

# Testing Theories of Dietary Behavior Change in Youth Using the Mediating Variable Model with Intervention Programs

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## ABSTRACT

**Objective:** To review and critique current experimentally-based evidence of theoretical mechanisms of dietary behavior change in youth and provide recommendations on ways to enhance theory evaluation.

**Methods:** Interventions that examined mediators of dietary behavior change in youth (age 5–18 years) were identified via electronic database searches and reference scanning. Selected studies were reviewed for quality and content and findings were tabulated.

**Results:** Seven published interventions were found. All were school-based but differed substantially in dietary outcome, target population, measures, methods of mediation analyses, and theoretical framework. Interventions were relatively unsuccessful in changing mediators. Self-efficacy and outcome expectations were the mechanisms most consistently associated with dietary behavior change. However, only outcome expectancies were identified as mediators in multiple interventions.

**Conclusions and implications:** Few interventions have assessed the validity of theoretical mechanisms of dietary behavior change in youth. The variability in the design and target populations across studies makes it impossible to draw conclusions regarding the validity of theories and mediators of dietary behavior change in youth. Future intervention trials need to focus on the identification of effective procedures for mediator change and adopt a more rigorous and systematic approach to theory testing. This is likely to result in more effective interventions.

**Key Words:** theory validation, mediation, dietary behavior, youth (*J Nutr Educ Behav.* 2009;41:309–318.)

## INTRODUCTION

Pediatric obesity is at epidemic proportions in the United States (US)<sup>1</sup> and is continuing to increase nationally<sup>1</sup> and internationally.<sup>2,3</sup> Obesity prevention and treatment programs seek to regulate the balance between energy expenditure and intake. Energy-intake program components typically aim at reducing the consumption of high-energy-dense, low-nutrient-dense food (eg, soft drinks, high-caloric snacks, and food items that are high in fat) and/or increase fruit and vegetable intake, the latter being associated with increased satiety, lower energy intake,<sup>4</sup> and lower body fat.<sup>5</sup>

Reviews have repeatedly indicated that most interventions have attained only limited or no changes in dietary behavior.<sup>6–8</sup> The general lack of success may be due to incorrect theoretical suppositions regarding the mechanisms (mediators; see [Table 1](#)) through which dietary behavior can be modified,<sup>9</sup> the ways in which mediators can be activated and changed,<sup>10</sup> and the strategies through which interventions can be effectively implemented, disseminated, and adopted in the real world.<sup>11</sup> This review focuses on the assessment of the validity of behavioral theories used to inform and develop interventions as 1 of the main strategies for enhancing the effectiveness

of interventions aimed at dietary behavior changes.

Theories of dietary behavior provide systematic sets of hypothetical constructs, definitions, and propositions that explain or predict dietary behavior change by illustrating the relationships between their key concepts. There is general consensus that the application of theories to the development and implementation of dietary behavioral interventions can enhance their effectiveness.<sup>10,12</sup> Whereas theories inform behavioral interventions by pinpointing possible determinants of dietary behavior, findings from theory-based interventions provide a foundation for theory development and refinement. Thus, there is a synergetic feedback loop between dietary interventions and theories.

Randomized controlled trials (RCTs) represent the recommended methodological framework for testing theories of dietary behavior change.<sup>13</sup> However, a simple demonstration of the effectiveness of a theory-based RCT does not provide evidence for the validity of a theory, as mechanisms

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**Table 1.** Definitions of Key Terminology Related to the Mediating Variable Model

Key Concept (references)	Definition
Mediator or mediating variable <sup>25,26</sup>	A variable that occurs as a causal pathway from an IV to a DV (outcome). It causes variation in the DV and itself is caused to vary by the IV.
Action theory link <sup>14</sup>	The way an intervention affects a mediating variable.
Conceptual theory link <sup>14</sup>	The way a mediating variable affects the outcome.
Baron and Kenny's approach <sup>26</sup>	One of the ways of testing mediation. To function as a mediator, a variable must meet 4 criteria: an IV must be significantly associated with the DV and the potential mediator; the potential mediator must be significantly associated with the DV after adjustment for the IV; after adjustment for the potential mediator, a previously significant relation between the IV and DV is no longer significant or is significantly attenuated.
Sobel's test <sup>25,26</sup>	A method for testing the statistical significance of a mediated effect represented by the product of the effect of the IV on the mediator and the IV-adjusted effect of the mediator on the DV. The product of the 2 effects is divided by its standard error, as defined by Sobel, and compared to a standard normal distribution to establish whether the product of the effects is significantly different from zero.
Bootstrapping <sup>24,25,42</sup>	Computer-intensive approach to statistical inference based on resampling methods. Within the mediating variable model framework, bootstrapping refers to the practice of estimating the precision (eg, 95% confidence intervals) of the mediated effect by drawing with replacement a large number (N = 1000 or more) of samples (termed bootstrap samples) from the original data. Mediated effects are calculated for each of the bootstrap samples, and the average mediated effect and 95% confidence intervals around it are computed across bootstrap samples.
CONSORT criteria <sup>44</sup>	The CONSORT (Consolidated Standards of Reporting Trials) statement comprises a checklist and flow diagram for reporting a randomized controlled trial. It was developed by an international group of clinical trialists, statisticians, epidemiologists, and biomedical editors to improve the quality of reports of randomized control trials.

DV indicates dependent variable; IV, independent variable.

other than those postulated by a theory can lead to changes in behavior. Theories of behavior change are supposed to inform RCT protocols and techniques that are hypothesized to lead to changes in theoretical constructs (mediators), which in turn are hypothesized to lead to changes in dietary behavior.<sup>10</sup> Hence, 2 essential steps in the evaluation of the extent to which a theory provides a valid explanation of changes in the observed behavior are to examine (1) whether the intervention produced significant changes in the hypothesized mediators; and (2) whether the intervention-induced changes in the outcome are attributable to changes in the mediators. The first type of evaluation is usually termed test of the action theory link, whereas the second is referred to as test of the conceptual theory link (Table 1).<sup>14</sup>

In the search of important predictors or determinants of dietary behavior, most studies tend to focus on conceptual theories. For example, numerous investigations have looked

into correlates of consumption of specific food in children.<sup>15,16</sup> However, only a handful of studies have tried to identify significant determinants of behavior change using data from RCTs,<sup>17-21</sup> which can provide stronger evidence of causal relationships of theoretical mediators with dietary behaviors.<sup>22</sup> Moreover, very little attention has been devoted to the evaluation of action theories (ie, how to affect mediators of dietary behavior), although this information is crucial for the development of effective interventions.<sup>10,14</sup>

To enhance understanding of the reasons for the limited success of current behavioral dietary interventions, it is important to test, using appropriate strategies, the validity of theories that inform and guide interventions.<sup>23,24</sup> These strategies include: (1) action theory links; (2) conceptual theory links; and (3) a simultaneous test of the action and conceptual theories.<sup>25</sup> The third test represents an evaluation of whether and the extent

to which the intervention effect was mediated by the mechanisms hypothesized to cause changes in dietary behavior. Optimally, this test would involve establishing if changes in the mediator preceded changes in the outcome.<sup>13</sup> The main aim of this paper is to review and critique current evidence of theoretical mechanisms of dietary behavior change in youth interventions. A secondary aim is to provide recommendations on ways to enhance theory evaluation with the scope of gaining a better understanding of dietary behaviors in youth.

## METHODS

### Identification of Studies

A comprehensive search of published studies was conducted using the following electronic databases: Cumulative Index to Nursing and Allied Health Literature, Embase, Medline, PsychINFO, and PubMed. Searches

included various combinations of the following key terms: mediator, mediation, mediating variables, intermediate variable, intervening variable, youth, child, adolescents, boys, girls, nutrition, diet, fat intake, dietary fat, fruit, vegetable, soft drink, sweetened beverage, snack, milk, and dairy product. Other sources used to identify potential papers were references cited in full-text articles retrieved, and hand-searches of scientific journals frequently reporting on mediators of behavior change and locally available in print form (*Preventive Medicine, American Journal of Preventive Medicine, and Health Psychology*). Abstracts, references, and titles of potential articles were reviewed to identify studies that met the selection criteria. The compiled and refined search results were further examined to identify duplicate entries.

### Criteria for Exclusion/Inclusion

Studies were selected for review if they met all of the following criteria: (1) dietary behavior interventions involving experimental or quasi-experimental designs; (2) participants were children aged from 5 to 18 years with no specific medical condition; (3) quantitative assessment of dietary behavior; (4) quantitative assessment of potential mediators of behavior change; (5) study published in English; and (6) study published before November 1, 2008 (including on-line ahead of print publication). Finally, to be included, a study needed to either (1) report the effect of the intervention on hypothesized mediators and the effect of the mediator on dietary behavior after adjustment for the intervention effect or (2) state that 1 of the study aims was to examine mediators of dietary behavior change using Baron and Kenny's approach (Table 1).<sup>26</sup>

### Study Quality

Criteria for the assessment of study quality used in a recent review of mediators of physical activity change were modified for the purpose of this review.<sup>27</sup> A quality score was computed for each study included in this review by summing responses (yes = 1; no = 0) to 9 questions: (1) Did the

study cite a theoretical framework? (2) Did the study use an experimental design? (3) Were all 3 essential steps for testing the validity of a theory of behavior change performed? (4) Were the psychometric characteristics of the outcome measure reported, and were they within acceptable ranges (ie, test-retest reliability or Cronbach  $\alpha > 0.60$ )? (5) Were the psychometric characteristics of the mediator variables reported, and were they within acceptable ranges? (6) Were the study methods/procedures designed to influence mediating variables? (7) Did the study report a power calculation, and was the study powered to detect mediation? (8) Were statistically appropriate/acceptable methods of data analysis used? (9) Did the study ascertain whether changes in the mediating variables preceded changes in the outcome variables? Studies scoring 0-3 were classified as low-quality studies, those scoring 4-6 as medium quality, and studies that scored 7-9 as high quality.

## RESULTS

### Study Characteristics and Quality

A total of 713 potential relevant articles were identified using literature searches, of which 11 were eligible for review after exclusionary criteria were applied. Of these remaining studies, 4 were subsequently excluded because the authors did not perform an analysis of mediators (2 studies), dietary behavior change was not the outcome (1 study), or participants were young adults (over 18 years; 1 study). Hence, 7 experimental or quasi-experimental studies (behavioral interventions) testing hypothetical mechanisms of dietary behavior change in youth were reviewed.<sup>17-21,28,29</sup>

All 7 interventions were school based. Four were conducted in the US,<sup>18,20,21,29</sup> 2 in the Netherlands,<sup>17,28</sup> and 1 in Belgium.<sup>19</sup> Four studies targeted secondary-school students,<sup>17-19,29</sup> whereas the others focused on primary-school children.<sup>20,21,28</sup> All interventions—with the exception of 1, which was a quasi-experimental study<sup>28</sup>—were RCTs with school-level randomization. The study sample size ranged from 522 to 1676 students (Table 2).

The shortest post-baseline assessment period was 7 weeks, and the longest 2 years. Studies examined different dietary outcomes and used different types of instruments to assess them (scales, food frequency questionnaires, and 24-hour dietary recalls). Some studies were grounded on a single theory—namely, the Social Cognitive Theory.<sup>30</sup> Other studies were polytheoretical and based on 1 or a combination of the following theories: Transtheoretical Model<sup>31</sup>; Theory of Planned Behavior<sup>32</sup>; Habit Strength Theory<sup>33</sup>; the Dual-Process Theory<sup>34</sup>; and the Health Belief Model.<sup>35</sup> Two studies<sup>18,28</sup> tested potential theoretical mediators of dietary behavior change using Baron and Kenny's approach,<sup>26</sup> 2 studies<sup>19,24</sup> used the product-of-coefficient test,<sup>24,25</sup> and the remaining studies employed a combination of the 2.<sup>17,20,21</sup> Six studies examined multiple mediators.<sup>17-21,29</sup> However, only 4 of them conducted both single- and multiple-mediator analyses.<sup>19-21,29</sup>

The quality of studies ranged from medium to high (Table 2). All interventions except for one<sup>27</sup> were explicitly based on at least 1 theoretical framework and used an experimental design. All studies included methods/procedures to influence the hypothesized mediators of dietary behavior change, but only 2 of them reported power calculations related to testing mediated effects.<sup>19,29</sup> All, with the exception of 1 study,<sup>18</sup> tested both action and conceptual theories conjointly with performing a mediation analysis. Only 2 studies reported the reliability of both outcome and mediator measures,<sup>19,29</sup> although the reliability of a mediator measure in 1 of these studies was unacceptably low.<sup>19</sup> The statistical methods used were generally appropriate. However, Reynolds and colleagues did not adjust their analyses for school clustering effects, which might have affected the reliability and accuracy of their findings.<sup>20,21</sup> Importantly, no study evaluated whether changes in the mediator(s) preceded changes in the outcome(s).

### Study Findings

*Tests of action theory links.* Table 3 reports the results of action theory tests, that is, whether there were

**Table 2.** Characteristics of Interventions Examining Potential Mediators (Mechanisms) of Dietary Behavior Change in Youth

Study (quality of study: score)	Sample	Theory	Assessments	Outcome Variables (reliability)	Mediators Tested (reliability)
Chin A Paw et al <sup>17</sup> (medium: 6)	18 schools 854 students Age = 12.7 ± 0.5 y	TPB, HST, DPT	Baseline; 8 months post-baseline	Soft drinks and high-caloric snack consumption – FFQ (NR)	Attitude ( $\alpha = 0.72-0.94$ ) Subjective norms ( $\alpha = 0.79-0.89$ ) Perceived control ( $\alpha = 0.80-0.91$ ) Habit ( $\alpha = 0.82-0.96$ )
Dzewaltowski et al <sup>18</sup> (medium: 5)	16 schools 1582 students Age = 12.0 ± 0.4 y	SCT	Baseline; 1 and 2 y post-baseline	F&V – from 24-h dietary recall ( $r = 0.54$ )	Self-efficacy (NR) Proxy efficacy–school (NR) Proxy efficacy–parents (NR) Group norm (NR)
Haerens et al <sup>19</sup> (high: 7)	15 schools 788 girls Age = 12.9 ± 0.8 y	TTM, TPB, SCT	Baseline; 1 y post-baseline	Fat intake – FFQ ( $r = 0.86$ )	Attitude ( $\alpha = 0.83$ ) Self-efficacy ( $\alpha = 0.38$ ) Social support ( $\alpha = 0.71$ ) Perceived benefits ( $\alpha = 0.83$ ) Perceived barriers ( $\alpha = 0.85$ )
MacKinnon et al <sup>29</sup> (high: 8)	31 schools 1506 football players Age = 15.8 y ± NA	SCT, TBP, HBM	Baseline; 7 wk and 1 y post-baseline	Dietary behavior – scale ( $\alpha = 0.81$ )	Team norms ( $\alpha = 0.76-0.82$ ) Peer norms ( $\alpha = 0.84-0.88$ ) Belief in media ( $\alpha = 0.75-0.81$ )
Reynolds et al <sup>20</sup> (medium: 4)	2 sites; 28 and 20 schools 1584 fourth-graders Age = 8.7 ± 0.6 y 522 fourth-graders Age = 10.0 ± 0.4 y	SCT	Baseline; 1 y post-baseline	F&V – from 24-h dietary recall (NR)	Knowledge (NR) Parental consumption (NR) Availability ( $\alpha = 0.69$ )
Reynolds et al <sup>21</sup> (medium: 4)	28 schools 1676 fourth-graders Age = 8.7 ± 0.6 y	SCT	Baseline; 1 and 2 y post-baseline	F&V – from 24-h dietary recall (NR)	Availability ( $\alpha = 0.69$ ) Eating meals together (NR) Knowledge ( $\alpha = 0.23$ ) Positive outcome expectancy ( $\alpha = 0.67$ ) Parent consumption (NR) Self-efficacy ( $\alpha = 0.86$ ) Family norms ( $\alpha = 0.62$ ) Peer norms ( $\alpha = 0.79$ ) Teacher norms ( $\alpha = 0.84$ ) Project appreciation (NR)
Tak et al <sup>28</sup> (medium: 4)	5 sites; 45 schools 771 children Age = 10.0 ± 0.5 y	Not stated	Baseline; 1 and 2 y post-baseline	F&V – FFQ ( $r = 0.70$ )	

$\alpha$  indicates Cronbach  $\alpha$ ; DPT, Dual-Process Theory; F&V, fruits and vegetables; FFQ, food-frequency questionnaire; HBM, Health Belief Model; HST, Habit Strength Theory; NR, not reported;  $r$ , test-retest reliability coefficient; SCT, Social Cognitive Theory; TPB, Theory of Planned Behavior; TTM, Transtheoretical Model.

significant intervention effects on the potential mediators. Although the examined interventions were supposedly designed to affect theoretical mediators of behavior change, they were not particularly successful in doing so. Only 22 out of 56 intervention effects on mediators were significant. Three of these effects were in the opposite direction to those expected (perceived barriers,<sup>19</sup> self-efficacy,<sup>18</sup> family

norms<sup>21</sup>). The Dutch Obesity Intervention in Teenagers was the only study that targeted and affected habits related to specific dietary behaviors.<sup>17</sup> However, this effect was limited to soft drink consumption in boys. All interventions aimed at changing subjective or group norms were in part<sup>17,21</sup> or consistently successful<sup>18,29</sup> in doing so. The partial success of 2 interventions depended on the

dietary outcome,<sup>17</sup> child's sex,<sup>17</sup> reference group,<sup>21</sup> and the time of assessment.<sup>21</sup> Among the studies that targeted self-efficacy and similar constructs (eg, perceived control) as mediators,<sup>17-19,21</sup> only the Healthy Youth Places study yielded significant intervention effects,<sup>18</sup> however, in the opposite direction to that desired. Interventions failed to change availability of fruits and vegetables,<sup>20,21</sup>

**Table 3.** Results of Theory Testing in Intervention Studies Designed to Promote Healthful Eating Among Youth

Study	Mediators	Action Theory Test	Conceptual Theory Test	Mediated Effect
Chin A Paw et al <sup>17</sup> (outcome: soft drinks; subsample: girls) <sup>a</sup>  (outcome: soft drinks; subsample: boys)  (outcome: high- energy snacks; subsample: girls)  (outcome: high- energy snacks; subsample: boys)	Attitude	NS	-	NS
	Subjective norms	NS	NS	NS
	Perceived control	NS	-	NS
	Habit	NS	+	NS
	Attitude	+	-	Mediator
	Subjective norms	NS	NS	NS
	Perceived control	NS	-	NS
	Habit	-	+	Mediator
	Attitude	NS	-	Not tested
	Subjective norms	NS	NS	because intervention effect
	Perceived control	NS	-	on snack consumption
	Habit	NS	+	was not significant
Dzewaltowski et al <sup>18</sup> (outcome: F&V) <sup>a</sup>	Attitude	NS	-	Not tested
	Subjective norms	+	NS	because intervention effect
	Perceived control	NS	-	on snack consumption
	Habit	NS	+	was not significant
	Self-efficacy	-	Not tested	NS
	Proxy efficacy - school	NS	because the intervention effect on F&V consumption was not significant	NS
Haerens et al <sup>19</sup> (outcome: fat intake) <sup>b</sup>	Proxy efficacy - parents	NS	NS	NS
	Group norm	+	NS	NS
	Attitude	NS	- (-)	NS (NS)
	Self-efficacy	NS	NS (NS)	NS (NS)
	Social support	NS	NS (NS)	NS (NS)
	Perceived benefits	NS	NS (NS)	NS (NS)
MacKinnon et al <sup>29</sup> (outcome: healthful eating; period: baseline to post-test) <sup>b</sup> (period: baseline to 1 yr follow-up)	Perceived barriers	+	NS (NS)	Suppressor (NS)
	Peer norms	+	+	Mediator (Mediator)
	Team norms	+	+	Mediator (Mediator)
	Belief in media	-	NS (+)	NS (Suppressor)
	Peer norms	+	+	Mediator (Mediator)
	Team norms	+	+	Mediator (Mediator)
Reynolds et al <sup>20</sup> (outcome: F&V intake; subsample: site 1) <sup>b</sup>	Belief in media	-	NS (+)	NS (Suppressor)
	Knowledge	+	+	Mediator (Mediator)
	Parental consumption	NS	NS (NS)	NS (NS)
	Availability	NS	NS (NS)	NS (NS)
	Knowledge	+	NS (NS)	NS (NS)
	Parental consumption	NS	NS (NS)	NS (NS)
Reynolds et al <sup>21</sup> (outcome: F&V intake; period: baseline to 1 yr post-baseline) <sup>b</sup>	Availability	NS	NS (NS)	NS (NS)
	Eating meals together	NS	NS (NS)	NS (NS)
	Knowledge	+	NS (NS)	NS (NS)
	Pos. outcome expectancy	+	+	Mediator (NS)
	Parent consumption	NS	NS (NS)	NS (NS)
	Self-efficacy	NS	+	NS (NS)
	Family norms	NS	NS (NS)	NS (NS)
	Peer norms	NS	NS (NS)	NS (NS)
	Teacher norms	+	NS (NS)	NS (NS)

(continued)

Table 3. Continued

Study	Mediators	Action Theory Test	Conceptual Theory Test	Mediated Effect
(outcome: F&V intake; period: baseline to 2 y post-baseline)	Availability	NS	NS (NS)	NS (NS)
	Eating meals together	NS	NS (NS)	NS (NS)
	Knowledge	+	+(NS)	NS (NS)
	Positive outcome expectancy	+	NS (NS)	NS (NS)
	Parent consumption	+	+(+)	NS (NS)
	Self-efficacy	NS	NS (NS)	NS (NS)
	Family norms	-	NS (NS)	NS (NS)
	Peer norms	NS	NS (NS)	NS (NS)
	Teacher norms	NS	NS (NS)	NS (NS)
Tak et al <sup>28</sup> (outcome: F&V)	Project appreciation	+	+	Mediator

F&V indicates fruits and vegetables; -, negative; NS, not significant; +, positive.  
<sup>a</sup>Only single-mediator models tested; <sup>b</sup>Single- and multiple-mediator models tested. Results of multiple-mediator models are in parentheses.

social support,<sup>19</sup> and eating together in families.<sup>21</sup> In 1 of 4 instances, there was a positive impact on parental consumption of fruits and vegetables, whereas attempts to increase knowledge about the daily recommended amounts of fruits and vegetables were consistently successful.<sup>20,21</sup> Positive intervention effects on outcome expectancies and similar concepts (perceived benefits and attitude) were observed in two<sup>17,21</sup> of the 3 studies that measured them.<sup>17,19,21</sup> Intervention effects on attitudes were dependent on the child's sex and dietary outcome in 1 study.<sup>17</sup> One study reported a positive intervention effect on children's appreciation of the program.<sup>28</sup>

**Test of conceptual theory links.** A test of the conceptual theory link is concerned with evaluating whether a mediating variable affects the outcome variable according to the adopted theoretical framework. No support was found for a relationship of changes in social support,<sup>19</sup> availability of food,<sup>20,21</sup> eating meals together,<sup>21</sup> and perceived barriers<sup>19</sup> with changes in dietary behaviors. Some support was found for knowledge about a healthful diet and parental consumption in primary-school children<sup>20,21</sup> and for group norms in secondary school children.<sup>29</sup> Changes in perceived control and self-efficacy were somewhat consistently related

to changes in dietary behavior.<sup>17,20,21</sup> However, the strongest support was found for the constructs of habit<sup>17</sup> and attitudes/positive outcome expectancies.<sup>17,19,21</sup>

#### Test of mediated intervention effect.

The study conducted by Tak et al was the only intervention not to be based on a specific theoretical framework.<sup>28</sup> These authors found that appreciation of the project partly mediated the effect of the intervention on fruit intake (Table 3). Other, theory-based interventions reported very few significant mediators of intervention effects. In the multisite intervention by Reynolds et al,<sup>20</sup> these mediators were knowledge at 1 site, and positive outcome expectancies at the other site (Table 3). However, only knowledge remained a significant mediator of the intervention effect after adjustment for other potential mediators. Increases in positive attitude toward reducing soft drink consumption and decreases in habitual consumption of soft drinks explained the positive effects of an intervention on reduction in soft drink consumption in boys, but not in girls.<sup>17</sup> In the study by Haerens et al, perceived barriers acted as a suppressor of the intervention effect, that is, the intervention led to an increase in perceived barriers, which in turn reduced the intervention's effectiveness on fat intake.<sup>19</sup> However, this suppressor effect was

not present in the multiple-mediator models, and thus could have been due to the action of confounders. Peer and team norms were significant mediators of intervention effects on changes in healthful eating behavior, whereas beliefs in media were found to suppress the intervention effects in a group of high school football players.<sup>29</sup>

## DISCUSSION

One of the main aims of this paper was to review the evidence for the validity of theoretical mechanisms of dietary behavior change in youth, based on data from experimental and quasi-experimental intervention trials. Only 7 such published trials were identified. Studies differed in their theoretical framework; populations (age groups and sex); outcomes (eg, soft drink, fruit and vegetable, and fat intake); type of measures (food frequency questionnaires, 24-hour questionnaire, and dietary behavior scales); and methods of mediational analysis employed. Also, findings differed within the same studies across sites and sexes. Hence, conclusions are difficult to draw.

A certain level of consistency between and/or within studies was found for self-efficacy/perceived control, outcome expectations/attitude, and habit as being positively related to behavior change. These constructs

also emerged as important correlates of dietary behavior in adults<sup>9</sup> and children<sup>15,36-38</sup> in nonexperimental studies. Although cross-sectional and nonexperimental longitudinal studies also consistently identified knowledge,<sup>9,36,38,39</sup> social support,<sup>9,37</sup> modeling,<sup>14,37-39</sup> and availability of food<sup>36,38,39</sup> as potential determinants of dietary behavior change, the small number of interventions reviewed in this report provided insufficient or no support for the predictive validity of these constructs. Similar to previous reports,<sup>9,36</sup> subjective/group norms were inconsistently related to dietary behavior change. In summary, evidence from this review and other experimental and nonexperimental studies<sup>9,14,36-38</sup> suggests that interventions aimed at changing dietary behavior in youth should target self-efficacy, habit, and outcome expectations, which are key constructs of the Social Cognitive Theory<sup>30</sup> and the Theory of Planned Behavior.<sup>32</sup> The concordance in findings across different populations and research paradigms suggests that these constructs are important and reliable mechanisms of dietary behavior that can be changed using extant intervention programs. It is, however, premature to draw conclusions on the validity of other theoretical determinants of dietary behavior change in youth due to the small number of available RCTs and the use of less than optimal measures of mediators. For example, the fact that nonexperimental studies generally point at a connection of dietary behavior with knowledge,<sup>9,36,38,39</sup> social support,<sup>9,37</sup> and food availability,<sup>36,38,39</sup> but the reviewed RCTs failed to detect such connections may be due to using measures that are not sufficiently reliable to be sensitive to change.<sup>24,25</sup> Hence, although the findings of this review emphasize the need for further accumulation of good-quality, experimentally based evidence, they do not disprove the importance of these potential mediators in changing dietary behavior.

Applied researchers often find theories of dietary behavior change unhelpful because they do not explain how to modify the constructs of a theory.<sup>40,41</sup> As a result, the specification of procedures for changing mediators is often based on "intuition" and in-

volves a combination of techniques, which hinders the identification of what works and what does not.<sup>10,41</sup> This common practice may partly explain why the reviewed interventions were not particularly successful in evoking statistically significant changes in the mediators. Furthermore, it is important to note that the effectiveness of interventions targeting multiple behaviors depended on the dietary outcome, child's sex, time of assessment, and reference group. This finding suggests that procedures targeting mediators of change may need to be highly specific and tailored to particular outcomes and demographic groups. The current intuitive approach to the specification of procedures capitalizes on chance and, therefore, is not helpful in establishing strategies for the modification of mechanisms of dietary behavior change. A clear and detailed theory-based taxonomy of change procedures for diverse demographic groups, dietary outcomes, and intervention-delivery channels is needed.<sup>10,41</sup> In this regard, Michie and Abraham suggested that change procedures should be identified using rigorous experimental studies assessing the effects of single, and combinations of, techniques delivered through different channels and applied to various target populations.<sup>41</sup> Additionally, intervention reports should provide a detailed description of the techniques employed so that they can be exactly replicated and cross-validated.

Given that interventions were largely unsuccessful in changing the selected theoretical constructs, it is not surprising that very few mediators of dietary behavior change were reported. These mediators were attitude/outcome expectancies, knowledge, habit, project appreciation, and group norms. However, only attitude/outcome expectancies were identified as mediators in multiple interventions, age groups, and dietary outcomes. Interestingly, although Reynolds and colleagues found that the intervention had a positive effect on knowledge and parent consumption of fruits and vegetables, and changes in these potential mediators were associated with changes in fruit and vegetable intake (after controlling for the intervention effect),<sup>21</sup> the mediating effects of knowledge and

parent consumption were not statistically significant. This finding is likely due to the use of Sobel's test to establish mediation, which is conservative.<sup>25</sup> The use of resampling techniques, such as bootstrapping,<sup>42</sup> might have provided more power to detect mediating effects.<sup>24,25</sup>

In 2 cases, hypothesized mediators acted as suppressors, that is, they had a negative influence on the intervention.<sup>19,29</sup> In MacKinnon's study,<sup>29</sup> the suppression effect was caused by an unexpected effect of changes in belief in media on changes in healthful eating, that is, a failure of the conceptual theory. In the study by Haerens et al,<sup>19</sup> the intervention yielded an increase rather than a decrease in the level of perceived barriers to a low-fat diet (action theory failure). This suppression effect might have been the result of a recalibration of the measure of barriers by participants becoming more realistic about obstacles to keeping a low-fat diet in the course of the intervention.<sup>19,41,43</sup> Recalibration of measures of mediators might have also partly precluded the detection of mediated effects in the study by Chin A Paw et al,<sup>17</sup> in which psychosocial factors regarding changing rather than executing specific dietary behaviors were assessed. In such an instance, as behavior changes across an intervention, the interpretation of items gauging attitudes for changing a behavior is also bound to change because it refers to different levels of behavior. As demonstrated in a recent article by Baranowski and colleagues,<sup>43</sup> sophisticated psychometric procedures are now available to study eventual recalibration of items along a latent variable (measured construct). These procedures can assist the development of reliable self-report measures of mediators of dietary behavior sensitive to change.

The main strengths of the studies reviewed in this paper, with 1 exception,<sup>28</sup> are the experimental design (randomized controlled trial) and the "attempted" adoption of a theory-based approach. Most studies were limited by the use of outcome and mediator measures with unknown or unacceptable psychometric properties, the lack of power calculations, unclear theoretical links between procedures of behavior change and targeted

mediators, and a suboptimal approach to theory validation and testing of mediated effects. Although all the reviewed studies examined the effect of the intervention on the mediators, an evaluation of the conceptual theory link was sometimes missing as a result of not finding a significant intervention effect on a dietary outcome.<sup>18</sup> However, results of tests of action and conceptual theories should always be reported, regardless of whether a significant intervention effect on the outcome is observed, because they can help identify sources of methodological or substantive problems and can guide action and conceptual theory refinement. Similarly, the absence of a significant intervention effect should not discourage the evaluation of potential mediators of dietary behavior change. It is possible for an intervention effect to be channeled through multiple pathways whose influences are of opposite direction and cancel out.<sup>24</sup> For example, MacKinnon and colleagues found that although the group norm mediated the effects of an intervention on changes in healthful eating, belief in media had the opposite effect.<sup>29</sup> Fortunately, in this case, the 2 effects did not cancel out.

Another major methodological limitation of studies reviewed in this paper is the failure to assess whether changes in the mediators preceded changes in dietary intake, an important criterion of mediation.<sup>13</sup> In some instances, it would have been plausible to hypothesize that changes in dietary behavior would cause changes in the mediator. Specifically, according to Bandura's social cognitive theory,<sup>30</sup> the observed association of self-efficacy with dietary behavior may result from reciprocal effects. In other words, changes in self-efficacy may lead to changes in dietary behavior and vice versa. It is thus important that RCT evaluating mediating mechanisms include more than 2 assessments of both mediators and outcome variables. Such an approach can clarify the direction of causal effects and, hence, mechanisms of change.

Most theories hypothesize the existence of multiple mechanisms of behavior change, leading to the development of interventions that target multiple mediators. In such

cases, it is necessary to conduct single-mediator analyses as well as simultaneously test multiple mediators, as illustrated in 4 studies included in this review.<sup>19-21,29</sup> Limiting the analyses to testing single mediators is not particularly useful, as doing so hinders the identification of suppressors and redundant mediators that may unduly increase the cost of an intervention.<sup>24,25</sup> Additionally, single-mediator models do not provide a valid test of multiple-mediator theories because they do not assess the independent contribution of each targeted mediator to the explanation to the intervention effect, although the theory usually postulates the existence of such independent effects.<sup>36</sup>

When possible, it is important to communicate the magnitude of the mediated effect, ie, the amount of the intervention effect attributable to changes in the mediator. This communication can be done by computing the product of 2 regression coefficients: the first represents the magnitude of the intervention effect on the mediator (action-theory effect), and the second represents the amount of change in dietary outcome per unit change in the mediator conditional on the experimental condition (conceptual-theory effect). When possible, mediated effects should be presented in the original metric of the dietary outcome (eg, grams of fat or fruit servings per day), as this information is helpful in evaluating the practical and clinical significance of a mediator. A report of mediated effects should also be accompanied by their 95% confidence intervals, thereby providing information on the plausible values of the mediated effect in the target population.<sup>24</sup> Only 4 out of 7 reviewed studies reported mediated effects and their 95% confidence intervals in the original outcome metric.

In summary, not much is known about the mechanisms underlying dietary behavior change in youth. Even less is known about how to affect potential mechanisms of behavior change. The lack of published experimental studies reporting information that can be used to identify effective theories and mediators of dietary behavior in children and adolescents is likely due to a failure to produce inter-

vention effects in the mediators; a failure to detect significant associations between mediators and dietary outcomes (null findings); and the misconception that significant intervention effects are an essential condition for mediation to occur.<sup>24</sup> Although the last problem is easily addressable, the first 2 require considerable efforts directed toward the development of more reliable and valid measures of dietary outcomes and their mediators<sup>36</sup>; the careful planning of theory-based interventions following CONSORT criteria<sup>44</sup>; and the development of a comprehensive, theory-based taxonomy of change procedures diversified by demographic groups, dietary outcomes, and intervention-delivery channels. It is also important for intervention trials to perform and report mediating variable analyses, even in the presence of null findings. The authors know a number of mediating variable studies were not submitted for publication because they showed no effects. This finding makes it impossible to obtain a balanced (unbiased) picture of effective theoretical frameworks and strategies for dietary behavior change in youth. Lastly, it is essential to identify factors and mechanisms that facilitate the translation of behavior-change research evidence into effective delivery and dissemination of programs in practice.<sup>11</sup> Needless to say, a considerable amount of work remains to be done.

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