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What works in school-based energy balance behavior interventions and what does not? A systematic review of mediating mechanisms

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Abstract

Objective: Obesity prevention requires effective interventions targeting the so-called energy balance-related behaviors (that is, physical activity, sedentary and dietary behaviors). To improve (cost-)effectiveness of these interventions, one needs to know the working mechanisms underlying behavioral change. Mediation analyses evaluates whether an intervention works via hypothesised working mechanisms. Identifying mediators can prompt intervention developers to strengthen effective intervention components and remove/adapt ineffective components. This systematic review aims to identify psychosocial and environmental mediators of energy balance-related behaviors interventions for youth.

Method: Studies were identified by a systematic search of electronic databases (Pubmed, Embase, PsycINFO, ERIC and SPORTDiscus). Studies were included if they (1) were school-based randomised controlled or quasi-experimental studies; (2) targeted energy balance behaviors; (3) conducted among children and adolescents (4–18 years of age); (4) written in English; and (5) conducted mediation analyses.

Results: A total of 24 studies were included. We found strong evidence for self-efficacy and moderate evidence for intention as mediators of physical activity interventions. Indications were found for attitude, knowledge and habit strength to be mediators of dietary behavior interventions. The few sedentary behavior interventions reporting on mediating effects prevented us from forming strong conclusions regarding mediators of sedentary behavior interventions. The majority of interventions failed to significantly change hypothesised mediators because of ineffective intervention strategies, low power and/or use of insensitive measures.

Conclusion: Despite its importance, few studies published results of mediation analysis, and more high-quality research into relevant mediators is necessary. On the basis of the limited number of published studies, self-efficacy and intention appear to be relevant mediators for physical activity interventions. Future intervention developers are advised to provide information on the theoretical base of their intervention including the strategies applied to provide insight into which strategies are effective in changing relevant mediators. In addition, future research is advised to focus on the development, validity, reliability and sensitivity of mediator measures.

Introduction

Prevention of obesity is one of today's major public health challenges (1). Obesity prevention should start early in life, because the prevalence of obesity among youth has increased steadily over the past several decades (2,3) and childhood obesity is associated with major health risks (4,5). Overweight and obesity are the results of an enduring positive energy balance, that is, when energy intake is larger than energy expenditure. Hence, overweight and obesity prevention requires effective intervention programmes targeting behaviors that contribute to both sides of this energy balance. These so-called energy balance-related behaviors include dietary behaviors (for example, consumption of fruit and vegetables, or sugar-sweetened beverages), sedentary behaviors (for example, television (TV) viewing or computer use) and physical activity behaviors (for example, sports or active commuting to school). The importance of effective interventions that aim at improving energy balance-related behaviors to prevent overweight and obesity in youth have been highlighted in previous reviews (6-9).

Recent reviews showed that studies that focused on dietary or physical activity behavior produce a significant and clinically meaningful reduction in body mass index status of children and adolescents both in preventing obesity (10,11) as well as treating obesity (12). The effect sizes were, however, small. This might be due to not targeting potentially effective working mechanisms (that is, theoretical mediating variables) that are substantially related to the energy balance-related behaviors (13-15). By specifying what works (that is, effective intervention components) and what does not work (that is, ineffective intervention components) in energy balance-related behavior interventions, we can prompt future intervention developers to add effective intervention components and remove/ adapt ineffective intervention components. This will not only increase the effectiveness and clinical relevance of these interventions but also reduce their costs (17,18).

Mediation analyses can be used to evaluate whether an intervention works via the hypothesised working mechanisms (13,15,16). Mediating variables specify the causal sequence between an intervention and an outcome (for example, behavior; Figure 1). Different approaches have been suggested to establish mediation (see Table 1 for an overview) (19-21). Basically, a mediation analysis consists of three tests:

1. The action theory test, which refers to how the independent variable changes the mediating variable (path a in Figure 1). For example, intervention participants have significantly increased their intention to be physically active when compared with control participants.
2. The conceptual theory test, which refers to how the mediating variable influences the outcome variable controlling for the independent variable (path b in Figure 1). For example, changes in intention are significantly associated with changes in physical activity behavior independent of the intervention effect.
3. The mediated effect test: a simultaneous test of the action and conceptual theories, wherein the extent of the mediated effect on the intervention effect on energy balance behavior is evaluated.

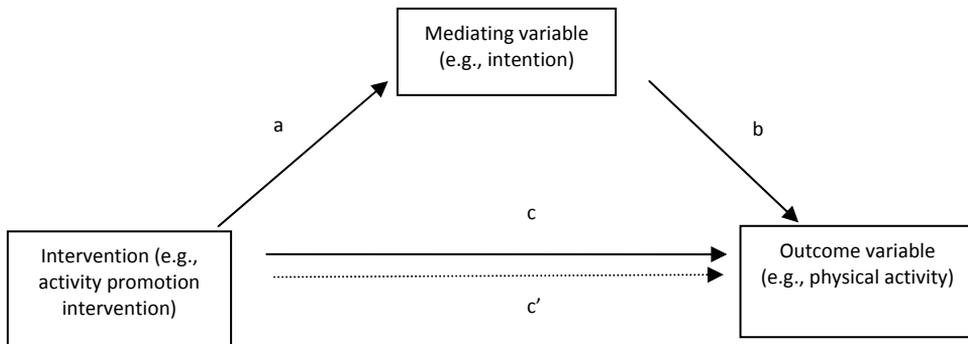


Figure 1. Conceptual mediating framework.

In a mediation analysis, a potential mediating variable is added to the model of an independent and outcome variable. As the independent variable is expected to exert its effect on the outcome variable via the mediating variable, adding the mediating variable to the model is expected to attenuate the association between the independent and outcome variable (19). Inconsistent mediated effects, also called suppressor effects, are mediated effects with a different sign than other mediated or direct effects in a model (22). This inconsistent mediator suppresses the intervention effects. In other words, the intervention would have been more successful when it had not changed the suppressor (22). One of the conditions of mediation is causality in which it is assumed that changes in the mediator precede changes in the outcome (22).

Table 1. Definitions of mediation tests and significance tests of mediation.

Approaches for mediation	Definition
Baron and Kenny approach (19)	In establishing mediation, four criteria must be met: 1) an independent variable (X) must be significantly associated with the dependent variable (Y); 2) and the potential mediator (M); 3) M must be significantly associated with Y after adjustment for X; and 4) the effect of X on Y controlling for M should no longer significant or should be significantly attenuated. Mediation is present, if each of the four steps of the Baron and Kenny approach are satisfied
Product of coefficient test (21,22)	This approach assumes that mediation depend on the extent to which the independent variable X changes the mediating variable M (a-coefficient) and the extent to which M affects the dependent variable Y (b-coefficient). The mediated effect is the product of the two coefficients (a*b).
Difference in coefficient test (64,65)	This approach assumes that the mediated effect is the reduction in the effect of the independent variable X on the outcome variable Y when adjusted for the mediator M. The value of the mediated effect could be estimated by taking the difference in the coefficients of the effect of X on Y (c) and the effect of X on Y when controlling for M (c'). This difference in coefficient (c-c') equals the product of coefficient (a*b) in ordinary least squares regressions.

MacArthur mediation framework (20)	This approach is similar to the Baron and Kenny approach but in addition assumes that there could be an interaction between X and the M variable. The MacArthur approach includes the interaction term between X and M in the model, and establishes mediation by demonstrating the presence of either a main effect of M or an interaction between X and M.
Confirmatory test of complete mediation (66)	Confirmatory test of complete versus partial mediation models and consists of testing whether the effect of X on Y when controlled for M (c' -coefficient) is statistically significant, and consists of two steps: 1). A complete or partial mediation model is hypothesized in which the c' -coefficient is specified to be zero; 2). The path relating X to M (a -coefficient) and the path relating M to Y not adjusted for X ($b_{unadjusted}$) should be statistically significant. Model fit is used as a statistical test.
(Significance) tests of mediation	Definition
Joint significant test (67)	A variation of Baron and Kenny's causal-steps test, that ignores the first step of the causal step test, and uses the significance of the path relating X to M (a -coefficient) and the path relation M to Y when controlled for X (b -coefficient) to analyze mediation. If both a - and b -coefficients are found to be significant, mediation is present.
Sobel first-order test (68)	This test is the most common product-of coefficients test and assesses the statistical significance of a mediated effect by dividing the product of coefficients ($a*b$) by its standard error and compared to a standard normal distribution to establish whether the product of the effects is significantly different from zero.
PRODCLIN (69)	Approach that tests mediation by computing the critical values using a program called PRODCLIN, to create asymmetric confidence intervals based on the distribution of the product of two variables. This approach handles with a shortcoming of the product-of-coefficient tests that relies on normal theory. However, the distribution of the product of two normally distributed random variables, in this case a and b , is rarely normally distributed
Bootstrapping (70)	Approach to statistical inference that takes a large number ($> 1,000$) of random samples (bootstrap samples) from the original data with replacement. For each bootstrap sample the a , b and ab -coefficients are estimated and the average mediated effect and 95% confidence intervals around it are computed across the bootstrap samples.

Mediation analyses can prompt future intervention developers to add effective intervention components or remove/adapt ineffective intervention components (17,18). Regarding the latter, assuming that the mediator was measured with a sensitive and valid measure, the study had enough power and the variability in the mediator was high, there are two possible explanations that a mediation effect is not observed (17). First, despite a significant effect of the intervention on the mediator, it is possible that the changes in the mediator are unrelated to the outcome (that is, a nonsignificant conceptual theory test). In this case, the mediator may be irrelevant in changing the behavior, and should not be included in future interventions. Second, it is possible that a potential mediator is related to the outcome but is not affected by the intervention (that is, a nonsignificant action theory test). In this case, intervention developers should be prompted to look for other intervention strategies targeting this potential mediator (17).

At this time, we have insufficient knowledge about which psychosocial and environmental mediating variables are important for changing particular behaviors (23). Current behavior theories still assume that similar mediating variables underlie changes in different energy balance-related behaviors. To summarise the most important psychosocial and environmental mediators of interventions aimed at dietary, sedentary or physical activity behavior, and to examine whether similar mediators underlie different energy balance-related sub-behaviors, we performed a combined systematic review. To date, two reviews of psychosocial and environmental mediators of energy balance behavior interventions in youth have been published: one review examined physical activity interventions (24) and one review examined dietary interventions (25). Each included seven intervention studies. Lubans et al. (24) found some support for the mediating role of self-efficacy and self-regulation strategies in physical activity interventions. The mediators of interventions targeting sedentary behavior were not examined. Cerin et al. (25) found support for the mediating role of outcome expectancies on dietary behavior promotion. When these reviews were conducted (18,19), few studies performed mediation analyses. Neither review, therefore, was able to draw strong conclusions regarding relevant psychosocial and environmental mediators of energy balance behavior interventions. More recently, however, the mediation analysis field has been developing rapidly, resulting in further publications on mediation analyses. Therefore, we updated both reviews and compared mediators of interventions targeting sedentary, physical activity and/or dietary behaviors, emphasising implications for future interventions and research. Hence, the aim of this systematic literature review was to identify the psychosocial and environmental mediators of interventions targeting energy balance-related behaviors in school-aged children and adolescents.

Materials and Methods

Literature Search

We systematically searched the electronic databases PubMed, EMBASE, PsycINFO, ERIC, Cochrane and Sportdiscus from January 1990 to July 2010. The search of manuscripts published in English included free text terms, in which search terms for children and adolescents (for example, child, schoolchild, adolescent and student) were used in AND-combinations with terms for energy balance-related behaviors (for example, physical activity, exercise, sport, nutrition, food and diet), with terms for mediators (for example, mediat*, indirect and 'structural equation modelling') and with terms representing intervention studies (for example, intervention, prevention, promotion, treatment). Supplementary file 2 shows the search strategy for the Pubmed database.

Inclusion criteria

Studies were included if they (1) were school-based randomised controlled trials or quasi-experimental studies; (2) targeted energy balance-related behaviors such as physical activity behaviors (for example, sports, active transport, recreational activities, playing, walking and cycling), sedentary behaviors (for example, screen viewing and sitting) or

dietary behaviors (for example, soft drink, fruit and vegetable consumption, snacking and having breakfast); (3) were conducted among children and adolescents aged between 4 and 18 years; (4) were written in English; and (5) had conducted an appropriate mediation analysis. We chose to only include school-based interventions, as they are promising, as they are able to reach almost all children and enable the combination of educational and school-environmental strategies for health behavior change (10). In addition, we chose to include studies that targeted pupils aged 4-18 years, as this is school age. A mediation analysis was considered appropriate if it conducted one of the mediation analysis tests (for example, product of coefficient test, difference in coefficient test, Baron and Kenny's causal steps of mediation, MacArthur mediation framework or confirmatory test of complete mediation) and conducted one of the significance tests of mediation (for example, Baron and Kenny's causal-step test; joint significant test, Sobel first-order test, PRODCLIN or bootstrapping). Table 1 provides the definitions of each of these different approaches and statistical tests. Only full-text articles were included. Studies that included an outcome other than energy balance-related behaviors associated with overweight prevention (for example, dental health, sports nutrition) were excluded.

Selection process

Two authors (MVS and MY) independently reviewed article titles and abstracts to identify relevant articles. They also checked the full-text articles of potentially relevant articles for the eligibility criteria; extracted data from the remaining relevant articles; and performed a quality assessment.

Data extraction and quality assessment

The top row of Supplementary file 3 shows the data extracted from the relevant articles. Mediators were categorised into four groups: psychological (for example, self-efficacy), environmental (for example, availability), behavioral (for example, habitual behavior and TV-viewing behavior) and intervention-related mediators (for example, programme evaluation).

The quality of all included studies were examined using 10 quality criteria. These 10 criteria were based on the Delphi study of Verhagen et al. (26) or were applied in the reviews of Lubans et al. (24) or Cerin et al. (25). These criteria are described in the top row of Supplementary file 4. When a study did not report a power calculation, we assessed whether the study had enough power to detect mediation by the applied mediation test, based on the criteria set by Fritz and MacKinnon (27). In case the text provided insufficient information, we contacted the authors for clarification. All 10 criteria have response options of 'yes' (=1), 'no' (=0) or 'don't know' (=0). The 'don't know' answer format was used when the author did not provide information on the specific criteria (for example, did not test selectiveness of dropout). For each study, we calculated a total quality score by summing the scores for each individual quality item and dividing by the total number of quality criteria, resulting in a possible quality score of 0–100%. We considered a study to be of high quality if the methodological score was at least 0.70, that is, 70%. A lower score was defined as low quality.

Levels of scientific evidence

To synthesise the methodological quality of the studies and to be able to draw conclusions regarding the mediators of energy balance-related behavior interventions, we applied a best evidence synthesis (28,29). This rating system consists of three levels and takes into account the number, the methodological quality and the consistency of outcomes of the studies:

- Strong evidence: consistent findings in multiple (≥ 2) high-quality studies.
- Moderate evidence: consistent findings in one high-quality study and at least one low-quality study, or consistent findings in multiple low-quality studies.
- Insufficient evidence: only one study available or inconsistent findings in multiple (≥ 2) studies.

Similar to previous reviews applying this best evidence syntheses, we considered results to be consistent when at least 75% of the studies demonstrated results in the same direction, which was defined according to significance ($p < 0.05$) (28-30). If there were two or more high-quality studies, we disregarded the studies of low methodological quality in the evidence synthesis; those studies were thus not incorporated in the conclusion.

Results

Study characteristics

Supplementary file 1 presents the flow of the studies through the selection process. From the 6860 initially identified titles, 24 studies fulfilled our inclusion criteria. Most studies were excluded because they addressed health behaviors other than dietary, physical activity or sedentary behaviors (for example, smoking or alcohol consumption) or because they focused on a different target group (for example, pre-schoolers and adults). Supplementary file 3 presents the study characteristics. The included intervention studies were conducted in eight countries (in alphabetical order: Australia, Belgium, Iran, Italy, the Netherlands, Portugal, United Kingdom and the United States of America). The sample size ranged from 1 to 55 schools and from 78 to 2840 students. The majority was conducted in secondary schools. The shortest follow-up period was three weeks (31), whereas the longest was three years (32). Two studies did not report which mediation analysis was applied (33,34). A total of 13 studies applied regression models (32,35-46), four studies reported generalised linear modeling (31,34,47,48), four studies reported using path analysis (49-52) and two studies reported using latent variable mediation modelling (that is, structural equation modelling) (53,54) to analyse mediation effects. In total, eight studies analysed multiple mediator models (39,40,43,44,49,50,53,54) of which four reported both single and multiple mediator analyses (39,40,44,50). To test the mediated effect, six studies used the Baron and Kenny causal-step test (35,36,38,41,45,47), three studies used the joint significance test (51,53,54), twelve studies applied the Sobel test (31,32,37,39,40,42,44,46,48-50,52) and one study applied the PRODCLIN test (43).

Study quality

Supplementary file 4 presents the quality assessment; 10 studies were of high quality, and most (n=20) applied randomised controlled trial designs with school level randomisation. Of the 21 studies that reported the dropout rate, half examined whether the dropout rate was selective. Most studies described social cognitive theory as the theoretical framework (32,34,36,39-44,47,48,50,51,53,54), whereas four studies were based on the theory of planned behavior (31,37,39,40). Four studies were not explicitly guided by behavioral theory (33,35,38,45). Except for four studies (31,35,38,51) all studies reported using outcome measures with known reliability or validity. Seven studies reported using mediator measures of low to moderate reliability (Cronbach's $\alpha < 0.70$) (31,39,40,43,44,50,51). Although some studies reported a power calculation, none of the studies reported a power calculation based on assessing mediation effects. Based on the criteria set by Fritz and MacKinnon, we assessed whether the studies were powered enough to detect mediation with the applied mediation test, resulting in nine underpowered studies (33-36,38,41,42,47,51). Only one study (49) had measured changes in the mediating variables before the changes in the outcome variables.

Study findings

Intervention effect on outcome: As shown in Supplementary file 3, 18 studies aimed to change physical activity (31-33,36-38,40-43,46-49,51-54) and three studies aimed to improve sedentary behavior (34,37,52). Of the eight studies that aimed to change dietary behaviors, the majority (n=6) targeted fruit and vegetable consumption (35,43-45,48,50), one targeted soft drink consumption (37), two targeted snacking/ fat intake (37,39) and one targeted total dietary behavior (51). Of these studies, four were aimed at changing both sides of the energy balance (37,43,48,51). To be able to make stronger conclusions, and as few studies targeted a dietary behavior other than fruit and vegetable consumption, we combined all dietary behavior interventions.

All published studies found significant intervention effects on at least one of the examined energy balance behaviors. Shilts et al. (51) only observed a significant intervention effect among a subgroup that had set specific change goals during the intervention.

Intervention effect on mediator (action theory test)

Physical activity behavior: The action theory test (21) examines whether the intervention changed the potential mediator. Among the physical activity intervention studies, of the 107 action theory tests reported, only 44 were significant (see Table 2, column 3). The majority of the interventions found a significant intervention effect on intention (31,36,49), self-regulation skills (36,41,43,46,54), enjoyment (47,54) and intrinsic motivation (49) in the desired direction. About half of the interventions aimed at changing self-efficacy (31-33,36,37,40-43,46-48,51,53,54), perceived benefits (40,46) and social norm (31,37,46) were successful. Physical activity interventions aimed at changing the potential mediators: attitude (31-33,36,37,40-42,53), social support (32,40-42,46,47), satisfaction (53), counterconditioning (46), stimulus control (46), social modeling (46), other physical activity-related behaviors (32,38) and habit strength (37) appeared to be

less successful. Five physical activity promotion interventions affected a mediator in the undesired direction (32,32,40,47,48). Notably, three out of five intervention studies aimed at changing barriers found an effect in the undesired direction (32,33,40,46,47) wherein intervention participants perceived more barriers as a result of the intervention.

Table 2. Results of studies examining potential mediators of intervention schemes promoting physical activity in youth.

Mediator	Quality score	Action theory	Conceptual theory	Mediated effect	Outcome
<i>Psychological</i>					
Attitude					
Araujo-Soares et al. (36)	80%	+	NR*	NR*	MVPA
Chinapaw et al. (37)	80%	NS	-	NR*	Active transport boys
	80%	NS	+	NR*	Active transport girls
Dishman et al. (53)	78%	NS	+	NS	Total PA girls
Haerens et al. (40) ¹	60%	-	+	Suppressor/ Suppressor	Total PA & PA at home and school
Haerens et al. (40) ²	60%	-	+	Suppressor/ Suppressor	Total PA & PA at home and school
Hill et al. (31)	60%	+	NR	NR	Exercise
Hortz et al. (41)	60%	NS	NR**	NS	MPA
Lubans et al. (42)	56%	NS	NS	NS	MVPA boys
	56%	NS	NS	NS	MVPA girls
Lytle et al. (32)	56%	NR	NR	NS	MVPA girls weekdays
	56%	NR	NR	NS	MVPA girls weekend
Zizzi et al. (33)	56%	NS	NR**	NR**	Daily step count
Satisfaction					
Dishman et al. (53)	78%	NS	+	NS	Total PA girls
Perceived benefits					
Health					
Haerens et al. (40) ¹	60%	-	+	Suppressor/ suppressor	PA at home and school
Haerens et al. (40) ²	60%	NS	+	NS	Total PA & PA at home and school
Psychosocial					
Haerens et al. (40) ¹	60%	NS	+	Suppressor/ suppressor	Total PA & PA at home and school
Haerens et al. (40) ²	60%	NS	+	NS	Total PA & PA at home and school
General					
Taymoori et al. (46) ¹	70%	+	+	Mediator	Total PA girls
Taymoori et al. (46) ²	70%	NS	NR**	NR**	Total PA girls
Perceived barriers					
General					
Taymoori et al. (46) ¹	70%	-	-	Mediator	Total PA girls
Taymoori et al. (46) ²	70%	NS	NR**	NR**	Total PA girls
Zizzi et al. (33)	56%	NS	NR**	NR**	Daily step count
Health					
Haerens et al. (40) ¹	60%	NS	NS	NS	Total PA & PA at home and school
Haerens et al. (40) ²	60%	NS	NS	NS	Total PA & PA at home and school

Mediator	Quality score	Action theory	Conceptual theory	Mediated effect	Outcome
Environmental/external					
Dunton et al. (47)	60%	+	NS	NS	VPA girls
Haerens et al. (40) ¹	60%	+	-	Suppressor/ suppressor	Total PA & PA at home and school
Haerens et al. (40) ²	60%	NS	-	NS	Total PA & PA at home and school
Lytle et al. (32)	56%	+	-	Suppressor	MVPA girls weekdays
	56%	+	-	Suppressor	MVPA girls weekend
Motivational/ internal					
Dunton et al. (47)	60%	+	NS	NS	VPA girls
Haerens et al. (40) ¹	60%	+	-	Suppressor/ suppressor	Total PA & PA at home and school
Haerens et al. (40) ²	60%	NS	-	NS	Total PA & PA at home and school
PBC/ Self-efficacy					
Araujo-Soares et al (36)	80%	NS	NR*	NR*	MVPA
Chinapaw et al. (37)	80%	NS	NS	NR*	Active transport boys
	80%	NS	NS	NR*	Active transport girls
Dishman et al. (53)	78%	+	+	Mediator	Total PA girls
Dishman et al. (54)	89%	+	+	Mediator	Total PA girls
Dunton et al. (47)	60%	NS	NS	NS	VPA girls
Dzewaltowski et al. (48)	70%	-	NR**	NR	VPA and MVPA
Haerens et al. (40) ¹	60%	NS	+	NS	PA at school
	60%	-	+	Suppressor/ suppressor	PA at home
Haerens et al. (40) ²	60%	+	+	Mediator/ Mediator	PA at school
	60%	NS	+	NS	PA at home
Hill et al. (31)	60%	+	NR	Mediator	Exercise
Hortz et al. (41)	60%	NS	NR**	NS	MPA
Lubans et al. (42)	56%	NS	NS	NR**	MVPA boys
	56%	+	+	NS	MVPA girls
Lubans et al. (43)	89%	NS	NS	NS	Total PA
Lytle et al. (32)	56%	-	+	Suppressor	MVPA girls weekdays
	56%	-	+	Suppressor	MVPA girls weekend
<i>Shilts et al. (51)</i>	40%	+	NR	Mediator	Total PA
Taymoori et al. (46) ¹	70%	+	+	Mediator	Total PA girls
Taymoori et al. (46) ²	70%	+	+	Mediator	Total PA girls
Zizzi et al. (33)	56%	NS	NR**	NR**	Daily step count
Proxy efficacy					
Dzewaltowski et al. (48)					
School	70%	+	NR	Mediator	VPA and MVPA
Parents	70%	NS	NR**	NR**	VPA and MVPA
Peers	70%	NS	NR**	NR**	VPA and MVPA
Counterconditioning					
Taymoori et al. (46) ¹	70%	NS	NR**	NR**	Total PA girls
Taymoori et al. (46) ²	70%	NS	NR**	NR**	Total PA girls
Intention					
Araujo-Soares et al (36)	80%	NS	NR*	NR*	MVPA
Chatzisarantis et al. (49)	89%	+	+	Mediator	Leisure time PA

Table 2 (continued)

Mediator	Quality score	Action theory	Conceptual theory	Mediated effect	Outcome
Hill et al. (31)	60%	+	NR	Mediator	Exercise
Intrinsic motivation					
Chatzisarantis et al. (49)	89%	+	+	Mediator	Leisure time PA
Enjoyment					
PE					
Dishman et al. (54)	89%	+	NS	NS	Total PA girls
PA					
Dishman et al. (54)	89%	+	+	Mediator	Total PA girls
Dunton et al. (47)	60%	NS	NS	NS	VPA girls
Self-regulation					
Araujo-Soares et al (36)					
Action planning	80%	NS	NR*	NR*	MVPA
Coping planning	80%	+	NR*	NR*	MVPA
Dishman et al. (54)	89%	+	NS	NS	Total PA girls
Hortz et al. (41)	60%	+	+	Mediator	Moderate intensity exercise
Lubans et al. (43)	89%	NS	NS	NS	Total PA
Taymoori et al. (46) ¹	70%	+	+	Mediator	Total PA girls
Taymoori et al. (46) ²	70%	+	+	Mediator	Total PA girls
Stimulus control					
Taymoori et al. (46) ¹	70%	NS	+	NS	Total PA girls
Taymoori et al. (46) ²	70%	NS	NR**	NR**	Total PA girls
<i>Social and Physical environment</i>					
Social support					
General					
Hortz et al. (41)	60%	+	+	Mediator	MPA
Taymoori et al. (46) ¹	70%	NS	NR**	NR**	Total PA girls
Taymoori et al. (46) ²	70%	NS	NR**	NR**	Total PA girls
Haerens et al. (40) ¹	60%	NS	+	NS	Total PA
Haerens et al. (40) ²	60%	NS	+	NS	Total PA
Lytle et al. (32)	56%	-	+	Suppressor	MVPA girls weekdays
	56%	-	+	Suppressor	MVPA girls weekend
Family & friends					
Lubans et al. (42)	56%	NS	NS	NS	MVPA boys
	56%	+	NS	NS	MVPA girls
Dunton et al. (47)	60%	NS	NS	NS	VPA girls
Haerens et al. (40) ¹	60%	NS	+	NS	PA at home
Haerens et al. (40) ²	60%	NS	+	NS	PA at home
Friends & teacher					
Haerens et al. (40) ¹	60%	NS	+	NS	PA at school
Haerens et al. (40) ²	60%	NS	+	NS	PA at school
Lytle et al. (32)	56%	-	+	Suppressor	MVPA girls weekdays
	56%	-	+	Suppressor	MVPA girls weekend
Parents/ family					
Haerens et al. (40) ¹	60%	NS	NS	NS	PA at school
Haerens et al. (40) ²	60%	NS	NS	NS	PA at school
Lubans et al. (43)	89%	NS	NS	NS	Total PA
Lytle et al. (32)	56%	NR***	NR***	NS	MVPA girls weekdays
	56%	NR***	NR***	NS	MVPA girls weekend

Mediator	Quality score	Action theory	Conceptual theory	Mediated effect	Outcome
Social norm					
Chinapaw et al. (37)	80%	+	NS	NR*	Active transport boys
	80%	NS	NS	NR*	Active transport girls
Hill et al. (31)	60%	+	NR***	NR***	Exercise
Taymoori et al. (46) ¹	70%	NS	NR**	NR**	Total PA girls
Taymoori et al. (46) ²	70%	NS	NR**	NR**	Total PA girls
Social modeling					
Taymoori et al. (46) ¹	70%	NS	NR**	NR**	Total PA girls
Taymoori et al. (46) ²	70%	NS	+	NS	Total PA girls
Autonomy support					
Chatzisarantis et al. (49)	89%	+	+	Mediator	Leisure time PA
Access to facilities					
Lytle et al. (32)	56%	NR***	NR***	NS	MVPA girls weekdays
	56%	NR***	NR***	NS	MVPA girls weekend
<i>Behavioral</i>					
Participation in out-of-school PA programs					
Lytle et al. (32)	56%	NR***	NR***	NS	MVPA girls weekdays
	56%	NR***	NR***	NS	MVPA girls weekend
Participation in sports programs					
Lytle et al. (32)	56%	NR***	NR***	NS	MVPA girls weekdays
	56%	NR***	NR***	NS	MVPA girls weekend
TV-viewing					
Graham et al. (38)	20%	NS	NS	NS	VPA girls
Habit					
Chinapaw et al. (37)	80%	NS	NS	NR*	Active transport boys
	80%	NS	NS	NR*	Active transport girls

MPA: Moderate intensity Physical Activity; MVPA: Moderate and Vigorous Physical Activity; NS: not significant; NR*: not reported because intervention effect on outcome was not significant; NR**: not reported because intervention effect on mediator was not significant or in opposite direction; NR***: not reported because no significant mediated effect was found; PA: Physical activity; VPA: Vigorous Physical Activity.
Haerens¹: Intervention without parental support; Haerens²: Intervention with parental support; Taymoori¹: Intervention based on health promotion model and transtheoretical model; Taymoori²: intervention based on health promotion model.

Sedentary behavior: As shown in Table 3 (column 3), of the 10 action theory tests reported, only one was significant. In this TV-viewing intervention, the authors found a significant effect on intrinsic motivation (52). No significant intervention effects were found on attitude (37,52), self-efficacy (37), social norm (37) or habit behavior (37).

Dietary behavior: As shown in Table 4 (column 3), 15 of the 51 possible intervention effects on potential mediators were significant; 3 of these were in the unexpected direction (that is, perceived barriers (39); self-efficacy (48); and social norm (44)). The majority of the interventions were effective in changing knowledge (35,44,50) and attitude (37,39,44). We found some studies showing intervention effects on habit behavior (37), parental consumption (44,50) and social norm (37,44,48). All included studies that aimed at changing perceived benefits (39), perceived barriers (39), self-efficacy (37,39,43,44,48), proxy efficacy (48), social support (39), and availability (43,44,50) were unsuccessful.

Table 3. Results of studies examining potential mediators of intervention schemes changing sedentary behavior in youth.

Mediator	Quality score	Action theory	Conceptual theory	Mediated effect	Outcome
<i>Psychological</i>					
Attitude					
Chinapaw et al. (37)	80%	NS	NS	NR*	Screen viewing boys
	80%	NS	-	NR*	Screen viewing girls
Spruijt- Metz et al. (52)	78%	NS	NR**	NR**	TV viewing girls
PBC/ Self-efficacy					
Chinapaw et al. (37)	80%	NS	-	NR*	Screen viewing boys
	80%	NS	-	NR*	Screen viewing girls
Intrinsic motivation					
Spruijt- Metz et al. (52)	78%	+	-	NS	TV viewing girls
<i>Social and Physical environment</i>					
Social norm					
Chinapaw et al. (37)	80%	NS	NS	NR*	Screen viewing boys
	80%	NS	+	NR*	Screen viewing girls
<i>Behavioral</i>					
Habit					
Chinapaw et al. (37)	80%	NS	+	NR*	Screen viewing boys
	80%	NS	+	NR*	Screen viewing girls
<i>Intervention related</i>					
Parents read newsletter					
Robinson et al (34)	67%	NR***	NR***	NS	Screen viewing elementary school children
TV allowance was used					
Robinson et al (34)	67%	NR***	NR***	NS	Screen viewing elementary school children
TV allowance requested					
Robinson et al (34)	67%	NR***	NR***	NS	Screen viewing elementary school children
Number of incentives					
Robinson et al (34)	67%	NR***	NR***	NS	Screen viewing elementary school children

NS: not significant; NR*: not reported because intervention effect on outcome was not significant; NR**: not reported because intervention effect on mediator was not significant or in opposite direction; NR***: not reported because no significant mediated effect was found;

Effect of mediator on behavior (conceptual theory test)

Physical activity behavior: In the conceptual theory test (21), the relationship between changes in the potential mediator and changes in the outcome variable is examined. Convincing support was found for the relationship between attitude (37,40,42,53), perceived benefits (40,46), perceived barriers (32,40,46,47), self-efficacy (32,37,40,42,43,46,53,54), self-regulation skills (41,43,46,54), and social support (40-43,46,47) and physical activity behavior (see Table 2, column 4). Some support was found for the association between satisfaction (53), intention (49), intrinsic motivation (49),

stimulus control (46), social modelling (46), autonomy support (49), habit strength (37) and physical activity. No evidence was found for a relationship between enjoyment (47,54) social norm (37) or changing TV-viewing behavior (38) and physical activity behavior.

Table 4. Results of studies examining potential mediators of intervention schemes promoting healthy diet in youth.

Mediator	Quality score	Action theory	Conceptual theory	Mediated effect	Outcome
<i>Psychological</i>					
Knowledge					
Amaro et al. (35)	33%	+	NS	NS	Vegetable intake
Reynolds et al. (44) ¹	50%	+	NS/NS	NS/NS	FV intake elementary school children
Reynolds et al. (44) ²	50%	+	+/NS	NS/NS	FV intake elementary school children
Reynolds et al. (50) ¹	89%	+	+ (+)	Mediator/ Mediator	FV intake elementary school children
Reynolds et al. (50) ²	89%	+	NS/NS	NS/ NS	FV intake elementary school children
Attitude					
Chinapaw et al. (37)	80%	+	-	Mediator	Soft drink boys
	80%	NS	-	NS	Soft drink girls
	80%	NS	-	NR*	Snack boys
	80%	NS	-	NR*	Snack girls
Haerens et al. (39)	60%	NS	-/-	NS/NS	Fat intake girls
Reynolds et al. (44) ¹	50%	+	+/NS	Mediator/NS	FV intake elementary school children
Reynolds et al. (44) ²	50%	+	NS/NS	NS/NS	FV intake elementary school children
Perceived benefits					
Haerens et al. (39)	60%	NS	NS/NS	NS/NS	Fat intake girls
Perceived barriers					
Haerens et al. (39)	60%	+	NS/NS	Suppressor/NS	Fat intake girls
PBC/ Self-efficacy					
Chinapaw et al. (37)	80%	NS	-	NS	Soft drink boys
	80%	NS	-	NS	Soft drink girls
	80%	NS	-	NR*	Snack boys
	80%	NS	-	NR*	Snack girls
Dzewaltowski et al. (48)	70%	-	NR*	NS	FV intake
Haerens et al. (39)	60%	NS	NS	NS	Fat intake girls
Lubans et al. (43)	89%	NS	NS	NS	FV intake
Reynolds et al. (44) ¹	50%	NS	+/+	NS/NS	FV intake elementary school children
Reynolds et al. (44) ²	50%	NS	NS/NS	NS/NS	FV intake elementary school children
Shilts et al. (51)	40%	NS	NR	NS	Dietary behavior
Proxy efficacy					
School					
Dzewaltowski et al. (48)	70%	NS	NR*	NS	FV intake
Parents					
Dzewaltowski et al. (48)	70%	NS	NR*	NS	FV intake

table 4 (continued)

Mediator	Quality score	Action theory	Conceptual theory	Mediated effect	Outcome
<i>Social and Physical environment</i>					
Social support					
Haerens et al. (39)	60%	NS	NS/NS	NS/NS	Fat intake girls
Social norm					
Chinapaw et al. (37)	80%	NS	NS	NS	Soft drink boys
	80%	NS	NS	NS	Soft drink girls
	80%	+	NS	NR*	Snack boys
	80%	NS	NS	NR*	Snack girls
Dzewaltowski et al. (48)	70%	+	NR*	NS	FV intake
Reynolds et al. (44) ¹	50%	NS	NS/NS	NS/NS family	FV intake elementary school children
	50%	NS	NS	NS/NS peers	FV intake elementary school children
	50%	+	NS/NS	NS/NS teacher	FV intake elementary school children
Reynolds et al. (44) ²	50%	-	NS/NS	NS/NS family	FV intake elementary school children
	50%	NS	NS/NS	NS/NS peers	FV intake elementary school children
	50%	NS	NS/NS	NS/NS teacher	FV intake elementary school children
Eating together					
Reynolds et al. (44) ¹	50%	NS	NS/NS	NS/NS	FV intake elementary school children
Reynolds et al. (44) ²	50%	NS	NS/NS	NS/NS	FV intake elementary school children
Parent consumption					
Reynolds et al. (44) ¹	50%	NS	NS/NS	NS/NS	FV intake elementary school children
Reynolds et al. (44) ²	50%	+	+/+	NS/NS	FV intake elementary school children
Reynolds et al. (50) ¹	89%	NS	NS/NS	NS/NS	FV intake elementary school children
Reynolds et al. (50) ²	89%	NS	NS/NS	NS/NS	FV intake elementary school children
Availability					
Lubans et al. (43)	89%	NS	+	NS	FV intake
Reynolds et al. (44) ¹	50%	NS	NS/NS	NS/NS	FV intake elementary school children
Reynolds et al. (44) ²	50%	NS	NS/NS	NS/NS	FV intake elementary school children
Reynolds et al. (50) ¹	89%	NS	NS/NS	NS/NS	FV intake elementary school children
Reynolds et al. (50) ²	89%	NS	NS/NS	NS/NS	FV intake elementary school children
<i>Behavioral</i>					
Habit					
Chinapaw et al. (37)	80%	-	+	Mediator	Soft drink boys

Mediator	Quality score	Action theory	Conceptual theory	Mediated effect	Outcome
<i>Intervention related</i>	80%	NS	+	NS	Soft drink girls
	80%	NS	+	NR*	Snack boys
	80%	NS	+	NR*	Snack girls
Appreciation program					
Tak et al. (45)	30%	+	+	Mediator	Fruit intake elementary school children

FV intake= Fruit and Vegetable intake ; NS: not significant; NR*: not reported because intervention effect on outcome was not significant; NR**: not reported because intervention effect on mediator was not significant; when both the single- and multiple mediation analyses were presented, results of multiple mediation are behind the “/”. Reynolds, 2002¹ analysis on change from baseline to one year post-baseline; Reynolds, 2002² analysis on change from baseline to two year post-baseline;

Sedentary behavior: As shown in Table 3 (column 4), indications for relationships between attitude (37), self-efficacy (37), intrinsic motivation (52), social norm (37), habit strength (37) and sedentary behavior were found. The association between social norm and sedentary behavior was in the unexpected direction. Additionally, the relationships between attitude, social norm and screen-viewing behavior were identified only among girls.

Dietary behaviors: As shown in Table 4 (column 4), convincing evidence was found for the association between attitudes (37,39,44) and habit strength (37) and dietary behavior. Some evidence was found for an association between dietary behavior and knowledge (35,44,50) and self-efficacy (37,39,43,44) as about half of the studies found a significant effect. No or insufficient evidence was found for an association between perceived benefits (39), perceived barriers (39), proxy efficacy (48), social support (39), social norm (37,44), parent consumption (44,50), eating together (44), availability (43,44,50) and dietary behavior.

Mediated effects

Physical activity behavior: Among the intervention studies aimed at changing physical activity behavior, strong evidence was found for a mediating effect of self-efficacy, and moderate evidence was found for a mediating effect of intention (see table 2, column 5). Among the five high-quality studies that reported the mediated effect of self-efficacy, four found that changes in self-efficacy induced by the interventions were associated with significant increases in physical activity behavior (43,46,53,54). Both intervention studies that reported on the mediated effect of intention (31,49) found intention to be an important mediator of the effect of the intervention on physical activity behavior.

Indications for a mediated effect of self-regulation (41,43,46,54), intrinsic motivation (49), enjoyment (47,54), perceived benefits (40,46), proxy efficacy (48) and autonomy support (49) on physical activity interventions were found, as half of the (high quality) studies, or only one high-quality study found a mediated effect. Moderate evidence for a lack of mediation was found for attitude (32,40-42,53), perceived barriers (32,40,46,47) and social influences (32,40-43,46) mostly because of the fact that the interventions were not able to change the presumed mediator in the desired direction. Studies examining the mediating effects of social modelling (46), counterconditioning (46), satisfaction (53), stimulus control (46), habit strength (37) or physical activity-related behaviors (for example, TV viewing and participation in sports programmes) (32,38) found no support for mediating effects.

Sedentary behavior: No mediated effects were identified for the interventions aimed at changing sedentary behavior (see Table 3, column 5). This was partly due to studies that did not report the mediated effect because the intervention effect on sedentary behavior (37) or on the potential mediator (52) was not significant. Studies that did report mediated effects, however, did not find mediated effects of intrinsic motivation (52) or intervention-related concepts (for example, parents read the newsletters and the number of incentives received by the child) (34) on sedentary behavior interventions.

Dietary behavior: With regard to dietary interventions, we found no convincing evidence for significant mediators. Indications for a mediating effect were found for knowledge (that is, one out of two high-quality studies (44,50)), attitude (that is, one out of two high-quality studies (37,39,44)) and habit strength (that is, one out of two high-quality studies (37); see Table 4, column 5). Chinapaw et al. (37) and Reynolds et al. (44) found that attitude was a partial mediator of the intervention effect on soft drink consumption, and fruit and vegetable intake, respectively. Chinapaw et al. (37) identified the mediated effect among boys only, and Reynolds et al. (44) identified the mediated effect only in the single mediator and short-term analysis. No support was found for the mediating effect of other potential mediators. Strong evidence for a lack of mediation by social influences (that is, social support, social norm, eating together, parent consumption (37,39,44,48,50), availability (43,44,50) and self-efficacy (37,39,43,44,48) was found. The lack of a mediating effect of self-efficacy was due to the limited ability of the interventions to change self-

efficacy. For the other potential mediators, there was no support for the action theory or conceptual theory.

Discussion

The aim of this study was to review the published literature on mediators of school-based interventions aimed at changing energy balance-related behaviors in youth. In total, 24 intervention studies were included: 18 studies aimed at changing physical activity, 3 studies aimed at improving sedentary behavior and 8 studies aimed at changing dietary behaviors.

We found consistent evidence for self-efficacy and moderate evidence for intention as mediators of intervention effects on physical activity behavior. In addition, we found indications that self-regulation, intrinsic motivation, enjoyment, autonomy support and proxy efficacy were mediators of the effects of physical activity interventions. Confirmation of the hypothesised mediating mechanisms can prompt developers of future interventions to strengthen or add the intervention components targeting these specific mediators. It is therefore recommended that future interventions aimed at changing physical activity behavior among youth include effective intervention strategies aimed at improving self-efficacy and intention. Consistent evidence for a lack of mediation was found for social influences, perceived barriers, perceived benefits and attitude. This lack of mediation was mainly because of the fact that the interventions were not able to change these constructs. Moreover, the majority of interventions aimed at changing barriers increased the perceived barriers instead of decreasing them. This assumes that future interventions aimed at targeting social influences, perceived barriers, perceived benefits and attitude should include other strategies that are effective in changing these potential mediators. As these concepts were associated with physical activity behavior, they have the potential to be a relevant mediator. To optimally inform future interventions, we need to know which interventions strategies are effective for which mediator. Unfortunately, lack of information on the theoretical basis of interventions and the wide variety of strategies makes it difficult to draw conclusions regarding which strategies are effective and which are not (55,56). Abraham and Michie (55) developed a taxonomy and identified 26 strategies used in behavior change interventions. Although this taxonomy is not exhaustive and needs further elaboration, we recommend that future intervention studies apply this taxonomy in their description of the intervention strategies, as done, for example, by Araújo-Soares et al. (36). On the basis of these detailed descriptions, the effectiveness of each intervention strategy in changing specific mediators can be determined, providing relevant information for future interventions.

For the sedentary behavior interventions, no mediated effects were found. Few interventions targeted sedentary behaviors and few reported their mediation analyses, mainly because they did not find intervention effects on the outcome or potential mediator. Significant associations were found between sedentary behavior and attitude, self-efficacy, intrinsic motivation and habit strength, confirming their potential as mediators. Thus, future sedentary behavior interventions aimed at targeting these concepts should include other strategies that are effective in changing these potential

mediators. Additionally, determinant studies suggest that, unlike physical activity, sedentary behaviors such as TV viewing may not be well-considered, planned behaviors among children and adolescents. Rather than being influenced by conscious cognitions, sedentary behavior may instead be influenced by individual biological factors, habit strength and parental factors (57,58). Future intervention research should, therefore, explore the mediation effects of potential social and physical environmental variables (for example, parental rules and number of TVs at home) in sedentary behavior interventions. With regard to dietary interventions, some evidence was found that knowledge, attitude, and habit may be relevant mediators of dietary intervention effects. Thus, future dietary interventions in youth are recommended to target knowledge, attitude and habit strength. However, more research is needed to confirm these mediating mechanisms. Consistent evidence for a lack of mediation was found for social influences, self-efficacy and availability. This lack of mediation could be because of the fact that the interventions were not able to affect self-efficacy, social influences (that is, social support, social norm and eating together) or availability (that is, nonsignificant action theory test), and that for social influences and availability, no association with dietary behavior was found (nonsignificant conceptual theory test). These nonsignificant action and conceptual theory tests could be due to a lack of power; insensitive measures; or limited variability in the mediator. The development of relevant scales, tested on their reliability, validity and sensitivity, is important in future research (59). Further, several studies did not conduct a conceptual theory test or calculate the mediated effect, for the reason that the intervention did not affect the behavior (31,37) or mediator (33,42,46,48,52). Conducting a conceptual theory test is, however, very informative for future interventions and should be included in further research.

A comparison between the results regarding physical activity and dietary behaviors suggests differences in working mechanisms between the two behaviors. Different intervention strategies may be required for changing the mediators of different energy balance behaviors. This is an interesting finding, considering the rapidly developing field of interventions targeting multiple energy balance-related behaviors, wherein similar mediators are targeted using similar intervention strategies for different behaviors.

Compared with the earlier reviews of Lubans et al. (24) and Cerin et al. (25), this review conducted a more extensive literature search and used different inclusion criteria, resulting in more included studies (24 compared with a sum of 13 unique studies included in both previous reviews). We confirmed the finding of Lubans et al. (24) that self-efficacy is a relevant mediator of physical activity interventions; and we additionally found moderate support for the mediating role of intention in physical activity interventions. In addition, we identified self-regulation, intrinsic motivation, enjoyment, autonomy support and proxy efficacy as mediators of physical activity interventions. Perceived benefits, perceived barriers and social influences have the potential to be mediators of physical activity interventions; however, as none of the interventions was effective in changing these constructs, appropriate strategies are needed. In addition, we were able to identify some potential mediators of sedentary behavior intervention; however, the small number of sedentary behavior interventions reporting on mediating effects prevented us from

forming strong conclusions. Compared with Cerin et al. (25), our review confirmed the relevance of attitude and additionally identified knowledge and habit strength as potential mediators of dietary interventions. In addition, we found strong evidence that social and environmental influences did not mediate dietary interventions, probably because of invalid or insensitive measurement instruments.

Limitations

As the quality of the literature review highly depends on the quality of the reviewed studies, some limitations have to be taken into account. First, the studies differed substantially in their intervention content, outcome behavior, duration and measurement instruments. In addition, the included studies were conducted in eight different countries, with major differences in cultural, social and economical background. These differences may have influenced the acceptance and effectiveness of the interventions in changing the outcomes and mediators, and should be taken into account when interpreting the results. Second, recent evidence suggests that intervention effectiveness differs among age group (60) and by sex (60,61). This suggests that that the working mechanisms could differ between the subgroups (low age versus high age; boys versus girls). However, because of the low number of studies analysing the mediators in specific subgroups (that is, four studies were conducted in elementary schools; no studies were conducted among boys only), or analysing the mediators for separate subgroups (that is, only two studies analysed the mediators for boys and girls separately), no comparison between the specific subgroups could be made. This prevented us from drawing conclusions on the working mechanisms of obesity prevention in relevant subgroups.

Third, the quality of the majority of reviewed studies was moderate. Among these, four studies used a quasi-experimental design, making the test for mediation less ideal. In addition, four interventions were not based on a theoretical model, making it impossible to confirm or replicate the theoretical assumptions regarding the intervention development and evaluation. None of the included studies conducted a power analysis to examine whether they had included sufficient participants to enable mediation analyses. Fritz and MacKinnon (27) calculated that when applying the Baron and Kenny causal-step test, about 21000 participants are needed to achieve an 80% power in condition of complete mediation and small effect size, whereas other statistical tests require smaller sample sizes between 460 and 670 participants (22,27). Researchers conducting mediation analysis in future should therefore choose a test of mediation that is appropriate for their sample size and choose a test for mediation with increased power, such as bootstrapping tests, the joint significance test or the PRODCLIN test (27). Regarding the measures used, four studies used behavioral measures with unknown validity or reliability, whereas eight studies used mediator measures with a low reliability. Latent variable modelling (for example, structural equation modelling) was applied in very few studies, whereas this method of analysis deals better with unreliability of measurement instruments by conducting confirmatory factor analysis. In addition, structural equation modelling enables analyses of more complex models (for example, three-path-mediated effects,

moderated mediation effects and latent growth modelling) in comparison with regression techniques (21,22,62).

Fourth, to draw stronger conclusions, we combined all dietary interventions (for example, fruit, vegetable, soft drink and snack consumption), neglecting the possible differences between the sub-behaviors. As the majority of dietary interventions targeted fruit and vegetables, translating the conclusions to interventions targeting other sub-behaviors (for example, snacking or soft drink consumption) should be done with caution. Fifth, as in any review of published literature, publication bias may have influenced the results. The fact that all included studies found significant intervention effects and most studies did identify one or more mediators suggests that publication bias occurred. It is likely that studies that did not find a significant intervention effect did not conduct a mediation analyses or that studies that did not find significant mediated effects did not publish their results. Our findings might therefore not be representative for all energy balance-related behavior interventions in youth. This should be taken into account when interpreting our results. Potential mediating effects can still be examined, even in the absence of a significant main effect (for example, intervention effect on behavior) (22,63). As a significant intervention effect is not a requirement for mediation to occur, researchers of intervention studies are prompted to conduct a mediation analyses even when a significant main effect was not found. Sixth, because of the criteria of mediation analyses, we may have neglected several potential relevant mediators. Several potential mediators, such as perceived benefits, perceived barriers and social influences, were relevant to the outcome behavior (significant conceptual theory), but were not affected by the intervention (nonsignificant action theory) and could therefore not be identified as a mediator. Finally, because of the high variety in (the measures of) the outcome variables, a systematic literature review was in our opinion the best way to examine the data. We, however, believe that in future, a meta-analytic review of the literature would be a next best step.

Conclusion

Evidence was found for self-efficacy and intention as mediators of intervention effects of school-based physical activity promotion interventions. Some evidence was found for attitude, knowledge and habit strength as mediators of interventions aiming to change dietary behaviors. The few sedentary behavior interventions reporting on mediating effects prevented us from forming strong conclusions regarding the most effective mediators of sedentary behavior interventions. Another important finding was that the majority of interventions failed to significantly change hypothesised mediators because of ineffective intervention strategies, low power and/or the use of insensitive measures. Developers of future interventions are advised to provide information on the theoretical basis of their intervention including the strategies applied. This will provide more insight into the strategies that are effective in changing relevant mediators. In addition, future research should focus on the development, validity, reliability and sensitivity of mediator measures.

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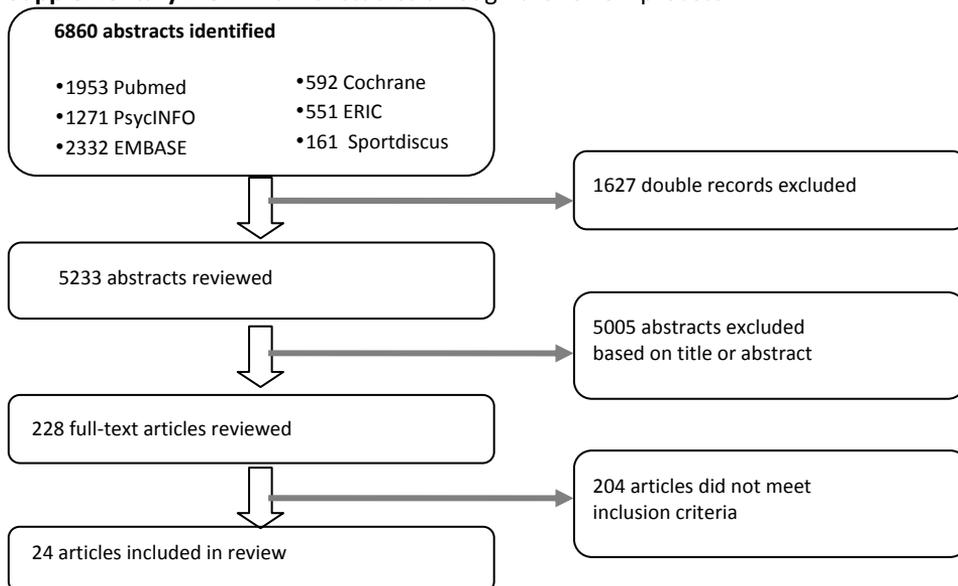
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SUPPLEMENTARY FILES

Supplementary file 1. Flow of studies through the review process



Supplementary file 2. Search strategy for the electronic database Pubmed

#1 Children and Adolescents
("child"[MeSH] OR (child) OR (children) OR (schoolchild) OR (schoolchildren) OR "adolescent"[MeSH] OR (adolescent) OR (adolescents) OR (adolescence) OR (boy) OR (boys) OR (girl) OR (girls) OR (youth) OR (teen) OR (teens) OR (teenager) OR (student) OR (students))
#2 Energy Balance Related Behaviors
("physical activity" OR exercise OR exercising OR sport OR sports OR active OR inactive OR activities OR activity OR walking OR cycling OR sedentary OR computer OR television OR TV OR internet OR games OR gaming OR recreation OR play OR viewing OR nutrition OR food OR diet OR intake OR beverages OR snack OR snacking OR snacks OR "soft drink" OR soft drink OR fruit OR fruits OR vegetables OR vegetable OR drinks OR soda OR drinking OR breakfast OR supper OR lunch OR meal OR dinner OR tea OR fat OR 5-a-day OR eating OR sit OR obese OR obesit* OR overweight OR "Body mass" OR "body weight" OR "weight gain" OR "weight loss" OR BMI)
#3 School-based intervention
((prevention) OR (intervention) OR (interventions) OR (promotion) OR (treatment) OR (program) OR (programs) OR (programme) OR (programmes) OR (change) OR (changing) OR (trial) OR (trials) OR (approach) OR (approaches)) AND ((school) OR (school-based) OR (institution) OR (institutional) OR (class))
#4 Mediation analyses
(mediat* OR indirect OR "structural equation modeling" OR "structural equation modelling" OR "path" OR (Baron and Kenny) OR "MacKinnon" OR "product of coefficient" OR "difference in coefficient")
End Search #1 AND #2 AND #3 AND #4

Supplementary file 3. Characteristics of studies examining potential mediators of intervention schemes promoting physical activity or healthy dietary behavior in youth.

Study (quality score)	Sample	Design	Assessment	Theory	Mediation analysis (method; single/multiple; significance test)	Mediators tested (reliability)	Outcome (reliability)	Intervention effect on outcome
Amaro et al. (2006) (35) (low: 3)	Italy 3 middle school 241 students 45% female Age: 12.5 ± 0.7 Drop-out: 15%	RCT I: weekly educational board-game C: no intervention	Baseline; 24 weeks post-baseline	-	<ul style="list-style-type: none"> Regression model Single mediation Baron and Kenny causal steps 	- Nutrition knowledge ($\alpha=0.70$)	Vegetable intake- from 1 week dietary intake recall questionnaire (unvalidated)	Significant intervention effect on vegetable intake
Araujo-Soares et al. (2009) (36) (high:8)	Portugal 8 secondary schools 291 students 53% female Age: 12.1 ± 1.0 Drop-out: NR	RCT I: two 90-minute classroom sessions and homework aimed at changing PA by targeting SCT variables and post-intentional strategies, including keeping a diary, working sheets, and a information leaflet. C: no-intervention	3-weeks pre-intervention, 2-weeks, 3 months and 12 months post-intervention	SCT; SRT	<ul style="list-style-type: none"> Regression model Single mediation Baron and Kenny causal steps 	- situation outcome expectancies ($\alpha=.88-.90$) -action outcome expectancies ($\alpha=.79-.85$) - self-efficacy($\alpha=.84-.90$) -behavioral intentions ($\alpha=.86-.90$) -action planning ($\alpha=.90-.93$) -coping planning ($\alpha=.75-.85$)	MVPA measured 7 day recall method of validated IPAQ	Significant intervention effect on MVPA
Chatzisarantis et al. (2009) (49) (high: 8)	UK 10 secondary schools 235 students; 51% female; Age: 14.8 ±0.5 Drop-out= 8.5%	RCT I: training of teachers to adopt an autonomy-supportive interpersonal teaching style C: no-training but instructions only	Baseline; 10 weeks post-baseline	SDT	<ul style="list-style-type: none"> Path model Multiple mediators Sobel test 	- Autonomy support ($\alpha= 0.89$) - Motivational orientation (autonomous: $\alpha= 0.75$; controlling: $\alpha= 0.85$) - Intention ($\alpha= 0.93$)	PA leisure time- from Godin's Leisure Time Exercise Questionnaire	Significant intervention effect on PA behavior

Study (quality score)	Sample	Design	Assessment	Theory	Mediation analysis (method; single/multiple; significance test)	Mediators tested (reliability)	Outcome (reliability)	Intervention effect on outcome
Chinapaw et al. (2008) (37) (medium: 8)	Netherlands 18 secondary schools 1,053 students 51% girls Age= 12.7 ± 0.5 Drop-out: 2%	RCT I: DO-it: multi-component 8-months intervention: individual component (11 lessons educational program) + environmental component (encouraging additional physical education classes and changes at school canteen) C: no intervention	Baseline; 8 months post-baseline	TPB; HT; DPT; EnRG;	<ul style="list-style-type: none"> Regression model Single mediation Sobel test 	<ul style="list-style-type: none"> - Attitude (α: 0.72-0.94) - Subjective norm (α= 0.79-0.89) - PBC (α= 0.80-0.91) - Habit strength (α= 0.82-0.96) 	Screen viewing (ICC= 0.94) , active transport (r =0.14-0.39 against energy expend) SBC and Snacking (r =0.6 against 7-day diet records)	Significant intervention effect on SBC. No intervention effect on snacking, screen viewing and active transport
Dishman et al. (2004) (53) (medium: 7)	USA 24 high schools 2,087 students 100% girls; Age= 13.6 ± 0.6 Drop-out: 24%	RCT I: LEAP: 2-year intervention targeting social cognitive variables and school environment C: no intervention	Baseline; 12 month post-baseline	SCT	<ul style="list-style-type: none"> SEM Multiple mediation Joint significance 	<ul style="list-style-type: none"> - Self-efficacy (χ^2= 39.93; df= 20) - Outcome expectations (χ^2=47.4; df= 20) - Goal setting (χ^2=18.6; df=9) - Satisfaction (1 item) 	PA- from 3 day PA Recall (r = 0.27–0.46; P < 0.05 against CSA's)	Significant intervention effect on total PA
Dishman et al. (2005) (54) (high: 8)	USA 24 high schools 2,744 students 100% girls Age: 13.6 ± 0.6 Drop-out: 24%	RCT I: LEAP: 2-year intervention targeting social cognitive variables and school environment C: no intervention	Baseline; 12 months post-baseline	SCT	<ul style="list-style-type: none"> SEM Multiple mediation Joint significance 	<ul style="list-style-type: none"> - PE enjoyment (χ^2=220.8; df= 52) - PA enjoyment (χ^2=1481.6; df= 104) - Self-efficacy (χ^2= 39.93; df= 20) 	Total PA-from 3 day PA Recall questionnaire (r = 0.27–0.46; P < 0.05 against CSA's)	Significant intervention effect on total PA
Dunton et al. (2007) (47) (medium: 6)	USA 2 secondary schools 146 students 100% girls Age:15.1 ± 0.8 Drop-out: 16%	QE I: FAB intervention: 5 day weekly supervised PA class + 1 weekly education class C: no-intervention group	Baseline; 4 and 9 months post-baseline	SCT	<ul style="list-style-type: none"> HGLM Single mediation Baron and Kenny causal steps 	<ul style="list-style-type: none"> - Self-efficacy (α= .81-.85) - Social support (α= .79-.80) - Perceived barriers (α= .65-.71) - Enjoyment (α= .91) 	VPA- from 3 day PA Recall (r = 0.27–0.46; P < 0.05 against CSA's)	Significant intervention effect on VPA

Dzewaltowski et al. (2009) (48) (medium: 7)	USA 16 secondary schools 2,211 students 53% girls Age: 12.4 ± 0.4 Drop-out: 28%	RCT I: Healthy Youth Places: intervention promoting personal and proxy agency to built healthy school environments that promote FV and PA C: no-intervention	Baseline; 12 and 24 months post-baseline	SCT	<ul style="list-style-type: none"> GLM Single mediation Sobel test 	<ul style="list-style-type: none"> - Self-efficacy (1-item) - Proxy efficacy (nr) - Group norm (1 item) 	MVPA and VPA- from previous day PA recall questionnaire (r>.50) FV: 24-hr Youth/ Adolescent FFQ (r= .21-.58)	No intervention effect on FV consumption Significant intervention effects on VPA and MVPA
Graham et al. (2008) (38) (low: 2)	USA 2 high schools 122 students 100% girls Age: 15.0 ± 0.8 Drop-out: 2.5%	QE I: 1 school year intervention: 4 weekly supervised exercise sessions + 1 weekly health education C: no intervention	Baseline; 9 months post-baseline	-	<ul style="list-style-type: none"> Regression model Single mediation Baron and Kenny causal steps 	TV viewing behavior (self-report, no reliability or validity data)	VPA- from 3 day PA recall (r=NR)	PA: significant intervention effects on VPA
Haerens et al. (2008) (40) (medium: 5)	Belgium 15 secondary schools 2,840 students 37% girls Age range: 11-15 drop-out: ?	3- arm RCT I: two 1-year interventions with 1) individual component: computer tailored PA intervention + environmental component: promoting PA availability 2) individual component: computer tailored PA intervention + environmental component: promoting PA availability + parental component: creating supportive environment C: no-intervention	Baseline; 1 year post- baseline	TPB; TTM; SCT	<ul style="list-style-type: none"> Regression model Single and multiple mediation Sobel test 	<ul style="list-style-type: none"> -Attitude ($\alpha= 0.73$) -Social support (total: $\alpha=0.76$; family $\alpha=0.77$; friends $\alpha=0.58$) -Self-efficacy ($\alpha=nr$) -Perceived benefits (health: $\alpha=0.54$; psychosocial: $\alpha=0.80$) -Perceived barriers (motivational $\alpha=0.64$; environmental $\alpha=0.59$) 	Total PA, Active transport to school, sports at school, active transport leisure time, sports leisure time- from Flemish PA questionnaire (ICC= 0.70; r= 0.43-0.79)	<u>Intervention 1:</u> no intervention effect <u>Intervention 2:</u> significant intervention effect on total PA, active transport to school and school related sport
Haerens et al. (2007) (39) (medium: 5)	Belgium 15 secondary schools 843 students 100% girls Age: 12.9 ± 0.8 Drop-out: 6.5%	RCT I: two 1-year interventions with 1) individual component: computer tailored healthy diet intervention + environmental component: promoting availability healthy products C: no intervention	Baseline; 1 year post- baseline	TPB; TTM; SCT	<ul style="list-style-type: none"> Regression model Single and multiple mediation Sobel test 	<ul style="list-style-type: none"> -Attitude ($\alpha= 0.83$) -Social support ($\alpha=0.38$) -Self-efficacy ($\alpha=0.71$) -Perceived benefits ($\alpha=0.83$) -Perceived barriers ($\alpha=0.85$) 	Fat-intake from food frequency questionnaire (ICC= 0.86, r= 0.67)	Significant intervention effects on daily fat intake

Study (quality score)	Sample	Design	Assessment	Theory	Mediation analysis (method; single/multiple; significance test)	Mediators tested (reliability)	Outcome (reliability)	Intervention effect on outcome
Hill et al. (2007) (31) (medium: 6)	UK 1 secondary schools 620 students 51% girls age: 16.9 ± 1.4 drop-out: 16%	4-arm RCT I: 1) Leaflet; 2) Leaflet + motivational incentive and quiz; 3) Leaflet + implementation intention C: no-intervention	Baseline; 3 weeks post-baseline	TPB; ELM; GT	<ul style="list-style-type: none"> ANCOVA Single mediation Sobel test 	<ul style="list-style-type: none"> Intention (r=.64) PBC (α=.72) Attitude (r=.59) Normative beliefs (1-item) 	Exercise- from 1 item weekly exercise measure (Not validated)	Significant effects on weekly exercise. No differences between interventions
Hortz et al. (2008) (41) (high: 6)	USA 2 high schools 294 students 42% girls Age: 15.2 ±. Excluded: 18%	QE I: usual PE curricula and 8-lesson SCT based skill building curriculum C: usual PE curricula	Baseline; 10 weeks post-baseline	SCT	<ul style="list-style-type: none"> Regression model Single mediation Baron and Kenny causal steps 	<ul style="list-style-type: none"> Social situation (α= .90, r= 0.78) Self-efficacy (α=.90 r= 0.82) Outcome expectance (α=.94) Self-regulation (α=.88) 	Exercise moderate intensity- from previous day PA recall questionnaire (r= .98; v= .88)	Significant intervention effect on moderate intensity exercise
Lubans et al. (2009) (42) (medium: 5)	UK 1 secondary school 78 students 62% girls, Age: 16.7 ± nr drop-out: nr	RCT I: 10-week PE intervention consisting of weekly information sessions and exercise training C: no intervention exercise group	Baseline; 3 and 6 months post-baseline	SCT; SET	<ul style="list-style-type: none"> Regression model Single mediation Sobel test 	<ul style="list-style-type: none"> Self-efficacy (α=.75) Outcome expectancy (α=.83) Peer support (α=.73) 	PA (MVPA)- from 7 day recall Oxford PA Questionnaire (ICC=.76-.91; r= .32)	Significant intervention effect on MVPA among girls and borderline significant effect among boys
Lubans et al. (2010) (43) (high:8)	AUS 6 secondary schools 124 students 57% girls Age: 14.1 ± 0.8 Drop-out: 13%	RCT: I: 10-week extra-curricular school sport program including additional strategies to support behavior change including information sessions, handbooks, e-mails, and pedometers. C: 10-week extra-curricular school sport program without behavior change strategies	Baseline, 6 months post-baseline	SCT	<ul style="list-style-type: none"> Regression model Multiple mediation PRODCLIN 	<ul style="list-style-type: none"> PA self-efficacy (α=.84; r= .89) PA social support(α=.82; r=.81) PA self-management strategies(α=.88; r=NA) F&V availability(α=.42; r=.66) F&V self-efficacy(α=.78; .64) 	PA- using a reliable and valid pedometer (>.708 against VO ₂ max and heart rate) FV- from NSW Schools Physical Activity and Nutrition Survey (r=NR)	Significant intervention effect on PA for both boys and girls. Significant intervention effect on FV consumption was found among girls only.

Lytle et al. (2009) (32) (medium:6)	USA 36 middle schools 1,603 students at baseline 100% girls Age=12 Drop-out=5.5% (Analysis unit was school)	RCT I: 3-year environmental and organizational changes supportive of PA, cues, messages and incentives to be more PA, lessons to enhance behavioral skills. C: no intervention	Baseline, 2 year and 3 year post-baseline	SET	<ul style="list-style-type: none"> Regression model Single mediation Sobel test 	<ul style="list-style-type: none"> - self-efficacy for PA ($\alpha=0.81-0.84$; $r=0.67-0.69$) -outcome expectations($\alpha=0.82-0.84$; $r=0.64-0.68$) -outcome expectancy value($\alpha=0.92-0.94$; $r=0.58-0.58$) -participation in school sports programs(1 item) - participation in out-of-school PA program(1 item) -participation in after school PA program(1 item) -participation in before school PA program(1 item) - difficulty getting home from school(1 item) - difficulty getting to community activity(1 item) - difficulty getting home from community activity(1 item) - access to facilities($\alpha=-0.80-0.81$; $r=0.78$) -provide social support to others for PA(1 item) - friend social support for PA($\alpha=0.74-0.79$; $r=0.86$) - family social support for PA($\alpha=NR$) - Social support for PA(sum of three items) 	Out-of-school PA measured by Actigraph accelerometers	Significant intervention effect on out-of-school levels of PA measured in minutes or MET minutes.
Reynolds et al. (2002) (44) (medium:5)	USA 28 elementary schools 1,676 students 51% girls Age: 8.7 ± 0.6 Drop-out: 18%	RCT I: 1-year 14-lesson curriculum; goal-setting and self-monitoring; parental involvement; environment (cafeteria) component C: usual care	Baseline; 12 and 24 months post-baseline	SCT	<ul style="list-style-type: none"> Regression model Single and multiple mediation Sobel test 	<ul style="list-style-type: none"> -Availability ($\alpha=.69$) -Eating meals together (1 item) -Knowledge ($\alpha=.23$) -Parent consumption(nr) -Self-efficacy ($\alpha=.86$) -Family norm ($\alpha=.62$) -Peer norm ($\alpha=.79$) -Teacher norm ($\alpha=.84$) -Positive outcome expectancies ($\alpha=.67$) 	FV- from 7 day 24-h diet recall interviews (single recall per student) (r=NR)	Intervention significantly increased FV consumption over 1 year and 2 years

Study (quality score)	Sample	Design	Assessment	Theory	Mediation analysis (method; single/multiple; significance test)	Mediators tested (reliability)	Outcome (reliability)	Intervention effect on outcome
Reynolds et al. (2004) (50) (high: 8)	USA <u>Study 1:</u> 28 elem schools 1,584 students 51% girls Age: 8.7 ± 0.6 Drop-out: 7% <u>Study 2:</u> 20 elem schools 522 students 51% girls age: 10.0 ± 0.4 Drop-out: 18%	<u>Study 1:</u> I: 1-year 14-lesson curriculum; parental involvement; environment component (cafeteria) C: usual care <u>Study 2:</u> I: 1-year 16 lesson curriculum; parental involvement; school food service changes; industry involvement C: usual care	Baseline; 12 months post-baseline	SCT	<ul style="list-style-type: none"> • Path model • Single and multiple mediation • Sobel test 	<ul style="list-style-type: none"> - Availability of F&V in home ($\alpha=.69$) - Knowledge of number of servings of F&V that should be eaten (1-item) - Number of F&V consumed by parents 	<u>Study 1:</u> FV- 7day 24-h diet recall interviews (single recall per student) ($r=NR$) <u>Study 2:</u> FV- 24-h recall in a random sample of 34 students/ school ($r=.45-.79$ against observed nutrients)	Significant intervention effect on FV consumption in study 1 and study 2
Robinson et al. (2006)(34) (moderate: 6)	USA 2 elementary schools 197 students 46% girl Age: 8.9 ± 0.6 Drop-out: 8.1%	RCT I:6-month classroom curriculum consisting of 18 30-50 minutes lessons on 1)TV awareness, 2)TV turnoff (i.e., attempt to watch no tv, play no games), 3)Stay in Control in which they received TV allowance (electronic tv time manager) and SMART slip (incentive for maintaining media-use budget), and Help Others. Parents received newsletters. C: no intervention	Baseline; ?	SCT	<ul style="list-style-type: none"> • ANCOVA • Single mediation • ? 	<ul style="list-style-type: none"> - days with no television, videotapes or games (1 item) - whether TV allowance was hooked-up (1 item) - number of TV allowances (i.e., electronic tv time manager) requested (1 item) - whether TV allowance was still used (1 item) - proportion of newsletters read by parent (1 item) - number of under budget SMART slips (1 item) 	Sedentary behavior (e.g., watching TV, movies/videos, playing video games, on a computer) ($r=.91$)	Significant intervention effect on weekday television viewing and weekday and Saturday video game playing

Shilts et al. (2009) (51) (low: 4)	USA 1 middle school 136 students 45% girls Age: 14.0± 0.4 drop-out: 31%	RCT I: 5 weeks 10-lesson curriculum including: nutrition and fitness information; goal setting C: 5 weeks 10-lesson curriculum including: nutrition and fitness information;	1 week pre-intervention; 1 week post-intervention (= 7 week post-baseline)	SCT	<ul style="list-style-type: none"> • Path model • Single mediation • Joint significance 	Dietary self-efficacy ($\alpha=.59$) PA self-efficacy ($\alpha=.48$)	Dietary behavior- from CDC Youth Risk Behavior Survey ($r=.73$) PA –CDC Youth Risk Behavior Survey ($r=.55$)	No significant effects for total sample. Significant effect on PA and diet for goal-setting sub group)
Spruijt-Metz et al. (2008) (52) (medium: 7)	USA 7 secondary schools 459 students 100% girls age: 12.5 ± 0.6 drop-out: 7.4%	RCT I: 5-7 schooldays of media-based intervention, including PA information and participation in learning activities C: no-intervention	3 months pre-intervention; 3 months post-intervention	SDT	<ul style="list-style-type: none"> • Path model • Single mediation • Sobel test 	- Motivation for PA ($\alpha=0.76$) - Meaning of PA	Sedentary behavior and PA- from Previous Day PA Recall questionnaire ($r = 0.27-0.46$; $P < 0.05$ against CSAs)	Significant intervention effect on sedentary behavior. No significant effect on PA behavior
Tak et al. (2008) (45) (low: 3)	Netherlands 55 primary schools 1,328 students 55% girls age:10.0 ±0.6 drop-out: 40%	QE I: 2-year free provision of fruit and vegetables twice weekly + school curriculum aimed at increasing knowledge and skills related to FV C: no- intervention	Baseline, 12 and 24 months	-	<ul style="list-style-type: none"> • Regression model • Single mediation • Baron and Kenny causal steps 	- Appreciation of program (single item)	FV- from food frequency question reported by child ($r=0.40-0.53$; ICC= 0.47-0.84) and parent ($r=NR$)	Significant intervention effect on fruit consumption. No effect on vegetable consumption
Taymoori et al. (2008) (46) (medium: 7)	Iran 3 secondary schools 161 students 100% girls Age: 14.8 ± 0.4 Drop-out: NR	3-arm RCT I: two six months tailored PA interventions (1.) group education; individual counselling; follow-up phone calls targeting TTM and HPM determinants (2.) group education; individual counselling; follow-up phone calls targeting HPM determinants C: usual PE program	Baseline; 6 and 12 months	HPM; TTM	<ul style="list-style-type: none"> • Regression model • Single mediation • Sobel test 	-Perc. benefits ($\alpha=.83$) -Perc. barriers ($\alpha=.78$) -Self-efficacy ($\alpha=.90$) -Social support ($\alpha=.82$) -Social modelling($\alpha=.84$) -Social norms ($\alpha=.72$) -Counter conditioning ($\alpha=.70$) -Stimulus control ($\alpha=.83$) -Commitment to planning ($\alpha=.86$)	PA total- from 6 days recall Child/ Adolescent Activity Log ($r=.98$)	Significant intervention effects for both intervention groups on total PA.
Zizzi et al. (2006) (33) (medium: 5)	USA 4 secondary schools 165 students 63% girls age: 14-17yrs Drop-out= 22%	QE I: three week intervention (1) pedometer-only group; (2) pedometer plus goal setting group	Baseline; 3 weeks	-	<ul style="list-style-type: none"> • NR 	- Attitudes ($\alpha=.89$) - Perceived barriers - Self-efficacy ($\alpha=.82$)	PA daily steps; from pedometer (validity and reliability NR)	No goal setting intervention effect and no significant increase in daily step count

DPT: dual- process theory; ELM: elaboration likelihood model; EnRG: EnRG framework; FV: Fruit and Vegetable; GT: goal theory; HPM: Health promotion model; HT: Habit theory; MVPA: moderate and vigorous intensity physical activity; NR: not reported; NS: no significant association; PA: physical activity; QE: quasi experimental design; RCT: randomized controlled trial; SBC: sugar sweetened beverage consumption; SCT: social cognitive theory; SDT: self-determination theory; SET: self-efficacy theory; TTM: transtheoretical model; TPB: theory of planned behavior; VPA: vigorous intensity physical activity.

Supplementary file 4. Quality assessment of intervention studies aiming at physical activity or dietary behavior in youth conducting mediation analysis, sorted by quality score.

Study	Quality criteria										Total score
	1. Was a method of randomization performed?	2. Were groups similar at baseline regarding important indicators (i.e., age, gender, BMI, baseline behavior)	3. Were point estimates and variability presented for primary outcomes?	4. Did the analysis include an intention-to-treat analysis?	5. Was the drop-out rate non-selective?	6. Did the study cite a theoretical framework?	7. Was the outcome measure tested on reliability and validity?	8. Were psychometric characteristics of mediators reported, and within acceptable range (reliability >0.70)?	9. Was power calculation reported and high enough to detect mediation?	10. Was it ascertained whether changes in mediators preceded changes in outcome?	
Chatzisarantis et al. (49)	Y	Y	Y	N	?	Y	Y	Y	Y	Y	89%
Dishman et al. (54)	Y	Y	Y	Y	?	Y	Y	Y	Y	N	89%
Lubans et al. (43)	Y	Y	Y	Y	?	Y	Y	Y	Y	N	89%
Reynolds et al. (50)	Y	Y	Y	Y	?	Y	Y	Y	Y	N	89%
Araujo-Soares et al. (36)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	80%
Chinapaw et al. (37)	Y	N	Y	Y	Y	Y	Y	Y	Y	N	80%
Dishman et al. (53)	Y	Y	N	Y	?	Y	Y	Y	Y	N	78%
Spruijt- Metz et al. (52)	Y	Y	Y	N	?	Y	Y	Y	Y	N	78%
Dzewaltowski et al. (48)	Y	Y	Y	N	N	Y	Y	Y	Y	N	70%
Taymoori et al. (46)	Y	Y	Y	N	N	Y	Y	Y	Y	N	70%
Robinson et al. (34)	Y	Y	Y	Y	?	Y	Y	N	N	N	67%
Dunton et al. (47)	N	Y	Y	Y	N	Y	Y	Y	N	N	60%
Haerens et al. (40)	Y	Y	Y	N	N	Y	Y	N	Y	N	60%
Haerens et al. (39)	Y	Y	Y	N	N	Y	Y	N	Y	N	60%
Hill et al. (31)	Y	Y	Y	N	Y	Y	N	N	Y	N	60%
Hortz et al. (41)	N	Y	Y	N	Y	Y	Y	Y	N	N	60%
Lubans et al. (42)	Y	Y	N	?	N	Y	Y	Y	N	N	56%
Lytle et al. (32)	Y	Y	N	N	?	Y	N	Y	Y	N	56%
Zizzi et al. (33)	Y	Y	Y	N	?	N	Y	Y	N	N	56%
Reynolds et al. (44)	Y	Y	N	N	N	Y	Y	N	Y	N	50%
Shilts et al. (51)	Y	N	Y	N	Y	Y	N	N	N	N	40%
Amaro et al. (35)	Y	N	Y	N	?	N	N	Y	N	N	33%
Tak et al. (45)	N	N	Y	N	N	N	Y	N	Y	N	30%
Graham et al. (38)	N	Y	Y	N	N	N	N	N	N	N	20%

N – no; Y – yes; ? don't know