluded. However, studies that targeted overweight/obese adults with diabetes, glucose intolerance, impaired glucose tolerance, insulin resistance, hyperinsulinaemia, hypercholesterolaemia and hypertension were included.

Interventions based on one or several psychosocial theories were considered. Because most of these theories were developed in the late 1970s and thereafter, only studies published after 1980 were included. Interventions that used weight loss pharmacotherapy, herbal/natural products, very-low-calorie diets, meal replacement or food provision were excluded. Studies reporting the effect of structured physical activity programmes or diets were also excluded. Finally, studies that were included had to report results based on an objective (e.g. accelerometers and pedometers) or subjective (self-reported questionnaires) measure of participation in physical activity or an indicator of participation (i.e. physical fitness), at baseline, post-intervention and at follow-up.

Randomized control trials as well as quasi-experimental designs were included in the review, with the exception of studies adopting a one-group pre–post design. The follow-up period was defined as no contact with participants for at least 3 weeks. All studies that maintained some form of contact, even at low intensity (or frequency) during a maintenance phase, were not considered concurrent with our follow-up definition and were excluded if no additional follow-up was reported.

Data abstraction

Data were independently abstracted by two reviewers and disagreements were resolved by consensus with a third reviewer. Where necessary, attempts were made to contact authors by email for information on key missing data elements.

Before analysing the data set, a number of decisions were taken. First, several studies reported both on physical activity behaviour and physical fitness levels. Because this study concerns observable behaviours, results for physical activity instead of fitness were reported when information for these two outcomes was available. In an attempt to standardize outcome measures to the recommended amount of physical activity (i.e. 150 min/week of moderate physical activity) (18), only results on frequency or duration were abstracted when several physical activity outcomes were reported in the same study. Second, the attrition rate at follow-up was calculated only when the exact number of participants was clearly reported. Third, the analysis of behaviour change techniques was based on a taxonomy developed by Abraham and Michie (19) (Table A2). This analysis, as well as the analysis of the theoretical constructs targeted and assessed, was limited to intervention components explicitly related to physical activity. For more information on technical terms and expressions used in the present systematic review, please refer to Table S1.

Results

Characteristics of the interventions

The flow diagram of the bibliographic screen is presented in Fig. 1. For the analysis, 23 studies describing 18 interven-

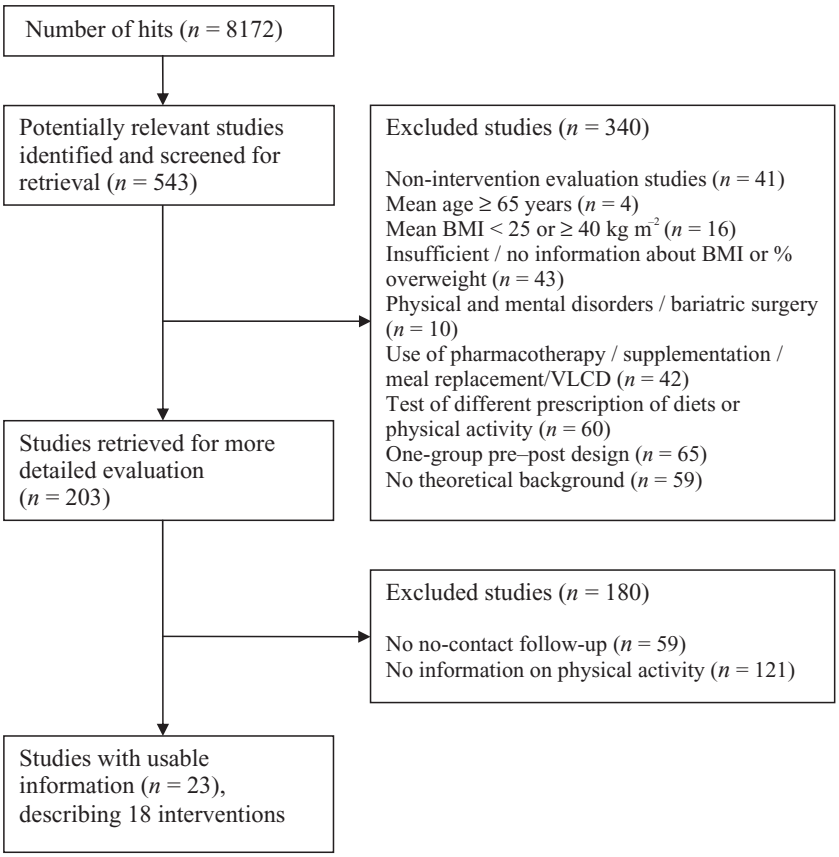

Figure 1 The flow diagram of included studies. BMI, body mass index; VLCD, very low calorie diet.

tions were included (see Table 1 for the summary of results and Tables S2 and S3 for more information on abstracted data).

All studies included were described as randomized control trials but, for 11 studies (20–30), it was impossible to determine the randomization procedure used. No quasi-experimental design met the inclusion criteria. Increasing physical activity was the primary purpose of three of the studies (22,29,31), whereas all other studies were interested primarily in weight management (i.e. weight loss and/or post-weight-reduction weight maintenance).

The duration of the studies, as well as the intensity and frequency of contacts with the participants, varied substantially across the studies. For most studies, the treatment phase lasted 3 months (20,32,33) or less (23,24,26,31,34). The longest treatment phases were 6 months (21,22,27,35) or more (28). For studies including a maintenance phase (20,25,27,36), the duration varied between 3 and 12 months. Finally, for most of the studies, the duration of the no-contact follow-up period was 6 months or more (20–23,25–28,30,33–37). Unfortunately, it was not possible to extract a clear picture of the intensity and frequency of contacts, given the variability of the studies.

Characteristics of the participants

The mean age and body mass index of the participants varied between 37.7 and 55.1 years and 29.7 and 37.9 kg m^{-2}, respectively. Participants in the studies were mostly female and highly educated Caucasian adults. African Americans were targeted in one study (34). Two studies were conducted among individuals with type 2 diabetes (29,30) and one targeted hypertensive (36) obese participants. The number of participants varied between 24 and 389 individuals at baseline, with an attrition rate at follow-up varying between 6% and 46.3%. Only three studies reported an attrition rate lower than 20% at 6- or 12-month follow-up (26,28,30).

Characteristics of physical activity behaviour

For the most part, physical activity behaviour was subjectively (20–22,24,27,28,30,31,35,36) rather than objectively assessed (23,25,26,29,32–34,37). Subjective physical activity was usually assessed by means of self-reported questionnaires (21,22,24,27,30,31,35,36). The exact validity and reliability values of the instruments used for evaluating subjective physical activity were rarely reported (22,28,35), although analysis of the cited references

Table 1 Summary table of main characteristics of studies included and results of the interventions on physical activity participation

Authors (year)	Study design	Sample characteristics	Theory used	Techniques used†	Measures of physical activity	Principal results on physical activity
Ash *et al.* (2006) (35)	RCT	*N* = 176 adults‡ 73.3% ♀ Age: 48 ± 13 years BMI: 34 ± 5.5 kg m^{-2}	[BM]	Exp: **1,18,19** Cont: –	Subjective measure: IPAQ	Post-intervention & follow-up: • No between-group or time effects
Baum *et al.* (1991) (20)	RCT*	*N* = 43 adults§ 97% ♀ Age: 39.9 years BMI: 30.6 kg m^{-2}	RPM & [BM]	Exp: 12,17,18,19,**23** Cont: 12,17,18,19	Subjective measure: N/R	Post-intervention & follow-up: • No between-group effect • Significant time effect+
Berry *et al.* (2007) (32)	RCT	*N* = 80 adults 87.5% ♀ Age: 42.3 ± 8.2 years BMI: 37.7 ± 7.0 (exp) & 37.9 ± 10.8 (cont) kg m^{-2}	SLT	Exp: **4,5,6**,8,**9**,12,**17**,19,**22,23,27** Cont: 8,12,19	Objective measure: pedometers	Significant group × time interaction Post-intervention: • No between-group effect Follow-up: • Significant between-group effect+
Burke *et al.* (2005, 2007, 2008) (36,39,54–56)	RCT	*N* = 241 hypertensive adults 55.6% ♀ Age: 55.3 & 57.1 years BMI: 30.4 ± 2.9 (exp) & 29.7 ± 2.5 (cont) kg m^{-2}	HBM, TTM, TPB, SCT & DB	Exp: 1,**2,4,5,6,8,9,11,12,13,17,18,**19,**20,23,24,26** Cont: 1,19	Subjective measure: 7-d recall	Post-intervention: • No between-group effect Follow-up: • No between-group effect • Significant time effect+
Carels *et al.* (2004) (21)	RCT*	*N* = 44 women Age: 54.7 ± 7.9 years BMI: 36.4 ± 5.5 kg m^{-2}	SC	Exp: 4,12,19,23,**24** Cont: 4,12,19,23	Subjective measure: Paffenbarger questionnaire	Post-intervention & follow-up: • No between-group effect • Significant time effect+
Craighead and Blum (1989) (33)	RCT	*N* = 61 women§¶ Age: N/R % overweight: 22.8 ± 8.5 (exp) & 21.4 ± 5.2 (cont)	[BM]	Exp: 1,8,12,13,**17,19** Cont: 1,8,12,13,**16**	Objective measure: Harvard step test	Post-intervention: • No between-group effect • Significant time effect+ Follow-up: • No between-group effect
Dallow and Anderson (2003) (22)	RCT*	*N* = 58 women Age: 46.7 years BMI: 36.1 kg m^{-2}	TTM & SCT	Exp: **1,2,4,5**,7,8,**9,17,19,**20,**23,24,26,27** Cont: 7,8,**12**,20	Subjective measure: 7-d recall	Post-intervention & follow-up: • Significant between-group+ or time+ (in the exp group only) effects
Decker (2007) (31)	RCT	*N* = 39 women§ Age: 36.72 ± 9.44 years BMI: 32.57 ± 4.29 kg m^{-2}	[TTM] & [SCT]	Exp: 4,6,7,8,**12**,18 Cont: 4,6,7,8,18	Subjective measure: 7-d recall	Post-intervention & follow-up: • No between-group effect
Dubbert and Wilson (1984) (37)	RCT	*N* = 62 adults†† 77.4% ♀ Age: N/R Weight: 207.7, 208.9, 190.4 & 195.0 lb	SLT	Exp: 4,5,**6,7**,8,**9**,12,13,**14,16**,19,**20** Cont: 4,5,8,12,13,19	Objective measure: Harvard step test	Post-intervention & follow-up: • Between-group (N/A) • Significant time effect+
James and May Hampton (1982) (23)	RCT*	*N* = 80 women‡‡ Age: 37.7 years Overweight: 26.5 kg	[BM]	Exp: 8,12,19,20,24 Cont: 8,12,19,20,24	Objective measure: Kash pulse recovery test	Post-intervention:§§ • Significant between-group effect+ Follow-up: • No between-group effect • Significant time effect+
Kreuter *et al.* (2000) (24)	RCT*	*N* = 198 adults 83% ♀ Age: 47 ± 12.3 years BMI: 36.6 kg m^{-2}	ELM & [SCT]	Exp: 1,**4,5**,20 Cont: 1,**8**,20	Subjective measure: 1-item	Post-intervention & follow-up: • No group × time interaction

Table 1 *Continued*

Authors (year)	Study design	Sample characteristics	Theory used	Techniques used†	Measures of physical activity	Principal results on physical activity
Leermakers *et al.* (1999) (25)	RCT*	*N* = 67 adults 80% ♀ Age: 50.8 ± 11.1 years BMI: 30.8 ± 4.5 kg m^{-2}	[RPM]	Exp: 8,12,**14,17,**19,**23** Cont: **5**,8,12,19	Objective measure: accelerometer	Post-intervention & follow-up: • No between-group or time effects
Mathieu (2005) (34)	RCT	*N* = 389 African American women Age: 45 years BMI: 30.16 kg m^{-2}	SLT	Exp: **1,8**,19,**20** Cont: 19	Objective measure: one-mile run/walk test	Post-intervention & follow-up: • No between-group effect • Significant time effect^{+}
Rapoport *et al.* (2000) (26)	RCT*	*N* = 84 women Age: 47.5 years BMI: 35.4 kg m^{-2}	BM	Exp: 1,4,6,**7,8**,12,19,**24,25** Cont: 1,4,6,12,**13**,19	Objective measure: Techumseh step test	Post-intervention & follow-up: • No group × time interaction • No between-group effect • Significant time effect^{+}
Riebe *et al.* (2003, 2005) (27,57)	RCT*	*N* = 190 adults¶¶ 78% ♀ Age: 50.2 ± 9.2 years BMI: 32.5 ± 3.8 kg m^{-2}§	TTM & RPM	Exp: 2,6,7,8,12,13,14,17,19,20,23 Cont: **1**,2,6,7,8,12,13,14, 17,19,20,23	Subjective measure: 3-item	Post-intervention & follow-up: • No between-group effect • Significant time effect^{+}
Sbrocco *et al.* (1999) (28)	RCT*	*N* = 24 women Age: 18–55 years BMI: 32.82 ± 3.20 (exp) & 32.5 ± 3.6 (cont) kg m^{-2}	DT & BM	Exp: 8,12,19 Cont: 8,12,19	Subjective measure: daily exercise logs	Post-intervention & follow-up: • No group × time interaction • No between-group or time effects
Tudor-Locke *et al.* (2004) (29)	RCT*	*N* = 60 adults with type 2 diabetes 45% ♀ Age: 52.7 ± 5.2 years BMI: 33.9 ± 5.6 kg m^{-2}	SCT	Exp: **4,5,7,12,13,15,16,17,18,19,20,23** Cont:–	Objective measure: pedometers	Post-intervention: • Significant between-group^{+} & time effects^{+} (in the exp group only) Follow-up: • No between-group effect
Wing *et al.* (1985) (30)	RCT*	*N* = 53 adults with type 2 diabetes 62.3% ♀ Age: 55.1 ± 1.0 years Weight: 96.4 ± 2.3 kg	BM	Exp: 1,**7,8,9,13,17,**19,**20** Cont: 1,19	Subjective measure: Paffenbarger questionnaire	Post-intervention & follow-up: • No between-group effect • Significant time effect^{+}

[ ]: Theory extrapolated by authors.
The direction of changes in physical activity:
+: Results favoured the experimental group (between-group effect) or the level of physical activity increased (time effect).
*The randomization procedure was not specified.
†Differencing techniques are presented in bold character.
‡For the present systematic review, only the characteristics and results of the FBI and BO groups were reported.
§Baseline characteristics of the completers.
¶For the present systematic review, only the characteristics and results of the supervised exercise and minimal contact groups were reported.
††For the present systematic review, couple groups were considered as one group, as well as the groups of individuals.
‡‡For the present systematic review, only the characteristics and results of the HD and PD groups were reported. Note that a no-contact control group was initially formed, but participants in this group received the HD condition before follow-up assessment.
§§At post-intervention, experimental groups are compared with the no-contact group. At follow-up, only the HD and PD conditions were compared given the cross-over design of the study.
¶¶Completers of the initial weight management programme only.
BM, Behavioural Model; BMI, body mass index; BO, booklet only; Cont, control group; DB, Decisional Balance; DT, decision theory; ELM, Elaboration Likelihood Model; Exp, experimental group; FBI, Fat Booters Incorporated; HBM, Health Belief Model; HD, highly directive; IPAQ, International Physical Activity Questionnaire; N/A, not applicable; N/R, not reported; PD, partially directed; RCT, randomized control trial; RPM, Relapse Prevention Model; SC, Self-Control Theory; SCT, Social Cognitive Theory; SLT, Social Learning Theory; TPB, Theory of Planned Behaviour; TTM, Transtheoretical Model.

revealed that almost all questionnaires used were adequate, except for three studies in which the instruments used were not validated (20,24,27).

Measurements of objective physical activity were obtained by means of pedometers (29,32), accelerometers (25) or physical fitness indicators (23,26,33,34,37). Three studies specified that the tool was valid or reliable (25,29,34). For physical fitness, however, there was no mention of the reliability and validity of almost all of the tests used (23,26,33,37).

Results of interventions on physical activity

One study reported results for an intention-to-treat analysis at follow-up (36). Two additional authors mentioned that they used this statistical approach (27,35), but provided no information on the management of missing data; likewise, the number of participants included in the analysis was either missing or inexact.

Overall, three studies reported significant between-group effects at post-intervention (including treatment and maintenance phases) on physical activity behaviour (22,23,29); one of these studies reported a sustained and significant between-group effect at follow-up (22). Another study reported a significant between-group effect at follow-up without significant results at post-intervention (32). Twelve of the 18 studies reported a significant effect of time at post-intervention and/or at follow-up (20–23,26,27,29,30,33,34,36,37). Given the observed variability between the studies for almost all methodological parameters, no meta-analysis of the results was performed.

Theoretical framework and psychosocial variables

The traditional Behavioural Model used in clinical psychology (i.e. behaviour therapy) and the Social Learning/Cognitive Theory were the two theories most often applied (83%). They were used alone (23,26,29,30,32–35,37) or in combination with other theories (20,22,24,28,31,36). No long-term between-group effect on physical activity was observed in any of the interventions based on the Behavioural Model (20,23,26,28,30,33,35), whereas a significant effect of time was observed in five studies (71%). On the other hand, the two studies that had reported significant between-group effects at follow-up were partially (22) or exclusively (32) based on the Social Learning/Cognitive Theory.

Others theories used included the Transtheoretical Model (22,27,31,36), Relapse Prevention Model (20,25,27), Self-Control Theory (21), Elaboration Likelihood Model (24), Decision Theory (28) and the Health Belief Model, Decisional Balance and Theory of Planned Behaviour (36). Some of these theories were used alone (21,25), but most were applied in combination with other theories. Among the four studies based on the Transtheoretical Model, only one reported a between-group difference at follow-up (22). However, this latter study was also based on the Social Learning/Cognitive Theory. As it was observed for the Behavioural Model, the majority of the studies based on the Transtheoretical Model (75%) reported a significant effect over time. None of the studies based on the Relapse Prevention Model reported significant between-group effects at follow-up, although they observed significant effects over time (66%).

Eight of the theory-based interventions clearly specified which theoretical variables were targeted to change physical activity (21,22,24,27,29,31,34,36). Among these, self-efficacy was the predominant variable targeted (22,24,27,29,31,34,36), as most of the studies were based on Social Learning/Cognitive Theory. Two studies based on this model did not explicitly target self-efficacy (32,37). In one study, self-control was targeted according to the Self-Control Theory (21). In the same way, both stages and processes of change were targeted in almost all interventions partially or exclusively based on the Transtheoretical Model (22,27,31). Any of the studies based on the Behavioural Model specified the mechanisms of behavioural change. The psychometric qualities of the constructs were reported (or retrieved in cited reference) as adequate in five studies (22,27,31,34,35), but this information was not always retrievable (21,24,31,36).

Two studies reported significant between-group effects on some theoretical variables at post-intervention (22,36). For instance, in the intervention by Burke *et al.* (36), between-group effects were reported for perceived barriers, self-efficacy (this effect was observed in post-treatment, but was not sustained after the maintenance phase) and some coping mechanisms. In the intervention by Dallow and Anderson (22), between-group effects were observed for some processes of change, but not for self-efficacy. This effect was not sustained at follow-up.

Two studies reported significant group effects on some theoretical variables at follow-up, but there was no consistency in the results obtained. In the study by Ash *et al.* (35), general self-efficacy was higher in the experimental group than in the control group, whereas no significant group effect was observed for this variable in the study by Kreuter *et al.* (24). In this latter study, some between-group effects were observed for several levels of thought, personal connection, self-assessment and intention.

Theoretical techniques used

Providing opportunities for social comparison was the technique most often used in the experimental groups (20–23,25–30,32–37). Significant effects of time were observed in 75% of the studies using this technique (20–23,26,27,29,30,33,34,36,37), and a between-group effect

at follow-up was observed in the two studies that reported significant effects of their treatment on physical activity (22,32). The other main techniques used in the experimental groups were providing instructions (22,23,25–28,30–34,36,37) and self-monitoring (20,21,23,25–29,31–33,36,37). Significant time effects were observed in six of the studies (67%) using the combination of these three techniques (23,26,27,33,36,37). Two studies reported significant short-term (23) and long-term (32) effects of the treatment. Finally, among all techniques listed by Abraham and Michie (19), providing information on others' approval, setting specific goals and identification as a role model were not used in any of the included studies.

Notwithstanding the above observations, the techniques that distinguished or characterized the experimental groups from the control groups were prompting practice (22,25,29,30,32,33,36), barrier identification (22,24,25,29,32,36) and prompting intention formation (22,24,29,32,36,37). All of the studies that reported significant between-group effects on physical activity at post-intervention (22,29) and follow-up (22,32) used a combination of these three techniques, except for the study by James and May Hampton (23).

The number of theoretical techniques used varied substantially across studies, although the interventions referred to the same theoretical background. For instance, between four and twelve techniques were used for interventions based exclusively on the Social Learning/Cognitive theory (32,34,37). Moreover, for these interventions based exclusively on the Social Learning/Cognitive Theory, there was no consistency in the techniques used that could characterize the differences between the experimental groups and the control groups. This was also observed for studies exclusively based on the Behavioural Model in which between three and nine techniques were used in the experimental groups (23,26,30,33,35).

Discussion

Findings of the present systematic review indicate that the most frequently observed pattern of results was a significant improvement in the level of physical activity over time, suggesting that all participants increased their level of physical activity regardless of the assignment group. In addition, it was observed that the long-term effectiveness of theory-based interventions to increase the level of physical activity among overweight/obese is weakly supported because very few studies observed a superior effect of their experimental conditions (22,32). Overall, the information in the literature adds little to our understanding of how interventions succeed or fail to change physical activity among this population.

These findings are somewhat surprising, given that the use of theoretical frameworks should increase the likelihood of developing more effective interventions (13–15). In a recent meta-analysis (38), strong support was provided for several behaviour change theories in the context of HIV prevention. In the present context, however, it must be acknowledged that almost all interventions were driven by problem-solving rather than theory-testing. Thus, the theoretical processes underlying behaviour change were seldom explicitly described and no mediation test was carried out in most of the studies.

This apparent lack of concern for theoretical issues limits the possibility of developing evidence-based interventions for overweight/obese individuals to increase physical activity. According to our systematic review, appropriate mediation analysis was performed only by Burke *et al.* (39). Their analysis revealed that the short-term effect of the Activity, Diet and Blood Pressure Trial (ADAPT) programme was mediated by self-efficacy. Their results compared favourably with a previous review in which self-efficacy was the most supported mediator of interventions aimed at increasing physical activity among adults (40) and could provide some empirical support for Bandura's Social Cognitive Theory.

A second finding of this systematic review was that most of the interventions failed to modify the theoretical mediators of change under experimental conditions when compared with the control group. This apparent lack of support for theories could be attributed to the failure to experimentally manipulate the theoretical constructs. Indeed, in many studies, several techniques related to the theoretical framework were used in both experimental and control conditions. For instance, self-monitoring, a technique usually associated with behavioural treatment programmes, and providing opportunities for social comparison, a fundamental technique of the Social Learning/Cognitive Theory, were used in all groups. Moreover, when looking at the techniques that can distinguish characteristics of experimental groups and control groups, no similarity was observed between studies based on the same theoretical model. This lack of coherence suggests that there are some problems with the correct operationalization of theoretical frameworks. Consequently, no clear conclusion could be drawn regarding the most effective theories or components, as well as the most effective combination of these to promote a long-term physical activity pattern among overweight/obese individuals. Notwithstanding the above conclusion, our results suggest that it could be interesting, in future studies, to investigate the effect of combining techniques such as prompting practice, barrier identification and prompting intention formation. According to Michie *et al.* (41), these latter three techniques could be used to enhance beliefs about capabilities, motivation and goals.

Interestingly, little attention has been paid to the literature on the determinants of physical activity and the important contribution of theories such as the Theory of Planned

Behaviour (42). Recently, this theory was suggested as one of the most appropriate theories to guide the development of interventions aimed at weight management (43). According to this theory, intention is the proximal determinant of behaviour. Perceived behavioural control, or perceived ease or difficulty associated with the performance of the behaviour, is also viewed as a determinant of behaviour along with intention. Meta-analyses of the predictive value of this theory have reported that both intention and perceived control are significant determinants of physical activity among adults, with intention responsible for most of the explained variance (21–27%) (44,45). Among obese adults, intention has also been identified as the most important determinant of physical activity (46).

Finally, given that these interventions were quite intensive and involved multiple assessments of participants' physiological and/or behavioural characteristics, it cannot be excluded that mere-measurement effects interfered with the effect of interventions (47). Mere-measurement refers to the reactivity of measures on participants' future behaviour; some individuals change their behaviour following examination of information obtained from measurement. In previous investigations, it was observed that the measurement of physical fitness or the completion of a psychosocial questionnaire has a significant impact on future behaviour (48–50).

A number of limitations should be noted. First, only a limited number of studies met the inclusion criteria. It would appear that most of the effort deployed by such interventions concerned the evaluation of short-term effects on weight loss. Also, most of the studies included were conducted among well-educated and healthy participants, involved a greater proportion of women and reported high attrition rates. Second, this systematic review was only descriptive, as too much variability was observed in the studies included. This limited the possibility of reporting accurate pooled effect sizes. Likewise, the small number of studies included limited the possibility of resorting to more sophisticated meta-analysis techniques. Third, it is noteworthy that the taxonomy used to identify techniques of behaviour change was probably not exhaustive. Indeed, Michie *et al.* (41) recently published another taxonomy in which more techniques are listed. It may be possible that some techniques used in the studies included were not listed in the present review. Also, given that the description of the intervention was frequently incomplete or unclear, other techniques could have been missed. However, this was a first attempt to apply this new taxonomy to a systematic review among overweight/obese individuals. Finally, most of the studies relied on subjective physical activity assessments to evaluate the impact of their interventions. Consequently, between-group effects might have been overshadowed because of the lack of power of self-report instruments to detect small effect size.

Recommendations for future studies

Based on this systematic review, a few recommendations could be made. First, more evaluation studies of long-term effect of interventions (i.e. after all the intervention contacts ceased) are needed to gain better insight into the long-term efficacy of modifying physical activity. Second, to increase the likelihood of developing more effective interventions, researchers should isolate targeted theoretical constructs and, more importantly, techniques in their experimental conditions to evaluate the specific contribution of these variables. In the same way, they should pay particular attention to carefully selecting and describing the theoretical techniques adopted to change key theoretical constructs. Presently, taxonomies developed by Abraham and Michie (19) and Michie *et al.* (41) could help researchers select the most appropriate techniques. Also, targeted theoretical variables should be assessed in order to perform mediation analysis (51). Finally, researchers should try to test the effectiveness of alternative social cognitive models having good predictive validity such as the Theory of Planned Behaviour (42) and the Self-Determination Theory (52). Likewise, strategies such as implementation intentions deserve more attention, considering their estimated large effect size in changing health-related behaviours (53).

Conflict of Interest Statement

No conflict of interest was declared.

Acknowledgement

The first author is supported by a grant from the Canadian Institute of Health Research

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Glossary of technical terms and expressions used in the systematic review.
Table S2. Characteristics of the studies included and principal results of the interventions on physical activity participation.
Table S3. Theoretical characteristics of the studies included and principal results of the intervention on theoretical variables.

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Appendix

Table A1 The search strategy

	Keywords, descriptors or operators
Type of behavior	Physical activity OR Exercise OR Diet OR Nutrition OR Behavior or behavior OR Lifestyle
Targeted population	Obesity OR Obese OR Overweight
Intervention	Intervention OR Program

Table A2 Behaviour change techniques*

Techniques included in the interventions
1. Information about behaviour–health link
2. Information on consequences
3. Information on others' approval
4. Intention formation
5. Barrier identification
6. General encouragement
7. Graded tasks
8. Instruction
9. Model/demonstration of the behaviour
10. Specific goal setting
11. Review of behavioural goals
12. Self-monitoring
13. Feedback on performance
14. Contingent rewards
15. Use prompts/cues
16. Behavioural contract
17. Practice
18. Follow-up prompts
19. Opportunities for social comparison
20. Social support/social change
21. Identification as role model
22. Self-talk
23. Relapse prevention
24. Stress management
25. Motivational interviewing
26. Time management
27. Cognitive restructuring
28. Stimulus control

Adapted from Abraham and Michie (19).
*Note that we added cognitive restructuring and stimulus control to the list, given the predominance of the Behavioural Model in the field of obesity treatment.