

A Systematic Review of Randomized Trials on the Effectiveness of Computer-Tailored Education on Physical Activity and Dietary Behaviors

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ABSTRACT

Background: Although computer-tailored promotion of dietary change and physical activity has been identified as a promising intervention strategy, there is a need for a more systematic evaluation of the evidence. **Purpose:** This study systematically reviews the scientific literature on computer-tailored physical activity and nutrition education. **Methods:** Intervention studies published from 1965 up to September 2004 were identified through a structured search in PubMed, PsycInfo, and Web of Science and an examination of reference lists of relevant publications. Studies were included that applied a pretest–posttest randomized-controlled trial design, were aimed at primary prevention among adults, used computer-tailored interventions to change physical activity and dietary behaviors, and were published in English. The search resulted in 30 publications—11 on physical activity behaviors and 26 on nutrition behaviors, some studies investigated multiple behaviors. **Results:** Three of 11 of the physical activity studies and 20 of 26 of the nutrition studies found significant effects of the tailored interventions. The evidence was most consistent for tailored interventions on fat reduction. **Conclusions:** Overall, there seems to be potential for the application of computer tailoring for promoting healthy diets, but more research is needed to test computer-tailored interventions against other state-of-the-art intervention techniques and to identify the mechanisms underlying successful computer tailoring.

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INTRODUCTION

Physical activity and nutrition are related to important burdens of disease (1,2) such as obesity (3), cardiovascular diseases

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(4), diabetes mellitus, and cancer (5). Large proportions of the populations of many countries worldwide engage in too little physical activity (6–8) and have undesirable eating habits, such as high intakes of energy, salt, and saturated fat, and low intakes of fruits, vegetables, and fiber (9,10). Therefore, there is a need for effective intervention strategies to motivate people to adopt healthier diets and to increase physical activity.

Many such attempts have been made (11–13), but not all have been successful. One promising intervention strategy is computer-tailored health education. In computer tailoring, a number of important characteristics of interpersonal counseling are mimicked without the necessity of face-to-face contact (14). The diagnostic assessment necessary for personal feedback is done by means of written or electronic questionnaires and personalized feedback is provided in, for example, personal letters or on computer screens. Detailed descriptions of the development of computer-tailored information can be found elsewhere (14–17).

Because the expertise of the counselor, or in fact the pooled expertise of many counselors as well as the underlying behavior-change theories, is documented in a computerized expert system, computer tailoring enables personalization of health education without the high costs of interpersonal counseling. Computer-tailored physical activity and nutrition education provides people with individualized feedback and advice on personal performance levels (i.e., activity or intake), and awareness of their own performance, as well as personal motivation to change, goals, outcome expectations, subjective norms, self-efficacy, and other possible behavioral determinants (14,17). It has been argued that computer-tailored health education may be especially suited to promote physical activity and dietary changes, because people often lack personal awareness of performance levels for these complex health behaviors (18,19). Computer tailoring enables easy and valid self-assessment and comparison of one's own performance to recommendations or peer group performance levels.

It is considered a promising health education strategy not only because of the features of computer tailoring mentioned earlier but also because of its applicability in electronic nonprint media (like the World Wide Web or computer kiosks), enabling wide distribution with relatively low cost (15,20).

Although computer-tailored promotion of dietary change and physical activity has been identified as a promising intervention strategy (21–23), there is a need for a more systematic evaluation of evidence for the effectiveness of this intervention approach. This study, therefore, systematically reviews the scientific literature on expert-driven computer-tailored physical activity and nutrition education.

METHODS

We developed and used a study protocol based on guidelines extracted from the Cochrane Reviewers' Handbook (24). In the study protocol, the procedures to identify primary studies based on eligibility criteria, and relevant study and intervention characteristics, were made explicit. Willemieke Kroeze and Andrea Werkman independently reviewed the articles and extracted general information on objectives, design, intervention characteristics, and outcomes. Disagreements were discussed with Johannes Brug until consensus was reached.

Search Strategy and Data Sources

Intervention studies published from 1965 up to September 2004 were identified through a structured electronic database search in PubMed, PsycInfo, and Web of Science.

The following search strings were used for interventions on nutrition: (((nutrition OR feeding OR food OR diet OR dietary OR intake) AND (education OR behavior OR behavio*)) OR feeding behavior OR food consumption) AND (tailored OR tailoring OR tailor* OR expert system); for physical activity, ((exercise OR motor activity OR leisure activities OR physical activity OR physical activit*) AND (education OR behavior OR behavio*) AND (tailored OR tailoring OR tailor* OR expert system)). These search strings were further limited to the adult age (18 years and older). Furthermore, reference lists of relevant publications that were found through the computerized searches were examined.

Selection of Studies

For inclusion in this review, the studies had to examine a computer-tailored intervention aimed at physical activity or nutrition behaviors in primary prevention. *Primary prevention* was defined as the initiation of lifestyle or behavioral changes to prevent the onset of chronic diseases in apparently healthy participants. Only randomized controlled trials with pretest and posttest were included. Furthermore, this review is restricted to studies among adults and to publications in the English language.

We used the definition suggested by Kreuter, Strecher, and Glassman (14): Tailored materials are “intended to reach one specific person, are based on characteristics that are unique to that person, are related to the outcome of interest, and have been derived from an individual assessment” (p. 276). We did not include studies that evaluated targeted generic materials, defined as “intending to reach some specific subgroup of the general population usually based on one or more demographic characteristics shared by its members” (p. 276). We considered

studies computer tailored if the tailored advice was generated through a computerized process. Furthermore, the information had to be delivered in a “nonpersonal” way (printed format, direct interaction with computer, or other media device) without person-to-person interference of a counselor.

Studies that tested the tailored intervention as part of a larger generic strategy or combined it with interpersonal counseling in a research design that made it impossible to isolate the effect of tailoring in the analysis were excluded.

Data Extraction

Detailed information was extracted only from studies that met the aforementioned inclusion criteria. Willemieke Kroeze and Andrea Werkman independently summarized the studies for content and methods. We extracted intervention and study characteristics as well as effect indicators.

Specific intervention characteristics that have been identified previously by health education experts as being associated with behavior change (through computer tailoring) interventions were extracted (15,17,25). These characteristics included theories used for intervention development, the variables that were used to tailor the computer-tailored information, the feedback tool, the frequency of feedback, and health-education activities that were provided next to the computer-tailored intervention.

To review the characteristics of the evaluation studies, we extracted the following information: the country where the study was conducted, size and source of the study population, eligibility criteria, comparison group, the primary outcome measures, and follow-up period.

Finally, to interpret and compare results from different outcome measures better, we calculated effect sizes (ESs) when data were available according to the formula suggested by Cohen (26) and applied by Dolan and colleagues (27). ESs were interpreted according to Cohen's guidelines (26), with cutoff points of 0.2 to 0.5 for small ES, 0.5 to 0.8 for moderate ES, and > 0.8 for large ES.

Measurement periods were divided into three categories: short term (< 3 months), medium term (3–6 months), and long term (> 6 months). When two measurements within one defined category were included in one study, only the results of the last measurement in that category were included in this review. We summarized the main findings separately for physical activity for the two categories of dietary behavior that have been addressed most often in computer-tailoring studies (i.e., fat intake and fruit and vegetable consumption) and for remaining dietary topics less frequently addressed.

Reviewers were not blinded to authorship, journal, or other information in the study, but assessment of publications was done based on criteria defined a priori. The heterogeneity of the included studies hindered the pooling of data. Our findings, therefore, resulted in a descriptive systematic literature review. Studies varied, among others, in recruitment method, characteristics of the study population, time frame, setting, measurement of effects, and intervention goals.

RESULTS

Study Selection

The initial cross-database search yielded 693 publications. After eliminating duplicates and reviewing the titles and abstracts of all these publications, the total was reduced to 72. Checking references in these articles identified another 24 references, and 2 were brought up by colleagues. After completely reviewing the 98 articles, 68 publications were excluded because they did not meet one or more of the inclusion criteria. Almost half of the excluded publications turned out not to be effect evaluation studies of computer tailoring: either they were design articles or theoretical articles or just recommended tailoring of health education in their Discussion section. Other important reasons for exclusion were that the intervention was group targeted rather than individually tailored or that the intervention was not fully computerized. Finally, some studies applied a computer-tailored intervention in a package with several other educational strategies that hampered the isolation of the tailoring effect. Definite inclusion in the review followed after agreement among all authors about meeting the inclusion criteria. Thus, 30 publications were included: 11 on physical activity behaviors and 26 on dietary behaviors. Two of these publications were on a single physical activity study (28,29), and 2 publications were on the same weight-loss study (30,31). In several publications, more than one behavior of interest for this review was addressed.

Data Extraction

The characteristics of the reviewed tailored interventions are summarized in the next paragraph. An extensive table with a detailed overview of the intervention characteristics can be obtained from Willemieke Kroze or from the Web site (http://mgzlx4.erasmusmc.nl/intern_scripts/pwp?wkroeze). The study characteristics and results are shown in the Appendix. The results and characteristics of studies on physical activity can be found in section A of the Appendix. Within the diet category, a further distinction was made between studies aimed at fat reduction (section B, Appendix), studies aimed at fruit and vegetable promotion (section C, Appendix), and other diet-related studies (section D, Appendix). Finally, we explored differences in the effects of single-component interventions studies versus multiple component interventions in Table 1.

Intervention characteristics. Eleven studies investigated a computer-tailored intervention aimed at promoting physical activity (28–38), 20 studies at decreasing fat intake (30,33–36,39–52), and 14 at effects on increasing fruit and vegetable intake (33,39–44,47,50–55). Five studies dealt with fiber intake (39,50–52,56), 1 with calcium intake (32), and 2 with weight loss (31,36). Many of these studies investigated interventions that addressed more than one health behavior, especially combinations of dietary behaviors.

The interventions used in the studies were sometimes similar and closely related. For example, Bock et al. (28) and Marcus et al. (29) reported on the same intervention, and the same evalu-

ation study, but on different measurement periods. The study reported by De Bourdeaudhuij and Brug (45) was based on the intervention reported by Brug et al. (40) but was adapted for use in a Belgian population. Furthermore, the intervention reported by Brug et al. (41) was very similar to their 1996 intervention (40) but was enriched with a second follow-up computer-tailored feedback tool. Anderson and colleagues (39) and Winett et al. (52) both used the same intervention, which was an adapted version of the interventions used by Winett and colleagues in different studies in the late 1980s and early 1990s (49–51). Most of the interventions were explicitly informed by one or more behavioral theories. The Transtheoretical Model (57), Social Cognitive Theory (58), and the Theories of Reasoned Action and of Planned Behavior (59) were used most often.

All interventions gave tailored feedback on the current behavior of the respondents. One physical activity intervention (32) and five of the dietary interventions (32,40,41,45,55) provided feedback on the participant's awareness of own performance. Most interventions also gave feedback on intentions (stage of change or readiness to change) and self-efficacy. Furthermore, variables like knowledge, outcome expectations, and benefits and barriers of changing a behavior were used for providing further tailored information.

Almost all interventions were delivered by means of computer-tailored letters, pamphlets, or brochures. Two physical activity studies (35,36) and nine dietary interventions (35,36,39,44,47,50,52,55,60) used computers not only to generate the messages but also to deliver the tailored information, often with the possibility of an additional printout. Four of these computer-delivered interventions used multimedia (text and video) (44,47,52,60). None was implemented through the Internet.

Most interventions used single contacts, that is, one tailored letter, brochure, or interactive feedback moment. Five of the physical activity intervention studies used multiple feedback, ranging from 2 (32) to 4 (28,29,33). In the fifth study (36), the respondents determined the frequency of feedback moments themselves, however, the mean or range of feedback frequency was not reported. Thirteen of the dietary-change studies used multiple feedback, ranging from 2 (32,41,44,46) to 15 (39).

Study characteristics. Most of the studies were conducted in the United States, three in The Netherlands, two in Belgium, two in the United Kingdom, and one in Australia. Study populations usually consisted of healthy volunteers without a prescribed diet, recruited from the general population through worksites or through health-maintenance organizations and general practices. Study population size varied from 84 to 1,317 participants.

Three studies promoting physical activity recruited only sedentary respondents (28,29,37), whereas two studies were specifically aimed at participants who were overweight (30,36). Age (32) and motivational stage (37) were further eligibility criteria used in the physical activity promotion studies. Some of the fat-reduction studies also used additional eligibility criteria such

as income (60), gender (32,44), ethnicity (33,43), household characteristics (45,51), health behaviors (46), or body-weight status (30,36). Three of the fruit and vegetable promotion interventions had specific eligibility criteria, such as age (53), gender (44), and ethnicity (33,43).

Effects on physical activity (section A, Appendix). Physical activity was measured with different questionnaires, varying in length from 3 to 31 items. In about half the studies, the use of validated questionnaires was explicitly mentioned.

Three studies looked at short-term effects (29,30,37); one found a significant tailoring effect (29). Five studies assessed medium-term effects (29,32,35,37,38); two studies reported significant differences in favor of the tailored intervention for respondents who were not physically active at baseline (29,35). However, effects in favor of the control group were also found (32,35). Six studies conducted long-term measurements (28,32–34,36,37); one found a significant effect of tailoring with a small ES.

Effects on fat consumption (section B, Appendix). Almost all studies measured fat consumption with a validated food frequency questionnaire (FFQ). Many of the studies conducted in the United States used the FFQ developed by Block and colleagues (61), all studies conducted in The Netherlands used the FFQ designed by Van Assema and colleagues (62,63), and the three studies conducted in Belgium used an adapted version of the FFQ developed by Feunekes et al. (64), which was further validated for use in a Belgian population (65). The FFQs consisted of 16 to 60 items to measure dietary fat intake and enabled calculation of percentage of energy from fat or total fat intake, either a fat-score or grams of fat. Two studies used a so-called Dietary Habit Questionnaire (30,47), one study used a 7-day food record (48), and four studies used shopping receipts (39,50–52) to assess fat intake. Most studies reported on total fat, whereas some studies reported on saturated fat intakes (42,45,49), and only one study assessed intake of unsaturated fat (45).

Eleven of the 14 fat-reduction studies that tested short-term effects showed a significant effect in favor of the tailored interventions. Of the 11 studies, 6 compared the tailored intervention with no intervention (39,47,50–52,60) and 4 compared tailoring with generic information (30,40,41,45). In all 6 studies that allowed calculation of ES at short term, a small ES was found. Winett et al. (52) also found a moderate ES for cooking fats and a large ES for fat from dairy products. Five of the 7 studies testing medium-term effects found a significant effect in favor of the tailored intervention compared to no-intervention comparison groups (35,39,42,46,52). Most of the calculated ESs were small, but Winett et al. (52) also found a large ES for changes in fat from dairy foods. The two studies on long-term follow-up did not find a significant effect on fat intake (36,46).

Effects on fruit and vegetable consumption (section C, Appendix). Fruit and vegetable consumption was also typically measured with validated FFQs; many of the studies conducted

in the United States used the FFQ developed by Block and colleagues (61). The Dutch studies used the FFQ validated by Van Assema and colleagues (66) and Bogers et al. (67). The number of items in the FFQs varied between 2 and 17. Fruit and vegetable consumption was quantified by the number of servings per day. Two studies quantified fruit and vegetables by purchased daily servings per 1,000 kcals (39,52).

Ten studies measured short-term intervention effects. In 6 studies, a significant effect on fruit and vegetable consumption (combined or separately) in favor of the tailored intervention group was found, 5 in comparison with no intervention (39,47,52,53,55) and 2 in comparison with generic information (41,55). Calculated ESs were small (39,41).

Four of five studies testing medium-term effects found a significant difference in favor of the tailored intervention compared to no intervention with small ESs but only on the combined fruit and vegetable outcome (39,43,52,54). Two studies that reported long-term effects (33,43) found a significant tailoring effect.

Effects on other diet-related behaviors (section D, Appendix). Fiber intake was measured with a variety of methods, although all validated. The one study on calcium intake used a validated self-report instrument as well. Weight loss was measured with self-reported weight-loss behavior.

Significant positive short-term effects for fiber intake (or fiber-rich products) were found in three studies (39,50,52) out of four studies testing short-term effects. The calculated ESs from Anderson et al. (39) and Winett et al. (52) were moderate. The three studies testing medium-term effects found significant differences in favor of the tailored intervention group (39,52,56), with moderate ESs reported by Anderson et al. (39).

Effects on calcium intake were not significant, neither at medium or long term (32). At short term, Bull and colleagues (31) did not find a significant effect on the self-reported item “use of weight loss behavioral suggestions.” Wylie-Rosett and colleagues (36) found a significant long-term effect on weight loss with a small ES.

Effects of single-component and multicomponent studies. From the 15 studies on fat intake, 10 also addressed other dietary behaviors, and 3 of the 14 studies on fruits and vegetables also included at least one other dietary behavior. Although the number of studies was too small to draw any firm conclusions, it appears that targeting more than one behavior does not reduce the chances for significant effects, whereas for fat intake, the available evidence may indicate that combining fat reduction with other goals may even improve chances of success (see Table 1).

DISCUSSION

Based on a systematic review of the relevant literature, the evidence for the effectiveness of computer-tailored nutrition-education interventions is quite strong. Nevertheless, ESs were mostly small, and the evidence is mostly restricted to short and medium term, with a follow-up period of up to 6 months. The

TABLE 1
Results for Single-Component and Multicomponent Interventions

Target Behavior	No. of Studies			
	Total	Significant Effect	Mixed Effects ^a	No Effect
Physical activity: Single component study	4	1	—	3
Physical activity in a multicomponent study addressing dietary behaviors as well	6	1	1	4
Fat consumption: Single component study	5	1	3	1
Fat consumption in a multi-component study addressing other dietary behaviors as well	10	5	3	2
Fruit and vegetable consumption: Single component study	3	2	1	—
Fruit and vegetable consumption in a multi-component study addressing other dietary behaviors as well	11	4	2	5

^aWithin one study both significant and nonsignificant results were found for either different subgroups or different outcome measures related to the target behavior.

majority of studies on fat consumption and on fruit and vegetable consumption showed significant favorable effects of tailoring, and no studies found effects in favor of one of the control groups. The effects of computer-tailored nutrition education on fat reduction were found in comparison with no intervention as well as generic information. The interventions aimed at fruit and vegetable consumption were mainly compared with no-intervention control groups. Based on the few studies available on the effect of computer-tailored interventions to promote physical activity, no conclusions in favor of tailoring can be drawn. Furthermore, given the still relatively small number of studies for each of the health behaviors addressed, this review provided only limited information on mediators and working mechanisms of computer tailoring.

The review was conducted according to a systematic protocol in line with most of the Cochrane instructions, using objective criteria for inclusion and exclusion of studies, but no blinding of authorship or journal was done before reviewing the articles. There is, however, no unequivocal scientific evidence that blinding is essential to obtain a more objective assessment of the quality of an article (68,69). Furthermore, the review was restricted to publications available via established electronic literature databases, and no attempts were made to also incorporate the “gray literature,” such as publications in the form of internal or locally distributed reports, or manuscripts that were not accepted for publication. A common problem with reviews is the possibility of a “publication bias,” causing an overestimation of positive findings (24), but the relatively large number of studies that did not report any tailoring effects may indicate that lack of effects was generally not a reason to judge an article to be unacceptable for publication in studies on computer tailoring. Finally, a review is dependent on the information reported in the publications and on the interpretation of this information by the reviewers, which may limit the validity of the review results.

Notwithstanding these potential limitations, this review provides the most detailed overview of the content and effects of computer-tailored interventions in the field of physical activity and healthy diet promotion to date. Earlier, and somewhat less systematic, reviews (23,70) were conducted more than 5 years ago, and a number of studies on tailoring have been published since (28,30–32,35–39,43–45,47,48,53,54,56,60).

The two studies on physical activity promotion that did find medium-term positive effects may have been somewhat more intensive than most other, noneffective, interventions: Vandelanotte et al. (35) included a detailed survey and detailed feedback on determinants of motivation and behavior in their computer-tailored advice, whereas Marcus et al. (29) used an intervention with four feedback moments. The fat-reduction interventions included in this article appear to be quite similar and thus provide no information on what made most interventions effective but others not. Differences in study designs or effect measures can also not explain the differences in effects. Effects of interventions aimed at increasing fruit and vegetable consumption might be partially explained by the fact that most of the studies that found a positive effect of computer tailoring made the comparison with a no-intervention control group, which may indicate that computer tailoring may be effective for fruit and vegetable promotion, but there is no evidence that computer-tailored fruit and vegetable education is more effective than generic fruit and vegetable education.

Although the available evidence points to the conclusion that computer tailoring has its merits for healthy diet promotion, it remains difficult to draw more definite conclusions. Effectiveness of interventions depends on more than only the use or amount of tailoring. Interventions, whether tailored or not, should be based on a detailed planning process that should include a careful epidemiological analysis and an assessment of the most important and best changeable determinants of the target behaviors (21,71). Furthermore, persuasion-communication theory points out that nutrition education that meets these effectiveness-enhancing criteria can only be effective if people are exposed and attentive to the health-education message, when the message includes sufficiently strong and convincing arguments, and is communicated by a source that is perceived as credible and trustworthy (72). The studies reviewed here varied in how they were developed, the theoretical framework used, behavioral determinants addressed, and based on the articles reviewed, it is in most cases impossible to judge the actual exposure to the tailored feedback, the strength of the arguments in the feedback, or the trust in the message source.

The outcomes of both the physical activity and the dietary computer-tailored interventions were based mostly on self-re-

port measures. Although most of these self-report measures were validated instruments, studies would be strengthened when self-reports were verified with more objective monitoring. However, objective measures of dietary intake that can be used in external valid and population-based studies are basically non-existent and the existing objective measures for physical activity, such as accelerometers, are not gold standards (73). Using where possible combinations of validated self-reports and more objective measures or biomarkers of behavior change, to ensure a sort of triangulation in evaluation, should be recommended (73,74). The ability to detect effects varies according to the reliability, validity, and sensitivity of the effect indicator used, and although many studies did use validated questionnaires, this does not necessarily mean that these were valid enough to be used to measure behavior changes (11).

This article also does not show that one theoretical framework improves the chances for effects or that certain feedback strategies are more effective than others. In most studies, more than one theory was used as a basis for the tailored intervention. Such a problem-driven multiple-theory approach is indeed advocated in recent volumes and articles on applying theory in health education (75–77). The Transtheoretical Model (57) was reported most often as one of the theories used. Although this model is under debate, especially for applications in the nutrition and physical activity field (78,79), its application in individually tailored interventions is still regarded as promising (80).

As we argued in the Introduction section to this article, computer tailoring incorporates a number of characteristics that have been found to improve the effectiveness of health education interventions, but more research is needed on why and when computer tailoring will initiate changes in diet or physical activities. Some evidence exists that perceived personal relevance and interestingness, and more intensive cognitive processing, mediate the effects of computer-tailored interventions (55,81).

De Bourdeaudhuij et al. (82) investigated the effect of individually tailored dietary advice versus family-based tailored advice, and Campbell and colleagues (43) varied the message source (the local preacher or a public health expert) and context (religious or scientific) of the information in a church-based intervention for African Americans. No significant differences in effects between the different tailored interventions were found.

It is also unclear how elaborate a computer-tailored intervention should be to have effects. It is not possible to relate the effects of the interventions to the amount of information given (the dose), because interventions are usually not described in enough detail to make meaningful comparisons possible. Only few studies have explicitly compared more elaborate computer tailoring with more restricted versions (34,56,83) but did not find significant differences, and one study that included explicit goal-setting in the tailored intervention could not prove the additional effect of this strategy (54).

A possible problem with more elaborate tailoring is that the amount of feedback may become too extensive for people to process, remember, and put into use. This may be especially true

for interventions aimed at multiple behaviors. A study that explored this issue (35), by investigating if tailored feedback on different health behaviors (fat intake and physical activity) was more effective if provided simultaneously or sequentially, did not find significant differences in effects between the two intervention approaches.

Exploring the effects of tailoring on potential mediators of behavior change, instead of behavior change itself, may possibly provide more insight into why and when tailored feedback is effective. A number of studies (31,37,40,41,44,45,47,48,60,84) evaluated the effectiveness of computer-tailored interventions on motivation to change, either as goal intentions or stages of change. Only one study on physical activity (37) reported changes in motivation. Higher motivation for decreasing fat intake due to the computer-tailored intervention was found in four studies (40,47,60,84). Three other studies did not find a significant effect on motivation to eat less fat (44,48,82).

The tailored feedback in the interventions reviewed is mostly print computer-tailored personal feedback letters or newsletters. Very few of the studies published to date used more interactive systems (35,36,39,43,47,50,52,60). However, computer-tailored print materials only utilize part of the potential of computer tailoring, because interactivity and immediate feedback is not possible (21,30). It has been argued that more interactive systems, such as Web-based computer tailoring, may hold more promise.

The individualization is most probably an important reason why computer-tailored nutrition education is effective (15,17,55). However, computer tailoring has also been criticized for its lack of social components (21). It has also been argued that personalized advice may not be enough because dietary habits may not always be volitional or personally determined. Interactive technology in computer tailoring may offer some opportunities for combining computer-tailored feedback with Internet-based social support. Computer-tailored physical activity and nutrition education for primary prevention may also become more effective if it is incorporated in ongoing or routine preventive community services (42,43,85).

A comprehensive review of Contento et al. (25) concluded that nutrition education was more likely to be effective when behavior change goals were made explicit and when the education strategies were explicitly directed to that goal. Furthermore, Contento et al.'s review showed that personal relevance, feedback, and interactivity contribute to effectiveness. Computer tailoring enables incorporation of these characteristics in combination with a wide distribution for relatively low costs. For physical activity, comparable findings were concluded in a review of Kahn et al. (13). In contrast with education strategies like mass media campaigns, there is strong support for the effectiveness of individually adapted health behavior change programs.

The results of this systematic review confirm the conclusions drawn in earlier reviews and position articles: computer tailoring is a promising means to promote healthy diets and possibly physical activity. Tailoring, however, is not a guarantee for

success, and more research is needed on what makes tailoring effective. Unfortunately, authors of recent articles often have not complied with recommendations made in those earlier reviews (e.g., extensive description of intervention used, objective outcome measures, comparison with generic information, long-term follow-up).

Campbell and colleagues proposed a stepwise approach to the development and evaluation of complex interventions, from exploration, via tests in controlled settings, to field studies and implementation research, and such a stepwise approach should be recommended for computer-tailoring studies too (86). This stepwise approach should also include studies comparing computer-tailored interventions to other state-of-the-art intervention strategies as well as cost-effectiveness studies. Finally, to improve the quality of the scientific evidence of the effectiveness of behavioral change interventions, it is important that studies are reported according to certain standards so that studies can be better compared (24). A good example is The Consolidated Standards for Reporting Trials, developed to improve the design and reporting of interventions involving randomized controlled trials (87). We recommend that future articles on studies on computer tailoring adhere to these standards

We are only beginning to explore the possibilities of using the World Wide Web and other interactive media for computer tailoring, and future studies should explore and evaluate these channels for computer-tailored nutrition and physical activity education (20,88,89). A review on the effectiveness of physical activity interventions highlights two key challenges for approaches using Internet communication technologies: "engagement" and "retention" of participants (88). This touches on implementation of computer-tailored interventions in real-life settings; true implementation studies are much needed to further explore the public health effects of computer tailoring.

We conclude that computer-tailored interventions have promise, especially in dietary change interventions. Although this review indicates that effects of tailored interventions are mostly small, when such small effects can be reached in the population at large, public health effects may be substantial (90).

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APPENDIX TABLE A1
Study Characteristics and Effects

<i>First Author</i>	<i>Country</i>	<i>Study Population (N)</i>	<i>Tailoring Compared to Measure</i>	<i>Validated Measure</i>	<i>Outcome Measurement Instruments</i>	<i>Outcome Measurement Units</i>	<i>Results^a and ES^b at Short, Medium, or Long Term^c</i>
Section A: PA promotion							
Blalock 2002 (32)	USA	Women (714), 40–56 years, recruited from the general population	Generic info	?	Self-report on type, frequency, and duration of PA	Total number of hr/week engaged in weight-bearing exercise activities	No significant effects at medium or long term in <i>unengaged</i> participants. Significant adverse effect at medium term and no significant effect at long term in <i>engaged</i> participants. No significant effects at medium or long term in participants in action.
Bock 2001 (28) ^d	USA	Sedentary participants (120) recruited from the general population	Generic info	Yes	Self-report adapted from the 7-day PA recall questionnaire (91)	Total PA (min/week)	No significant effect at long term
Bull 1999 (37)	AUS	Sedentary participants (658) recruited from family practices	Generic info	Yes	Assessment (3 item) derived from the National Heart Foundation of Australia Risk Factor Prevalence Survey (1991)	Total time spent exercising in previous 2 weeks	No significant effects at short, medium, or long term
Bull 1999 (38)	USA	Participants (203) in contemplation or preparation stage who have set a PA goal, without contraindications for PA, recruited from primary care practices	No info Generic info	?	No. of days /week on which participants spent at least 30 min divided in 8 PA categories	LTAs, PADLs, Total activity (sum of LTAs and PADLs)	No significant effect at medium term ^e
Campbell 2004 (33)	USA	Church members (587) of African American churches in rural area	No info	Yes	16-item questionnaire derived from existing instruments and modified for cultural appropriateness	MET hr/week	Significant effect at long term for recreational activity (moderate + vigorous). ES ^f at long term: 0.32. No significant effect for total PA
Kreuter 1996 (34)	USA	Participants (674) recruited from family medical practices	No info	?	1 item	Engaging in regular aerobic exercise	No significant effect at long term
Kreuter 2000 (30)	USA	Overweight participants (198) interested in losing weight recruited from the general population	Generic info	?	1 item	Frequency of moderate PA for 30+ min	No significant effect at short term

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APPENDIX TABLE A1 (Continued)

<i>First Author</i>	<i>Country</i>	<i>Study Population (N)</i>	<i>Tailoring Compared to</i>	<i>Validated Measure</i>	<i>Outcome Measurement Instruments</i>	<i>Outcome Measurement Units</i>	<i>Results^a and ES^b at Short, Medium, or Long Term^c</i>
Marcus 1998 (29) ^d	USA	Sedentary participants (150) recruited from the general population	Generic info	Yes	Self-report adapted from the 7-day PA recall questionnaire (91)	Total PA (min/week)	Significant effect at short and medium term. ES at medium term: 0.42
Vandelanotte 2005 (35)	B	Participants (771) recruited from the general population	No info	Yes	31-item IPAQ (92)	Total PA (min/week)	<u>Results in the total population^e:</u> Significant adverse effect at medium term for total PA. No significant effect on moderate + high intensity PA at medium term. ES for total PA: -0.01. <u>Results for the population not meeting PA recommendations:</u> Significant effect at medium term for total PA. No significant effect on moderate + high intensity PA at medium term. ES for total PA: 0.02.
Wylie-Rosett 2001 (36)	USA	Participants (280) with BMI > 25 kg/m ² or BMI > 24 kg/m ² + 1 risk factor for cardiovascular diseases, recruited from health maintenance organizations and the general population	Self-help workbook ^h	?	Self-report adapted from Paffenbarger 1978 (93)	Walking time No. of blocks walked and stairs climbed	No significant effects at long term.
Section B: Fat reduction							
Anderson 2001 (39)	USA	Participants (277; 163 participants left at medium term) recruited among supermarket customers	No info	?	Block 95 FFQ (94) Shopping receipts	% kcal from daily fat intake	<u>Results measured with FFQ:</u> Significant effect at short and medium term. ES at short term: -0.36. ES at medium term: -0.38. <u>Results measured with shopping receipts:</u> Significant effect at short term. ES at short term: -0.25
Brug 1996 (40)	NL	Participants (347) recruited from worksites	Generic info	Yes	25-item FFQ covering 12 (groups of) food products (62)	Fat score	Significant effect at short term among the total population and among participants not meeting recommendations. ES at short term among total population: -0.06. ES at short term among risk consumers: -0.25

Brug 1998 (41)	NL	Participants (646) recruited from the general population	Generic info	Yes	25-item FFQ covering 12 (groups of) food products (62)	Fat score	<u>Single computer-tailored feedback compared to generic info:</u> Significant effect at short term. ES at short term: - 0.24. Iterative computer-tailored feedback compared to generic info. Significant effect at short term. ES at short term: -0.37
Campbell 1994 (42)	USA	Participants (394) recruited from family medical practices	No info Generic info	Yes	13-item FFQ derived from Health Habits and History questionnaire assessing fat intake (59) and 5 additional items on high-fat foods consumed in southern USA	Total fat (g/day). Saturated fat (g/day).	<u>Compared to no info:</u> Significant effect at medium term on total and saturated fat. ES' at medium term total fat: -0.22. ES' at medium term saturated fat: - 0.22.
Campbell 1999 (60)	USA	Low-income women (378) recruited among Food Stamp Program participants	No info	Yes	16-item FFQ derived from Block 1986, 1989 (61,95) and 2 additional items on low-fat foods	Fat (g/day)	No significant effect at short term for fat intake. Significant effect at short term for eating meat baked in oven and eating low-fat snacks.
Campbell 2004 (44)	USA	Women (306) receiving benefits for themselves or their child(ren) from the "Special Supplemental Nutrition Program for Women, Infants and Children"	No info	Yes	25-item fat, fruit, vegetable, and fiber screener (96)	Fat (g/day)	No significant effect at short term
Campbell 2004 (33)	USA	Church members (587) of African American churches in rural area	No info	Yes	60-item FFQ (61)	Total fat. Fat (en%).	No significant effect at long term
De Bourdeaudhuij 2000 (45)	B	Participants (140) from 2-parent families with at least 2 adolescents, recruited from the general population	Generic info	Yes	56-item FFQ derived from Feunekes 1993 (64)	Total fat, saturated fat, monounsaturated fat, polyunsaturated fat in % of total energy intake	<u>Results at short term for mothers:</u> Significant effect on total fat intake, saturated fat intake and monounsaturated fatty acids. No significant effect on polyunsaturated fatty acids. Results at short term for fathers: No significant effects.
Greene 1998 (46)	USA	Nonsmoking participants (296) with fat intake > 30 en% recruited from the general population	No info	Yes	46-item FFQ derived from Kristal 1990 (97) 24-item Dietary Behaviors (97,98)	Fat (en%). Dietary behavior.	Significant effect at medium term. No significant effects at long term.

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APPENDIX TABLE A1 (Continued)

<i>First Author</i>	<i>Country</i>	<i>Study Population (N)</i>	<i>Tailoring Compared to Measure</i>	<i>Validated Measure</i>	<i>Outcome Measurement Instruments</i>	<i>Outcome Measurement Units</i>	<i>Results^a and ES^b at Short, Medium, or Long Term^c</i>
Irvine 2004 (47)	USA	Participants (463) recruited from worksites	No info	Yes	21-item Diet Habits Questionnaire (97)	Fat eating habits/ behaviors	Significant effect at short term for fat eating behaviors. ES at short term: -0.49
Kreuter 1996 (34)	USA	Participants (1,317) recruited from medical practices	No info	Yes	18-item FFQ derived from Block 1986, 1989 (61,95)	Fat (g)	No significant effect for risk consumers motivated to change at medium term
Kreuter 2000 (30)	USA	Overweight participants (198) interested in losing weight, recruited from the general population	Generic info	?	Actual dietary habits, e.g., use of diet or reduced-calorie foods	Choosing low-fat alternatives. Choosing meals low in fat. Eating smaller portions. Cutting calories.	Significant effect at short term on choosing low-fat alternatives
Oenema 2005 (55)	NL	Participants (616) recruited at factories, institutes for health and social care, and local government institute	No info Generic info	Yes	35-item FFQ	Fat score	No significant effect at short term for computer-tailored feedback vs both comparison groups for total group, for those not meeting the recommendations at baseline, or for those unaware of personal intake at baseline
Raats 1999 (48)	UK	Participants (115) recruited from university staff	No info	Yes	7-day food and drink diary. UK Nutrient Databank	Total fat (en%)	No significant effect at short or medium term in the total population. No significant effect at short or medium term in the population that is unaware of own consumption and not meeting recommendations.
Vandelanotte 2005 (35)	B	Participants (771) recruited from the general population	No info	Yes	48-item FFQ (65)	Fat (g/day)	Results at medium term: Significant effect on fat intake measured as g/day and measured as en% for total population and for the population not meeting recommendations. ES fat g/day for total population: -0.29. ES fat en% for total population: -0.33. ES fat g/day for risk consumers: -0.49. ES fat en% for risk consumers: -0.51.
Winett 1988 (49)	USA	Primary shoppers of a household (126) recruited from the general population	Video-Modeling ^h . Video-Lecture ^h	?	6-page checklist for weekly purchases and standard nutritive and caloric values	Total fat and saturated fat (en%) of total weekly purchase	Significant effect at short term on total fat for computer-tailored feedback + video-lecture versus video-lecture. ES for tailoring versus video-lecture: -0.22
Winett 1991 (50)	USA	Participants (77) recruited among supermarket customers	No info	Yes	Shopping receipts	In frequency purchased: low-fat meat, high-fat meat, low-fat dairy, high-fat dairy, low-fat fish/poultry.	Results at short term: No significant effect on low-fat meat, high-fat meat, and low-fat fish/poultry. Significant effect on low-fat dairy and high-fat dairy

Winett 1991 (51)	USA	Participants with a household with 2+ people (61), no medically prescribed diet for all household members, recruited among supermarket customers	No info	Yes	Weekly shopping receipts	low-fat meat (g), high-fat meat (g), low-fat dairy (g), high-fat dairy (g), low-fat fish/poultry (g), Total fat in % of total energy	Results at short term: No significant effects on low-fat meat, high-fat meat, high-fat dairy, low-fat fish/poultry and total fat. Significant effect on low-fat dairy
Winett 1997 (52)	USA	Participants (105; 53 participants left at medium term) recruited among supermarket customers	No info	?	Shopping receipts (99)	% kcal from fat	Significant effects on fat from total food purchases at short and medium term: ES at short term: -0.47, ES at medium term: -0.41. Significant effects on fat from dairy food purchases at short and medium term: ES at short term: -0.85, ES at medium term: -0.96. Significant effects on fat from table and cooking fats purchased and on fat from prepared foods purchased at short term: No significant effects at medium term. ES at short term cooking fats: -0.61, ES at short term prepared foods: -0.26. No significant effects on fat from fat meat and from fat snack foods at short or medium term
Wyllie-Rosett 2001 (36)	USA	Participants (280) with BMI > 25 kg/m ² or BMI > 24 kg/m ² + 1 risk factor for cardiovascular diseases, recruited from health maintenance organizations and the general population	Self-help workbook ^h	Yes	Block FFQ (61)	kcal/day, % kcal from fat	No significant effect on total fat intake at long term
Section C: Fruit and vegetables consumption promotion							
Anderson 2001 (39)	USA	Participants (277; 163 participants left at medium term) recruited among supermarket customers	No info	?	FFQ (94), shopping receipts	Purchased daily servings of fruit and vegetables per 1000 kcal daily	Results measured with FFQ: Significant effect at short and medium term, ES at short term: 0.45, ES at medium term: 0.38. Results with shopping receipts: No significant effect at short or medium term

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APPENDIX TABLE A1 (Continued)

<i>First Author</i>	<i>Country</i>	<i>Study Population (N)</i>	<i>Tailoring Compared to</i>	<i>Validated Measure</i>	<i>Outcome Measurement Instruments</i>	<i>Outcome Measurement Units</i>	<i>Results^a and ES^b at Short, Medium, or Long Term^c</i>
Baker 2002 (53)	UK	Participants of bowel screening trial (742), 55–64 years, recruited from cancer screening clinics	No info	Yes	2-item fruit and vegetables tool (100)	Fruit: servings/day, Vegetables: servings/day	Significant effects at short term for vegetable intake and for fruit intake
Brug 1996 (40)	NL	Participants (347) recruited from worksites	Generic info	Yes	3-item FFQ (101)	Fruit: pieces/day, Vegetables: servings/day	No significant effects at short term on fruit or vegetable intake for total population and for population not meeting recommendations
Brug 1998 (41)	NL	Participants (646) recruited from the general population	Generic info	Yes	3-item FFQ (101)	Fruit: servings/day, Vegetables: servings/day	Single computer-tailored feedback compared to generic info: No significant effect at short term for fruit intake nor vegetable intake. <u>Iterative computer-tailored feedback compared to generic info:</u> Significant effect at short term on fruit and vegetable intake, ES at short term for fruit: 0.26, ES at short term for vegetables: 0.31
Campbell 1994 (42)	USA	Participants (394) recruited from family medical practices	No info	Yes	10-item FFQ derived from Health Habits and History questionnaire (61)	Fruit: servings/day, Vegetables: servings/day	No significant effects at medium term on fruit or vegetable intake. ^j
Campbell 1999 (43)	USA	Participants (459) recruited from African American churches	No info	Yes	7-item FFQ “5-a-day community studies” approach (102)	Servings/day	<u>Spiritual computer-tailored feedback compared to no info:</u> Significant effects at medium and long term on fruit and vegetable intake, ES ^f at medium term: 0.39, Expert computer-tailored feedback compared to no info, Significant effects at medium and long term on fruit and vegetable intake, ES ^f at medium term: 0.48
Campbell 2004 (44)	USA	Women (306) receiving benefits for themselves or their child(ren) from the “Special Supplemental Nutrition Program for Women, Infants and Children”	No info	Yes	25-item fat, fruit, vegetable and fiber screener (96)	Fruit: servings/day, Vegetables: servings/day	No significant effect at short term
Campbell 2004 (33)	USA	Church members (587) of African American churches in rural area	No info	Yes	60-item FFQ (61)	Fruit: servings/day, Vegetables: servings/day	Significant effect at long term on fruit and vegetables. ES ^f at long term: 0.18

Irvine 2004 (47)	USA	Participants (463) recruited from worksites	No info	Yes	5-item FFQ "5-a-day for better health studies" approach (103)	Fruit: servings/day, Vegetables: servings/day	Significant effect at short term on fruit and vegetable intake. ES at short term: 0.21
Lutz 1999 (54)	USA	Participants (573) recruited from health maintenance organizations	No info Generic info	?	17-item FFQ	Fruit: servings/day, Vegetables: servings/day	Computer-tailored feedback compared to no info: Significant effect at medium term, ES ^f at medium term: 0.23, Computer-tailored feedback and goal setting compared to no info. Significant effect at medium term. ES ^f at medium term: 0.35. No significant effect on fruit and vegetable intake at medium term for computer-tailored feedback compared to generic info or for computer-tailored feedback + goal setting compared to generic info
Oenema 2005 (55)	NL	Participants (616) recruited at factories, institutes for health and social care, and local government institute	No info Generic info	Yes	14-item FFQ including raw and cooked vegetables, fruit, and fruit juice	Fruit: servings/day, Vegetables: servings/day	Computer-tailored feedback compared to generic info. Significant effect at short term for vegetable intake for total group and for those not meeting the recommendations at baseline. Computer-tailored feedback compared to no info. Significant effect at short term for fruit intake for those not meeting the recommendations at baseline and those unaware of personal intake at baseline
Winett 1991 (50)	USA	Participants (77) recruited among supermarket customers	No info	Yes	Shopping receipts	Fruit and vegetable frequency purchased	No significant effect at short term
Winett 1991 (51)	USA	Participants with a household with 2+ people (61), no medically prescribed diet for household members, recruited among supermarket customers	No info	Yes	Weekly shopping receipts	Fruit and vegetable purchased (g)	No significant effect at short term
Winett 1997 (52)	USA	Participants (105; 53 participants left at medium term) recruited among supermarket customers	No info	Yes	Shopping receipts (99)	Fruit and vegetable servings/1,000 kcal purchased	Significant at short term and at medium term. ES at short term: 0.34. ES at medium term: 0.14 ^k

(continued)

APPENDIX TABLE A1 (Continued)

First Author	Country	Study Population (N)	Tailoring Compared to	Validated Measure	Outcome Measurement Instruments	Outcome Measurement Units	Results ^a and ES ^b at Short, Medium, or Long Term ^c
Section D: Other dietary topics							
Anderson 2001 (39) Fiber	USA	Participants (277; 163 participants left at medium term) recruited among supermarket customers	No info	?	FFQ (94) Shopping receipts	g/1,000 kcal	Results measured with FFQ. Significant effect at short term and at medium term. ES at short term: 0.55. ES at medium term: 0.62. Results measured with shopping receipts. No significant effect at short term or at medium term
Blalock 2002 (32) Calcium	USA	Women (714), 40–56 years, recruited from the general population	Generic info	Yes	15-item FFQ derived from Block 1986 (61). Nondietary sources of calcium. Calcium-fortified orange juice FFQ (104)	mg/day	No significant effect at medium term or at long term measured for unengaged and engaged participants, respectively. Significant adverse effect at long term for participants in action
Brinberg 2000 (56) Fiber	USA	College students not living with their parents (133), recruited from a university	Generic info. Generic info + intake feedback. No info	Yes	FFQ (104)	g/day	Significant effect on fiber consumption in all three comparison groups at medium term. No significant effects on food choice at medium term
Bull 2001 (31) Weight loss	USA	Participants with BMI > 27 kg/m ² (198), interested in losing weight and without the use of prescribed weight loss medication at any time during the previous 6 months, recruited from the general population	Generic info	Yes	1 item (105)	Weight loss suggestions tried yes/no	No significant effect at short term
Winett 1991 (50) Fiber	USA	Participants (77) recruited among supermarket customers	No info	Yes	Shopping receipts	High-fiber grains/cereals amount purchased	Significant effect on purchase of high-fiber grains/cereals at short term
Winett 1991 (51) Fiber	USA	Participants with a household with 2+ people (61), no medically prescribed diet for household members, recruited among supermarket customers	No info	Yes	Weekly shopping receipts	High-fiber grains/cereals in grams daily per capita fiber	No significant effect on purchase of high-fiber grains/cereals or on fiber intake at short term

Winett 1997 (52) Fiber	USA	Participants (105; 53 participants left at medium term) recruited from supermarket customers	No info	Yes	Shopping receipts (99)	Fiber g/1,000 kcal. Fiber from bread g/1,000 kcal. Fiber from cereal g/1,000 kcal	Significant effect on total fiber intake at short term and at medium term. ES at short term: 0.48. ES at medium term: 0.36. Significant effect on fiber from cereals at short term, no significant effect at medium term. ES at short term: 0.65. No significant at fiber from bread at short term or at medium term
Wylie-Rosett 2001 (36) Weight loss	USA	Participants (280) with BMI > 25 kg/m ² or BMI > 24 kg/m ² + 1 risk factor for cardiovascular diseases, recruited from health maintenance organizations and the general population	Self-help workbook ^h	Yes	Weight parameters Metabolic parameters	BMI (kg/m ²). Waist circumference (in.). % body fat	Significant effect on weight loss at long term. ES at long term: 0.21

Note. ES = effect size; PA = physical activity; USA = United States of America; AUS = Australia; LTAs = Leisure Time Activity score; PADLs = PA of daily living score; MET = metabolic equivalents; B = Belgium; IPAQ = International Physical Activity Questionnaire; BMI = body mass index; FFQ = Food Frequency Questionnaire; NL = The Netherlands; UK = United Kingdom; en% = percentage of daily energy intake.

^aSignificant effect = effect in favor of tailoring that reached statistical significance. Significant adverse effect = effect in favor of comparison group(s) that reached statistical significance. ^bESs were calculated when mean and standard deviation of both groups were available at posttest and a significant effect in favor of tailoring had been found. ES is interpreted according to Cohen's (24) guidelines based on an application in Dolan et al. (27); cut-off values of 0.2-0.5 = small, 0.5-0.8 = moderate, and > 0.8 = large effects. ^cShort term ≤ 3 months; medium term = 3-6 months; long term > 6 months. ^dBock (28) dealt with the long term effects of the same study as Marcus (29). ^eTailoring was compared with the no info and generic info groups combined. ^fStandard deviation used in calculation is a proximate, derived from the standard error reported in the article ($SD = SE \cdot \sqrt{n}$). ^gReported results and effect sizes from Vandelanotte (35) are derived from the comparison sequential tailored feedback versus no information. ^hThe computer-tailored intervention group and the control group received the same, but the intervention group received additional tailored feedback. ⁱTailoring versus generic info was not tested. ^jComparison computer-tailored feedback with generic info was not tested. ^kMedium term effect might be due to seasonal trend.