Computer-tailored dietary behaviour change interventions: a systematic review

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Abstract

Improving dietary behaviours such as increasing fruit and vegetable consumption and reducing saturated fat intake are important in the promotion of better health. Computer tailoring has shown promise as a strategy to promote such behaviours. A narrative systematic review was conducted to describe the available evidence on 'second'-generation computer-tailored primary prevention interventions for dietary behaviour change and to determine their effectiveness and key characteristics of success. Systematic literature searches were conducted through five databases: Medline, Embase, PsycINFO, CINAHL and All EBM Reviews and by examining the reference lists of relevant articles to identify studies published in English from January 1996 to 2008. Randomized controlled trials or quasi-experimental designs with pre-test and post-test behavioural outcome data were included. A total of 13 articles were reviewed, describing the evaluation of 12 interventions, seven of which found significant positive effects of the computer-tailored interventions for dietary behaviour outcomes, one also for weight reduction outcomes. Although the evidence of short-term efficacy for computer-tailored dietary behaviour change interventions is fairly strong, the uncertainty lies in whether the reported effects are generalizable and sustained long term. Further research is required to address these limitations of the evidence.

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Introduction

Chronic diseases, such as heart disease, stroke, cancer, chronic respiratory diseases and diabetes, are by far the leading cause of mortality in the world, representing 60% of all deaths [1]. Promoting increased fruit and vegetable consumption and reduced saturated fat intake is important in the prevention of chronic disease and promotion of better health [2, 3]. There is growing evidence that behaviour change programmes using computer tailoring can be effective in changing such lifestyle risk factors [4].

Computer-tailored interventions have been classified into three generations, according to their mode of delivery. First-generation interventions are delivered through printed materials such as letters, reports and pamphlets. Second-generation interventions are delivered through interactive technology or desktop applications such as websites, email and CD-ROM programs [5, 6]. Third-generation interventions include mobile and remote devices such as mobile phones and handheld computers which may enhance the potential for timely feedback [5].

Computer tailoring is promising as a strategy for health education [4]. Firstly, like personal counselling participants are assessed and the results then used to generate individualized feedback and advice [6], making the health information received

personalized and delivered at a relatively low cost [4]. Participant's behaviours can be compared with current recommendations, the behaviours of peers and previous assessments [7]. Feedback can then be provided that is relevant to performance levels, awareness, motivation, self-efficacy, expectations and goals [4]. Secondly, it has potential for wide distribution due to its application to electronic non-print media such as the Internet which provides an opportunity for remote access to the intervention [4].

The limitations of computer-tailored interventions include that participants must answer a large number of questions and that feedback is based on participant's self-reported behaviour. This may result in inaccurate estimates of behaviour, subsequently resulting in mismatched feedback and advice [8, 9]. Such limitations may be minimized through the use of a combination of validated self-reports with more objective measures of behaviour change; however, there is a lack of existing objective measures for dietary behaviour change [4].

Previous well-conducted systematic reviews on computer-tailored interventions [4], web-based interventions [10, 11] and interventions using interactive technology [5] targeting physical activity and dietary behaviours indicated that further research was required to form any conclusions on their effectiveness, but the evidence was promising for those targeting dietary behaviour change. To investigate the potential of developing computer-tailored dietary behaviour change interventions targeting Australian adults, the abovementioned reviews were found to be relevant, however, had a different purpose, focus and inclusion criteria and considerable time had lapsed in this rapidly developing field [4, 5, 10, 11]. The aim of this study was to conduct a narrative systematic review which would describe the range and quality of available evidence on second- and third-generation computer-tailored primary prevention interventions for dietary behaviour change and to determine their effectiveness and key characteristics of success. The two most recent reviews focused on Internet-based interventions [10, 11]: one review included both first- and second-generation computerized interventions up to 2004 and excluded those in which

there was any interpersonal contact with a counsellor [4] and one review that included studies up to 2005 was not exclusive to primary prevention interventions [5].

These reviews noted the significant heterogeneity of such studies. When there is significant heterogeneity of studies, it is considered more appropriate to undertake a narrative systematic review than a meta-analysis and to describe the variation in findings rather than attempt to combine findings into one overall estimate of effect [12].

Methods

Data sources and search strategy

Literature searches were conducted to retrieve articles from January 1996 to January 2008 that were written in English using five databases in February 2008: Medline, Embase, PsycINFO, CINAHL and All EBM Reviews. The search consisted of a combination of each of the following terms to represent computer-tailored or expert systems: expert system; web based; computer tailor*; computer based or Internet based; with each of the target domains: nutrition; diet; overweight; obesity and weight loss. Additional articles of relevance were sought by reviewing the reference lists of included articles and previous systematic reviews of relevance identified through the literature search [4, 5, 10, 11, 13–15].

Selection criteria

Articles identified through the literature search were restricted to those written in English and published in a scientific journal between January 1996 and January 2008 (inclusive). Only randomized controlled trials (RCTs) or quasi-experimental designs with pre-test and post-test behavioural outcome data were included.

For inclusion in this review, articles had to describe the evaluation of a 'second-' or 'third'-generation computerized intervention in which tailored nutrition advice was generated through a computerized system. Delivery was inclusive of but not exclusive to the electronic technology. Interventions

were considered tailored if the advice or feedback provided was specific to individuals and based on an individual assessment and their characteristics. Further, the intervention had to target adults for dietary behaviour as a primary prevention strategy. Kroeze *et al.* definition of primary prevention was utilized '… the initiation of lifestyle or behavioural changes to prevent the onset of chronic diseases in apparently healthy participants'. [4: 206] Dietary behaviour changes had to be described as the primary outcome measure.

Interventions were excluded that had significant face-to-face contact involving counselling in one of the main treatment arms of the study. Interventions with limited interpersonal contact such as provision of computer-tailored feedback through telephone or email; initial one-off face-to-face sessions for the purpose of instructing participants in the use of the technology or data collection (i.e. not for the purposes of behavioural counselling) were included. Interventions that had additional treatment arms such as face-to-face sessions were also included. However, the effects reported in this review are only that of the treatment arm with none or limited interpersonal contact as described above.

Articles identified through the literature search were excluded if they met the following criteria:

- Conference abstracts, dissertations, commentaries, descriptions of the technology or information architecture, description of the development of an intervention
- The target group for the intervention was caregivers, health professionals or those with a manifested chronic disease state and/or recruitment occurred using chronic disease registries
- Intervention included the delivery of individual therapist-generated feedback within the main treatment arm of the study
- Intervention described was a maintenance strategy for a previous intervention that had not been generated through such a system.

Where studies addressed multiple behaviours, only dietary behaviour and change in body mass or weight outcomes and the instruments used to measure these outcomes were considered. Although not the main purpose of this review, when dietary behaviour effects were absent, dietary behaviour mediator outcomes were considered.

Data synthesis

The Australian National Public Health Partnership (NPHP) guidelines for evaluating evidence on public health interventions [16] and previously published reviews [4, 5, 10] were used as a guide to reviewing and summarizing the studies included. Each article was reviewed by two of the authors with the following information extracted and tabulated: intervention context and description, study design and evaluation, outcome measures, findings, strengths and limitations. These two authors independently performed a quality coding assessment of all studies, which consisted of 17 criteria symbolizing the quality of the intervention and the study's internal and external validity (Table I). The internal validity criteria assessed whether the study was well conducted and the findings valid, whereas the external validity assessed whether the findings were generalizable. The purpose of the validity scores was not to categorize individual studies for comparison, but to provide an illustration of the overall state of the science in this area. These characteristics were adapted from those used in previous reviews [5, 11], the Australian NPHP guidelines for evaluating evidence on public health interventions [16] and external validity criteria outlined by Glasgow and Emmons [17]. Each criteria had the same value or weighting, the sum of which was used as a validity score, calculated as a percentage of the maximum obtainable score. Ranking disagreements were discussed by all authors until consensus was reached. All authors reviewed both the summarized review of studies and the quality assessment then convened to reach consensus on the strength of evidence.

Results

Study selection

The initial cross-database literature search yielded 1349 publications. After removing duplicates and

Table I. *Study internal and external validity coding criteria*

Criteria description	Scoring for criteria
Internal validity criteria	
Study design and methods	
1 Was the method of randomisation appropriate?	Y = 1; N = 0
2 Were baseline groups equivalent on important demographic measures?	Y = 1; N = 0; unknown = 0
If No, was analysis conducted to estimate/adjust for effect of demographic measure on outcomes?	Y = 1; N = 0; unknown = 0
3 Did the design of the study isolate the technology or the tailoring effect by comparing to a group with either no technology or no tailoring?	Y = 1; N = 0
4 Was retention rate ≥80% at post-test/post-intervention follow-up?	Y = 1; N = 0
5 Were outcome measurement instruments valid? Was there a description of instrument reliability/validity (reference or coefficients) or did they use a well-established known valid measure?	Y = 1; N = 0
Study analysis	
6 Was power analysis reported to determine sample size?	Y = 1; N = 0
7 Were analyses conducted with consideration for missing data that maintain fidelity of the randomization (e.g. intention to treat, imputation)? Note: if 100% retention then N/A	Y = 1; N = 0
Intervention design	
8 Was the intervention based on theory?	Y = 1; N = 0
External validity criteria	
Program reach and sample representativeness	
1 Were recruitment methods and/or inclusion and exclusion criteria sufficiently described?	Both = 1; either = 0.5; none = 0
2 Were participation/recruitment rates provided OR Are analyses reported on the similarity and differences between participants versus either those who decline or the intended target audience (individuals or settings)?	Y = 1; N = 0
3 Was a large heterogenous sample used? Was the representativeness of participants described? Was a homogenous/heterogeneous sample sought for target population? Do the exclusion criteria used reduce the generalisability of findings?	Generalizable population = 1
4 Was the representativeness of the setting described? Was the study conducted in an uncontrolled/controlled setting? Can their findings only be generalized to the limited conditions within which the research was carried out?	Generalizable setting (real-life) = 1; controlled = 0
5 Were all participants who entered trial accounted for at its conclusion i.e. Are data on attrition by condition reported OR was dropout rate described?	Y = 0.5; N = 0
Are dropouts compared with completers OR are the dropout's characteristics and reasons for dropout described?	Y = 0.5; N = 0
Important outcomes for decision making	
6 Was the use of comparison conditions relevant to real-world decisions? (the computer-tailored treatment group was compared with either non-computerized or non-tailored programs rather than no treatment)	Y = 1; N = 0
7 Are data on the costs presented?	Y = 1; N = 0
8 Was there sufficient description of the intervention, including: method of tailoring, duration and intensity (amount of contact time required)?	Y = 1; N = 0
Maintenance of effects	
9 Are data reported on maintenance or longer term effects?	Short term = 0; medium term = 0.5; long term = 1

reviewing the title and abstract of these publications against the inclusion criteria, the number of eligible published articles was 25. After reviewing the full articles, 16 were excluded for meeting one of the exclusion criteria, leaving nine articles. The search of reference lists of relevant papers, including previous reviews, yielded another three relevant articles. An additional article was included, identified by a colleague and undergoing peer review for journal publication.

There was a total of 12 interventions, evaluated in 13 separate studies which aimed to improve dietary behaviours [18–30] (Table II). Two articles described the post-test [25] and long-term follow-up [21] of one intervention programme. Another article described a similar intervention programme that had been trialled within a different setting [20].

Dietary behaviours targeted included reducing fat consumption, increasing fruit and vegetable consumption or increasing fiber intake. Six articles described multi-component computer-tailored health interventions that targeted both physical activity and dietary behaviours, representing five interventions [18, 19, 21–23, 25]. Three studies also measured weight reduction outcomes [18, 19, 22].

Outcome effects

Overall, seven computer-tailored intervention studies reported significant short to medium-term positive between group effects on dietary behaviour outcomes (Table III) [20, 22, 23, 25, 27–29]. The mode of delivery included desktop computer programs [23, 25, 28], the Internet/Intranet [20, 22], telephone [29] and multi-media [27].

Of the 10 interventions aimed to reduce fat consumption, eight found positive effects, five of which reported a significant between-group effect on fat intake in favour of the computer-tailored intervention over a control group [20, 25, 27–29]. Three of these reported within-group positive effects on fat intake but no significant between-group effects [18, 19, 30]. The two studies that did not find positive effects on dietary fat intake behaviours found positive between-group effects for mediators such as knowledge, awareness, self-

efficacy, stage of change and intention to change [24, 26]. Of the seven studies aiming to increase fruit and vegetable intake, four found positive effects in favour of the computer-tailored intervention over a control group [22, 23, 28, 29]. One found positive between-group effects on vegetable intake mediators, i.e. awareness and intention to change, but not on actual measures of behaviour [24]. Of the four studies aiming to increase fibre intake, three found positive effects in favour of the computer-tailored intervention over a control group [22, 28, 29].

It is worth noting the positive effects on fat intake found for the intervention programme used by Vandelanotte *et al.* [25] were maintained at 2-year follow-up; however, there was no control group and a potential dropout bias at the long-term follow-up [21]. The authors of this study noted the limitations of these findings in terms of real-life effectiveness, generalizability and application to practice due to the controlled setting and motivated sample [21, 25]. However, positive effects on fat intake were also reported in an adapted version of the same intervention programme in a real-life setting [20].

Internal and external validity characteristics

The internal validity scores ranged from 50% to 88%, with an average of 66% for all studies and 70% for those studies reporting significant positive between-group effects on dietary behaviour outcomes (Table III). Of the five studies which had an above average internal validity score (>66%), four reported positive between-group effects on dietary behaviour outcomes, one of which also found positive between-group weight reduction outcomes. Most criteria reflecting the internal validity of studies were met by a majority of studies, with the exception of three internal validity criteria: retention, reporting a rationale for sample size and conducting analyses with consideration for missing data that maintained the fidelity of the randomisation. For example, one study with the lowest internal validity score did not meet any of these three criteria in addition to appropriate randomization [30].

Table II. *Summary of dietary behaviour change interventions*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Booth *et al.* (2008) [18], Australia **Other behaviours targeted:** PA and weight	**Setting:** community **Recruitment:** local and city newspapers, flyers in local community centres, libraries and health centres **Eligibility/inclusion criteria:** $24.5 \leqslant BMI \leqslant 37$; Internet access **Exclusion criteria:** <18 years, pregnant/lactating, receiving medications for Type 1/2 DM **Participants (baseline):** 73 adults **Retention rate:** 73% **Final sample characteristics:** 79% females; 81% Anglo-Australian; 51% tertiary education	**Target:** weight reduction **G1:** CT Internet exercise programme **G2:** CT Internet diet + exercise program (as per G1 plus diet program and minimum three diet e-mails) **Tailoring:** current recommendations, previously set goals **Theory:** goal-setting theory **Frequency:** multiple exposure (weekly at minimum) **Duration:** 12 weeks **Incentives offered:** no	**Design:** Pilot randomized trial; randomized by individual; groups comparable at baseline (demographics and OM) **Follow-up:** 12 weeks (PT)	**Primary OM:** anthropometric measurements (weight, height, waist circumference), dietary intake **Instrument:** 24-h dietary recall **Validated:** yes	**Behaviour:** G2 reduced total energy intake and % energy from fat from baseline to follow-up; no significant difference between groups; no other dietary changes **WR:** significant fall in waist circumference and BMI in both groups, no differences between groups; 21% participants moved from having waist circumference in very high risk category to a lower risk category **Mediators:** no relationship between no. goals set and amount of weight lost
Cook *et al.* (2007) [19], United States **Other behaviours targeted:** PA and stress	**Setting:** workplace **Recruitment:** e-mail letter, online flyer, posters **Eligibility/inclusion criteria:** workplace employees ($n = \sim5000$) in three offices of a human resources co. **Exclusion criteria:** NR **Participation rate:** 10% **Participants (baseline):** 480 adults (G1 = 247; G2 = 233) **Retention rate:** 87% (G1 = 85%; G2 = 87%) **Final sample characteristics:** 72% females, 81% White; 95% college or higher education; mean age: G1 = 41.99 years; G2 = 42.03 years	**Target:** overall dietary practices (mainly to reduce fat intake) **G1:** CT Internet 'Health Connection' program (graphics, audio and video) **G2:** generic print materials on same topics (five commercially available booklets) **Tailoring:** stage of change, current recommendations **Theory:** SCT and TTM, health behaviour change theory **Frequency:** multiple exposure **Duration:** 3 months **Incentives offered:** yes	**Design:** RCT; randomized by individual; online questionnaire; baseline groups equivalent (demographics and OM) **Follow-up:** 3 months (PT)	**OM:** dietary practices (unclear what dietary OM were targeted and measured); attitudes towards diet, motivation to improve diet; behavioural intentions towards diet; dietary self-efficacy; stage of change for diet and weight; weight; process evaluation measures **Instrument:** online health survey consisting of many measurement items **Validated:** majority have been pre-tested and validated, validation of some unknown	**Behaviour:** both groups improved significantly from pre- to post-test in all dietary OM; no difference between groups **Mediators:** G1 performed significantly better than G2 on attitudes towards diet and dietary stage of change; dosage effect found: significant linear effects of web-based NU/weight control module on three of the seven dietary measures: self-efficacy, attitudes, stage of change **WR:** no significant differential change in weight between two groups

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
De Bourdeaudhuij *et al.* (2007) [20], Belgium	**Setting:** workplace **Recruitment:** mediating organizations recruited worksites through occupational health physician **Eligibility/inclusion criteria:** employees of six volunteer and randomly selected worksites **Exclusion criteria:** NR **Participation rate:** 21% **Participants (baseline):** 539 employees (G1: 192; G2: 197; G3: 150) **Final sample (retention rate):** 337 (63%) [G1: 108 (56%); G2: 124 (63%); G3: 105 (70%)] **Final sample characteristics:** 68% females; mean age 39.1 years (SD = 8.7); 44% had BMI >25; 63% had higher education **Incentives offered:** no	**Target:** reduce fat intake **G1:** CT Intranet intervention **G2:** generic print non-tailored information **G3:** no treatment control **Tailoring:** current recommendations, stage of change, self-efficacy, attitudes, knowledge, intentions **Theory:** Theory of Planned Behaviour, TTM **Frequency:** single exposure to intervention **Duration:** exposure occurred within 14-day period **Incentives offered:** no	**Design:** Quasi-experimental; randomization occurred at company level; baseline groups equivalent (demographics and OM); electronic questionnaires; both intention to treat analyses and separate complete case analyses conducted **Follow-up:** 6 months PI	**Primary OM:** fat intake, % energy from fat **Instrument:** 48-item FFQ **Validated:** yes **Other OM:**, psychosocial determinants of fat intake, process evaluation measures (G1 only) **Instrument:** electronic questionnaire **Validated:** NR	**Behaviour:** CT intervention more effective in reducing total fat intake and % energy from fat than a generic intervention and a no-treatment control group: steeper decrease in fat intake and % energy from fat found in G1 compared with Groups 2 and 3; stronger intervention effect found in older participants (≥40 years); **Mediators:** G1 participants had increased in perceived and objective knowledge, Groups 2 and 3 participants had decreased perceived knowledge, G2 no change in objective knowledge, G3 slight decrease in objective knowledge **Subgroup analyses:Participants not meeting fat intake recommendation at baseline:** G1 intervention more effective than Groups 2 and 3 in reducing fat intake and % energy from fat **Participants already meeting fat intake recommendation at baseline:** G1 intervention more effective than G2 in reducing fat intake and % energy from fat

Computer-tailored dietary behaviour change interventions

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Vandelanotte *et al.* (2005) [25] and (2007) [21], Belgium **Other behaviours targeted:** PA	**Setting:** university computer laboratory, controlled **Recruitment:** local media, posters, leaflets and e-mail. **Eligibility/inclusion criteria:** age 20–60 years **Exclusion criteria:** medical complaints related to PA or fat intake **Participants (baseline):** 1023 adults **Retention rate:** 6 months 75%; PI follow-up 38% **Final sample characteristics (6 months):** 65% females, mean age 39.1 years ± 9.6; 70% high level of education; 86% employed; mean BMI = 24.5 ± 4.1; men and younger participants more likely to dropout	**Target:** reduce fat intake G1–G3 received interactive CT intervention delivered through desktop computer application **G1:** tailored PA and fat intake interventions simultaneously **G2:** tailored PA intervention at baseline and tailored fat intake intervention 3 months later **G3:** tailored fat intake intervention at baseline and tailored PA intervention 3 months later **G4:** waitlist control; received tailored interventions at 6 months **Tailoring:** current recommendations, stage of change, self-efficacy, attitudes, intentions **Theory:** Theory of Planned Behaviour and TTM **Frequency:** ~50 minute single exposure **Duration:** 6 months **Incentives offered:** yes	**Design:** RCT; randomized by individual; mail questionnaires; % energy from fat calculated using recommended energy intake tables for total energy intake; FFQ only measured fat intake **Follow-up:** 6 months (PT), 2 years post-baseline (follow-up study in which control group omitted from analysis as were waitlist)	**6-months:** **OM:** frequency and amount of fat intake **Instrument:** 48-item FFQ **Validated:** yes **2 year follow-up:** **OM:** total fat intake; % energy from fat (Groups 1 and 3 only, *n* = 237)	**Behaviour:** **6 months:** Groups 1–3 had significantly lower fat intake scores (total fat intake and energy from fat) compared with G4 (control); fat intake and energy from fat decreased significantly more in the simultaneous group than the sequential group **2 years (no control group):** no differences in change between Groups 1 and 3 for total fat and % energy from fat but strong time effects for total group (except for those meeting fat intake recommendations at baseline); participants fat intake level decreased sharply from baseline to 6-month PT and then remained at that level at 2-year follow-up

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Winett *et al.* (2007) [22], United States **Other behaviours targeted:** PA	**Setting:** churches **Recruitment:** churches through letter and phone; individual church members through announcements, flyers, posters, bulletins and luncheons **Participation rate:** 14 of 23 churches **Eligibility/inclusion criteria:** members of consenting churches **Exclusion criteria:** certain medical conditions necessitated medical clearance before participating in PA component **Participants (baseline):** 1071 church members [(G1 = 364 (five churches), G2 = 364 (five churches), G3 = 343 (four churches)] **Retention rate:** PT 89% (G1 = 91%; G2 = 85%; G3 = 87%); PI follow-up 87% (G1 = 90%; G2 = 85%; G3 = 85%) **Baseline sample characteristics:** 33% males, median age 53 years; 23% African-American, 57% BMI $\geqslant$25, 60% sedentary (<7500 steps/day)	**Target:** decrease fat and increase fibre, F&V **G1:** CT Internet intervention (through church) and additional church-based support **G2:** CT Internet intervention (through church) **G3:** waitlist control **Tailoring:** current recommendations, previously set goals **Theory:** SCT **Frequency:** multiple exposure, minimum weekly **Duration:** 12 weeks **Incentives offered:** yes	**Design:** group randomized trial; randomized by church (after being stratified by denomination, size and primary racial background of members); food shopping receipts analysed using The Grocery Receipt Recording Program; pragmatic analyses conducted; unequal % of African-American participants across groups **Follow-up:** 12 weeks (PT) and 6 months PI	**Primary OM:** consumption of fat, fibre, F&V, weight, height **Instrument:** Block98 FFQ, food shopping receipts (6 weeks worth at each assessment point) **Validated:** yes **Other OM:** social support, self-efficacy, outcome expectations, self-regulation variables, process measures **Instrument:** the Health Beliefs Survey, log-ins	**12 weeks:** **Behaviour:** participants in G1 and G2 increased fibre, F&V intake more than those in G3; no significant differences between G1 and G2 in terms of fibre, F&V intake; no significant differences between G1, G2 and G3 for fat intake **WR:** G1 participants lost small amount weight and compared with small weight gain in G3 participants difference was significant; marginally significant difference between G2 and G3; no difference between G1 and G2. **Mediators:** G1 and G2 made greater changes in NU self-regulation behaviours compared with G3 but changes in NU behaviour were not related to use of NU self-regulation strategies **6-months:Behaviour and mediators:** similar effects observed as for PT **WR:** no differences between G1, G2 and G3

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Kypri *et al.* (2005) [23], New Zealand **Other behaviours targeted:** PA, alcohol consumption and smoking	**Setting:** primary care **Recruitment:** invited in person by research assistant **Eligibility/inclusion criteria:** attending primary care at university **Exclusion criteria:** NR **Participants (baseline):** 218 young adults attending student health service of university **Retention rate:** 86% **Baseline sample characteristics:** 49% females, mean age = 20.2 years (SD = 1.5); 75% European, 8% Maori	**Target:** increase F&V consumption **G1:** CT intervention via desktop computer program **G2:** computerized assessment only **G3:** no treatment control **Tailoring:** current recommendations, peer behaviour **Theory:** NR **Frequency:** single exposure (one computer session) **Duration:** 6 weeks **Incentives offered:** yes	**Design:** RCT; participants assigned computerized random number generator in blocks of 15 (five per group); baseline questionnaire completed in clinic; follow-up was web-based survey **Follow-up:** 6 weeks PI	**Primary OM:** F&V consumption **Instrument:** computerized questionnaire **Validated:** no	**Behaviour:** G1 had significantly greater compliance with F&V recommendations than G3
Oenema *et al.* (2005) [24], The Netherlands	**Setting:** workplace, controlled **Recruitment:** in-house newsletters; personal invitation letters **Eligibility/inclusion criteria:** 18–65 years, sufficient command of Dutch, access to personal computer with a CD-Rom drive at work/home **Exclusion criteria:** no access to personal computer **Recruitment rate:**37% **Participants (baseline):** 782 employees: (G1 = 261, G2 = 260, G3 = 261) **Retention rate:** 79% (G = 72%, G2 = 75%, G3 = 89%) **Final sample characteristics:** 43% females; mean age = 42 years (SD = 9), 94% born in The Netherlands; 11% university degree, 30% higher professional training	**Target:** decrease saturated fat intake and increase F&V intake **G1:** CT nutrition intervention via worksite Intranet or CD-Rom **G2:** generic nutrition intervention via worksite Intranet or CD-Rom **G3:** no treatment control **Tailoring:** current recommendations, peer behaviour, stage of change **Theory:** Precaution Adoption Process Model **Frequency:** multiple exposure (access program as often as liked, program did not change over time) **Duration:** 3 weeks **Incentives offered:** yes	**Design:** RCT; randomized by individual; baseline groups equivalent (demographics and OM), mail questionnaires; subgroup analyses performed on at-risk group and unaware group **Follow-up:** 3 weeks PI	**Primary OM:** saturated fat, F&V intake, awareness of personal intake levels, intention to change **Instrument**: FFQs (35-item fat, 14-item F&V) **Validated:** yes **Other OM:** process evaluation measures	**Behaviour:** no effects found **Mediators:** lower level of awareness and intention to change in Groups 2 and 3 than in G1 for fat and vegetable intake; subgroup analysis indicated similar but stronger group effects for determinants of fat and vegetable intake and also found Groups 2 and 3 had a lower intention to change fruit consumption and G3 had lower fruit intake than G1

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Campbell *et al.* (2004) [26], United States	**Setting:** two Women, Infants and Children (WIC) clinic sites **Recruitment:** staff recruited participants on scheduled nutrition education visit **Eligibility/inclusion criteria:** client of one of two selected WIC sites; ≥18 years, receiving WIC benefits for self or children, English language **Exclusion criteria:** those deemed high risk by WIC nutritionist **Participants (baseline):** 410 low-income women **Retention rate:** 74.8% **Final sample characteristics:** 96% females, 20% pregnant, 55% White non-Hispanic, 45% minority groups (primarily African-American); G1 had significantly more African-American and less Caucasian than G2	**Target:** lower fat and increase F&V consumption, improve infant and child nutrition **G1:** CT intervention via multi-media (video soap opera, interactive infomercials) and take-home print materials **G2:** waitlist control **Tailoring:** current recommendations, stage of change **Theory:** SCT, TTM **Frequency:** single exposure **Duration:** 20–25 min computer session **Incentives offered:** yes	**Design:** RCT; randomized by individual; self-administered computer-based survey or telephone interview (majority) **Follow-up:** 1–2 months post-intervention	**Primary OM:** total fat, F&V intake **Instrument:** 26-item FFQ **Validated:** yes **Other OM:** knowledge, self-efficacy, stages of change, process evaluation measures	**Behaviour:** no significant differences between groups for any dietary behaviours **Mediators:** G1 participants' knowledge and self-efficacy for consuming low-fat dairy foods increased significantly more than G2 participant's; no effect on stage of change movement

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Irvine *et al.* (2004) [27], United States	**Setting:** workplace (hospital) **Recruitment:** staff meeting announcements, flyers, newsletter articles, e-mail messages, promotion at health fair, letters **Eligibility/inclusion criteria:** employee of hospital system **Exclusion criteria:** NR **Participants (baseline):** 517 adults (G1 = 260, G2 = 257) **Retention rate:** 90% **Baseline sample characteristics:** 73% females; mean age 43 years; 85% Caucasian, 90% college/ postgraduate education	**Target:** decrease fat consumption **G1:** CT intervention via multi-media (interactive video program on personal computer stations at worksite) **G2:** waitlist control **Tailoring:** current recommendations, stage of change **Theory:** TTM, Theory of Reasoned Action, SCT, Health Communication Theory **Frequency:** one session average ~35 min; multiple exposure encouraged but not commonly re-engaged for second and third visits, static programme **Duration:** 60 days (G1); 30 days (G2) **Incentives offered:** yes	**Design:** RCT; participants blocked based on gender, age, ethnic/racial self-identification and worksite then paired within blocks and randomly assigned to group; groups demographically equivalent at baseline **Follow-up:** 2 months PI (G1), comparison testing at 1 month PI	**Primary OM:** low-fat dietary habits, F&V intake, meeting programme recommendations, stage of change for low-fat diet, attitudes, behavioural intention, self-efficacy **Instrument:** 42-item diet habits questionnaire (including 21-item diet habits questionnaire, F&V survey items) **Validated:** yes	**Behaviour (1 month):** G1 significantly better scores than G2 for all seven OM (including decreased fat consumption, increased F&V consumption) **Behaviour (2 months):** G1 maintained effects; At this time point G2 replicated positive findings (their 1 month PI follow-up)

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Anderson *et al.* (2001) [28], United States	**Setting:** community **Recruitment:** brief face-to-face contact in five supermarkets followed by mail-out of enrolment materials. **Eligibility/inclusion criteria:** participants had to complete demographic survey and mail back with at least 4 weeks worth food shopping receipts **Exclusion criteria:** none **Participants (baseline):** 363 supermarket customers (148 in each group) **Retention rate:** PT 76% (G1 = 87%, G2 = 100%); PI follow-up 45% (G1 = 49%, G2 = 61%) **Final sample (PT) characteristics:** 96% females; 92% White; 80% >12 years education	**Target:** increase fibre & F&V, decrease fat in purchases and consumption **G1:** CT intervention via computers in stand-alone kiosks in five supermarkets (pictures, graphics and audio) **G2:** no treatment control **Tailoring:** current recommendations **Theory:** SCT **Frequency:** multiple exposure (~weekly); each session at least 5–10 min **Duration:** 15 weeks **Incentives offered:** yes	**Design:** RCT; randomized by individual after being stratified by race, education and family size; no significant differences between groups at baseline for OM; controlled for demographic characteristics and baseline fat levels at PT; the NLS Supermarket Foods database, the NLS Grocery Receipt Recording Program (software) and the Block Dietary Data Systems were used **Follow-up:** 4–6 months (unknown whether PI/post-baseline)	**Primary OM:** %kcal from fat, fibre per kcal purchased, servings F&V per 1000 kcal **Instruments:** Block95 FFQ and food shopping receipts **Validated:** yes **Secondary OM:** social cognitive variables: self-efficacy and outcome expectations at 4 weeks and end of intervention; **Instrument:** NLS Food Beliefs Survey; Process measures	**PT:** **Behaviour:** G1 had lower fat, higher fibre(g) /1000 kcal and higher F&V servings/1000 kcal than G2 **Mediators:** G1 also had higher levels of self-efficacy for decreasing fat than G2 **4–6 month follow-up:** **Behaviour:** findings maintained

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Delichatsios *et al.* (2001) [29], United States **Other behaviours targeted:** PA [31]	**Setting:** community **Recruitment:** letter through medical practice **Eligibility/inclusion criteria:** patients of a multi-site, multi-specialty group practice in Eastern Massachusetts **Exclusion criteria:** <25 years, existing medical or psychological condition, engaged in regular moderate or vigorous intensity PA, did not have 'suboptimal' diet **Participants (baseline):** 298 (G1 = 148; G2 = 150). **Retention rate:** 6 months 83% (completed PrimeScreen) **Baseline sample characteristics:** 72% females; mean age 45.9 years, 85% employed; 45% White; 45% African-American; 71% ≥13 years education	**Target:** increase F&V and fibre consumption, reduce fat intake **G1:** CT NU intervention via an automated telephone counselling system and printed status reports **G2:** CT PA intervention via an automated telephone counselling system and printed status reports **Tailoring:** stage of change, current recommendations **Theory used:** SCT, TTM and decision-making theory **Frequency:** multiple exposure (weekly); each session 5–7 min **Duration:** 6 months **Incentives offered:** no	**Design:** RCT; randomized by individual; baseline groups demographically equivalent; analyses controlled for age, gender, race and baseline intake; intention to treat analyses using last observation carried forward approach for missing data. Assessments conducted at home visit for baseline then by Computer-Assisted Telephone Interviewing **Follow-up:** 3, 6 months (PT)	**Primary OM:** changes in: consumption of each of five food groups (F&V, red and processed meats, whole fat dairy foods, and whole grain foods); FFQ global diet quality score; intakes of selected nutrients; stage of readiness to change, intent and attempts to change dietary behaviour, confidence in making changes **Instruments:** FFQ and PrimeScreen **Validated:** yes **Other OM:** process measures	**Behaviour:** **FFQ:** G1, compared with G2: increased fruit intake by 1.1 servings/day; dietary fibre intake by 4 g/day and decreased saturated fat as % energy intake by 1.7% G1 had an 8.9 point greater increase in global diet quality score than G2 **PrimeScreen:** **Behaviour:** corroborated findings from FFQ, however, less so (increased fruit intake by 0.4 serves/day and dietary fibre by 1 g/day and decreased saturated fat as % energy intake by 1%); increased intake folate, vitamin A, vitamin C and beta-carotene **Mediators:** G1 showed statistically significant positive movements in stage of readiness to change between baseline and 6 months for fruits and whole grains compared with G2

Table II. *Continued*

Study and focus	Context/setting and sample characteristics	Intervention characteristics and control condition	Study design and evaluation method	Outcome measures	Key findings
Campbell *et al.* (1999) [30], United States	**Setting:** community (food stamp office) **Recruitment:** trained research assistants at a food stamp certification office **Eligibility/inclusion criteria:** ≥18 years, English language, either had children <18 years living at home or pregnant **Exclusion criteria:** NR **Participants (baseline):** 526 low-income women **Retention rate:** 72% **Baseline sample characteristics:** 100% females; mean age 29.3 years, 33% low education; 85% African-American; G2 participants significantly more likely to report need to lose weight, self-rate in action, maintenance and pre-contemplation stages and report consuming more fat than G1 participants at baseline	**Target:** reduce fat consumption **G1:** CT intervention via multi-media (video, interactive infomercials) through computer kiosk at food stamp office **G2:** waitlist control **Tailoring:** current recommendations, stage of change **Theory:** SCT, TTM **Frequency:** single exposure **Duration:** 30-min computer session **Incentives offered:** yes	**Design:** pilot RCT; randomization based on day participant attended office; study groups comparable at baseline for demographics; three different methods of survey: computer self-administered, self-administered with research assistant help and telephone administered **Follow-up:** 1–3 months PI	**Primary OM:** fat consumption **Instruments:** 16-item FFQ, six-items eating behaviour questionnaire (follow-up only) **Validated:** yes **Other OM:** stage of change, self-efficacy, knowledge, perceived overweight, autonomy (food purchasing, planning and preparation), process measures	**Behaviour:** both groups significantly lowered fat consumption but no difference between groups; G1 participants more likely to use low-fat cooking methods (oven baking) and consume low fat snacks than G2 participants **Mediators:** G1 participants' knowledge significantly greater than G2 participant's; more G1 participants in preparation, action/maintenance stages than G2 participants; higher % G1 participants had advanced in stage compared with G2

BMI, body mass index; CT, computer tailored; F&V, fruit and vegetables; FFQ = Food Frequency Questionnaire; G, Group; NU, nutrition; OM, outcome measure; PA, physical activity; PI, post-intervention; PT, post-test; RCT, randomized controlled trial; SCT, Social Cognitive Theory; TTM, Transtheoretical Model; WR, weight reduction.

Table III. *Outcome effects* and validity scores of reviewed studies*

Study	Dietary behaviour	Physical activity	Weight reduction	Internal validity score (%)	External validity score (%)
Dietary behaviour					
De Bourdeaudhuij *et al.* (2007) [20]	+ fat[ab]			75	78
Oenema *et al.* (2005) [24]	M (fat & vegetable)[ac]			63	56
Campbell *et al.* (2004) [26]	M fat[a]			63	39
Irvine *et al.* (2004) [27]	+ fat[a]			75	33
Anderson *et al.* (2001) [28]	+ fat, fibre, F&V[a]			63	50
Delichatsios *et al.* (2001) [29]	+ fat, fibre, F&V[d]			75	50
Campbell *et al.* (1999) [30]	(+) fat[a]			50	56
Combined physical activity, dietary behaviour and/or weight reduction					
Booth *et al.* (2008) [18]	(+) fat only[d]	(+)[d]	(+)[d]	50	67
Cook *et al.* (2007) [19]	(+)[b] (overall diet including fat)	(+)[b]	(+)[b]	75	33
Vandelanotte *et al.* (2005 and 2007) [21, 25] (6 month post-test)	+ fat[a]	+[a]		50	56
2-y follow-up	(+) fat[e]	(+)[e]			
Winett *et al.* (2007) [22]	+ fibre, F&V[a]	M[a]	+[a] (3 months only, not maintained at 6 months)	88	61
Kypri *et al.* (2005) [23]	+ F&V[a]	+[a]		63	39

+ significant difference over time between treatment and control group OR significant difference between groups at post-test.
(+) significant difference within groups over time but no significant difference between groups.
M, positive effects on behaviour mediators but not on actual behaviour.
*Outcome effects are reported for the effect of the computer-tailored intervention group as compared with the following control groups:
[a]No treatment control group.
[b]Generic print comparison group.
[c]Generic-computerized comparison group.
[d]Comparison treatment group on different/additional targeted behaviour.
[e]Comparison group of lower intensity.

The study with the highest internal validity score met all criteria apart from having equivalent groups at baseline based on ethnicity [22].

The external validity scores ranged from 33% to 78%, with an average of 52% for all studies and 54% for those studies reporting significant positive between-group effects on dietary behaviour outcomes (Table III). Of the five studies which had an above average external validity score (>52%), four reported positive between-group effects: three for dietary behaviour outcomes and one for weight reduction outcomes. Only a minority of studies met the following external validity criteria: describing the maintenance of long-term post-intervention effects; using representative samples; reporting on intervention costs and reporting on participation or recruitment rates or the similarity and differences between participants to either those who declined participation or the intended target audience. For example, one study with the lowest external validity score did not meet any of these four criteria in addition to insufficient description of the intervention. Two criteria were only partially met: accounting for all participants who entered the trial at its conclusion and describing recruitment methods and/or inclusion and exclusion criteria sufficiently [19]. The study with the highest external validity score met all criteria apart from providing cost information and two criteria were only partially met: reporting exclusion criteria and long-term follow-up effects [20].

Intervention and study characteristics

Mode of delivery

All interventions were classified as second-generation computerized interventions. The majority were delivered using the Internet and/or email [18–20, 22, 24], followed by desktop computer programs [21, 23–25, 28], multi-media (combination of audio, video and graphics) [26, 27, 30] and telephone [29].

Study sample

Baseline sample size ranged from 73 to 1071. Eight studies either described dropouts compared with study completers and/or described reasons for dropout [18, 20–24, 28, 30] and only two studies reported a rationale for sample size [22, 23].

The generalizability of findings was a limitation of all studies due to one or more of the following: a small or unrepresentative sample; an unrepresentative target population or the controlled nature of the setting within which the study was conducted. Only four studies reported on the characteristics of participants compared with the target population [20, 22, 28, 30].

The majority of study samples usually consisted of healthy adults recruited through community settings [18, 21, 22, 25, 26, 28, 30], the workplace [19, 20, 24, 27] and primary health care settings [23, 29]. The majority of interventions recruited self-select volunteer individuals [18, 19, 22–30]. Some studies used additional eligibility or exclusion criteria related to medical conditions [22, 25, 29], age [25, 29], gender [26, 30], health behaviour status [29], medication [18], body mass index [18], income [30] and household characteristics [30].

The majority of samples were predominately female, well educated and Caucasian. Eleven studies reported a predominately female baseline or follow-up sample [18–22, 25–30], with a median proportion of 72% for all 13 studies. Eight of the 12 studies reporting on education level of their baseline or follow-up sample had a predominately well-educated sample, as determined by level of educational attainment or years of education [18–21, 23, 25, 27, 28], with a median proportion of 67% for all 12 studies. Six of the seven studies reporting on the ethnic racial background of their baseline or follow-up sample had a predominately Caucasian/White sample [18, 19, 26–29], with a median proportion of 81% for all seven studies.

Duration and exposure

Of the seven computer-tailored studies reporting significant positive between-group effects on dietary behaviour outcomes [20, 22, 23, 25, 27–29] three were single exposure [20, 23, 25] and four involved varied frequencies of multiple exposures, ranging from 12 weeks to 6 months duration [22, 27–29]. Three of these used controlled programme delivery which meant that the information was new at each exposure [22, 28, 29].

Intensity

Two interventions compared computer-tailored intervention groups which differed in intensity in terms of the number of behaviours targeted, neither of which could report significant differences between such groups [18, 21]. A web-based study comparing computer-tailored intervention groups with the same physical activity and dietary behaviour intervention in addition to personal support [22] reported that the intervention group receiving the additional social supports had better outcomes. However, both groups had significantly better outcomes than the waitlist control group.

Use of theory

Of the seven computer-tailored intervention studies reporting significant positive between-group effects on dietary behaviour outcomes [20, 22, 23, 25, 27–29], a wide range of theories were used, most commonly the transtheoretical model [20, 25, 27, 29] and social cognitive theory [22, 27–29]. These were also the most commonly used theories overall. Other theories of successful interventions included the theory of planned behaviour [20, 25], the theory of reasoned action [27], health communication theory [27] and decision-making theory [29].

Tailoring

Ten studies isolated the effect of the tailoring by comparing the computer-tailored intervention

group to either a no treatment or waiting list control, or a comparison treatment group receiving generic information. Six of these found evidence in favour of the computer-tailored intervention for dietary behaviour outcomes [20, 22, 23, 25, 27, 28], one of which also reported positive between-group effects on weight reduction outcomes [22].

Of the six studies that isolated the effect of the tailoring and found evidence of a positive effect, all compared participant's behaviour to current recommendations [20, 22, 23, 25, 27, 28]. Half also tailored feedback according to the participant's stage of change [20, 25, 27]. The majority of these studies tailored feedback in more than one way [20, 22, 23, 25, 27]. These tailoring methods were also common for studies overall.

Other ways of tailoring included providing feedback that compared participant's behaviour to the behaviour of peers [23, 24], to previously set goals [18, 22] and tailoring feedback to the participant's self-efficacy, perceived benefits and barriers to behaviour, intentions and attitudes [20, 25].

Outcomes and instrument validity

Only one dietary behaviour study did not indicate the use of valid instruments to measure dietary behavioural outcomes. The most commonly used were food frequency questionnaires [20–22, 24–26, 28–30]. Other instruments included a 24-h dietary recall questionnaire [18] and a dietary habits questionnaire [27]. Food shopping receipts were also used in two studies [22, 28].

Three studies included weight reduction outcomes, only one of which used objective measures of height, weight and waist circumference taken in a clinic [18], the remaining two using self-reported measures of weight and/or height [19, 22].

Retention rates

Studies reported retention rates for different time-frames making comparisons difficult. Retention rates were compared by considering post-test retention rates when reported [18, 19, 22, 25, 29], and when not available the earliest post-intervention follow-up retention rate was used as the best ap-

proximation, the majority of which were short term (<3 months) [23, 24, 26–28, 30], one medium term (3≤ month ≤6) [20] and one long term (>6 months) [21].

Estimated retention rates ranged from 63% to 90%. Five studies had a retention rate >80% [19, 22, 23, 27, 29]. It must be noted that all studies with relatively higher retention rates were actual post-test measurements [19, 22, 29] or estimates based on short-term post-intervention follow-up retention rates [23, 27]. Those studies reporting retention rates <80% were often approximations based on retention rates reported for post-intervention follow-up: short term [24, 26, 30], medium term [20] and long term, [21] which may account for the relatively lower rates. Only two of the studies with rates <80% were actual post-test measurements [18, 25].

There were some commonalities between the five studies with relatively high retention rates: all used highly motivated and/or self-select samples; a majority were intended as multiple exposure interventions ranging from 2 to 6 months [19, 22, 27, 29] and a majority offered incentives to participants [19, 22, 23, 27]. Due to the small number of heterogenous studies reviewed, a consistent relationship between retention rates and the intervention mode of delivery, duration or intensity could not be found.

Study design: isolating the effect of the technology and tailoring

Ten of the studies isolated the effect of the computer-tailored intervention in terms of both the tailoring and the technology effect by comparing to either a no treatment or waiting list control, group or a non-tailored non-technology control group. Six of these found evidence in favour of the computer-tailored intervention on dietary behaviour outcomes [20, 22, 23, 25, 27, 28], one of which also found evidence in favour of the computer-tailored intervention for weight reduction outcomes [22].

Intervention costs

Although many articles referred to the cost effectiveness of computer-tailored interventions [18–20, 25, 27, 29], only one reported on any basic economic

measures for their intervention such as costs. This included an indication of the cost of a website-delivered intervention, a face-to-face nutrition counselling intervention and an Internet-based intervention with nutrition counselling [18]. They reported that although the original set-up costs for a website are costly (minimum $20 000 AUD), ongoing costs are minimal and additional cost savings may be had by participants due to no travel time or costs.

Discussion

This narrative systematic review has described the range and quality of evidence on second-generation computer-tailored primary prevention interventions targeting dietary behaviour change in adults. It also describes common characteristics of interventions that produced significant between-group effects and interventions with good retention rates. To our knowledge, previous reviews have not attempted to gauge the external validity of such intervention studies although they have included varying measures of external validity in their quality criteria. Doing so is important in determining their generalizability and relevance to health promotion practice [32].

The majority of studies that isolated the effect of both the technology and tailoring in their study design reported significant positive outcomes, indicating computer-tailored interventions targeting these behaviours as a promising primary prevention strategy. The efficacy of computer-tailored interventions is dependent on many factors such as the intervention quality, duration, exposure, intensity, use of theory, method of tailoring, source credibility and mode of delivery. The quality, intensity and duration of intervention studies reporting significant positive between-group effects on dietary behaviour outcomes differed widely. However, it appears that tailoring and the use of theory are important factors for success.

Success of the intervention is not dependent on the technology used in its delivery or its intensity. However, this could be due to the small number of heterogeneous studies reviewed and the very small number of studies comparing intervention groups of differing intensity. There seems little evidence that success is more likely in interventions of greater intensity than of lower intensity, and this is the case whether additional support is delivered through the technology or interpersonal communication. Kroeze et al. [4] reported similar findings. There is insufficient evidence to determine the optimal intensity for computer-tailored interventions generally and the best way of delivering interventions targeting more than one behaviour. Therefore, more research is needed in this area [21, 33].

It has been recommended that studies use a combination of validated self-reports with more objective measures of behaviour change; however, for dietary behaviour change, there is a lack of existing objective measures [4]. Although valid measurement instruments were used, there was a lack of objective outcome measures. Future studies may benefit from collecting objective outcome measures to determine whether the behaviour changes reported are real.

The real-life effectiveness of such interventions is dependent on the setting, the characteristics and representativeness of the targeted and recruited population sample and the methods of recruitment. These factors influence the external validity and generalizability of findings to practice [32]. The external validity of reviewed studies was generally poor, resulting in uncertainty about such interventions' generalizability This finding is not surprising given the majority of studies were RCTs as such designs aim to maximize internal validity and can sacrifice external validity, with results only generalizable to those participants who are willing to accept randomization [32]. A stronger focus on effectiveness and dissemination may assist in the development of programmes in population-based effectiveness settings. Future RCTs should attempt to increase their external validity by including representative participants and answering real-world questions [32]. This review found such characteristics of design lacking, with the common use of small, homogenous or unrepresentative samples and for some a lack of comparison conditions

relevant to real-world decisions. Such characteristics significantly limit the dissemination of such interventions into practice [17].

Although determining cost effectiveness was not the purpose of this review, it is recommended that future studies at the very least report on basic economic measures such as costs. This information is of great relevance to decision makers and can assist in intervention uptake, dissemination and inform more advanced cost-effectiveness studies [17, 32]. Cost-effectiveness analyses of computer-tailored interventions would also be worthwhile. The potential cost savings gained by participants due to no travel time or costs may be particularly important for those living in rural or isolated areas.

There was a fundamental lack of long-term post-intervention follow-up, with only one study demonstrating that intervention effects were maintained at 2 years post-baseline [21]. However, the generalizability of this study's findings and application to practice may be limited. More studies with long-term follow-up of 12 months post-intervention are needed [34].

Previously noted poor retention rates of computer-tailored interventions, in particular web-based interventions [4–6, 10], prompted consideration of characteristics of interventions that might maintain engagement and retention. Such characteristics include the intervention's interactivity, duration and intensity, the length of follow-up, setting and sample population characteristics. However, with the small number of studies comparing retention rates became problematic due to their varied follow-up length and therefore we could not form any definite conclusions. Based on the findings of this review and other published reviews [5, 10], it seems the following intervention characteristics may be important in enhancing participant retention: ensuring multiple exposures to the intervention material, preferably using controlled programme delivery; the use of incentives; prompts through another medium; interactive and dynamic web components and individualized tailoring. Each of these characteristics may be insufficient on its own to result in good retention and therefore all will need to be considered in intervention design, sample size

calculations and probable retention rates in the future.

The limitations of this review must also be acknowledged. Firstly, this review did not actively seek unpublished studies although one such study was included. Therefore, when considering the findings of this review, the possibility of publication bias should be noted, resulting in a bias of studies with positive findings. However, given the fairly high proportion of published studies reviewed that did not have significant findings, it is believed that the likelihood of publication bias is minimal.

Secondly, this review did not include articles in which dietary behaviour was not a primary outcome. This meant articles were excluded in which psychological indicators, behaviour mediators or process measures were the only outcome measures reported. Process measures were not described, limiting this paper's discussion on retention, engagement and acceptability of computer-tailored interventions and their components in different population subgroups and settings. Although this was not the purpose of the review, reviewing computer-tailored intervention research describing process outcomes would be worthwhile as it may indicate different levels of acceptance and the relative effectiveness in different population subgroups. This may be particularly important given the majority of reviewed studies had predominantly female, Caucasian and well-educated samples.

Thirdly, this review has not attempted to estimate a pooled effect size or to calculate and compare effect sizes of different studies due to the heterogeneity of studies in terms of their intervention design, delivery method, exposure and intensity, participants, study design and methods and outcome measures. Such factors make comparisons difficult [35] and inadequate [12], and hence a narrative systematic review was conducted. The two previous reviews on computer-tailored or interactive technology health behaviour interventions most relevant to this review reported small to medium effect sizes [4, 5]. Despite the small effect sizes found, such interventions can have substantial impact at a population health level, with their potential for wide distribution at relatively low cost compared with face-to-face

interventions [4, 5, 27]. However, it will be critical to determine whether such findings are generalizable, can be replicated and to ensure adequate reach and engagement within varied population groups for such interventions.

Lastly, the findings on common characteristics of successful interventions and those with good retention are limited due to the small number of heterogeneous studies included and reliance on varying levels of detail provided in each article. Only a small proportion of the retrieved articles were included in this review. The main reasons for this include: many studies were duplicated in the databases that were searched, broad search terms were used and the exclusion criteria were specific and detailed. For example, the search terms did not distinguish between first- and second-generation interventions, and first-generation interventions which make up a substantial proportion of the literature were not considered in this review.

Future research should endeavour to replicate studies in different populations to indicate effectiveness and generalizability. The work of Vandelanotte and colleagues where the same theory-based intervention was trialed and adapted in different population groups and settings and followed up long term [20, 21, 25, 33, 36] is important in building the evidence base. Their reports on the acceptability and feasibility of these interventions in individuals of different age, sex, education level and computer literacy [8, 9] are also valuable.

Conclusions

The evidence of effectiveness for computer-tailored dietary behaviour change interventions is fairly strong and they have the potential to reach large groups of people albeit self-selected groups. The uncertainty lies in whether the reported behaviour changes can be sustained long term and whether they are generalizable. Also, the relative success of different components of efficacious interventions is unclear in addition to the optimal intervention intensity. Interventions should be tailored to the individual and based on theory. To enhance retention,

the use of incentives, individualized tailoring, interactive and dynamic components, multiple exposures to the intervention material, preferably using controlled programme delivery, and prompts through another medium should be considered.

Further research will be needed on computer-tailored dietary behaviour primary prevention interventions including: the replication of successful efficacy trials in different settings and population groups; effectiveness studies in representative heterogenous populations; a review of the research on engagement and acceptability of such interventions; long-term post-intervention follow-up studies and cost-effectiveness studies. More research is also needed to determine the optimal intensity for population-level interventions.

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