

# **Adaptive e-learning to improve dietary behaviour: a systematic review and cost-effectiveness analysis**

J Harris, L Felix, A Miners, E Murray, S Michie, E Ferguson, C Free, K Lock, J Landon and P Edwards



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# Adaptive e-learning to improve dietary behaviour: a systematic review and cost-effectiveness analysis

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# Abstract

## Adaptive e-learning to improve dietary behaviour: a systematic review and cost-effectiveness analysis

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**Background:** UK public health policy strongly advocates dietary change for the improvement of population health and emphasises the importance of individual empowerment to improve health. A new and evolving area in the promotion of dietary behavioural change is 'e-learning', the use of interactive electronic media to facilitate teaching and learning on a range of issues including health. The high level of accessibility, combined with emerging advances in computer processing power, data transmission and data storage, makes interactive e-learning a potentially powerful and cost-effective medium for improving dietary behaviour.

**Objective:** This review aims to assess the effectiveness and cost-effectiveness of adaptive e-learning interventions for dietary behaviour change, and also to explore potential psychological mechanisms of action and components of effective interventions.

**Data sources:** Electronic bibliographic databases (Cumulative Index to Nursing and Allied Health Literature, The Cochrane Library, Dissertation Abstracts, EMBASE, Education Resources Information Center, Global Health, Health Economic Evaluations Database, Health Management Information Consortium, MEDLINE, PsycINFO and Web of Science) were searched for the period January 1990 to November 2009. Reference lists of included studies and previous reviews were also screened; authors were contacted and trial registers were searched.

**Review methods:** Studies were included if they were randomised controlled trials, involving participants aged  $\geq 13$  years, which evaluated the effectiveness of interactive software programs for improving dietary behaviour. Primary outcomes were measures of dietary behaviours, including estimated intakes or changes in intake of energy, nutrients, dietary fibre, foods or food groups. Secondary outcome measures were clinical outcomes such as anthropometry or blood biochemistry. Psychological mediators of dietary behaviour change were also investigated. Two review authors independently screened results and extracted data from included studies, with any discrepancies settled by a third author. Where studies reported the same outcome, the results were pooled using a random-effects model, with weighted mean differences (WMDs), and 95% confidence

intervals (CIs) were calculated. Cost-effectiveness was assessed in two ways: through a systematic literature review and by building a de novo decision model to assess the cost-effectiveness of a 'generic' e-learning device compared with dietary advice delivered by a health-care professional.

**Results:** A total of 36,379 titles were initially identified by the electronic searches, of which 43 studies were eligible for inclusion in the review. All e-learning interventions were delivered in high-income countries. The most commonly used behavioural change techniques reported to have been used were goal setting; feedback on performance; information on consequences of behaviour in general; barrier identification/problem solving; prompting self-monitoring of behaviour; and instruction on how to perform the behaviour. There was substantial heterogeneity in the estimates of effect. E-learning interventions were associated with a WMD of +0.24 (95% CI 0.04 to 0.44) servings of fruit and vegetables per day; -0.78 g (95% CI -2.5 g to 0.95 g) total fat consumed per day; -0.24 g (95% CI -1.44 g to 0.96 g) saturated fat intake per day; -1.4% (95% CI -2.5% to -0.3%) of total energy consumed from fat per day; +1.45 g (95% CI -0.02 g to 2.92 g) dietary fibre per day; +4 kcal (95% CI -85 kcal to 93 kcal) daily energy intake; -0.1 kg/m<sup>2</sup> (95% CI -0.7 kg/m<sup>2</sup> to 0.4 kg/m<sup>2</sup>) change in body mass index. The base-case results from the E-Learning Economic Evaluation Model suggested that the incremental cost-effectiveness ratio was approximately £102,112 per quality-adjusted life-year (QALY). Expected value of perfect information (EVPI) analysis showed that although the individual-level EVPI was arguably negligible, the population-level value was between £37M and £170M at a willingness to pay of £20,000–30,000 per additional QALY.

**Limitations:** The limitations of this review include potential reporting bias, incomplete retrieval of completed research studies and data extraction errors.

**Conclusion:** The current clinical and economic evidence base suggests that e-learning devices designed to promote dietary behaviour change will not produce clinically significant changes in dietary behaviour and are at least as expensive as other individual behaviour change interventions.

**Future work recommendations:** Despite the relatively high EVPI results from the cost-effectiveness modelling, further clinical trials of individual e-learning interventions should not be undertaken until theoretically informed work that addresses the question of which characteristics of the target population, target behaviour, content and delivery of the intervention are likely to lead to positive results, is completed.

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# Contents

<b>Glossary</b>	<b>vii</b>
<b>List of abbreviations</b>	<b>ix</b>
<b>Executive summary</b>	<b>xi</b>
<b>1. Background</b>	<b>1</b>
The need for improved dietary behaviour	1
Adaptive e-learning via interactive computerised interventions	1
Previous reviews	3
<b>2. Methods for the descriptive analysis and systematic review of effectiveness</b>	<b>5</b>
Objectives	5
Design	5
Study eligibility criteria	5
Identification of eligible studies and data extraction	6
Methodological quality assessment	8
Analysis	8
<b>3. Results of the descriptive analysis</b>	<b>11</b>
Results of the literature search	11
Overview of included studies	11
Overview of excluded studies	37
Methodological quality of included studies	39
<b>4. Results of the systematic review of effectiveness</b>	<b>47</b>
Dietary outcomes	47
Clinical outcomes	51
<b>5. Assessing the cost-effectiveness of e-learning devices for obesity</b>	<b>53</b>
Published economic evaluations	53
The E-Learning Economic Evaluation Model	53
Results	61
Discussion	64
<b>6. Discussion</b>	<b>67</b>
Explanations of effectiveness	67
Can e-learning interventions change dietary behaviour?	69
Are e-learning interventions cost-effective to the NHS?	70
What is the potential population health impact of e-learning interventions?	70
Budget impact analysis	71
Limitations	71

<b>7. Conclusions</b>	<b>73</b>
Effectiveness	73
Cost-effectiveness	73
Recommendations for future research	73
<b>Acknowledgements</b>	<b>75</b>
<b>References</b>	<b>77</b>
<b>Appendix 1</b> Research protocol	<b>85</b>
<b>Appendix 2</b> Search strategies	<b>97</b>
<b>Appendix 3</b> Screening form	<b>109</b>
<b>Appendix 4</b> PRISMA flow diagram	<b>111</b>
<b>Appendix 5</b> Bibliography of included studies	<b>113</b>
<b>Appendix 6</b> List of excluded studies	<b>117</b>
<b>Appendix 7</b> Additional analysis of effectiveness	<b>123</b>
<b>Appendix 8</b> Behaviour change techniques and effectiveness	<b>153</b>
<b>Health Technology Assessment programme</b>	<b>155</b>

## Glossary

**Accessibility** Extent to which an intervention reaches the target population (e.g. including those with differing literacy skills in use or application of information and support supplied through e-learning).

**Adaptive** Requires contributions from users (e.g. entering personal data, making choices) which alters pathways within programs to produce tailored material and feedback that is personally relevant to users of the program.

**Computer kiosk** A computer terminal that provides access to information via electronic methods.

**Diet** Food that is eaten (may be categorised into food groups), including fortified or functional foods, but excluding supplements.

**Dietary behaviour** Food intake (including what, where, how and when food is eaten).

**Dietary log** Diary to keep track of one's dietary intake.

**E-learning** Anything electronic (e.g. SMS, digital TV, personal digital assistant, CD-ROM, internet, etc.) where the goal of the intervention is to improve knowledge/behaviour.

**European Quality of Life-5 Dimensions (EQ-5D)** Standardised instrument used to measure health status.

**Metformin** Drug used for treating diabetes.

**Minitel** Videotex online service accessible through the telephone lines.

**Multimedia** Media that contains a combination of different forms of content (e.g. text, audio, video, still images, animation, etc.).

**QDScore<sup>®</sup>** Diabetes risk calculator.

**Orlistat** Drug used for treating obesity.

**QRISK<sup>®2</sup>** Cardiovascular disease risk calculator.

**Recall bias** Systematic error due to differences in accuracy or completeness of recall to memory of past events or experiences.

**Statin therapy** Drug used for preventing cardiovascular disease in patients with high levels of cholesterol.

**Usability** Ease of use and satisfaction with an intervention.



## List of abbreviations

BMI	body mass index
CBT	cognitive behavioural therapy
CD-ROM	compact disk read-only memory
CI	confidence interval
CVD	cardiovascular disease
DES	discrete event simulation
E-LEEM	E-Learning Economic Evaluation Model
EDE-Q	Eating Disorder Examination-Questionnaire
EDI	Eating Disorder Inventory
EPHPP	effective public health practice project
EVPI	expected value of perfect information
EVPPPI	expected value of partial perfect information
FFQ	Food Frequency Questionnaire
ICER	incremental cost-effectiveness ratio
MONICA	Multinational MONItoring of trends and determinants in CARDiovascular disease
NICE	National Institute for Health and Clinical Excellence
PDA	personal digital assistant
PRISMA	preferred reporting items for systematic reviews and meta-analyses
PSA	probabilistic sensitivity analyses
QALY	quality-adjusted life-year
RCT	randomised controlled trial
SD	standard deviation
SES	socioeconomic status
SMR	standardised mortality ratio
T2D	type 2 diabetes
WMD	weighted mean difference

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All abbreviations that have been used in this report are listed here unless the abbreviation is well known (e.g. NHS), or it has been used only once, or it is a non-standard abbreviation used only in figures/tables/appendices, in which case the abbreviation is defined in the figure legend or in the notes at the end of the table.



# Executive summary

## Background

The composition of habitual diets is associated with adverse or protective effects on health. Consequently, UK public health policy strongly advocates dietary change for the improvement of population health and emphasises the importance of individual empowerment to improve health.

A new and evolving area in the promotion of dietary behavioural change is 'e-learning', the use of interactive electronic media to facilitate teaching and learning on a range of issues including health. The high level of accessibility, combined with emerging advances in computer processing power, data transmission and data storage, makes interactive e-learning a potentially powerful and cost-effective medium for improving dietary behaviour. E-learning also has a number of potential advantages compared with traditional approaches for the promotion of dietary behaviour change, such as the possibility of tailoring to individual circumstances; translating complex information through video, graphics and audio systems; and potential cost savings on face-to-face interventions involving health-care practitioners. Some evidence that individualised, tailored e-learning approaches are more effective than traditional non-tailored interventions has given them a promising lead in health education.

## Objectives

The aims of this systematic review were to assess the effectiveness and cost-effectiveness of adaptive e-learning for improving dietary behaviours. The specific objectives were to:

- describe the range of e-learning technologies in use for promoting dietary behavioural change
- evaluate the effectiveness of interactive e-learning in terms of improvement in dietary behaviour and clinical outcomes
- analyse the e-learning interventions in order to determine the components contributing to effects of e-learning interventions for dietary behaviour change
- investigate potential explanations of dietary behaviour change and mechanisms of action
- evaluate cost-effectiveness compared with current standard interventions, and estimate the likely budget impact in England and Wales.

## Methods

We included all randomised controlled trials (RCTs) of effectiveness of e-learning in adolescents or adults to promote dietary behavioural change and all clinical conditions in which dietary advice plays a major part in case management. Interventions were included if they were interactive computer software programs that tailored output according to user input (including interventions where users enter personal data, or make choices about information, that alter pathways within programs to produce tailored material and feedback that is personally relevant).

Primary outcomes were measures of dietary behaviours, including estimated intakes or changes in intake of energy, nutrients, dietary fibre, foods or food groups. Secondary outcome measures

were clinical outcomes that would be expected to respond to changes in dietary behaviours (e.g. anthropometric status and blood biochemistry). We also sought data on the costs of providing the intervention, any unintended adverse consequences of the interventions, process outcomes (e.g. usage) and data relating to potential cognitive and emotional mediators of dietary behaviour.

### **Searching, screening and data extraction**

Eligible studies were identified by searches of 11 electronic bibliographic databases, trial registers for ongoing and recently completed trials, inspection of the reference lists of all included studies and previously published reviews, and by contact with authors of included studies. There were no restrictions by language. Searches covered the period January 1990 to November 2009.

Two review authors independently examined the titles, abstracts and keywords of electronic records according to the eligibility criteria above. The results of this initial screening were cross-referenced between the two review authors and full-text records obtained for all potentially relevant reports of trials. These potentially eligible trials went through a secondary screening by each reviewer using a screening form based on the eligibility criteria for final inclusion in the systematic review, with disagreements resolved by discussion with a third author.

Two review authors extracted relevant data into a Microsoft ACCESS 2007 database (Microsoft Corporation, Redmond, WA, USA) specifically designed for the review. Two measures of methodological quality were used in the review: the Cochrane Collaboration's risk of bias assessment and the Effective Public Health Practice Project (EPHPP) quality assessment. The dietary assessment tools and techniques used to estimate dietary behaviour were critically examined in terms of quality.

### **Analysis of effectiveness**

For studies that reported the same outcome, we pooled the results using a random effects model, with weighted mean differences (WMDs), and calculated 95% confidence intervals (CIs) and two-sided *p*-values for each outcome. When outcomes were assessed more than once during follow-up, the final assessment was used in analysis. We assessed evidence for selection bias using Egger's test for small study effects. Heterogeneity among the trial results was assessed using both a chi-squared test and the *I*<sup>2</sup> statistic (we considered *I*<sup>2</sup> > 50% to reflect 'substantial heterogeneity'). We conducted sensitivity analyses to investigate possible sources of heterogeneity including study quality and sociodemographic factors that could act as effect modifiers. Causes of heterogeneity and subgroup effects were assessed using random effects meta-analysis. This was implemented in STATA (StataCorp LP, College Station, TX, USA) using the 'metareg' command and including trial characteristics as covariates. All statistical analysis was conducted using STATA statistical software version 11.

### **Economic evaluation**

The intention was to estimate cost-effectiveness in two ways: through a systematic literature review and by building a de novo decision model to assess the cost-effectiveness of a 'generic' e-learning device compared with dietary advice delivered by a health-care professional. However, no perfectly fitting published economic evaluations were identified; thus, the results from the literature review were instead primarily used to inform the model design. The key assumption within the model was that the interventions were designed to promote weight loss in already obese people with a body mass index (BMI) of  $\geq 30$  kg/m<sup>2</sup>. The evaluation was performed from a UK NHS cost perspective and outcomes were expressed as quality-adjusted life-years (QALYs). The estimate of relative treatment effect was derived from the systematic review of effectiveness, and the model was based on discrete event simulation techniques referred to as the 'E-Learning Economic Evaluation Model' (E-LEEM).

## Results

A total of 36,379 titles were initially identified by the electronic searches, of which 2977 were duplicates and were removed. The remaining 33,402 records were screened and 33,129 records were excluded because they did not meet the inclusion criteria. Full-text reports were sought for 273 potentially eligible studies, of which 233 studies were excluded after inspection of the full report. Three eligible studies were identified through searching reference lists of the included studies, yielding a total of 43 studies for inclusion in the review.

### Description of included studies

Of the 43 included studies, one was a crossover trial and two were cluster-randomised trials, whereas the rest were parallel-group RCTs. The majority of interventions evaluated sought to reduce fat intake (28 interventions) and/or to increase fruit and vegetable intake (21 interventions). Other interventions sought to increase fibre intake, reduce overall energy intake, reduce or maintain weight, or reduce or maintain BMI.

All e-learning interventions were delivered in high-income countries: the majority were delivered in the USA (29 interventions), the Netherlands (five studies) and Belgium (three studies). Many interventions were offered over the internet or via a mobile device and without a specific setting. Of those that were delivered in a specific setting, nine were designed to be delivered in the home, eight in the workplace, three in community centres, four in schools/colleges and two in supermarkets. Many study reports did not provide information on the intended intensity or frequency of use; of those that did, intended intensity of interventions varied between a single session to weekly interaction with the intervention over 1 year.

A majority of interventions involved the presentation of nutrition, health and lifestyle information (31 studies), the entering of food consumption data (28 studies), and the presentation of personalised feedback on food and nutrient consumption (21 studies). Other interventions focused on the setting of goals and providing feedback on attainment of these goals (15 studies). The most commonly used behavioural change techniques reported were goal setting (behaviour) (14 studies); provide feedback on performance (14 studies); provide information on consequences of behaviour in general (14 studies) or to the individual (11 studies); barrier identification/problem solving (13 studies); prompt self-monitoring of behaviour (12 studies); provide instruction on how to perform the behaviour (12 studies); prompt review of behavioural goals (11 studies); and plan social support/social change (10 studies).

Of the 23 studies providing details of inclusion criteria, 11 offered the intervention only to those with BMI > 25 kg/m<sup>2</sup>; 10 required participants to be generally healthy and free of diagnosed disease; one trialled the intervention in patients with diabetes; and one required participants to have at least one diagnosed risk factor for cardiovascular disease. Three studies included adolescents aged < 18 years. Of studies targeting adults, the majority included participants with an average age of 40–49 years. One study included adults with an average age > 60 years.

Twenty-two studies measured total fat intake and eight studies measured saturated fat intake (either as grams consumed or as percentage of total energy consumed). Twenty-two studies assessed servings of fruit and/or vegetables consumed per day. Other food and nutrient outcomes measured included energy intake (nine studies) and fibre intake (five studies). In terms of clinical outcomes, 11 studies measured BMI, 14 studies measured weight or weight loss, four studies measured cholesterol, four studies assessed triglycerides and three studies assessed blood pressure. Four studies concentrated on the avoidance of eating disorders and used scales of eating disorder risk alongside measures of BMI and/or weight.

### Methodological quality

The Cochrane assessment was at 'low risk of bias' in 27 studies for methods of sequence generation; 18 studies for methods of allocation concealment; 15 studies for methods of blinding; 22 studies for addressing incomplete outcome data; 11 studies for not demonstrating selective outcome reporting; and 26 studies for providing a conflict of interest statement. The EPHP assessment was 'strong' in one study for selection bias criteria; 43 studies for study design; 36 studies for adjustment for confounders; five studies for criteria on blinding; 21 studies for data collection methods; and 24 studies for attrition criteria. Thirteen studies were rated overall as 'moderate' and 30 studies were rated overall as 'weak'; none was rated 'strong' overall.

Studies using 24-hour recall (two studies), or a combination of two or more dietary assessment methods (11 studies), especially two independent dietary assessment methods (two studies), had the strongest dietary assessment methods for measuring dietary change. Those studies that used a prospective dietary assessment method (e.g. multiple day diet record) alone are valid for measuring dietary change, as long as a compliance bias did not result in an overestimation of the intervention effect and dietary practices were not simplified to reduce respondent burden. The studies with the weakest dietary assessment methods were those using only shopping receipts (two studies), a screening Food Frequency Questionnaire (three studies) or a one- or two-item food group question (five studies). Most studies did not adequately describe their dietary assessment techniques and seven questionnaires were not validated for the target population or nutrient of interest.

### Analysis of effectiveness

There was substantial heterogeneity in the estimates of effect of e-learning interventions on many reported outcomes; however, there was relatively little evidence for heterogeneity in the estimates of effect on total fat intake per day, total energy intake per day and BMI. When studies reporting the same outcomes were pooled in a random effects meta-analysis, e-learning interventions were associated with a WMD of 0.24 servings (95% CI 0.04 servings to 0.44 servings;  $p=0.019$ ) of fruit and vegetables per day (heterogeneity  $p<0.001$  and  $I^2=83\%$ ); WMD of  $-0.78$  g (95% CI  $-2.5$  g to  $0.95$  g) of total fat consumed (heterogeneity  $p=0.18$  and  $I^2=28\%$ ); WMD  $-0.24$  g (95% CI  $-1.44$  g to  $0.96$  g;  $p=0.7$ ) of saturated fat intake (heterogeneity  $p=0.001$  and  $I^2=78\%$ ); WMD of  $-1.4\%$  (95% CI  $-2.5\%$  to  $-0.3\%$ ;  $p=0.012$ ) of total energy consumed from fat (heterogeneity  $p<0.001$  and  $I^2=77\%$ ); WMD of  $1.45$  g (95% CI  $-0.02$  g to  $2.92$  g;  $p=0.053$ ) of dietary fibre per day (heterogeneity  $p=0.11$  and  $I^2=60\%$ ); WMD of  $4$  kcal (95% CI  $-85$  kcal to  $93$  kcal;  $p=0.93$ ) of daily energy intake (heterogeneity  $p=0.33$  and  $I^2=13\%$ ); WMD of  $-0.1$  kg/m<sup>2</sup> (95% CI  $-0.7$  kg/m<sup>2</sup> to  $0.4$  kg/m<sup>2</sup>;  $p=0.69$ ) in BMI (heterogeneity  $p=0.92$  and  $I^2=0\%$ ); and WMD of  $0.6$  kg (95% CI  $-3.5$  kg to  $4.6$  kg;  $p=0.78$ ) of weight (heterogeneity  $p<0.001$  and  $I^2=86\%$ ).

### Economic evaluation

The literature review did not reveal any published economic evaluations of e-learning devices that were based purely on imparting nutritional advice. One published UK study that evaluated a device in conjunction with physical exercise suggested that it was not cost-effective compared with standard methods of providing advice. The base-case results from the E-LEEM model suggested that the incremental cost-effectiveness ratio was approximately £60,000 per QALY. The results were generally robust to most alternative assumptions, except the initial fixed cost of the device. In the base case this cost was assumed to be £854 per person. When the cost was assumed to be £0, the e-learning device was less costly and more effective than the alternative. Expected value of perfect information (EVPI) analysis showed that although the individual-level EVPI was arguably negligible, the population-level value was between £37M and £170M at a willingness to pay of £20,000–30,000 per additional QALY.

## Conclusions

### *Explanations of effectiveness*

We analysed the data with a view to determining reasons for the observed variability in effectiveness of e-learning interventions. We considered that potential reasons could include differences in:

- target populations
- target behaviours
- intervention content
- theoretical base
- mode of delivery
- 'dose' of intervention
- study quality.

Interventions trialled were so heterogeneous that no firm conclusions could be reached. More mechanistic research is required to address these questions, including whether or not adaptive e-learning tools are better suited for disease management than for health promotion; understanding the psychological mechanisms of action of interventions; and whether or not there is a relationship between 'dose' of the intervention and effectiveness. Our statistical assessment of the evidence suggests that trials with lower methodological quality may overestimate effects.

### *Can e-learning interventions change dietary behaviour?*

There are many factors affecting what foods people eat and why, and an intervention targeted at individual behaviour change can address only a selection of these. E-learning has not yet proved itself to be more effective or cost-effective than other behaviour change approaches at an individual level for improving diet, or for preventing or reducing overweight or obesity. Nor is there any research comparing e-learning approaches with population-level approaches to tackling dietary change or reducing obesity.

### *Are e-learning interventions cost-effective to the NHS?*

The results broadly suggest that the e-learning devices are not cost-effective at conventional levels of £20,000–30,000 per QALY gained and the probability that they are cost-effective was  $\approx 25\%$  at these threshold levels, a result that is perhaps not unsurprising given the relatively modest effects derived from the systematic review of effectiveness. However, the results were sensitive to the assumptions regarding the initial fixed cost of the devices; lowering this value dramatically increased the cost-effectiveness of the devices.

### *What is the potential population health impact of e-learning interventions?*

#### **Fruit and vegetables**

Dietary recommendations suggest five servings of fruit and vegetables per person per day; currently adults in the UK (aged 19–65 years) are eating on average 4.4 servings, so an increase of a quarter of a serving would still not raise the average intake to meet the guidelines.

#### **Fat**

Dietary recommendations suggest that  $\approx 35\%$  of calories consumed should come from total fat, and  $\approx 11\%$  of calories from saturated fats. Currently, UK adults consume an average of 34–36% of energy from total fat and 12.8% of energy from saturated fat, so a reduction of 1% would not facilitate achievement of guideline targets.

### **Fibre**

Recommendations suggest an intake of 18 g of dietary fibre per day, with current intake in UK adults at around 14 g. An increase of 1.5 g would therefore not facilitate achievement of the guideline.

Dietary behaviours are likely to be heavily influenced by macro factors at the environmental, organisational, population and sociocultural levels. These wider determinants of dietary behaviour are unlikely to be changed by individually targeted interventions such as e-learning; the results of this review seem to reflect this, with little evidence of effect found.

### ***Implications for health care***

The current clinical and economic evidence base suggests that e-learning devices designed to promote dietary behaviour change will not produce clinically significant changes in dietary behaviour and are at least as expensive as other individual behaviour change interventions.

### ***Implications for research***

Although the return on investment (in terms of the expected value of the reduction in decision uncertainty) from further clinical trials of individual e-learning interventions is expected to be high, we believe that further such clinical trials should not be undertaken until theoretically informed work, which addresses the question of which characteristics of the target population, target behaviour, content and delivery of the intervention are likely to lead to positive results, is completed.

### **Funding**

The National Institute for Health Research Health Technology Assessment programme.

# Chapter 1

## Background

### The need for improved dietary behaviour

The composition of habitual diets is associated with adverse or protective effects on health.<sup>1-3</sup> Specifically, diets high in saturated fats and sodium have been found to increase the risk of cardiovascular diseases (CVDs), whereas those high in fruit and vegetables and low in saturated fats have been linked with reductions in a range of diseases including some cancers, CVD and hypertension.<sup>4-7</sup> The World Health Organization reports that the consumption of up to 600 g per day of fruit and vegetables could reduce the total worldwide burden of disease by 1.8%, and reduce the burden of ischaemic heart disease and ischaemic stroke by 31% and 19%, respectively.<sup>8</sup> In the UK, the consumption of fruit, vegetables, dietary fibre, iron (pre-menopausal women only) and calcium are well below recommendations, whereas intakes of saturated fats and sodium exceed recommendations in large sections of the population.<sup>9</sup> Consequently, UK public health policy strongly advocates dietary change for the improvement of population health and emphasises the importance of individual empowerment to improve health,<sup>7,10</sup> thereby shifting the focus of the NHS from treatment to prevention of illness.<sup>11,12</sup>

### Adaptive e-learning via interactive computerised interventions

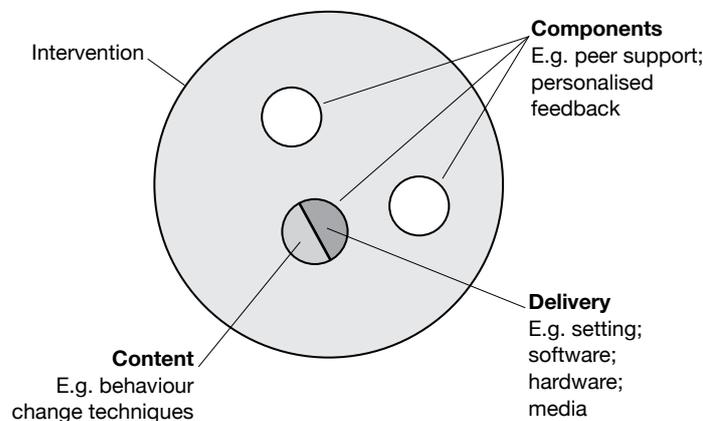
A new and evolving area in the promotion of dietary behavioural change is 'e-learning', the use of interactive electronic media to facilitate teaching and learning on a range of issues including health. E-learning has grown out of recent developments in information and communication technology, such as the internet, interactive computer programs, interactive television and mobile telephones.<sup>13-17</sup> These technologies are rapidly becoming more accessible to the general population (e.g. an estimated 70% of the UK population has access to the internet and this percentage is likely to continue to grow<sup>18</sup>).

The high level of accessibility, combined with emerging advances in computer processing power, data transmission and data storage, makes interactive e-learning a potentially powerful and cost-effective medium for improving dietary behaviour.<sup>19-21</sup> It also has a number of potential advantages compared with traditional approaches for promotion of dietary behaviour change, such as the possibility of tailoring to individual circumstances,<sup>22</sup> translating complex information through video, graphics and audio systems,<sup>23</sup> and potential cost savings on face-to-face interventions involving health-care practitioners. The evidence that individualised, tailored e-learning approaches are more effective than traditional non-tailored interventions<sup>24</sup> has given them a promising lead in health education.<sup>25-27</sup>

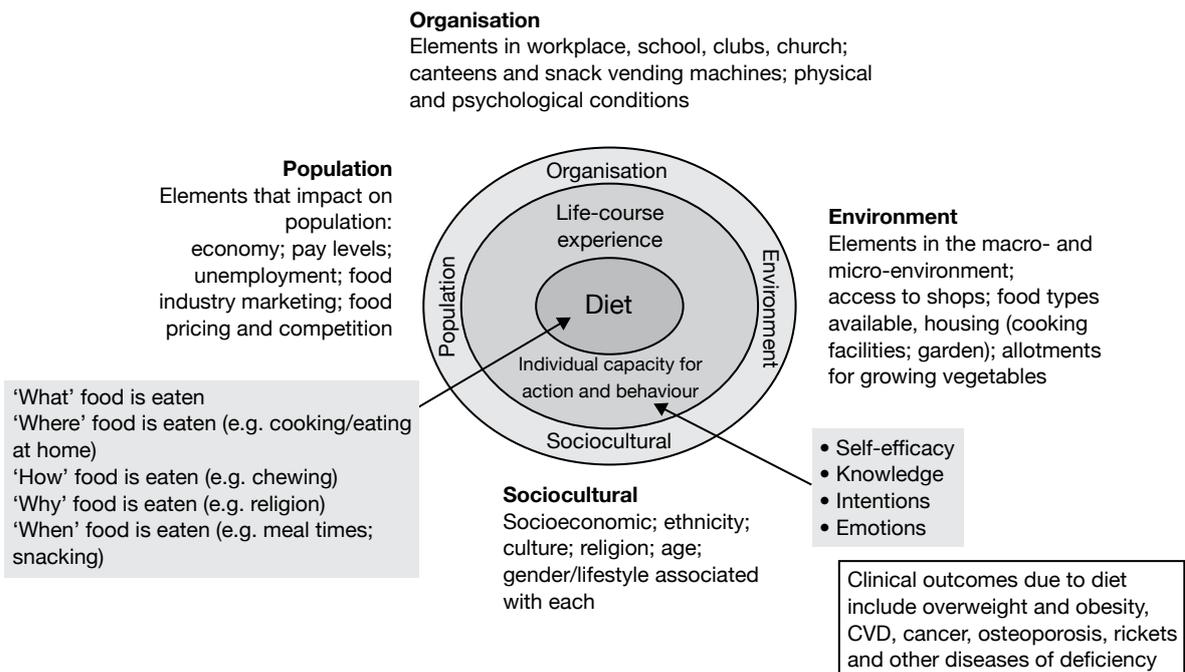
E-learning interventions may be classified into three 'generations', first-generation interventions use computers to tailor printed materials; second-generation interventions use interactive technology delivered on computers; and third-generation interventions use portable devices, such as mobile telephones, for more immediate interaction and feedback.<sup>28</sup> An exploration of the properties of different e-learning interventions is required in order to determine the possible effective components (where a component comprises both 'content' and 'delivery'; *Figure 1*).

Figure 2 illustrates that dietary behaviours are likely to be heavily influenced by macro factors at the environmental level (e.g. access to shops selling fruit and vegetables at affordable prices); organisational level (e.g. energy-dense ‘junk’ food vending machines in schools or workplaces); population level (e.g. low income and unemployment); and sociocultural level (e.g. interpersonal influences, such as where one person is responsible for meals eaten by others in a household). These wider determinants of dietary behaviour are unlikely to be changed by individually targeted interventions such as e-learning. Individual-level factors such as self-efficacy, knowledge and intention may be subject to change by e-learning. An exploration of the potential cognitive and emotional mediators of individual dietary behaviour change is required in order to elicit potential mechanisms of action.

There is a risk that e-health and the use of new technologies in health care might widen health inequalities on either side of the ‘digital divide’. Experience suggests that there are two dimensions to the digital divide and its impact on health inequalities: *access* (to physical hardware and



**FIGURE 1** Conceptual diagram of an intervention (reproduced from Edwards *et al.*<sup>29</sup>).



**FIGURE 2** Conceptual elements of behaviour and behaviour change (reproduced from Edwards *et al.*<sup>29</sup>).

software) and *accessibility* (or the ability of people with differing literacy/health literacy/IT literacy to use or apply information and support supplied through e-learning). It has been shown that it is possible to deliver e-health interventions specifically designed for people with low literacy skills (e.g. Hispanics in southern USA,<sup>30</sup> homeless drug users<sup>31</sup> and single teenage mothers<sup>32</sup>). What remains less clear is the extent to which people with low literacy skills will feel comfortable using e-learning devices or will be able to act on information or advice provided through these media.

Interactive e-learning programs to promote positive dietary behavioural changes may have the potential to benefit population health. However, before e-learning can be considered as a dietary behaviour change intervention, the effective components and mechanisms of action of e-learning programs should be explored, and their cost-effectiveness established in different contexts.

## Previous reviews

Three systematic reviews have examined the effectiveness of e-learning for dietary behaviour change. The first<sup>33</sup> was restricted to first-generation interventions for dietary change and did not include any web- or internet-based interventions. The second<sup>34</sup> examined a broad range of second-generation interactive interventions for dietary behaviour change. Both of these reviews reported studies published prior to 2006 that were carried out in a variety of settings. The third review<sup>28</sup> was more recent, reviewing second- and third-generation interventions trialled up to 2008, but only in primary prevention in adults (no participants with diagnosed disease). All reviews were restricted to publications in the English language and limited their searches to relatively few databases, increasing the potential for publication bias. The conclusions drawn from these systematic reviews were that e-learning shows some promise for dietary behavioural change, although the findings were mixed. Interstudy heterogeneity with respect to study design, participants, measures and outcomes precluded meta-analysis to estimate pooled intervention effects. Moreover, the cost-effectiveness of e-learning was not evaluated in any review, nor was there an attempt to identify potential mechanisms of action.



## Chapter 2

# Methods for the descriptive analysis and systematic review of effectiveness

The protocol for this review has been published as Edwards *et al.*<sup>29</sup> and is available from [www.biomedcentral.com/content/pdf/1471-2458-10-200.pdf](http://www.biomedcentral.com/content/pdf/1471-2458-10-200.pdf).

### Objectives

The aims of this systematic review were to assess the effectiveness and cost-effectiveness of adaptive e-learning for improving dietary behaviours. The specific objectives were to:

- describe the range of e-learning technologies in use for promoting dietary behavioural change
- evaluate the effectiveness of interactive e-learning in terms of improvement in dietary behaviour and clinical outcomes
- analyse the e-learning interventions in order to determine the components contributing to the effects of e-learning interventions for dietary behavioural change
- investigate potential explanations of dietary behavioural change, and mechanisms of action
- evaluate cost-effectiveness compared with current standard interventions.

### Design

The research consisted of a systematic review of the clinical and economic evidence.

### Study eligibility criteria

#### *Types of study*

We included randomised controlled trials (RCTs) for evidence of effectiveness and economic evaluations for evidence of cost-effectiveness (including cost-effectiveness, cost-utility and cost-benefit analyses).

#### *Types of population*

We included adolescents or adults (mean sample age  $\geq 13$  years) who have participated in a study designed to evaluate the effectiveness of e-learning to promote dietary behavioural change. We included all clinical conditions for which dietary advice plays a major part in case management.

#### *Types of intervention*

Interventions were included if there were interactive computer software programs that tailored output according to user input (i.e. second- and third-generation interventions). These include interventions for which users enter personal data, or make choices about information, that alter pathways within programs to produce tailored material and feedback that is personally relevant. Users may interact with the programs as members of a small group, as well as individually.

Programs should be available directly to users and allow independent access without the need for any expert facilitation.

Interventions were excluded if they were:

- first-generation tailored ‘information only’ (e.g. providing a leaflet or PDF file)
- simple information packages with no interactive elements
- non-interactive mass media interventions (such as TV advertisements)
- interventions designed to be used with others’ help (e.g. teacher or health professional)
- interventions targeted at health professionals or teachers
- computer-mediated delivery of individual health-care advice (e.g. online physicians)
- electronic history-taking or risk assessment with no health promotion or interactive elements.

### **Outcome measures**

We anticipated that most interventions would be aimed at dietary behaviours and were unlikely to have followed participants long enough to obtain changes in clinical measures. However, as measures of dietary behaviour tend to be based on self-report, they are prone to error (e.g. recall bias). Biological outcomes [e.g. body mass index (BMI)] tend to be measured more objectively (e.g. using measures of weight and height) and are also the necessary inputs to economic models of cost-effectiveness. We therefore specified dietary behaviour as our primary outcome, and also obtained data that allowed us to model the relationship between behaviours and clinical changes.

#### **Primary outcome measures**

Measures of dietary behaviours including estimated intakes or changes in intake of energy, nutrients, dietary fibre, foods or food groups. The dietary assessment tools or techniques used to estimate dietary behaviour were critically examined in terms of quality.

#### **Secondary outcome measures**

Objective measures that are likely to respond to changes in dietary behaviours and are associated with adverse clinical outcomes including measurements of anthropometric status and blood biochemistry.

#### **Other data**

We also sought data on economic outcomes, specifically the costs of providing the intervention and costs to the individual user, unintended adverse consequences of the interventions, and process outcomes (e.g. usage data). Data relating to potential cognitive and emotional mediators of dietary behaviour were also obtained.

## **Identification of eligible studies and data extraction**

### **Search process**

Our search comprised the following:

- a search of electronic bibliographic databases for published work
- a search of trial registers for ongoing and recently completed trials
- inspection of the reference lists of all included studies and previously published reviews
- contact with authors of included studies and e-health research groups to check for more trials.

There were no restrictions by language. The search strategy comprised two concepts: 'computer-/internet-based interventions' and 'dietary behaviour' (see *Appendix 2* for full electronic search strategies).

Eleven electronic databases, two trials databases and two theses databases were searched using the search strategy (*Table 1*). Searches covered the period January 1990 to November 2009 (we assumed that any studies of e-learning conducted in the 1980s would be identified through inspection of the reference lists of all included studies).

### Selection process

All studies identified through the search process were exported to a bibliographic database (ENDNOTE version X3; Thomson Reuters, CA, USA) for de-duplication and screening. Two review authors independently examined the titles, abstracts and keywords of electronic records according to the eligibility criteria above. Results of this initial screening were cross-referenced between the two review authors, and full-text records obtained for all potentially relevant reports of trials. These potentially eligible trials went through a secondary screening by each reviewer using a screening form based on the eligibility criteria (see *Appendix 3*) for final inclusion in the systematic review, with disagreements resolved by discussion with a third author.

### Data extraction

Two review authors extracted relevant data into a Microsoft ACCESS 2007 (Microsoft Corporation, Redmond, WA, USA) database specifically designed for the review (available from the authors on request). Corresponding authors of included studies were contacted directly by e-mail when required information or data were not reported in the published report, using a pre-notification e-mail followed by up to two contact attempts.

**TABLE 1** Databases searched for relevant references

Database	Records	Dates
Australian Digital Theses	67	1990–2009
CINAHL	6409	1990–2009
ClinicalTrials.gov	179	1990–2009
Current Controlled Trials	266	1990–2009
Dissertation Abstracts	2136	1990–2009
EMBASE	7843	1990–2009
ERIC	2990	1990–2009
globalhealth.gov	1447	1990–2009
HEED	18	1990–2009
HMIC	281	1990–2009
Index to THESES	214	1990–2009
MEDLINE	5483	1990–2009
PsycINFO	2376	1990–2009
The Cochrane Library	6448	1990–2009
Web of Science	222	1990–2009
Total	36,379	

CINAHL, Cumulative Index to Nursing and Allied Health Literature; ERIC, Education Resources Information Center; HEED, Health Economic Evaluations Database; HMIC, Health Management Information Consortium.

## Methodological quality assessment

Two measures of methodological quality were used in the review: The Cochrane Collaboration's risk of bias assessment,<sup>35</sup> and the Effective Public Health Practice Project (EPHPP) quality assessment.<sup>36</sup> The Cochrane assessment requires a judgement to be made by the review authors on the likely risk of bias arising from six domains. Risk of bias is presented as a chart showing the proportion of studies judged to have 'low risk of bias' or 'high risk of bias' or those for which risk of bias is unclear, for each of the six domains. The EPHPP assessment provides an overall rating for each study ('strong', 'moderate' or 'weak'), based on a series of questions about similar domains. The EPHPP assessment used in this review was unmodified, although it is a relatively new tool and there was some concern among the review authors that some of the questions were not relevant to e-learning interventions in particular (see *Methodological quality of included studies*). We chose to include EPHPP for its strengths regarding assessment of confounders, data collection methods, and withdrawal and dropouts (which are less well covered by the Cochrane tool).

## Analysis

### Descriptive analysis

We described all studies that met the inclusion criteria, including (where reported):

- study design:
  - study objectives (i.e. target outcomes)
  - trial design and quality
  - data collection methods, modes and techniques; validity of tools
- participants:
  - socioeconomic and demographic characteristics
  - health status: diagnosed disease versus no diagnosed disease
- intervention:
  - components of the intervention, including delivery and content
  - frequency, intensity and duration of the intervention
  - behaviour change theories employed in intervention design, and postulated mediators
- outcomes:
  - primary and secondary outcomes measured
  - information on process (ease of use) and usage (compliance).

Information on the sociodemographic characteristics of participants was used to address concerns over the 'digital divide'. Where sufficient data were provided by the primary studies, we planned to undertake subgroup analyses of intervention effects in low-income and low-educational-status users.

### Intervention content and mechanisms of action

In order to investigate the key behaviour change techniques' contribution to intervention effects, we coded techniques according to a taxonomy developed by Abraham and Michie.<sup>37</sup> To investigate how interventions might change dietary behaviour, we documented the theories that were reported to account for the process of behaviour change.<sup>38–40</sup> Where theories had been used to inform intervention design in trials, we documented the potential mediators of behaviour change, such as knowledge, intention, self-efficacy and emotions.

### Analysis of effectiveness

When studies reported the same outcome (e.g. servings of fruit and vegetables eaten per day, percentage of energy from fat), we pooled the results using a random effects model, with weighted mean differences (WMDs), and calculated 95% confidence intervals (CIs) and two-sided *p*-values for each outcome. When outcomes were assessed more than once during follow-up, the final assessment was used in analysis. In studies in which the effects of clustering were not taken into account, we adjusted the standard deviations (SDs) by the design effect, using intraclass coefficients if given in papers or using external estimates obtained from similar studies.<sup>41</sup>

We assessed evidence for selection bias using Egger's test for small study effects. Heterogeneity among the trial results was assessed using both a chi-squared test and the *I*<sup>2</sup> statistic, the percentage of among-study variability that is due to true differences between studies (heterogeneity) rather than to sampling error. We considered an *I*<sup>2</sup> value > 50% to reflect 'substantial heterogeneity'. We conducted sensitivity analyses in order to investigate possible sources of heterogeneity including study quality (adequate vs inadequate allocation concealment, low vs high attrition) and sociodemographic factors that could act as effect modifiers [e.g. gender and socioeconomic status (SES)].

When studies reported more than one measure of a single outcome, the measure used was that for which greatest validity had been demonstrated [e.g. if a validated Food Frequency Questionnaire (FFQ) was used to measure the number of portions of fruit and vegetables eaten daily, as well as an unvalidated single item 'how many portions of fruit and vegetables do you eat each day?', we chose the former for inclusion in any subsequent meta-analysis].

Causes of heterogeneity and subgroup effects were assessed using random effects meta-analysis. This was implemented in STATA (StataCorp LP, College Station, TX, USA) using the 'metareg' command, and included trial characteristics as covariates. All statistical analysis was conducted using STATA statistical software version 11.



## Chapter 3

# Results of the descriptive analysis

### Results of the literature search

A total of 36,379 titles were initially identified by the electronic searches, of which 2977 were duplicates and were removed. The remaining 33,402 titles (and abstracts where available) were screened independently by two review authors and the results compared. A total of 33,129 titles were excluded during this initial screening, primarily owing to not meeting our inclusion criteria for randomised trials of adaptive e-learning, yielding 273 potentially eligible studies for which full-text reports were sought.

A secondary screening process was undertaken on the full-text documents for the 273 studies, using the screening form provided in *Appendix 3*, by two review authors independently. A total of 233 studies were excluded through this process; a table of excluded studies is provided in *Appendix 6* (see *Table 28*). Three new eligible titles were identified through searching reference lists of the included studies, yielding a total of 43 studies for inclusion in the review. See the PRISMA (preferred reporting items for systematic reviews and meta-analyses) flow chart in *Appendix 4* for details.

### Overview of included studies

#### Included studies

*Table 2* summarises the 43 studies included in the review.

#### Study design

A total of 43 RCTs were identified as eligible for inclusion in the review (see *Table 2* for a summary of included studies; *Appendix 5* for a full bibliography of included studies; and *Appendix 4* for the PRISMA flow diagram detailing inclusion and exclusion during different stages of the review). Of the 43 included studies, one<sup>62</sup> was a crossover trial, two<sup>79,82</sup> were cluster randomised trials, whereas the rest were parallel-group RCTs.

#### Target outcomes of included studies

Although all interventions included in the review were designed to alter dietary behaviour, different interventions targeted different components of this behaviour and collected different outcome measures in order to measure success. *Table 3* summarises the target outcomes of the included studies, whereas *Table 15* summarises the dietary and clinical outcome measures used.

The majority of interventions sought to reduce fat intake<sup>44,45,49–51,54,55,58–62,64,65,67–69,72–74,76–83</sup> (28 interventions) and/or to increase fruit and vegetable intake<sup>43,44,47–51,55,56,58,59,62,67,68,71–73,75,80–82</sup> (21 interventions). Other interventions sought to increase fibre intake,<sup>44,45,55,59,80–82</sup> reduce overall energy intake,<sup>45,53,65,72–74,77,80,83</sup> reduce<sup>42,45,52,57,69–74,76,83</sup> or maintain<sup>53,59,82</sup> weight, or reduce<sup>46,53,71,73,77,79,83</sup> or maintain<sup>53,59,63,64,66,84</sup> BMI.

**TABLE 2** Overview of the 43 RCTs included in the review

Study	Intervention	Comparator <sup>a</sup>
<b>Agras (1990)<sup>42</sup></b>		
Country: USA	Setting: N/A	
Aim: weight down	Delivery mode: mobile device	
Description:	Tailored feedback for 12 weeks on intake and goals, plus an automated trainer to promote slow eating	A therapist-conducted weight-loss programme (behaviour therapy conducted in 10 sessions over a 12-week period)
Follow-up: baseline, 3 months, 6 months, 12 months		
n=90		
<b>Alexander (2010)<sup>43</sup></b>		
Country: USA	Setting: N/A	
Aim: FV up	Delivery mode: internet	
Description:	Four sessions over 15 weeks on a tailored website providing a broad range of practical strategies, information and support for dietary behaviour change	Non-tailored website, same layout, containing generic information
Follow-up: baseline, 3 months, 6 months, 12 months		
n=2540	n=839	n=836
<b>Anderson (2001)<sup>44</sup></b>		
Country: USA	Setting: supermarket	
Aims: fat down, fibre up, FV up	Delivery mode: computer kiosk	
Description:	Weekly 10-minute sessions over 15 weeks, providing tailored information and planning and monitoring strategies for food purchases, including financial incentives (targeted food coupons)	No treatment
Follow-up: baseline, 3 months, 6 months		
n=296	n=148	n=148
<b>Beasley (2008)<sup>45</sup></b>		
Country: USA	Setting: N/A	
Aims: energy down, fat down, fibre up, weight down	Delivery mode: mobile device	
Description:	Food diary record to be completed three times daily for one month, providing tailored feedback on intake	Paper-based food diary; no feedback
Follow-up: baseline, 1 month		
n=174	n=80	n=79
<b>Blanson Henkemans (2009)<sup>46</sup></b>		
Country: Netherlands	Setting: N/A	
Aim: BMI down	Delivery mode: internet	
Description:	Access for 1 month to a website providing tailored feedback on intake and goals, provided by an automated computer assistant (iCat)	Used same website and undertook same activities, but did not have an automated computer assistant providing feedback
Follow-up: baseline, 1 month		
n=118	n=65	n=53

**TABLE 2** Overview of the 43 RCTs included in the review (*continued*)

Study	Intervention	Comparator <sup>a</sup>
<b>Block (2004)<sup>47</sup></b>		
Country: USA	Setting: CD-ROM	
Aim: FV up	Delivery mode: community centre	
Description:	One 20-minute interaction with a computer program providing tailored feedback on intake, plus general nutrition information and goal setting	Similar interaction with a non-dietary CD-ROM programme on stress management
Follow-up: baseline, 2 months		
n=481	n=160	n=159
<b>Buller (2008)<sup>48</sup></b>		
Country: USA	Setting: N/A	
Aim: FV up	Delivery mode: internet	
Description:	Monthly sessions over 4 months on a website containing information and advice, broadly tailored to a local population	No intervention: delayed access to the intervention after the post-test
Follow-up: baseline, 4 months		
n=762	n=380	n=375
<b>Campbell (1999)<sup>49</sup></b>		
Country: USA	Setting: food stamp office	
Aim: fat down	Delivery mode: computer kiosk	
Description:	One 30-minute interaction with a multimedia intervention providing information and behaviour change strategies, including tailored feedback on intake and goal setting	No intervention
Follow-up: baseline, 1 month		
n=378	n=165	n=212
<b>Campbell (2004)<sup>50</sup></b>		
Country: USA	Setting: WIC clinic	
Aim: fat down, FV up	Delivery mode: computer kiosk	
Description:	One 25-minute interaction with a multimedia intervention providing information and behaviour change strategies, including tailored feedback on intake	No intervention: delayed access to the intervention after the post-test
Follow-up: baseline, 1 month		
n=307	n=141	n=166
<b>Carbone (1999)<sup>51</sup></b>		
Country: USA	Setting: primary care	
Aim: fat down, FV up	Delivery mode: CD-ROM	
Description:	One 30-minute interaction with an interactive game show, providing feedback tailored on participant knowledge	Non-tailored video intervention (C1) Non-intervention control group (C2)
Follow-up: baseline, 2 months.		
n=201	n=70	n=71/60

*continued*

**TABLE 2** Overview of the 43 RCTs included in the review (*continued*)

Study	Intervention	Comparator <sup>a</sup>
<b>Cook (2007)<sup>52</sup></b>		
<i>Country:</i> USA	<i>Setting:</i> workplace	
<i>Aim:</i> weight down	<i>Delivery mode:</i> internet	
<i>Description:</i>	Access over 3 months to a website providing information and guidance, including tailored feedback on intake and BMI	Received high-quality commercially available print materials on the same topics (but not necessarily the same content)
<i>Follow-up:</i> baseline, 3 months		
<i>n</i> = 419	<i>n</i> = 209	<i>n</i> = 210
<b>Cussler (2008)<sup>53</sup></b>		
<i>Country:</i> USA	<i>Setting:</i> N/A	
<i>Aim:</i> BMI down, energy down, weight maintain	<i>Delivery mode:</i> internet	
<i>Description:</i>	Weekly access over 1 year to a website providing information, communications tools (e-mail, chat rooms) and progress monitoring tools (dietary log) to support maintenance of the weight loss phase	No further intervention (permitted to continue to meet and practice the principles learned during the weight loss phase)
<i>Follow-up:</i> baseline, 12 months		
<i>n</i> = 135	<i>n</i> = 66	<i>n</i> = 69
<b>De Bourdeaudhuij (2007)<sup>54</sup></b>		
<i>Country:</i> Belgium	<i>Setting:</i> workplace	
<i>Aim:</i> fat down	<i>Delivery mode:</i> CD-ROM	
<i>Description:</i>	One interaction with an intervention providing tailored feedback on intake and knowledge	Generic dietary information (C1) Non-intervention control group (C2)
<i>Follow-up:</i> baseline, 6 months		
<i>n</i> = 539	<i>n</i> = 192	<i>n</i> = 197/150
<b>Delichatsios (2001)<sup>55</sup></b>		
<i>Country:</i> USA	<i>Setting:</i> home	
<i>Aim:</i> fat down, fibre up, FV up	<i>Delivery mode:</i> telephone (automated)	
<i>Description:</i>	5- to 7-minute interaction weekly over 6 months with an intervention providing goals, information and automated counselling tailored to intake	Physical activity promotion counselling via the same technology with similar length of exposure
<i>Follow-up:</i> baseline, 6 months		
<i>n</i> = 298	<i>n</i> = 148	<i>n</i> = 150
<b>Di Noia (2008)<sup>56</sup></b>		
<i>Country:</i> USA	<i>Setting:</i> community centre	
<i>Aim:</i> FV up	<i>Delivery mode:</i> CD-ROM	
<i>Description:</i>	Four 30-minute interactions over 1 month with an intervention providing feedback tailored on psychosocial variables	No intervention: participated in regular programmes offered at participating sites
<i>Follow-up:</i> baseline, 2 months		
<i>n</i> = 507	<i>n</i> = 117	<i>n</i> = 390

**TABLE 2** Overview of the 43 RCTs included in the review (*continued*)

Study	Intervention	Comparator <sup>a</sup>
<b>Ellrott (2005)<sup>57</sup></b>		
Country: Germany	Setting: N/A	
Aim: weight down	Delivery mode: mobile device	
Description:	Access for 12 weeks to a food diary record with tailored feedback on intake and nutrient content	Paper-based food diary and self-help manual
Follow-up: 1 month		
n=101	n=51	n=50
<b>Franko (2008)<sup>58</sup></b>		
Country: USA	Setting: school/college	
Aim: fat down, FV up	Delivery mode: internet	
Description:	Two 45-minute interactions with a website providing feedback tailored on intake, as well as information and goal setting	Interactive anatomy education website (Second intervention group: use of the intervention with an additional booster session)
Follow-up: baseline, 3 months, 6 months		
n=476	n=165	n=147 (164)
<b>Gow (2010)<sup>59</sup></b>		
Country: USA	Setting: N/A	
Aim: BMI maintain, fat down, fibre up, FV up, weight maintain	Delivery mode: internet	
Description:	Weekly 45-minute sessions over 6 weeks with an intervention delivered via Blackboard <sup>®</sup> , <sup>a</sup> including information, self-assessments, discussion and experiential activities	Feedback intervention arm does not participate in internet intervention, but receives weekly feedback on weight (C1) Non-intervention control group (C2)
Follow-up: baseline, 6 weeks		
n=159	n=40	n=39/40
<b>Haerens (2007)<sup>60</sup></b>		
Country: Belgium	Setting: school/college	
Aim: fat down	Delivery mode: CD-ROM	
Description:	One 50-minute interactive session delivered via Blackboard, including information and feedback tailored on intake and psychosocial data	Wait-list control
Follow-up: baseline, 3 months		
n=304	n=153	n=151
<b>Huang (2006)<sup>61</sup></b>		
Country: Australia	Setting: N/A	
Aim: fat down	Delivery mode: internet	
Description:	Access over 6 months to an intervention providing suggestions of lower-fat alternatives for each higher-fat item selected in an online shop	General advice about how to choose a diet lower in fat, as a static web page
Follow-up: 1 month, 6 months		
n=497	n=251	n=246

*continued*

**TABLE 2** Overview of the 43 RCTs included in the review (*continued*)

Study	Intervention	Comparator <sup>a</sup>
<b>Irvine (2004)<sup>62</sup></b>		
<i>Country:</i> USA	<i>Setting:</i> workplace	
<i>Aim:</i> fat down, FV up	<i>Delivery mode:</i> computer kiosk	
<i>Description:</i>	Access over 1 month to information and strategies for healthy eating tailored on intake, plus goal setting	Wait-list control
<i>Follow-up:</i> baseline, 1 month, 2 months		
<i>n</i> = 517	<i>n</i> = 260	<i>n</i> = 257
<b>Jacobi (2007)<sup>63</sup></b>		
<i>Country:</i> Germany	<i>Setting:</i> N/A	
<i>Aim:</i> BMI maintain	<i>Delivery mode:</i> Internet	
<i>Description:</i>	STUDENT BODIES software for prevention of eating disorders, adapted for German participants	Wait-list control
<i>Follow-up:</i> baseline, 3 months		
<i>n</i> = 97	<i>n</i> = 47	<i>n</i> = 50
<b>Jones (2008)<sup>64</sup></b>		
<i>Country:</i> USA	<i>Setting:</i> N/A	
<i>Aim:</i> BMI maintain, fat down	<i>Delivery mode:</i> internet	
<i>Description:</i>	Weekly access for 16 weeks to the STUDENT BODIES software for prevention of eating disorders, including psycho-educational material, asynchronous discussion group, goal setting and a handbook for parents	Wait-list control
<i>Follow-up:</i> baseline, 4 months, 9 months		
<i>n</i> = 105	<i>n</i> = 52	<i>n</i> = 53
<b>Kroeze (2008)<sup>65</sup></b>		
<i>Country:</i> Netherlands	<i>Setting:</i> home	
<i>Aim:</i> BMI down, energy down, fat down	<i>Delivery mode:</i> CD-ROM	
<i>Description:</i>	One-time access to an intervention providing information tailored on dietary habits	Non-tailored generic nutrition information
<i>Follow-up:</i> baseline		
<i>n</i> = 442	<i>n</i> = 151	<i>n</i> = 141
<b>Low (2006)<sup>66</sup></b>		
<i>Country:</i> USA	<i>Setting:</i> N/A	
<i>Aim:</i> BMI maintain	<i>Delivery mode:</i> internet	
<i>Description:</i>	Access over 8 weeks to the STUDENT BODIES software for the prevention of eating disorders, including psycho-educational material and goal setting	Intervention plus: the program is accompanied by an asynchronous online discussion group with a clinical psychologist
<i>Follow-up:</i> baseline, 9 months		
<i>n</i> = 61	<i>n</i> = 14	<i>n</i> = 14

**TABLE 2** Overview of the 43 RCTs included in the review (*continued*)

Study	Intervention	Comparator <sup>a</sup>
<b>Oenema (2001)<sup>67</sup></b>		
Country: Netherlands	Setting: school/college, workplace	
Aim: fat down, FV up	Delivery mode: internet	
Description:	Information and feedback tailored on intake	Non-tailored nutrition information letter
Follow-up: baseline, 1 month		
n=204	n=102	n=102
<b>Oenema (2005)<sup>68</sup></b>		
Country: Netherlands	Setting: home, workplace	
Aim: fat down, FV up	Delivery mode: CD-ROM	
Description:	Information and feedback tailored on intake	Non-tailored nutrition information delivered on the web
Follow-up: baseline, 1 month		
n=782	n=261	n=260
<b>Oenema (2008)<sup>69</sup></b>		
Country: Netherlands	Setting: N/A	
Aim: fat down	Delivery mode: internet	
Description:	Access over 1 month to information and feedback tailored on intake	Non-intervention control group
Follow-up: baseline, 1 month		
n=2159	n=1080	n=1079
<b>Rothert (2006)<sup>70</sup></b>		
Country: USA	Setting: N/A	
Aim: BMI down, weight down	Delivery mode: internet	
Description:	Access over 6 weeks to an intervention providing an action plan and information tailored on baseline assessment, plus opportunity to enrol a supportive 'buddy'	Information only: standard Kaiser Permanente member website (Kaiser Permanente, www.kaiserpermanente.org/, is a non-profit integrated health-care delivery system)
Follow-up: 3 months, 6 months		
n=2862	n=1475	n=1378
<b>Shapiro (2007)<sup>71</sup></b>		
Country: USA	Setting: home	
Aim: BMI down, FV up, weight down	Delivery mode: CD-ROM	
Description:	Access over 10 weeks to a program based on CBT providing information and psycho-education, and individualised CBT exercises	10 weeks of group CBT treatment (C1) Wait-list control (C2)
Follow-up: baseline, 2 months		
n=66	n=22	n=22/22

*continued*

**TABLE 2** Overview of the 43 RCTs included in the review (*continued*)

Study	Intervention	Comparator <sup>a</sup>
<b>Sternfeld (2009)<sup>72</sup></b>		
Country: USA	Setting: workplace	
Aim: fat down, FV up	Delivery mode: internet	
Description:	Access over 16 weeks to an intervention providing information, feedback and goal setting tailored on intake	Wait-list control
Follow-up: baseline, 4 months, 8 months		
n=787	n=351	n=436
<b>Svetkey (2008)<sup>73</sup></b>		
Country: USA	Setting: home	
Aim: energy down, fat down, FV up, weight down	Delivery mode: internet	
Description:	Feedback and motivational messages tailored on intake, plus general information	Non-tailored nutrition and lifestyle information
Follow-up: baseline, 30 months		
n=1032	n=348	n=342
<b>Tate (2006)<sup>74</sup></b>		
Country: USA	Setting: N/A	
Aim: BMI down, energy down, fat down, weight down	Delivery mode: internet	
Description:	Calorie-restricted diet based on baseline weight; meal replacements; feedback tailored on weight	Human e-counselling (C1) No intervention control group (C2)
Follow-up: baseline, 3 months, 6 months		
n=192	n=61	n=67/64
<b>Trinh (2009)<sup>75</sup></b>		
Country: USA	Setting: N/A	
Aim: FV up	Delivery mode: internet	
Description:	Access over 5 weeks to an intervention providing feedback tailored on baseline assessment, plus information and strategies for healthy eating	Wait-list control
Follow-up: baseline, 2 months		
n=307	n=159	n=148
<b>Turnin (1992)<sup>76</sup></b>		
Country: France	Setting: home	
Aim: fat down, weight down	Delivery mode: Minitel	
Description:	Feedback tailored on intake, plus meal analysis and general dietary information	Wait-list control
Follow-up: baseline, 6 months		
n=105	n=54	n=51

**TABLE 2** Overview of the 43 RCTs included in the review (*continued*)

Study	Intervention	Comparator <sup>a</sup>
<b>Turnin (2001)<sup>77</sup></b>		
Country: France	Setting: home	
Aim: BMI down, energy down, fat down	Delivery mode: Minitel	
Description:	Caloric recommendations tailored on baseline assessment, plus meal analysis and general dietary information	Usual care
Follow-up: baseline, 6 months, 12 months		
n = 557	n = 279	n = 278
<b>Vandelanotte (2005)<sup>78</sup></b>		
Country: Belgium	Setting: school/college	
Aim: fat down	Delivery mode: personal computer	
Description:	One 50-minute session providing feedback tailored on intake and psychosocial variables, plus tips and suggestions on healthy eating	Wait-list control
Follow-up: –		
n = 771		
<b>Verheijden (2004)<sup>79</sup></b>		
Country: Canada	Setting: home, workplace	
Aim: BMI down, fat down	Delivery mode: internet	
Description:	Counselling messages tailored on intake and psychosocial variables, plus general information	Usual care
Follow-up: baseline, 6 months		
n = 146	n = 73	n = 73
<b>Veverka (2003)<sup>80</sup></b>		
Country: USA	Setting: home, workplace	
aim: energy down, fat down, fibre up, FV up	Delivery mode: internet	
Description:	Monthly sessions over 6 months of an intervention providing information tailored by psychosocial variables	Non-intervention control group
Follow-up: baseline, 6 months		
n = 39	n = 20	n = 19
<b>Winett (1991)<sup>81</sup></b>		
Country: USA	Setting: supermarket	
Aim: fat down, fibre up, FV up	Delivery mode: computer kiosk	
Description:	Weekly 8-minute sessions over 6 weeks of an intervention providing feedback concerning intended purchases, with prompts to encourage lower-fat and higher-fibre purchases and general nutritional information	Used the program to enter food purchases only; no feedback
Follow-up: baseline, 3 months		
n = 77	n = 40	n = 37

*continued*

**TABLE 2** Overview of the 43 RCTs included in the review (*continued*)

Study	Intervention	Comparator <sup>a</sup>
<b>Winett (2007)<sup>82</sup></b>		
Country: USA	Setting: community centre	
Aim: fat down, fibre up, FV up, weight maintain	Delivery mode: internet	
Description:	Weekly 10-minute sessions over 12 weeks of an intervention providing individual goals with specific strategies, plus meal planner and general nutrition information	Wait-list control
Follow-up: baseline, 3 months, 6 months		
n = 1071	n = 364	n = 364
<b>Wylie-Rosett (2001)<sup>83</sup></b>		
Country: USA	Setting: Health Maintenance Organisation	
Aim: BMI down, energy down, fat down, weight down	Delivery mode: computer kiosk	
Description:	Workbook, plus monthly 30-minute sessions over 12 months of an intervention providing feedback tailored in intake, plus goal setting and general nutrition information	Workbook only (C1) Workbook + computer + staff consultation/therapy (C2)
Follow-up: baseline, 12 months		
n = 588	n = 236	n = 116/236
<b>Zabinski (2001)<sup>84</sup></b>		
Country: USA	Setting: N/A	
Aim: BMI maintain	Delivery mode: internet	
Description:	STUDENT BODIES software for the prevention of eating disorders, plus an electronic bulletin board	Wait-list control
Follow-up: baseline, 2 months		
n = 62	n = 31	n = 31

CBT, cognitive behavioural therapy; CD-ROM, compact disc read-only memory; FV, fruit and vegetables; iCat, intelligent computer-assisted training, N/A, not applicable; WIC, Women, Infants and Children Program.

a Two values for *n* indicate the sample sizes where two control groups were used.

b Blackboard Inc, Washington, DC, USA (<http://blackboardsupport.calpoly.edu/content/about/whatis.html>).

### Comparators used in included studies

Table 4 shows a summary of comparators used in the studies. Fourteen studies<sup>44,48–51,53,54,56,59,69,74,77,79,80</sup> trialled the intervention against a non-intervention control group. Three studies<sup>47,55,58</sup> used attention controls, whereby participants in the control group received non-adaptive information on a similar topic, or received a similarly interactive intervention, but on an unrelated health topic. Thirteen studies<sup>48,50,62–64,71,72,75,76,78,82,84</sup> used a wait-list control group that received the intervention after the data collection period. Two studies tested their intervention against a therapist-conducted intervention,<sup>42,74</sup> or the e-learning intervention plus a therapist-conducted intervention.<sup>66,83</sup>

### Interventions

#### Setting

Tables 5 and 6 summarise the countries and settings in which the interventions were delivered. All e-learning interventions were delivered in high-income countries, and the majority of interventions were delivered in the USA<sup>42–45,47–53,55,56,58,59,62,64,66,70–75,80–84</sup> (29 interventions), the Netherlands<sup>46,65,67–69</sup> (five studies) and Belgium<sup>54,60,78</sup> (three studies). There are several distinct

**TABLE 3** Target outcomes of included studies

Study	Increase fibre intake	Increase fruit and vegetable intake	Maintain BMI	Maintain weight	Reduce BMI	Reduce energy intake	Reduce fat intake	Reduce weight
Agras (1990) <sup>42</sup>								✓
Alexander (2010) <sup>43</sup>		✓						
Anderson (2001) <sup>44</sup>	✓	✓					✓	
Beasley (2008) <sup>45</sup>	✓					✓	✓	✓
Blanson Henkemans (2009) <sup>46</sup>					✓			
Block (2004) <sup>47</sup>		✓						
Buller (2008) <sup>48</sup>		✓						
Campbell (1999) <sup>49</sup>		✓					✓	
Campbell (2004) <sup>50</sup>		✓					✓	
Carbone (1999) <sup>51</sup>		✓					✓	
Cook (2007) <sup>52</sup>								✓
Cussler (2008) <sup>53</sup>			✓	✓	✓	✓		
De Bourdeaudhuij (2007) <sup>54</sup>							✓	
Delichatsios (2001) <sup>55</sup>	✓	✓					✓	
Di Noia (2008) <sup>56</sup>		✓						
Ellrott (2005) <sup>57</sup>								✓
Franko (2008) <sup>58</sup>		✓					✓	
Gow (2010) <sup>59</sup>	✓	✓	✓	✓			✓	
Haerens (2007) <sup>60</sup>							✓	
Huang (2006) <sup>61</sup>							✓	
Irvine (2004) <sup>62</sup>		✓					✓	
Jacobi (2007) <sup>63</sup>			✓					
Jones (2008) <sup>64</sup>			✓				✓	
Kroeze (2008) <sup>65</sup>						✓	✓	
Low (2006) <sup>66</sup>			✓					
Oenema (2001) <sup>67</sup>		✓					✓	
Oenema (2005) <sup>68</sup>		✓					✓	
Oenema (2008) <sup>69</sup>							✓	✓
Rothert (2006) <sup>70</sup>								✓
Shapiro (2007) <sup>71</sup>		✓			✓			✓
Sternfeld (2009) <sup>72</sup>		✓				✓	✓	✓
Svetkey (2008) <sup>73</sup>		✓			✓	✓	✓	✓
Tate (2006) <sup>74</sup>						✓	✓	✓
Trinh (2009) <sup>75</sup>		✓						
Turnin (1992) <sup>76</sup>							✓	✓
Turnin (2001) <sup>77</sup>					✓	✓	✓	
Vandelanotte (2005) <sup>78</sup>							✓	
Verheijden (2004) <sup>79</sup>					✓		✓	
Veverka (2003) <sup>80</sup>	✓	✓				✓	✓	
Winett (1991) <sup>81</sup>	✓	✓					✓	
Winett (2007) <sup>82</sup>	✓	✓		✓			✓	
Wyllie-Rosett (2001) <sup>83</sup>					✓	✓	✓	✓
Zabinski (2001) <sup>84</sup>			✓					
<b>TOTAL</b>	<b>7</b>	<b>21</b>	<b>6</b>	<b>3</b>	<b>7</b>	<b>9</b>	<b>28</b>	<b>12</b>

**TABLE 4** Comparators used in studies

Comparator	Number of studies <sup>a</sup>
Attention control, type 1: non-interactive information on a similar topic	14
No intervention (including usual care)	13
Wait-list control (intervention received at end of study)	12
Therapist-conducted intervention	4
Attention control, type 2: interactive intervention on an unrelated topic	3
Intervention plus therapist	2

a Total may add up to >43 as some interventions used more than one control group.

**TABLE 5** Country of intervention

Country	Number of studies
USA	29
Netherlands	5
Belgium	3
France	2
Germany	2
Australia	1
Canada	1

**TABLE 6** Intervention setting

Setting	Number of studies <sup>a</sup>
N/A <sup>b</sup>	16
Home	9
Workplace	8
Community centre	3
School/college	4
Supermarket	2
Food stamp office	1
Health Maintenance Organisation	1
Primary care	1
WIC clinic	1
Not specified	1

N/A, not applicable; WIC, Women, Infants and Children Program.

a Total may add up to >43 as some interventions are offered in several settings.

b Many interventions offered over the internet do not have a specific setting.

research groups dedicated to e-learning and diet research; hence, the geographic clustering of studies. For example, a single large e-learning research group produced all eight RCTs set in the Netherlands and Belgium. Interventions were also delivered in Australia,<sup>61</sup> Canada,<sup>79</sup> France<sup>76,77</sup> and Germany.<sup>57,63</sup>

Many interventions were offered over the internet or via a mobile device and without a specific setting. Of those that were delivered in a specific setting, nine were designed to be delivered in the home,<sup>55,65,68,71,73,76,77,79,80</sup> eight in the workplace,<sup>52,54,62,67,68,72,79,80</sup> three in community centres,<sup>47,56,82</sup>

four in schools/colleges<sup>58,60,67,78</sup> and two in supermarkets.<sup>44,81</sup> Other settings included a food stamp office,<sup>49</sup> a health maintenance organisation,<sup>83</sup> a primary care clinic<sup>51</sup> and a Women, Infants and Children Program clinic.<sup>50</sup> One study did not specify a setting.<sup>84</sup>

### Mode of delivery

Table 7 summarises the mode of delivery for interventions. Most interventions were delivered via the internet<sup>43,46,48,52,53,58,59,61,63,64,66,67,69,70,72–75,79,80,82,84</sup> (22 interventions), compact disk read-only memory (CD-ROM)<sup>47,51,54,56,60,65,68,71</sup> (eight interventions) and computer kiosks<sup>44,49,50,62,81,83</sup> in specific locations (six interventions). Other modes of delivery included Minitel<sup>76,77</sup> (an online system accessible through the telephone), mobile devices<sup>42,45,57</sup> [such as personal digital assistants (PDAs)] and automated telephone services.<sup>55</sup> One study used personal computers, but did not specify how the intervention was delivered on the computer.<sup>78</sup>

### Intervention usage and adherence

Although most studies reported the duration of the intervention, many did not report intended intensity or frequency, which precludes calculation of an intended 'dose' of the intervention. Of those that did, intended intensity of interventions varied enormously: several were one-day, one-off interactions with the intervention lasting under 1 hour,<sup>47,49–51,54,60,78</sup> whereas the two longest studies lasted 1 year, with either weekly<sup>53</sup> or monthly<sup>83</sup> interaction with the intervention. The latter study had 12 sessions of 30 minutes over 1 year, providing a potential 6 hours of contact. Beasley *et al.*<sup>45</sup> required participants to use their mobile device three times a day for 28 days, with a potentially much longer contact time (minutes per session were not reported). The majority of interventions lasted between 1 and 6 months, with participants expected to interact with the intervention daily or weekly for 10–45 minutes at a time.

Twenty-four studies reported on actual use of intervention programs, either making use of automated logon or usage features within programs (16 studies<sup>42,48,53,59,62–64,66,69,71,74,77,79,80,82,84</sup>) or obtaining self-reported usage data from participants (three studies<sup>52,58,60</sup>). Five studies<sup>44,55,57,70,80</sup> reported collecting usage data, but did not state how. The range of usage data collected varied: studies that specified an intended intensity or frequency of use calculated adherence to the intended programme; others reported number of logons or pages viewed, either as raw data or as a percentage of possible pages viewed. Reported adherence ranged from 43% to 85% in intervention groups.

Of the studies that assessed usage, few saw a drop-off over time.<sup>42,62,74,77,84</sup> In all five studies, compliance was high at onset but gradually declined from the second month. Usage was lowest in the final week in all but one study.<sup>42,62,74,84</sup> For example, in one study,<sup>42</sup> the adherence to the treatment was high in the initial weeks for all the three groups until the 10th week, when it declined sharply in the intervention group, reaching 29% in the final (12th) week. In another study,<sup>62</sup> the program usage was 14.7% and 7.5% in the second and third months, respectively. Tate *et al.*<sup>74</sup> found the median number of logins to be > 10 at the beginning of the study, but decreased

**TABLE 7** Mode of delivery for interventions

Mode of delivery/hardware	Number of studies
Internet	22
CD-ROM	8
Computer kiosk	6
Mobile device	3
Minitel	2
Personal computer	1
Telephone (automated)	1

to 5 by the second and third month, and finally to 2 by the sixth month. Turnin *et al.*<sup>77</sup> found the mean duration of intervention use was 260 minutes in the first month and 60 minutes in the next 2 months, and then gradually decreased to 30 minutes from the fourth month.

### Components

This review sought to investigate the different components of e-learning interventions, in order to assess whether or not they were associated with effective behaviour change. Interventions were reported and described using widely varying terminology and level of detail, making direct comparisons difficult.

The frequency of reported components is summarised in *Table 8* and is presented in detail for each study in *Table 9*.

A majority of interventions involved the presentation of nutrition, health and lifestyle information (32 studies<sup>43,44,46–54,57,58,60,62,65–73,75–77,79–83</sup>), the entering of food consumption data (25 studies<sup>42,45–47,49,50,52–55,57,58,65,67–69,72–79,83</sup>) and the presentation of personalised feedback on food and nutrient consumption (21 studies<sup>42,45–47,49,50,52,54,57,58,65,67–69,72–78</sup>). Other interventions focused more on the setting of goals and providing feedback on attainment of these goals (15 studies<sup>42,44–47,49,52,55,58,64,72,73,75,82,83</sup>). Several studies provided incentives for participation, mainly vouchers, but also cash or gifts (as opposed to incentives for providing follow-up data) (15 studies<sup>44,45,47–49,51,56,59,63,67,69,74,78,81,84</sup>). Several interventions also provided recipes or meal plans (20 studies<sup>42–45,47,51,52,62,65,67,68,70,73–77,79,81,82</sup>) or provided some kind of psychological support (14 studies<sup>59,62,64–68,70,71,73,74,78,82,84</sup>), for example motivational messages, help with overcoming barriers and forms of cognitive behavioural therapy (CBT).

**TABLE 8** Frequency of reported components of e-learning interventions

Component	Number of studies <sup>a</sup>
Information, advice, tips (written on-screen or printed)	31
Entering consumption data/food diary	28
Feedback on intake (written or visual)	21
Goal setting/action plans; feedback on goals/plans	15
Incentives (vouchers; cash)	15
Psychological help/motivation/addressing barriers	14
Recipes; cooking tips; menus; meal plans	12
Communication tools (chat room; bulletin board; asynchronous discussion)	9
Automated reminder e-mails	8
Links to websites	8
Help with food purchasing/meal planning	8
Information (multimedia/interactive)	6
Entering clinical data; feedback on clinical data	5
Web guide/i-moderator	4
Technical support available	4
Knowledge test/quiz; feedback on knowledge	3
Assignments/homework/putting techniques into practice	3
Supportive 'buddy'	3
Presentation of a role model	2

<sup>a</sup> Total may add up to >43 as some interventions had more than one component.

**TABLE 9** Reported components and behaviour change techniques used in interventions

Study	Reported components	Behaviour change techniques
Agras (1990) <sup>42</sup>	Entering caloric data; goal setting; meal planning; trainer to promote slow eating; feedback and feedback graphs	Action planning; goal setting (behaviour); motivational interviewing; prompt review of behavioural goals; shaping
Alexander (2010) <sup>43</sup>	Web program was divided into four intervention 'sessions' offered 1, 3, 13 and 15 weeks after enrolment; automated e-mails notified participants when a new website session was available. Each session included four to five pages of core content, illustrations, optional links to more detailed explanations and special features designed to supplement session content. Recipes and menus	Information on behaviour consequences in general; prompt identification as a role model; teach to use prompts/cues
Anderson (2001) <sup>44</sup>	Prescriptive information; suggested planning and monitoring strategies for food purchases; personalised goal setting and feedback; incentives [targeted food coupons (US\$8–12/week)]	General planning; goal setting (behaviour); information on behaviour consequences in general; information on when/where to perform behaviour; prompt review of behavioural goals; rewards contingent on successful behaviour; tailoring
Beasley (2008) <sup>45</sup>	Food diary record (prompted by audible beep); personalised comparisons of intake to goal by meal and by day; recipes and meal plans	Goal setting (behaviour); prompt review of behavioural goals
Blanson Henkemans (2009) <sup>46</sup>	Food diary; automated reminder e-mails; generated nutrient report; persuasive computer assistant (iCat) monitoring the diary and offering co-operative feedback; referral/linking to Dutch nutrition website for information	Goal setting (behaviour); information on behaviour consequences in general; motivational interviewing; prompt self-monitoring of behaviour; prompt self-monitoring of behavioural outcome
Block (2004) <sup>47</sup>	Screening and feedback; recipes and cooking tips; goal setting; information and tips	Barrier identification/problem solving; goal setting (behaviour); tailoring
Buller (2008) <sup>48</sup>	Routine e-mail notifications; information and advice; links to useful websites	Information on how to perform behaviour; normative information about others' behaviour; prompt generalisation of target behaviour; provide information about others' approval
Campbell (1999) <sup>49</sup>	Informative soap opera; 'infomercials'; feedback to knowledge quiz; comparison of individual intake to general goal intake; personal behavioural goal setting	Fear arousal; goal setting (behaviour); information on behaviour consequences in general; information on behaviour consequences to individual; model/demonstrate behaviour; tailoring
Campbell (2004) <sup>50</sup>	The FoodSmart intervention included four main components: a full-motion video soap opera, interactive 'infomercials', tailored dietary and psychosocial feedback determined by baseline assessment questions, and take-home print materials	Information on behaviour consequences to individual; model/demonstrate behaviour
Carbone (1999) <sup>51</sup>	Choice of two interactive game shows; feedback tailored on participant knowledge; low-fat recipe book	Tailoring
Cook (2007) <sup>52</sup>	Interactive assessment of daily calorie and fat intake; calculation of BMI; assessment of user's daily food categories based on the Healthy Eating Pyramid; video testimonials on benefits of good nutrition and weight management; information on popular diets (Atkins, South Beach, etc.); information and training; goal setting and progress tracking; meal planning and shopping strategies	Barrier identification/problem solving; emotional control training; general planning; goal setting (behaviour); information on behaviour consequences in general; model/demonstrate behaviour; normative information about others' behaviour; prompt review of behavioural goals; prompt self-monitoring of behaviour
Cussler (2008) <sup>53</sup>	Communications tools (e-mail, chat rooms); progress monitoring tools (bodyweight, dietary log); information; links to other websites	Goal setting (behaviour); prompt review of behavioural goals
De Bourdeaudhuij (2007) <sup>54</sup>	Screening questionnaire with tailored feedback; written information	Information on behavioural consequences in general; information on behavioural consequences to individual; normative information about others' behaviour; tailoring
Delichatsios (2001) <sup>55</sup>	Food consumption questions; tailored goals; education, advice and counselling (automated)	Goal setting (outcome); prompt focus on past success; prompt review of outcome goals

*continued*

**TABLE 9** Reported components and behaviour change techniques used in interventions (*continued*)

Study	Reported components	Behaviour change techniques
Di Noia (2008) <sup>56</sup>		Action planning; goal setting; information on behavioural consequences in general; information on behavioural consequences to individual; plan social support/social change
Ellrott (2005) <sup>57</sup>	Entry of foods/meals to a database; immediate feedback on nutrient content; information on, and comparison with, recommended intakes for the person's age and sex; self-help manual (used only in weeks 2, 3, 4, 8 and 12); once a week to the clinic, for measurement of weight	Prompt self-monitoring of behaviour; provide feedback on performance; tailoring
Franko (2008) <sup>58</sup>	(1) Three information links ( <i>Ask the Expert, Student Voices, College News</i> ); (2) rate myself assessment (questions that are part of the website that are used to provide feedback to the user); (3) four main topic pages (nutrition, eating on the run, weighing in, fitness); and (4) resources	Goal setting (behaviour)
Gow (2010) <sup>59</sup>	Self-assessments, group discussions via the 'Blackboard' discussion board and experiential activities (e.g. mindful eating); homework assignments to encourage implementation of new skills; online discussion; weekly weight check and graphic feedback; groups were facilitated by the principal investigator	Barrier identification/problem solving
Haerens (2007) <sup>60</sup>	Introduction page; diagnostic tool; intervention messages	Information on how to perform behaviour; normative information about others' behaviour; plan social support/social change; tailoring
Huang (2006) <sup>61</sup>	Suggestions of lower-fat alternatives for each higher-fat item selected in online shop	Tailoring
Irvine (2004) <sup>62</sup>	On-screen eating habits assessment; eating strategies, recipes, barriers to eating healthy, eating habits assessment, information centre and quick tips	Barrier identification/problem solving; goal setting (behaviour); information on behaviour consequences in general; information on when and where to perform behaviour; model/demonstrate behaviour; prompt review of behavioural goals; tailoring
Jacobi (2007) <sup>63</sup>	STUDENT BODIES software, adapted for a German audience	
Jones (2008) <sup>64</sup>	Psycho-educational material; self-monitoring journals; goals; asynchronous discussion group; a handbook for parents	Barrier identification/problem solving; environmental restructuring; goal setting (behaviour); information on when and where to perform behaviour; plan social support/social change; prompt self-monitoring of behaviour; relapse prevention/coping planning
Kroeze (2008) <sup>65</sup>	Screening questionnaire; individualised computer-tailored information (personalised opening, general introduction to the topic); feedback on fat intake and feedback about the fat intake of peers; suggestions for how to change; feedback on how to lower fat intake in situations perceived as difficult; recipes	Barrier identification/problem solving; facilitate social comparison; information on behaviour consequences in general; information on how to perform behaviour; provide feedback on performance; tailoring
Low (2006) <sup>66</sup>	Overview (included a description of the development and consequences of eating disorders); information (text, audio and video); on-line self-monitoring journals; behaviour change exercises; mandatory and optional assignments; discussion group	Information on behaviour consequences to individual; plan social support/social change; prompt self-monitoring of behaviour; tailoring
Oenema (2001) <sup>67</sup>	Short introduction; tailoring questionnaire on dietary habits; tailored feedback (short introduction, feedback messages on the respondent's own estimation of intake and the intake score computed from the baseline questionnaire); comparison of personal intake with recommended intake levels; messages on the most important sources of nutrients in the diet and possible alternatives; tips on altering consumption; recipes	Barrier identification/problem solving; facilitate social comparison; fear arousal; information on behavioural consequences to individual; information on how to perform behaviour; provide feedback on performance; tailoring

**TABLE 9** Reported components and behaviour change techniques used in interventions (*continued*)

Study	Reported components	Behaviour change techniques
Oenema (2005) <sup>68</sup>	Feedback on personal intake levels of fat, fruit and vegetables; feedback comparing intakes with recommendations and average intake of peers; tailored messages of encouragement; information about what changes to make and how to make changes; role model stories; recipe suggestions	Action planning; barrier identification/problem solving; facilitate social comparison; fear arousal; information on how to perform behaviour; model/demonstrate behaviour; provide feedback on performance; tailoring
Oenema (2008) <sup>69</sup>	Assessment of perceived fat intake and perceived physical activity level; information modules	Fear arousal; information on behaviour consequences to individual; prompt self-monitoring of behaviour; provide feedback on performance; tailoring
Rothert (2006) <sup>70</sup>	Individually tailored weight management plan; messages tailored to specific issues; opportunity to enrol a supportive 'buddy'	Action planning; barrier identification/problem solving; information on behaviour consequences to individual; plan social support/social change; prompt self-monitoring of behaviour; tailoring; teach to use prompts/cues
Shapiro (2007) <sup>71</sup>	Personal stories (of fictional characters) to emphasise: reasonable portion sizes and non-emotional eating; healthy levels of regular exercise and increased daily non-exercise activity; psycho-education on unhealthy eating and weight-related practices; basic concepts and techniques of CBT; individualised and interactive exercises for practising CBT techniques; guidelines and exercises for relapse prevention	Model/demonstrate behaviour; tailoring
Sternfeld (2009) <sup>72</sup>	Reports of intake of saturated fat, trans fats, added sugars, fruit and vegetables in relation to guidelines; feedback (including information on the participant's top three sources of problematic nutrients); tailored goal setting and review (goal tracker); e-mail suggesting tailored goals; 'personal home page' containing tips, a goal tracker, health information and links to sites for additional information; graphic presentation of how much any specific change in diet (or physical activity) might move participants closer towards the recommended level	Barrier identification/problem solving; fear arousal; information on behaviour consequences in general; information on behaviour consequences to individual; plan social support/social change; prompt review of behavioural goals; prompt self-monitoring of behavioural outcome; provide feedback on performance; set graded tasks; tailoring; teach to use prompts/cues
Svetkey (2008) <sup>73</sup>	Initial orientation; e-mail prompts; tailored motivational messages; relevant news and information; reminder to return to website (if necessary); self-monitoring data entry (food records, exercise, minimum daily calorie totals); tailored automated feedback; goal setting and action plan development; training modules for relapse prevention and problem solving; bulletin board discussions; e-mail with technical support 'contact us', reliable links, news and information, personal profiles, 'ask the expert' discussion group; telephone interactive voice response (if necessary) for encouragement to re-engage	Action planning; barrier identification/problem solving; plan social support/social change; prompt self-monitoring of behaviour; provide feedback on performance; tailoring; teach to use prompts/cues
Tate (2006) <sup>74</sup>	Calorie-restricted diet according to weight at baseline; instruction on structured meals and meal replacement strategies; interactive website (weekly reporting and graphs of weight, e-mail prompts to report weight, weight loss tips via e-mail, recipes and a weight loss e-buddy network system for peer support for weight loss via e-mail); electronic diary (to report weight, daily caloric intake, use of meal replacements and exercise); message board to post messages to other study participants randomised to same group; weekly e-mail to remind to complete online diary and included a weekly behavioural lesson; summary of reported behaviours and weight loss progress, ongoing support, praise or motivation, and suggested next steps	Information on how to perform behaviour; plan social support/social change; prompt review of outcome goals; prompt self-monitoring of behavioural outcome; provide feedback on performance; rewards contingent on progress towards behaviour; tailoring; teach to use prompts/cues; use of follow-up prompts

*continued*

**TABLE 9** Reported components and behaviour change techniques used in interventions (*continued*)

Study	Reported components	Behaviour change techniques
Trinh (2009) <sup>75</sup>	Online assessment; personalised, tailored feedback on number and size of servings for food groups; long-term goal setting and identification of first step to work towards goal for the next 7 days; online shopping list and food plan; weekly follow-up e-mail newsletters to support the messages and information provided on the website and to encourage further learning	Barrier identification/problem solving; goal setting (behaviour); information on how to perform behaviour; prompt review of behavioural goals; provide feedback on performance; set graded tasks; tailoring; teach to use prompts/cues
Turnin (1992) <sup>76</sup>	Individualised counselling; general information; energy requirement calculation; individualised meal analysis; specially adapted menus; recipes; MONICA; general dietary information; e-mail; meal analysis; menus adapted to user's energy requirements, pathology and seasonal food availability; recipes; general dietetic information	Information on behaviour consequences in general; information on how to perform behaviour; prompt review of behavioural goals; prompt self-monitoring of behaviour; provide feedback on performance; tailoring
Turnin (2001) <sup>77</sup>	Individualised help in meal analysis and composition; access to general information about diet; individually tailored caloric recommendations; assessment of meal balance (analysis, nutritional advice and suggestions for balanced meals over the whole day); individualised daily menus; recipes; discussion forum	Information on how to perform behaviour; prompt self-monitoring of behaviour; provide feedback on performance; tailoring
Vandelanotte (2005) <sup>78</sup>	Introduction page; tailored feedback (fat intake compared with current recommendations); tips and suggestions; feedback on participant's psychosocial attitudes, perceived benefits and barriers, social support and self-efficacy related to physical activity or fat intake	Information on behaviour consequences in general; information on behaviour consequences to individual; information on how to perform behaviour; provide feedback on performance; tailoring
Verheijden (2004) <sup>79</sup>	Monthly assessment tool to determine stage of change; information package for stage of change; self-assessment tool for dietary fat intake; recipes; bulletin board	Fear arousal; information on behavioural consequences to individual; information on how to perform behaviour; plan social support/social change; prompt self-monitoring of behavioural outcome; rewards contingent on progress towards behaviour; tailoring
Veverka (2003) <sup>80</sup>	Website containing stage-matched health information; welcome screen; messages; survey (staging algorithm); tailored newsletter (topics in diet and physical activity), reinforcement of topic through feedback (quizzes and facts), ancillary hyperlinks to information from government and professional diet and exercise websites); e-mail to lead researcher for technical difficulties	Prompt review of behavioural goals; prompt self-monitoring of behaviour; tailoring
Winett (1991) <sup>81</sup>	Video programmes; feedback concerning intended purchases; prompts to encourage lower-fat and higher-fibre purchases; preview of the following week's programme; basic information and rationale for dietary change; information on reducing fat, increasing complex carbohydrates and fibre in supermarket purchases and meals; options for purchases and meals; 'commit to' new purchases and meals by use of touch screens with feedback (comprising suggested substitutes for higher-fat and lower-fibre items; praise for new purchases of lower-fat or higher-fibre products)	Information on behaviour consequences in general; information on how to perform behaviour; provide feedback on performance; rewards contingent on progress towards behaviour; rewards contingent on successful behaviour; set graded tasks; teach to use prompts/cues
Winett (2007) <sup>82</sup>	Narrator guide; written information; weekly goals with specific strategies; positive and supportive feedback with suggested alternative strategies; 'fast-food planner' (virtually visit any restaurant and choose meal items < 750 kcal and 30 g of fat, with feedback); assessments of progress and feedback on meeting goals	Goal setting (behaviour); provide feedback on performance; rewards contingent on successful behaviour
Wylie-Rosett (2001) <sup>83</sup>	Workbook; behavioural goals; review of goals; information and guidance regarding weight reduction; block fat screener; food guide pyramid	Barrier identification/problem solving; goal setting (behaviour); prompt review of behavioural goals; prompt self-monitoring of behaviour; tailoring
Zabinski (2001) <sup>84</sup>	STUDENT BODIES software and an electronic bulletin board (forum for discussion of readings and assignments)	Plan social support/social change

CBT, cognitive behavioural therapy; iCat, intelligent computer-assisted training; MONICA, Multinational MONItoring of trends and determinants in Cardiovascular disease.

**TABLE 10** Frequency of reported use of behaviour change theories

Behaviour change theory	Number of studies
Social cognitive theory	12
Transtheoretical model	12
CBT	5
Theory of planned behaviour	5
Precaution adoption process model	4
Health beliefs model	2
Theory of reasoned action	2
Attitude, social influence and self-efficacy model	1
Diffusion theory	1
Goal theory	1
Health communication theory	1
Social marketing	1

**TABLE 11** Theories of behaviour change reported to have been used in developing interventions

Study	Behaviour change theories
Agras (1990) <sup>42</sup>	Not specified
Alexander (2010) <sup>43</sup>	Health beliefs model Social cognitive theory Transtheoretical model
Anderson (2001) <sup>44</sup>	Social cognitive theory
Beasley (2008) <sup>45</sup>	Not specified
Blanson Henkemans (2009) <sup>46</sup>	Not specified
Block (2004) <sup>47</sup>	Not specified
Buller (2008) <sup>48</sup>	Diffusion theory Social cognitive theory
Campbell (1999) <sup>49</sup>	Social cognitive theory Transtheoretical model
Campbell (2004) <sup>50</sup>	Social cognitive theory Transtheoretical model
Carbone (1999) <sup>51</sup>	Not specified
Cook (2007) <sup>52</sup>	Social cognitive theory Transtheoretical model
Cussler (2008) <sup>53</sup>	Not specified
De Bourdeaudhuij (2007) <sup>54</sup>	Theory of planned behaviour
Delichatsios (2001) <sup>55</sup>	Social cognitive theory
Di Noia (2008) <sup>56</sup>	Transtheoretical model
Ellrott (2005) <sup>57</sup>	Not specified
Franko (2008) <sup>58</sup>	Not specified
Gow (2010) <sup>59</sup>	Social cognitive theory
Haerens (2007) <sup>60</sup>	Attitude, social influence and self-efficacy model Social cognitive theory Theory of planned behaviour Transtheoretical model
Huang (2006) <sup>61</sup>	Not specified

*continued*

**TABLE 11** Theories of behaviour change reported to have been used in developing interventions (*continued*)

Study	Behaviour change theories
Irvine (2004) <sup>62</sup>	Health communication theory Social cognitive theory Theory of reasoned action Transtheoretical model
Jacobi (2007) <sup>63</sup>	Not specified
Jones (2008) <sup>64</sup>	CBT
Kroeze (2008) <sup>65</sup>	Precaution adoption process model Theory of planned behaviour
Low (2006) <sup>66</sup>	CBT
Oenema (2001) <sup>67</sup>	Precaution adoption process model
Oenema (2005) <sup>68</sup>	Precaution adoption process model
Oenema (2008) <sup>69</sup>	Precaution adoption process model
Rothert (2006) <sup>70</sup>	Not specified
Shapiro (2007) <sup>71</sup>	CBT
Sternfeld (2009) <sup>72</sup>	Goal theory Health beliefs model Social cognitive theory Social marketing Theory of reasoned action
Svetkey (2008) <sup>73</sup>	Motivational Interviewing
Tate (2006) <sup>74</sup>	CBT
Trinh (2009) <sup>75</sup>	Persuasive communication Social cognitive theory Theory of planned behaviour Transtheoretical model
Turnin (1992) <sup>76</sup>	Not specified
Turnin (2001) <sup>77</sup>	Not specified
Vandelanotte (2005) <sup>78</sup>	Theory of planned behaviour Transtheoretical model
Verheijden (2004) <sup>79</sup>	Transtheoretical model
Veverka (2003) <sup>80</sup>	Transtheoretical model
Winett (1991) <sup>81</sup>	Not specified
Winett (2007) <sup>82</sup>	Not specified
Wyllie-Rosett (2001) <sup>83</sup>	CBT Transtheoretical model
Zabinski (2001) <sup>84</sup>	Not specified

### Mechanism of action

The behavioural change theories reported to have been used in developing interventions are shown in *Table 10* (relative frequency of use) and *Table 11* (use of theories in each study).

Of the 26 studies that reported using behavioural theories, the most frequently used were social cognitive theory (12 studies<sup>43,44,48–50,52,55,59,60,62,72,75</sup>), the transtheoretical model (12 studies<sup>43,49,50,52,56,60,62,75,78–80,83</sup>), the theory of planned behaviour (five studies<sup>54,60,65,75,78</sup>), CBT (five studies<sup>64,66,71,74,83</sup>) and the precaution adoption process model (four studies<sup>65,67–69</sup>).

**TABLE 12** Frequency of behaviour change techniques used in interventions

Behaviour change technique <sup>a</sup>	Number of studies <sup>b</sup>	Behaviour change technique <sup>a</sup>	Number of studies <sup>b</sup>
Tailoring	43	Prompt review of outcome goals	2
Provide information on consequences of behaviour in general	14	Motivational interviewing	2
Goal setting (behaviour)	14	General planning	2
Provide feedback on performance	14	Prompting generalisation of a target behaviour	1
Barrier identification/problem solving	13	Provide information about others' approval	1
Provide instruction on how to perform the behaviour	12	Shaping	1
Prompt self-monitoring of behaviour	12	Prompting focus on past success	1
Prompt review of behavioural goals	11	Use of follow-up prompts	1
Provide information on consequences of behaviour to the individual	11	Prompt identification as role model/position advocate	1
Plan social support/social change	10	Environmental restructuring	1
Teach to use prompts/cues	7	Relapse prevention/coping planning	1
Model/demonstrate the behaviour	6	Emotional control training	1
Fear arousal	6	Stimulate anticipation of future rewards	0
Action planning	5	Prompt practice	0
Provide normative information about others' behaviour	4	Time management	0
Prompt self-monitoring of behavioural outcome	4	Prompt anticipated regret	0
Provide information on where and when to perform the behaviour	3	Prompt use of imagery	0
Set graded tasks	3	Prompt self-talk	0
Provide rewards contingent on effort or progress towards behaviour	3	Agree behavioural contract	0
Facilitate social comparison	3	Stress management	0
Goal setting (outcome)	2	General communication skills training	0
Provide rewards contingent on successful behaviour	2		

a Using taxonomy of behaviour change techniques.<sup>37</sup>

b Total may add up to >43 as some interventions used more than one behaviour change technique.

The relative frequency of use of behaviour change techniques used in interventions (shown in detail for each study in *Table 9*) is shown in *Table 12*. The most commonly used techniques were goal setting (behaviour) (14 studies<sup>42,44–47,49,52,53,58,62,64,75,82,83</sup>), provide feedback on performance (14 studies<sup>57,65,67–69,72–78,81,82</sup>), provide information on consequences of behaviour in general (13 studies<sup>43,44,46,49,52,54,56,62,65,72,76,78,81</sup>) or to the individual (11 studies<sup>49,50,54,56,66,67,69,70,72,78,79</sup>), barrier identification/problem solving (13 studies<sup>47,52,59,62,64,65,67,68,70,72,73,75,83</sup>), prompt self-monitoring of behaviour (14 studies<sup>46,52,57,64,66,69,70,72–74,76,77,80,83</sup>), provide instruction on how to perform the behaviour (12 studies<sup>48,60,65,67,68,74–79,81</sup>), prompt review of behavioural goals (11 studies<sup>42,44,45,52,53,62,72,75,76,80,83</sup>), and plan social support/social change (10 studies<sup>56,60,64,66,70,72–74,79,84</sup>). Tailoring of information or feedback to the individual based on personal data was an explicit inclusion criterion for this review of adaptive e-learning, and therefore all 43 studies provided some form of tailoring of information or feedback.

**TABLE 13** Baseline health measures used

Health measure	Number of studies
BMI	14
Obese/overweight	5
Smoking	4
Healthy	2
Binge eating disorder	1
Family history of disease	1
Fat intake/risk group	1
Hypertensive	1
Weight	1

## Participants

### Baseline health and eligibility criteria

Several studies had specific eligibility criteria related to clinical health status. Of the 23 studies providing details of the study inclusion criteria, 12 offered the intervention only to those with BMI > 25 kg/m<sup>2</sup>;<sup>2,42,45,46,53,57,64,70,71,73,74,77,83</sup> 10 required participants to be generally healthy and free of diagnosed disease;<sup>43,47,52,53,55,59,63,73,78,80</sup> one trialled the intervention in patients with type 1 or 2 diabetes;<sup>76</sup> and one required participants to have at least one diagnosed risk factor for CVD.<sup>79</sup>

Many studies recorded baseline measures of general health and nutrition status that were not primary outcomes of the research, in order to give a fuller picture of participants (*Table 13*). Fourteen studies<sup>46,53,59,63–66,70,74,77–79,83,84</sup> recorded BMI, and five<sup>45,46,53,57,73</sup> classified participants as overweight based on a BMI > 25kg/m<sup>2</sup>. Four studies<sup>61,75,79,80</sup> assessed participants' smoking status; two<sup>43,59</sup> classified participants as 'generally healthy'; and others looked at clinical measures such as family history of disease,<sup>73,74</sup> history of binge eating disorder,<sup>63,64,71</sup> hypertension,<sup>73,79</sup> weight and health risk based on fat intake.<sup>78</sup>

### Age

*Table 14* summarises the distribution of mean ages of participants; nine studies did not report the ages of the participants, although most stated an age range in their eligibility criteria. Of those papers reporting age of participants, three trialled interventions in adolescents under the age of 18 years.<sup>56,60,64</sup> Of those targeting adults, the majority of studies had participants with a mean age of 40–49 years. Only one study looked at adults with a mean age > 60 years.<sup>79</sup>

### Gender

Studies were predominantly mixed gender, although most studies contained more women than men; 15 studies included more than 75% women, and of these four were 100% women.<sup>42,47,49,53</sup> Nine studies<sup>45,48,52,64,65,70,72,74,76</sup> did not report the gender of participants.

### Race/ethnicity

Race/ethnicity was reported in all but three<sup>42,66,81</sup> of the 29 studies conducted in the USA, and in none of the 12 studies conducted in Europe. In the USA, most study populations were ethnically mixed, and racial mix tended to be a function of study location; participants were generally a mixture of Caucasian, African American and Hispanic, with Asian and Native American participants depending on geographic location.

### Socioeconomic status and education

Education level was reported with a highly diverse range of measures. Of the 22 studies that reported the educational levels of participants, some reported the average number of years in

**TABLE 14** Distribution of mean ages in included studies

Mean age of participants (years)	Number of studies
< 18	3
18–29	6
30–39	3
40–49	17
50–59	4
> 60	1
Not reported	9

education, some reported the highest educational qualification achieved and some reported the highest educational institution (e.g. university) attended. Most studies contained a mix of educational attainment ranging from postgraduate level to completion of primary-level education only. Educational level was partly a function of the setting of the intervention; some studies focused on higher-attaining participants (particularly those set in the workplace), whereas others focused on those with lower educational level (for instance those set in community centres and government support offices).

Socioeconomic status was also reported using a diverse range of indicators. Only 11 studies<sup>44,45,47,52,55,56,61,62,75,77,78</sup> reported any measure of SES, and these included income brackets, classification as low/high income, employment status and proportion of income over the 'poverty line'. Of the studies that reported measures of SES, only two targeted predominantly low-income groups: Di Noia *et al.*,<sup>56</sup> in which 87% of participants were defined as low income; and Block *et al.*,<sup>47</sup> in which 68% of participants were below the poverty line. Campbell *et al.*<sup>49,50</sup> also stated that the intervention was trialled with low-income participants (although no measure of SES was reported) as these interventions targeted women receiving government support.

## Outcomes

To measure achievement of dietary objectives, 17 studies<sup>45,49–51,54,57,59,60,64,65,68,69,74,76,78,80,81</sup> measured total fat intake and eight studies<sup>45,55,61,65,67,69,72,80</sup> measured saturated fat intake (either as grams consumed or as percentage of total energy consumed). Nineteen studies<sup>43,44,47,48,50,51,55,56,58,59,62,67,68,71,72,75,80–82</sup> assessed servings of fruit and/or vegetables consumed per day. Other food and nutrient outcomes measured included energy intake (eight studies<sup>45,53,57,65,74,77,80,83</sup>) and fibre intake (five studies<sup>44,45,55,59,82</sup>). In terms of clinical outcomes, 13 studies<sup>46,53,59,63–66,71,73,77,79,83,84</sup> measured BMI (kg/m<sup>2</sup>), 10 studies<sup>42,45,52,53,69,71,73,74,76,83</sup> measured weight or weight loss (Table 15), three studies<sup>77,79,83</sup> assessed cholesterol, three studies<sup>77,79,83</sup> assessed triglycerides and two studies<sup>79,83</sup> assessed blood pressure. Four studies<sup>63,64,66,84</sup> concentrated on the avoidance of eating disorders and used scales of eating disorder risk alongside measures of BMI and/or weight. See Table 16 for outcome measures used in each study.

## Usability

Almost two-thirds of included studies reported data on at least one aspect of process (accessibility, compliance, usability and acceptability). Table 17 presents the process measures reported in included studies. Accessibility was assessed in one study<sup>42</sup> by collecting data on computer literacy. In the same study it was reported that prior to the intervention, 69% and 46% of the participants had access to a computer at work and home, respectively.

More than half of the included studies collected data on compliance of the participants to the intervention. Compliance to an intervention was assessed by monitoring the frequency of computer/website/system use/page visited in 19 studies.<sup>42–44,48,53,55,59,62–64,66,69,74,76,77,79,80,82,84</sup> One study<sup>45</sup>

**TABLE 15** Frequency of outcomes used in included studies

Outcome measure	Number of studies <sup>a</sup>
<b>Food and nutrient outcomes</b>	
Fruit and/or vegetables (servings)	19
Total fat (g)	17
Energy (kcal; kJ; MJ)	8
Saturated fat (g;% fat intake)	8
Dietary fibre (g)	5
Other foods/food groups <sup>b</sup>	4
Other nutrients <sup>c</sup>	4
<b>Clinical outcomes</b>	
Weight/weight loss (kg, lbs)	10
BMI (kg/m <sup>2</sup> )	13
Serum cholesterol (mmol/l)	3
Serum triglycerides (mmol/l)	3
Eating disorder outcomes <sup>d</sup>	4
Blood pressure (mmHg)	2
Other clinical outcomes <sup>e</sup>	2

a Total may add up to > 43 as some studies used more than one outcome measure.

b Includes meat, dairy, whole grains, fast foods and added sugars.

c Includes carbohydrates, protein, trans fats, fructosamine, saccharose and glucose.

d Includes the eating disorder scales Eating Disorder Inventory (EDI), Eating Disorder Examination Questionnaire and Symptom-Checklist-90 (SCL-90).

e Includes waist circumference and percentage body fat.

used 24-hour dietary recall, two studies<sup>46,74</sup> used a diary and another two studies<sup>52,68</sup> used self-reported questions to capture compliance to an intervention. Four studies<sup>43,48,52,55</sup> found a positive association between compliance with an intervention and increase in fruit and vegetable servings, and one study<sup>74</sup> found a significant association between treatment compliance and weight loss.

Eleven studies<sup>42,46,52,54,60,63,65,68,70,77,78</sup> assessed the usability of the intervention program using various methods, such as questionnaires in which the participants were required to give their responses using a five- or seven- or 10-point Likert scale. One common item assessed was whether or not the intervention material was easy to use.<sup>46,52,65,68</sup> Two studies<sup>46,52</sup> achieved better ratings for this item than the control group, whereas in the other two studies<sup>65,68</sup> this item was rated higher in the control group. In three studies,<sup>54,60,78</sup> usability was evaluated in an earlier formative evaluation study<sup>85</sup> which showed that the computer-tailored intervention was usable for reducing fat intake in a general population of adults in the Belgian Flanders. The usability was assessed on a 6-point scale ranging from 1 (very good) to 6 (very poor) in Jacobi *et al.*,<sup>63</sup> and the internet-based program was rated as good, having achieved a mean rating of 2. Most of the participants in the tailored expert system in the Rotherth *et al.* study<sup>70</sup> reported reading the web-based materials more often than the control group. The intervention group also found the materials more helpful, easy to understand and personally relevant. More than 60% of the participants in the Nutri-Expert group in the study by Turnin *et al.*<sup>77</sup> found the telematics system easy to use.

Acceptability of interventions was assessed in 11 studies.<sup>42,43,49,50,52,54,60,68,70,71,78</sup> Most studies that collected data on program acceptability reported that participants found the program to be very good and that they would recommend the program to others.<sup>42,43,49,50,70</sup> In Cook *et al.*,<sup>52</sup> the participants in the web group found the program materials more informative and helpful

**TABLE 16** Outcomes used in included studies

Study	Outcomes measured
Agras (1990) <sup>42</sup>	Weight
Alexander (2010) <sup>43</sup>	Fruit and vegetables
Anderson (2001) <sup>44</sup>	% energy from fat Dietary fibre Fruit and vegetables
Beasley (2008) <sup>45</sup>	Energy Total fat; saturated fat Dietary fibre Weight Waist circumference
Blanson Henkemans (2009) <sup>46</sup>	BMI
Block (2004) <sup>47</sup>	Fruit and vegetables
Buller (2008) <sup>48</sup>	Fruit and vegetables
Campbell (1999) <sup>49</sup>	Total fat
Campbell (2004) <sup>50</sup>	Total fat Fruit and vegetables
Carbone (1999) <sup>51</sup>	Total fat Fruit and vegetables
Cook (2007) <sup>52</sup>	Weight
Cussler (2008) <sup>53</sup>	Weight BMI % body fat Energy
De Bourdeaudhuij (2007) <sup>54</sup>	% energy from fat Total fat
Delichatsios (2001) <sup>55</sup>	Dietary fibre Saturated fat Fruit; vegetables Red/processed meat Whole-fat dairy Wholegrain cereals
Di Noia (2008) <sup>56</sup>	Fruit and vegetables
Ellrott (2005) <sup>57</sup>	Energy Total fat % energy from fat
Franko (2008) <sup>58</sup>	Fruit and vegetables % energy from fat
Gow (2010) <sup>59</sup>	BMI Total fat Dietary fibre Fruit and vegetables
Haerens (2007) <sup>60</sup>	Total fat
Huang (2006) <sup>61</sup>	Saturated fat
Irvine (2004) <sup>62</sup>	Fruit and vegetables
Jacobi (2007) <sup>63</sup>	BMI EDI; EDE-Q; SCL-90-R

*continued*

**TABLE 16** Outcomes used in included studies (*continued*)

Study	Outcomes measured
Jones (2008) <sup>64</sup>	BMI EDE-Q
Kroeze (2008) <sup>65</sup>	Total fat
	BMI
	Saturated fat
Low (2006) <sup>66</sup>	Energy
	Total fat
	BMI
Oenema (2001) <sup>67</sup>	EDI-DT; EDI-B; EDI-BD
	Saturated fat
Oenema (2005) <sup>68</sup>	Fruit; vegetables
	Total fat
Oenema (2008) <sup>69</sup>	Fruit; vegetables
	Saturated fat; self-rated fat intake
Rothert (2006) <sup>70</sup>	Weight
Shapiro (2007) <sup>71</sup>	% age of baseline weight loss
	Fruit and vegetables
Sternfeld (2009) <sup>72</sup>	Fast foods
	BMI
	Weight
	Fruit and vegetables
Svetkey (2008) <sup>73</sup>	Saturated fat; trans fats
	Added sugars
	Weight
Tate (2006) <sup>74</sup>	BMI
	Weight
	Energy
Trinh (2009) <sup>75</sup>	Total fat
	Fruit
Turnin (1992) <sup>76</sup>	Vegetables
	Total fat
	Carbohydrate
	Caloric excess
	Protein
Turnin (2001) <sup>77</sup>	Weight
	HbA <sub>1c</sub>
	Fructosamine
	BMI
	Total cholesterol; HDL; HDL2
	Triglycerides; LDL cholesterol
	Energy
	Carbohydrate
% energy from fat	
Vandelanotte (2005) <sup>78</sup>	Protein
	Insulin
	Saccharose
	Total fat
	% energy from fat

**TABLE 16** Outcomes used in included studies (*continued*)

Study	Outcomes measured
Verheijden (2004) <sup>79</sup>	BMI Systolic BP; diastolic BP Total cholesterol; HDL; LDL Triglycerides
Veverka (2003) <sup>80</sup>	Energy Total fat; MUFA; PUFA; saturated fat % energy from fat Fruit and vegetables Dietary fibre
Winett (1991) <sup>81</sup>	% energy from fat Fruit and vegetables Wholegrain cereals Total fat
Winett (2007) <sup>82</sup>	% energy from fat Fruit and vegetables Fibre
Wylie-Rosett (2001) <sup>83</sup>	Energy % energy from fat Weight BMI Glucose Systolic BP; diastolic BP Total cholesterol; HDL; LDL Triglycerides
Zabinski (2001) <sup>84</sup>	BMI EDE-Q; EDI-DT; EDI-B

BP, blood pressure; EDE, Eating Disorder Examination; EOE-Q, Eating Disorder Examination-Questionnaire; EDI, Eating Disorder Inventory; EDI-B, Eating Disorder Inventory-Body; EDI-BD, Eating Disorder Inventory-Body Dissatisfaction; EDI-DT, Eating Disorders Inventory-Drive for Thinness; HbA<sub>1c</sub>, glycated haemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MUFA, mono-unsaturated fatty acid; PUFA, polyunsaturated fatty acid; SCL-90-R, Symptom-Checklist-90-Revised.

than the print group. In three studies,<sup>54,60,78</sup> acceptability was evaluated in an earlier formative evaluation study<sup>85</sup> that showed that the computer-tailored intervention was acceptable for reducing fat intake.

One study<sup>68</sup> achieved positive ratings for all aspects of the process measures except for novelty on specific information on fat, fruit and vegetables. The same study achieved higher ratings than the control group in all aspects except for credibility. In one study,<sup>71</sup> treatment acceptability was based on attrition rate, treatment choice (group vs CD-ROM) of individuals originally assigned to the waiting list condition, and treatment modality use (CD-ROM) after the program completion. Data on all three aspects favoured the CD-ROM, thus achieving good acceptability.

## Overview of excluded studies

Table 28 in Appendix 6 lists the studies that were deemed potentially eligible through screening of study titles and abstracts, but which were subsequently found to fail one or more of the inclusion criteria for the systematic review. Of the 233 excluded studies, 81 were excluded because they

**TABLE 17** Process measures reported in included studies

Study	Accessibility	Compliance	Usability	Acceptability
Agras (1990) <sup>42</sup>	✓	✓	✓	✓
Alexander (2010) <sup>43</sup>		✓		✓
Anderson (2001) <sup>44</sup>		✓		
Beasley (2008) <sup>45</sup>		✓		
Blanson Henkemans (2009) <sup>46</sup>		✓	✓	
Block (2004) <sup>47</sup>				
Buller (2008) <sup>48</sup>		✓		
Campbell (1999) <sup>49</sup>				✓
Campbell (2004) <sup>50</sup>				✓
Carbone (1999) <sup>51</sup>				
Cook (2007) <sup>52</sup>			✓	✓
Cussler (2008) <sup>53</sup>		✓		
De Bourdeaudhuij (2007) <sup>54</sup>			✓	✓
Delichatsios (2001) <sup>55</sup>		✓		
Di Noia (2008) <sup>56</sup>				
Ellrott (2005) <sup>57</sup>		✓		
Franko (2008) <sup>58</sup>		✓		
Gow (2010) <sup>59</sup>		✓		
Haerens (2007) <sup>60</sup>			✓	✓
Huang (2006) <sup>61</sup>				
Irvine (2004) <sup>62</sup>		✓		
Jacobi (2007) <sup>63</sup>		✓	✓	
Jones (2008) <sup>64</sup>		✓		
Kroeze (2008) <sup>65</sup>			✓	
Low (2006) <sup>66</sup>		✓		
Oenema (2001) <sup>67</sup>				
Oenema (2005) <sup>68</sup>		✓	✓	✓
Oenema (2008) <sup>69</sup>		✓		
Rothert (2006) <sup>70</sup>			✓	✓
Shapiro (2007) <sup>71</sup>		✓		✓
Sternfeld (2009) <sup>72</sup>		✓		
Svetkey (2008) <sup>73</sup>		✓		
Tate (2006) <sup>74</sup>		✓		
Trinh (2009) <sup>75</sup>				
Turnin (1992) <sup>76</sup>		✓		
Turnin (2001) <sup>77</sup>		✓	✓	
Vandelanotte (2005) <sup>78</sup>			✓	✓
Verheijden (2004) <sup>79</sup>		✓		
Veverka (2003) <sup>80</sup>		✓		
Winett (1991) <sup>81</sup>				
Winett (2007) <sup>82</sup>		✓		
Wylie-Rosett (2001) <sup>83</sup>				
Zabinski (2001) <sup>84</sup>		✓		

were found not to be an RCT of an intervention (of which 11 may have been RCTs, but were earlier versions of reports published more fully elsewhere), five because participants were children, 126 because the intervention did not meet our criteria of 'adaptive e-learning', where program output/feedback was generated automatically based on user input (of which 33 may have involved adaptive e-learning, but also involved significant contact with a qualified therapist, rendering it impossible to determine the contribution of the e-learning component to any dietary or clinical change) and 21 because they did not assess any dietary or clinical outcomes relevant to this review. Two papers could not be obtained.

## Methodological quality of included studies

Two methods to assess the methodological quality of studies were used in this review, the Cochrane Collaboration's tool for assessing risk of bias<sup>35</sup> and the EPHP tool.<sup>36</sup>

### Risk of bias in included studies

#### Sequence generation

One trial<sup>49</sup> was judged to be at high risk of bias for this domain. Of the 43 studies, 27<sup>42,43,45-48,50,52,59,61-67,69-74,78,79,81-83</sup> used an adequate method of sequence generation (table of random numbers and computerised randomisation). The remaining 15<sup>44,51,53-58,60,68,75-77,80,84</sup> were rated as unclear owing to no information being presented in the report or being available from the study author(s). *Table 18* summarises the methods used to generate allocation sequences.

**TABLE 18** Sequence generation

Sequence generation	Number of studies
Not specified	15
Simple randomisation, number generator	13
Stratified randomisation	5
Simple randomisation, number table	3
Random permuted blocks	2
Drawing lots	2
Minimisation	1
By day registered	1

**TABLE 19** Implementation of allocation concealment

Implementation of allocation concealment	Methods	Number of studies
Allocation generation	Not specified	28
	Computer	7
	Project team	6
	Independent researcher	2
Enrolment	Not specified	24
	Project team	16
	Independent researcher	2
	Self (via website)	1
Assignment	Not specified	18
	Self (via website)/computer	9
	Project team	12
	Independent researcher	4

### Allocation concealment

Allocation concealment was adequate in 16<sup>43,46,48,50,52,59,61,65-67,69,71-74,78</sup> of the 43 included studies. It was unclear in 24 studies,<sup>42,44,47,51,53-58,60,62-64,68,70,75-77,79-82,84</sup> and inadequate in three studies.<sup>45,49,78</sup> Two studies<sup>45,78</sup> used an open list to allocate the participants, whereas in the other study<sup>49</sup> the participants were allocated according to the day on which they were entered in the trial. Thirteen studies<sup>43,46,48,50,52,59,61,65,69,72-74,83</sup> achieved adequate allocation concealment as the allocation of the randomised sequence was determined by a computer. Three studies<sup>66,67,71</sup> used a closed list to allocate the participants. The information on who generated the allocation concealment was specified in 15 studies;<sup>43,46,49,50,52,54,66,67,69,71-74,78,83</sup> the information on who enrolled participants was known in 19 studies;<sup>43,45,48-50,54,58,62,64-69,71,72,74,78,81</sup> and the information on who assigned participants to treatment groups was described in 23 studies.<sup>43,45,46,48-50,52,54,59,62,64-67,69,71-74,78,79,81,83</sup> *Table 19* summarises the methods used to generate allocation, and to enrol and allocate participants.

### Blinding

Of the 43 studies, 15<sup>46,49,50,54,61,65-67,69-73,79,81</sup> reported adequate blinding of outcome assessment although there was a high risk of bias because of inadequate blinding of outcome assessment in seven studies.<sup>43,45,48,52,62,64,74</sup> Methods of blinding were unclear in the remaining 21 studies.<sup>42,44,47,51,53,55-60,63,68,75-78,80,82-84</sup>

### Incomplete outcome data

Twenty-one studies<sup>42,45,48-50,52,53,55,56,59,61,63,64,67,69-73,75,78</sup> were judged to be at a low risk of bias for this domain: there were no missing data in one trial,<sup>75</sup> whereas the others used appropriate methods for imputing missing data. Four studies<sup>46,47,62,74</sup> were judged as having a high risk of bias. There was insufficient information available to judge the risk of bias for the remaining 18 studies,<sup>43,44,51,54,57,58,60,65,66,68,76,77,79-84</sup> which have been classified as unclear for this domain.

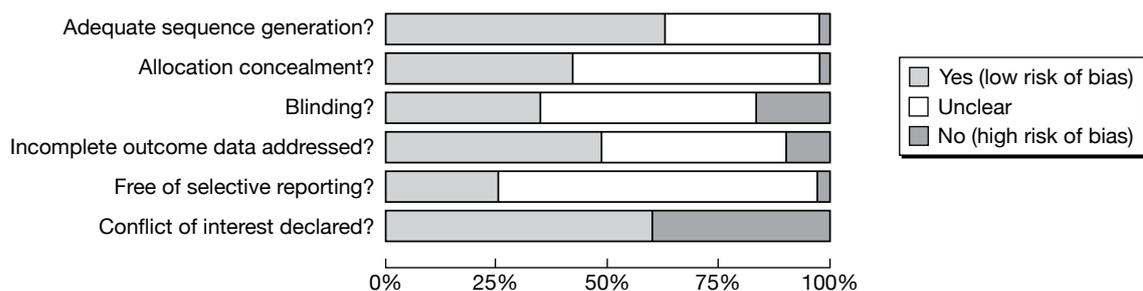
### Selective outcome reporting

The trial protocols were available for two studies.<sup>61,73</sup> In both studies the final report contained data for all the pre-specified outcomes. Nine more studies<sup>44,53-55,60,70-72,80,84</sup> were judged to be free from selective outcome reporting bias. In one study<sup>47</sup> there was potential for risk of selective outcome reporting bias. It was unclear in the remaining 31 studies<sup>42,43,45,46,48-52,56-58,60,62-69,74-79,81-84</sup> whether or not there was selective reporting of outcomes.

### Conflict of interest

Authors of 26<sup>44,45,51-53,58,59,61,64,65,67-82</sup> of the 43 studies provided a conflict of interest statement.

*Figure 3* presents the Cochrane Collaboration summary figure for risk of bias across all included studies (the review authors' judgement about the six bias items for each study is presented as overall percentages). *Table 20* presents the judgements about risk of bias for each study.



**FIGURE 3** Cochrane Collaboration's risk of bias summary. Figure produced using Cochrane Collaboration's RevMan 5 software.

**TABLE 20** Cochrane Collaboration's risk of bias summary

Study	Sequence generation	Allocation concealment	Blinding	Incomplete outcome data	Selective outcome reporting bias	Conflict of interest statement
Agras (1990) <sup>42</sup>	L	U	U	L	U	N
Alexander (2010) <sup>43</sup>	L	L	H	U	U	N
Anderson (2001) <sup>44</sup>	U	U	U	U	L	Y
Beasley (2008) <sup>45</sup>	L	H	H	L	U	Y
Blanson Henkemans (2009) <sup>46</sup>	L	L	L	H	U	N
Block (2004) <sup>47</sup>	L	U	U	H	H	N
Buller (2008) <sup>48</sup>	L	L	H	L	U	N
Campbell (1999) <sup>49</sup>	H	H	L	L	U	N
Campbell (2004) <sup>50</sup>	L	L	L	L	U	N
Carbone (1999) <sup>51</sup>	U	U	U	U	U	Y
Cook (2007) <sup>52</sup>	L	L	H	L	U	Y
Cussler (2008) <sup>53</sup>	U	U	U	L	L	Y
De Bourdeaudhuij (2007) <sup>54</sup>	U	U	L	U	L	N
Delichatsios (2001) <sup>55</sup>	U	U	U	L	L	N
Di Noia (2008) <sup>56</sup>	U	U	U	L	U	N
Ellrott (2005) <sup>57</sup>	U	U	U	U	U	N
Franko (2008) <sup>58</sup>	U	U	U	U	U	Y
Gow (2010) <sup>59</sup>	L	L	U	L	L	Y
Haerens (2007) <sup>60</sup>	U	U	U	U	U	N
Huang (2006) <sup>61</sup>	L	L	L	L	L	Y
Irvine (2004) <sup>62</sup>	L	U	H	H	U	N
Jacobi (2007) <sup>63</sup>	L	U	U	L	U	N
Jones (2008) <sup>64</sup>	L	U	H	L	U	Y
Kroeze (2008) <sup>65</sup>	L	L	L	U	U	Y
Low (2006) <sup>66</sup>	L	L	L	U	U	N
Oenema (2001) <sup>67</sup>	L	L	L	L	U	Y
Oenema (2005) <sup>68</sup>	U	U	U	U	U	Y
Oenema (2008) <sup>69</sup>	L	L	L	L	U	Y
Rothert (2006) <sup>70</sup>	L	U	L	L	L	Y
Shapiro (2007) <sup>71</sup>	L	L	L	L	L	Y
Sternfeld (2009) <sup>72</sup>	L	L	L	L	L	Y
Svetkey (2008) <sup>73</sup>	L	L	L	L	L	Y
Tate (2006) <sup>74</sup>	L	L	H	H	U	Y
Trinh (2009) <sup>75</sup>	U	U	U	L	U	Y
Turnin (1992) <sup>76</sup>	U	U	U	U	U	Y
Turnin (2001) <sup>77</sup>	U	U	U	U	U	Y
Vandelanotte (2005) <sup>78</sup>	L	H	U	L	U	Y
Verheijden (2004) <sup>79</sup>	L	U	L	U	U	Y
Veverka (2003) <sup>80</sup>	U	U	U	U	L	Y
Winett (1991) <sup>81</sup>	L	U	L	U	U	Y
Winett (2007) <sup>82</sup>	L	U	U	U	U	Y
Wylie-Rosett (2001) <sup>83</sup>	L	L	U	U	U	N
Zabinski (2001) <sup>84</sup>	U	U	U	U	U	N

H, High; L, Low; N, No; U, Unclear; Y, Yes.

### EPHPP assessment

The EPHPP tool consists of six criteria. Each criterion is rated as ‘strong’, ‘moderate’ or ‘weak’ depending on characteristics on each criterion reported in the study. From this rating, the overall assessment of strong, moderate or weak for each study is derived. A study that achieved at least four ‘strong’ ratings in each of the individual criteria with no ‘weak’ ratings would have received a ‘strong’ overall global rating. If fewer than four ‘strong’ ratings were achieved in the individual criteria and one ‘weak’ rating, then an overall rating of ‘moderate’ was achieved. If two or more criteria were rated ‘weak’ then an overall rating of ‘weak’ was given. *Table 21* summarises the number of studies achieving the rating in each criterion (component rating) and *Table 22* summarises the overall assessment of quality of the included studies.

### Selection bias

This part of the tool aims to assess the generalisability of study results by considering the likelihood that the selected participants are representative of the target population and participation rate.

Of the 43 studies, two<sup>60,64</sup> were judged ‘very likely’, three<sup>69,72,79</sup> as ‘somewhat likely’, and 36<sup>42-50,52-59,61-63,65-68,70,71,73-75,77,78,80-84</sup> as ‘not likely’ to be representative of the target population. In nine studies,<sup>44,45,48,49,53,55,59,60,78</sup> > 80% of the eligible participants agreed to participate in the trial, whereas in six studies,<sup>43,46,58,63,81,82</sup> 60–79% of the eligible participants took part. The participation rate was < 60% in 12 studies<sup>52,54,61,64,65,68,69,72,75,77,79,83</sup> and it was not possible to ascertain the participation rate in 14 studies.<sup>42,47,50,51,56,57,62,66,67,70,71,74,76,84</sup>

### Study design

Of the 43 studies, one<sup>62</sup> was a crossover trial and two<sup>79,82</sup> were cluster randomised trials. The remainder were parallel-group RCTs.<sup>42-61,63-78,80,81,83,84</sup> The methods used to randomly allocate participants were described in 25 studies.<sup>42,43,45-50,52,59,61-67,69,71-74,78,79,83</sup>

**TABLE 21** Component ratings of studies (EPHPP assessment)

Component	Ratings	Studies
Selection bias	Strong	1
	Moderate	0
	Weak	42
Study design	Strong	43
	Moderate	0
	Weak	0
Confounders	Strong	36
	Moderate	0
	Weak	7
Blinding	Strong	5
	Moderate	14
	Weak	24
Data collection methods	Strong	21
	Moderate	11
	Weak	11
Attrition	Strong	24
	Moderate	12
	Weak	7

**TABLE 22** Quality assessment of all included studies (EPHPP assessment)

Study	Selection	Allocation	Confounders	Blinding	Data collection	Attrition	Global rating
Agras (1990) <sup>42</sup>	W	S	S	W	S	S	W
Alexander (2010) <sup>43</sup>	W	S	S	M	M	M	M
Anderson (2001) <sup>44</sup>	W	S	S	W	W	W	W
Beasley (2008) <sup>45</sup>	W	S	W	W	M	S	W
Blanson Henkemans (2009) <sup>46</sup>	W	S	W	S	W	W	W
Block (2004) <sup>47</sup>	W	S	S	W	S	S	W
Buller (2008) <sup>48</sup>	W	S	S	W	M	M	W
Campbell (1999) <sup>49</sup>	W	S	W	S	M	M	W
Campbell (2004) <sup>50</sup>	W	S	S	S	M	M	M
Carbone (1999) <sup>51</sup>	W	S	S	W	W	W	W
Cook (2007) <sup>52</sup>	W	S	S	W	W	S	W
Cussler (2008) <sup>53</sup>	W	S	S	W	S	S	W
De Bourdeaudhuij (2007) <sup>54</sup>	W	S	S	S	M	M	M
Delichatsios (2001) <sup>55</sup>	W	S	S	W	M	W	W
Di Noia (2008) <sup>56</sup>	W	S	S	W	M	S	W
Ellrott (2005) <sup>57</sup>	W	S	S	W	W	W	W
Franko (2008) <sup>58</sup>	W	S	S	W	S	S	W
Gow (2010) <sup>59</sup>	W	S	S	W	M	M	W
Haerens (2007) <sup>60</sup>	S	S	S	W	S	S	M
Huang (2006) <sup>61</sup>	W	S	S	M	W	S	W
Irvine (2004) <sup>62</sup>	W	S	S	W	M	S	W
Jacobi (2007) <sup>63</sup>	W	S	S	W	M	S	W
Jones (2008) <sup>64</sup>	W	S	S	W	S	M	W
Kroeze (2008) <sup>65</sup>	W	S	S	S	S	S	M
Low (2006) <sup>66</sup>	W	S	S	M	S	S	M
Oenema (2001) <sup>67</sup>	W	S	S	W	S	S	W
Oenema (2005) <sup>68</sup>	W	S	W	W	S	M	W
Oenema (2008) <sup>69</sup>	W	S	S	M	S	M	M
Rothert (2006) <sup>70</sup>	W	S	S	M	W	W	W
Shapiro (2007) <sup>71</sup>	W	S	S	M	S	M	M
Sternfeld (2009) <sup>72</sup>	W	S	S	M	S	W	W
Svetkey (2008) <sup>73</sup>	W	S	S	M	S	S	M
Tate (2006) <sup>74</sup>	W	S	S	M	S	S	M
Trinh (2009) <sup>75</sup>	W	S	W	W	W	S	W
Turnin (1992) <sup>76</sup>	W	S	W	W	W	S	W
Turnin (2001) <sup>77</sup>	W	S	S	M	W	M	W
Vandelanotte (2005) <sup>78</sup>	W	S	S	W	S	M	W
Verheijden (2004) <sup>79</sup>	W	S	S	M	S	S	M
Veverka (2003) <sup>80</sup>	W	S	S	M	S	S	M
Winett (1991) <sup>81</sup>	W	S	S	M	W	S	W
Winett (2007) <sup>82</sup>	W	S	S	W	S	S	W
Wylie-Rosett (2001) <sup>83</sup>	W	S	W	M	S	S	M
Zabinski (2001) <sup>84</sup>	W	S	S	W	S	S	W

M, moderate; S, strong; W, weak.

### Confounders

Of the 43 studies, 34<sup>42–44,47,48,51–62,64–66,68–74,77–82,84</sup> explicitly reported that the intervention and the comparator groups were balanced at baseline. Seven studies had differences between treatment groups at baseline (differences in stages of change and/or fat intake,<sup>49,83</sup> race and ethnicity,<sup>50,75</sup> eating disorder scales,<sup>63</sup> awareness and intention to change fat intake<sup>68</sup> and mean BMI<sup>45</sup>). It was not clear in two studies<sup>46,76</sup> whether or not there were any differences at baseline. For the studies with differences at baseline, 80–100% of the confounders were controlled for in three studies,<sup>44,50,63</sup> whereas < 60% of confounders were controlled for in two studies.<sup>45,49</sup> Five studies<sup>46,68,75,76,83</sup> did not report how confounders were included in their analysis, or what proportion of confounders were addressed.

### Blinding

Of the 43 studies, the outcome assessors were blind to participants' treatment allocation in 11 studies.<sup>43,46,49,50,54,65,72–74,79,81</sup> It was unclear whether or not outcome assessors were aware of treatment allocation in 22 studies,<sup>42,44,47,51,53,55–60,63,67–69,75–78,82–84</sup> although in the remaining 11 studies<sup>45,48,52,61,62,64,66,69–71,80</sup> they were not blind to allocation. Blinding of participants to treatment allocation was achieved in eight studies.<sup>46,49,50,54,61,65,70,83</sup> It was unclear whether or not participants were aware of their intervention allocation in 24 studies,<sup>42–44,47,51,53,55–60,63,66–69,71,75,76,78,80,82,84</sup> whereas in the remaining 11 studies<sup>45,48,52,62,64,72–74,77,79,81</sup> the participants were not blind to allocation.

### Withdrawals and dropouts

Attrition was reported in all 43 studies. In 24 studies,<sup>42,45,47,52,53,56,58,60–63,65–67,73–76,79–84</sup> > 80% of participants completed the final data collection, and in 12 studies<sup>43,48–50,54,59,64,68,69,71,77,78</sup> 60–79% of participants completed the final data collection. Less than 60% of participants completed final follow-up in six studies.<sup>44,46,55,57,70,72</sup>

### Dietary assessment techniques

In the studies reviewed, dietary outcome variables were assessed in 39,<sup>42–62,64,65,67–69,71–83</sup> using FFQs ( $n = 27$ ; individual food items or food groups),<sup>43,44,48–51,54–56,58–60,62,64,65,67–69,72,74,78,80,82,83</sup> 24-hour recalls ( $n = 2$ ),<sup>45,47</sup> multiple-day food records ( $n = 6$ ),<sup>45,46,53,57,76,77</sup> questionnaires ( $n = 11$ )<sup>42,48,49,51,52,56,58,59,62,71,75</sup> and shopping receipts/online food purchases ( $n = 4$ ).<sup>44,61,81,82</sup> Eleven studies used two dietary assessment methods, combining a FFQ with a food pattern or screening FFQ ( $n = 2$ ),<sup>43,55</sup> a FFQ with one or two food habit/food pattern questions ( $n = 6$ ),<sup>48,49,51,58,59,62</sup> a FFQ with shopping receipts ( $n = 2$ )<sup>44,82</sup> or a 24-hour recall with food records ( $n = 1$ ).<sup>45</sup> Three studies<sup>63,66,84</sup> used an Eating Disorder Inventory, which does not quantify energy, nutrient or food intakes. One study<sup>70</sup> did not assess dietary outcomes. One study<sup>79</sup> did not report its dietary outcomes (FFQ) because of concerns about data accuracy.

The gold standard dietary assessment technique is a prospective multiple-day diet record.<sup>86</sup> However, for evaluating intervention-related dietary change, the multiple-day 24-hour recall is recommended for populations for whom memory error is not a barrier, because prospectively recording food intakes (i.e. diet records) heightens one's awareness of dietary practices and may result in compliance bias (i.e. an overestimation of the extent of dietary change).<sup>87,88</sup> Diet records can also lead to a simplification of dietary practices, because of the high respondent burden involved in recording food intakes.<sup>86</sup> The multiple-day 24-hour recall also has advantages over other dietary assessment methods: it is likely to be more responsive to dietary change than either the FFQ or food habit/food pattern questionnaires; and is likely to be more accurate than shopping receipts, because they do not account for household food distribution, food wastage or food gifts/purchases without receipts, which may differ pre and post intervention.

Although the multiple-day 24-hour recall is recommended for assessing intervention-related dietary change, it was not used in the studies reviewed. Two studies, however, used a 1-day

24-hour recall.<sup>45,47</sup> Of these two studies, only one used a 1-day 5-step pass 24-hour recall to reduce memory errors.<sup>45</sup> The primary outcomes of these two studies were intergroup comparisons of dietary intakes. For these outcomes, a 1-day 24-hour recall is adequate, because estimates of usual individual dietary intakes are not required.<sup>86</sup>

In contrast to the studies using a 24-hour recall, six studies used diet records that assessed dietary intakes on more than 1 day.<sup>45,46,53,57,76,77</sup> The number of days of assessment ranged from 3 to 6, which is adequate for evaluating the outcomes of interest, i.e. intergroup differences in dietary outcomes. Further, to reduce compliance bias, one study used both a diet record and a 1-day 5-stage multiple-pass 24-hour recall.<sup>45</sup>

The FFQ was the most common method used to assess dietary outcomes in the studies reviewed. Its accuracy depends on instrument characteristics such as the number and types of foods in the FFQ, the methods used to estimate serving sizes, the method of administration, the time required to complete the FFQ and methods of analysis. Characteristics of the target population are also important because the instrument is conceptually more abstract than other dietary assessment methods, i.e. the respondent must estimate 'usual intakes'. In most of the studies reviewed, insufficient detail was provided to fully evaluate the FFQs. In particular, there were gaps in information regarding the average time it took to complete the FFQ (one reported it),<sup>55</sup> the exact method of quantifying serving sizes (five reported it)<sup>43,49–51,78</sup> and the time frame of the dietary assessment period (six reported it).<sup>43,48,55,58,62,64</sup> Most FFQs were self-administered ( $n = 19$ ),<sup>43,44,54,55,58–60,62,64,65,67–69,72,74,78,80,82,83</sup> including one study of adolescents<sup>64</sup> despite its conceptual complexity for young people.<sup>86</sup> The number of items included in the FFQ ranged from 16 to 131. Nine studies did not report the number of items in their FFQ.<sup>44,48,72–74,79,80,82,83</sup> Eighteen FFQs had a limited number of items to reduce respondent burden (i.e. ranged from 16 to 35 foods/food groups), of which 12 were screening FFQs,<sup>43,48–51,55,58,59,64,67–69</sup> three were focused solely on fat intakes<sup>54,60,78</sup> and two were food group FFQs.<sup>62,65</sup> A screening FFQ will probably underestimate dietary change, especially if key food sources of target nutrients cannot be reported.<sup>89</sup> However, a social desirability bias may also occur with a screening FFQ,<sup>87</sup> so the direction of bias is unpredictable.

A full-length FFQ of  $\geq 90$  items was used in three studies.<sup>44,55,82</sup> Three other studies did not provide sufficient detail to determine whether or not they had used a full-length or shortened FFQ.<sup>72–74</sup> A full-length FFQ is more likely to be responsive to dietary change than a screening or shortened FFQ, especially if it has been validated for the population and nutrients of interest. Full-length FFQs, however, tend to overestimate food consumption, especially when there are many food items within a food group.<sup>86</sup> To reduce this bias, seven studies combined a FFQ with a shortened food group FFQ or food patterns questions, adjusting the full-length FFQ estimates to achieve concurrence.<sup>43,48,49,51,55,58,59</sup>

Sixteen studies reported using a validated FFQ.<sup>43,48,49,54,55,58–60,62,64,65,67–69,72,78</sup> However, in some studies, the FFQ was not validated for populations that were similar to their study population ( $n = 5$ ),<sup>49,55,58–60</sup> or for the dietary outcome variables of interest ( $n = 3$ ).<sup>43,48,49</sup> These validation studies also did not assess the instrument's accuracy for measuring dietary change.

Eleven studies used one or two questions to quantify the consumption of foods from one or two selected food groups (e.g. fruit and vegetables) within a more extensive questionnaire either alone ( $n = 5$ )<sup>42,52,56,71,75</sup> or in combination with another dietary assessment technique ( $n = 6$ ).<sup>48,49,51,58,59,62</sup>

A recent validation study showed that, unlike a screening FFQ, a one-item question did not overestimate an intervention effect,<sup>87</sup> presumably because less emphasis was placed on the desired dietary change in the questionnaire. The extent to which these results can be generalised to other studies is not known. One would expect that social desirability and compliance biases would

limit the validity of a simple one- to two-item food group question for measuring intervention-related dietary change. A further limitation of these brief questions is that they do not describe intervention-related impacts on overall dietary patterns.

In conclusion, accurate measurements of dietary intakes are notoriously difficult to obtain.<sup>86</sup> Among the studies reviewed, those using a 1-day 24-hour recall ( $n=2$ )<sup>45,47</sup> or a combination of two or more dietary assessment methods ( $n=11$ ),<sup>43-45,48,49,51,55,58,59,62,82</sup> especially two independent dietary assessment methods ( $n=2$ ),<sup>44,82</sup> had the strongest dietary assessment methods for measuring dietary change. Those using a diet record alone ( $n=5$ )<sup>46,53,57,76,77</sup> would also be responsive to dietary change, as long as a compliance bias did not result in an overestimation of the intervention effect and dietary practices were not simplified to reduce respondent burden. The studies with the weakest dietary assessment methods were those using shopping receipts alone ( $n=2$ ),<sup>61,81</sup> a screening FFQ alone ( $n=3$ )<sup>50,64,83</sup> or a one- or two-item food group question alone ( $n=5$ ).<sup>42,52,56,71,75</sup> Most studies did not adequately describe their dietary assessment techniques, and seven FFQs were not validated for the target population or nutrient of interest.<sup>43,48,49,55,58-60</sup>

## Chapter 4

# Results of the systematic review of effectiveness

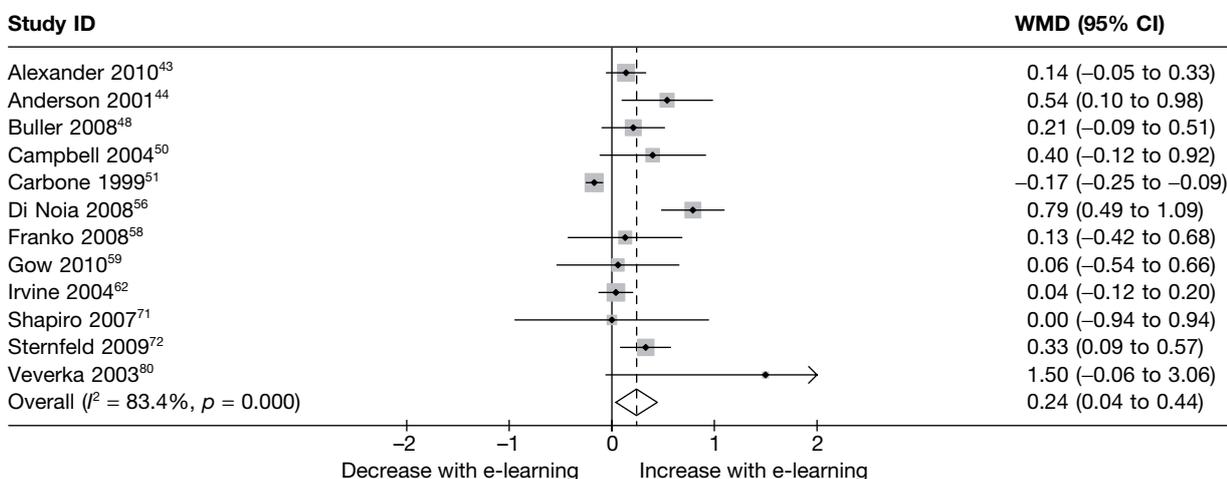
This chapter reports the results of meta-analyses and subgroup analyses undertaken to assess whether e-learning interventions were effective for improving dietary and clinical outcomes. *Appendix 7* contains the results of further statistical analyses.

### Dietary outcomes

#### Fruit and vegetable intake

Nineteen studies<sup>43,44,47,48,50,51,55,56,58,59,62,67,68,71,72,75,80–82</sup> reported intake of fruit, vegetables, or fruit and vegetables combined as ‘servings per day’, of which 12 provided adequate data for meta-analysis (*Figure 4*).<sup>43,44,48,50,51,56,58,59,62,71,72,80</sup> There was substantial heterogeneity in the trial results ( $p < 0.001$  and  $I^2 = 83\%$ ). There was also a strong suggestion of publication bias (smaller studies were associated with larger effects on servings of fruit and vegetables per day; Egger’s test,  $p = 0.008$ ). If the studies reporting fruit and vegetable servings per day are pooled in a random effects meta-analysis this would show a WMD of 0.24 servings (95% CI 0.04 to 0.44 servings;  $p = 0.019$ ); about a quarter of a serving more was therefore reported in the intervention groups than in the control groups combined.

There was substantial heterogeneity in the results of studies which reported fruit intake alone ( $p = 0.09$  and  $I^2 = 65\%$ ), but not in those reporting vegetable intake alone ( $p = 0.2$  and  $I^2 = 38\%$ ). A slightly smaller effect (but not statistically significant) was estimated in the studies that reported fruit intake alone (WMD 0.10 servings; 95% CI  $-0.27$  servings to 0.47 servings;  $p = 0.60$ ), whereas a similar size of effect was shown in studies reporting vegetable intake alone (WMD 0.29 servings; 95% CI 0.07 servings to 0.51 servings;  $p = 0.011$ ).



**FIGURE 4** Forest plot showing the effect of e-learning on the mean intake of fruit and vegetables (servings per day).

### Subgroups

There was no evidence to suggest that estimates of effect on servings of fruit and vegetables were associated with study quality (EPHPP global rating 'weak' vs 'moderate',  $p=0.82$ ; level of attrition in studies  $\leq 20\%$  vs  $> 20\%$ ,  $p=0.61$ ; allocation adequately concealed from investigators 'yes' vs 'unclear',  $p=0.80$ ). There was some evidence that estimates of effect on daily servings of fruit and vegetables were larger in studies with participants from low-income groups (WMD 0.5 servings; 95% CI  $-0.01$  to 1.00 servings;  $p=0.053$ ). None of the studies measuring average daily servings of fruit and vegetables included participants with a diagnosed illness.

There was no evidence that estimates of effect differed according to whether or not follow-up was earlier (within 3 months) or later ( $p=0.56$ ). Effects were not associated with whether or not the included participants were overweight ( $p=0.67$ ), whether or not the studies aimed to maintain or reduce BMI ( $p=0.67$ ) or whether or not interventions included a physical activity component ( $p=0.60$ ).

### Fat intake

Seventeen studies<sup>45,49-51,54,57,59,60,64,65,68,69,74,76,78,80,81</sup> looked at total fat, of which 12 provided sufficient data for meta-analysis (Figure 5),<sup>49-51,54,57,59,60,64,65,68,78,80</sup> and eight<sup>45,55,61,65,67,69,72,80</sup> at saturated fat intake, of which five provided sufficient data (Figure 6).<sup>65,67,69,72,80</sup> Fat intake was reported either as g/day or as a percentage of total energy consumed.

There was relatively little evidence for heterogeneity in the estimates of effect of e-learning on average grams of fat per day ( $p=0.18$  and  $I^2=28\%$ ). There was no evidence that smaller studies were associated with a larger or smaller treatment effect (Egger's test,  $p=0.495$ ). Random effects

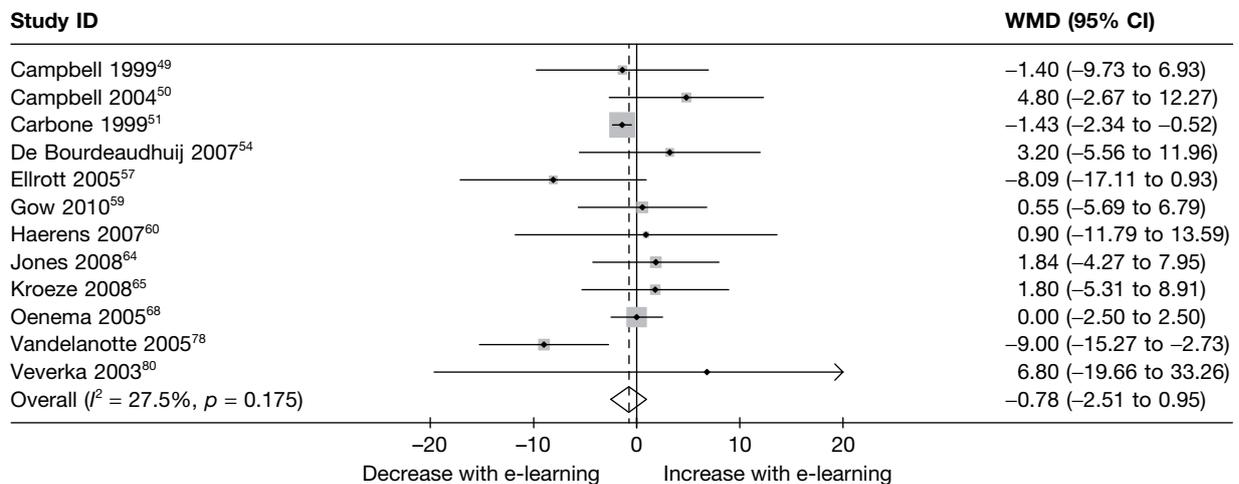


FIGURE 5 Forest plot showing the effect of e-learning on the mean intake of fat (g/day).

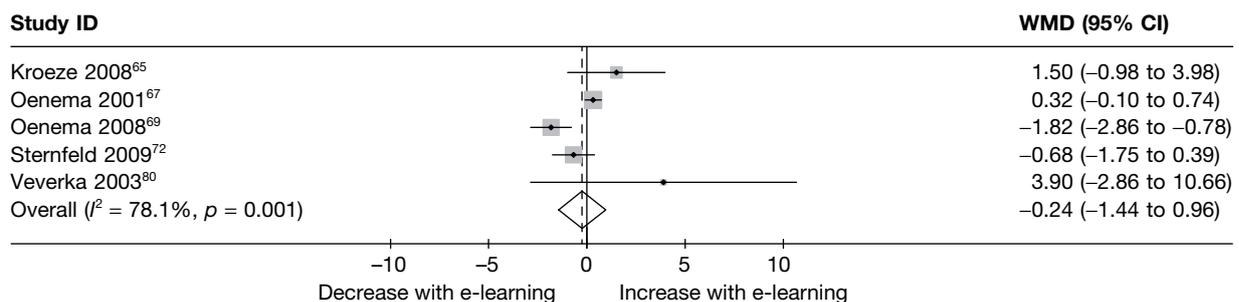


FIGURE 6 Forest plot showing the effect of e-learning on the mean intake of saturated fat (g/day).

meta-analysis of all studies that reported grams of total fat consumed showed a WMD of  $-0.78$  g (95% CI  $-2.5$  to  $0.95$  g), which was not statistically significant ( $p = 0.38$ ).

There was substantial heterogeneity in the estimates of effect on average saturated fat per day ( $p = 0.001$  and  $I^2 = 78\%$ ). There was no evidence that smaller studies were associated with a larger or smaller effect ( $p = 0.84$ ). Studies reporting saturated fat intake in grams found no evidence for effect (WMD  $-0.24$  g, 95% CI  $-1.44$  to  $0.96$  g;  $p = 0.7$ ).

Ten studies looked at percentage of total energy consumed from fat (Figure 7).<sup>44,54,57,58,65,74,76–78,80</sup> There was substantial heterogeneity in the results ( $p < 0.001$  and  $I^2 = 77\%$ ). There was no evidence that smaller studies were associated with larger or smaller treatment effects (Egger's test,  $p = 0.203$ ). Studies reporting percentage of total energy consumed from fat showed a WMD of  $-1.4\%$  (95% CI  $-2.5\%$  to  $-0.3\%$ ;  $p = 0.012$ ).

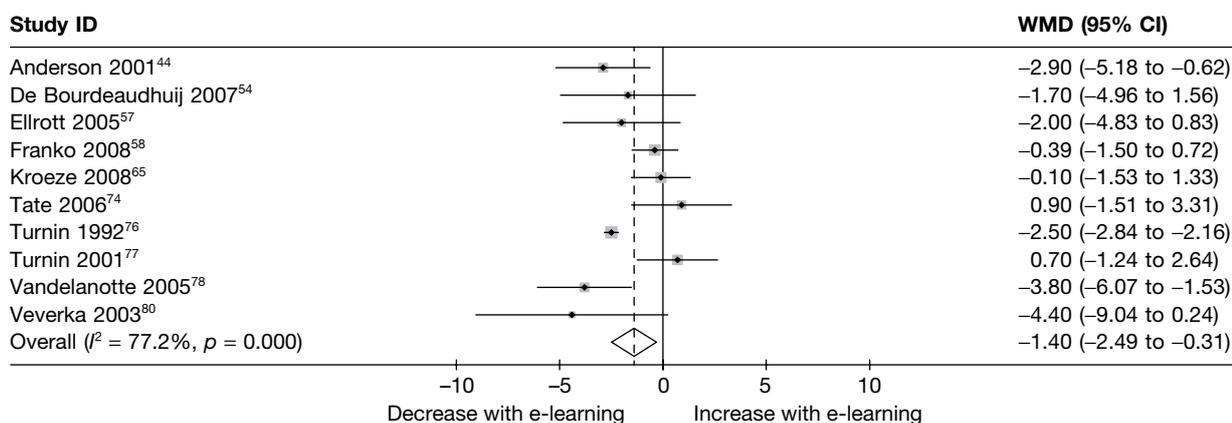
### Subgroups

There was no good evidence to suggest that the estimates of effect on fat intake were associated with study quality (EPHPP global rating 'weak' vs 'moderate',  $p = 0.08$ ; level of attrition in studies  $\leq 20\%$  vs  $> 20\%$ ,  $p = 0.50$ ; allocation adequately concealed from investigators 'yes' vs 'unclear',  $p = 0.87$ ). The results were similar for the estimates of effect on the percentage of fat intake ( $p = 0.39$ ,  $p = 0.49$  and  $p = 0.60$ , respectively).

There was no evidence that the estimates were associated with whether or not studies included participants from low-income groups ( $p = 0.39$ ). None of the studies measuring percentage energy from fat included participants predominantly from low-income groups. There was no evidence that estimates of the effect on percentage of energy from fat differed according to whether or not participants had a diagnosed illness ( $p = 0.37$ ). None of the studies measuring total fat intake included participants with a diagnosed illness.

There was no evidence that the estimates of effect differed according to whether or not follow-up was earlier (within 3 months) or later (average fat intake,  $p = 0.91$ ; percentage energy from fat,  $p = 0.77$ ). Effects were not associated with whether or not the included participants were overweight (average fat intake,  $p = 0.79$ ; percentage energy from fat,  $p = 0.13$ ) or whether or not the studies aimed to maintain or reduce BMI (average fat intake,  $p = 0.67$ ; percentage energy from fat,  $p = 0.23$ ).

There was some evidence that the estimates of effect on total fat intake were larger in studies in which interventions also included a physical activity component (WMD  $-7.1$  g; 95% CI  $-14.1$  to



**FIGURE 7** Forest plot showing the effect of e-learning on the mean percentage of energy from fat (%).

-0.1 g;  $p=0.047$ ). There was no evidence for a similar association for percentage energy from fat ( $p=0.20$ ).

### Fibre intake

Five studies<sup>44,45,55,59,82</sup> assessed average intake of fibre, reported as g/day, of which two provided sufficient data for meta-analysis (Figure 8).<sup>44,59</sup> There was some evidence for heterogeneity in the estimates ( $p=0.11$  and  $I^2=60\%$ ). Meta-analysis of these studies showed a WMD of 1.45 g (95% CI -0.02 to 2.92 g;  $p=0.053$ ). A single study assessed average change in fibre intake and found a 0.7 g (95% CI 0.1 g to 1.4 g) larger change in the e-learning group than in the control group. Subgroups were not examined owing to too few studies.

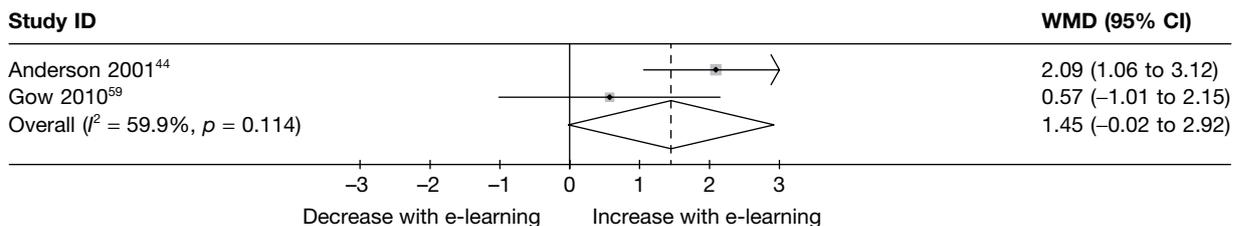
### Energy intake

Mean energy intake, reported as kilocalories, was addressed in eight studies,<sup>45,53,57,65,74,77,80,83</sup> five of which provided sufficient data for meta-analysis (Figure 9).<sup>57,65,74,77,80</sup> There was no evidence for heterogeneity in the estimates on difference in mean intake ( $p=0.33$  and  $I^2=13\%$ ). Meta-analysis of these studies showed no evidence for an effect on daily energy intake (WMD 4 kcal; 95% CI -85 kcal to 93 kcal;  $p=0.93$ ).

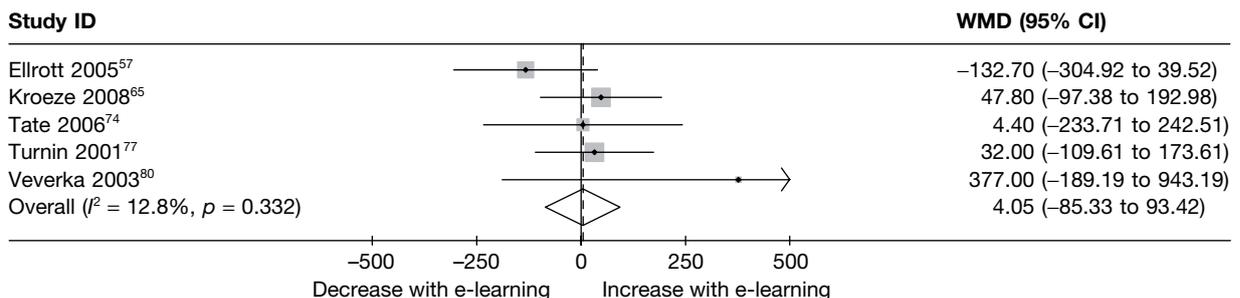
### Subgroups

There was no evidence to suggest that estimates of effect on energy intake were associated with study quality (EPHPP global rating 'weak' vs 'moderate',  $p=0.40$ ; level of attrition in studies  $\leq 20\%$  vs  $> 20\%$ ,  $p=0.40$ ; allocation adequately concealed from investigators 'yes' vs 'unclear',  $p=0.68$ ). None of the studies measuring mean energy intake included participants predominantly from low-income groups or with a diagnosed illness.

There was no evidence that estimates of effect differed according to whether or not follow-up was earlier (within 3 months) or later ( $p=0.18$ ). Effects were not associated with whether or not the included participants were overweight ( $p=0.37$ ), whether or not the studies aimed to maintain or reduce BMI ( $p=0.28$ ) or whether or not interventions included a physical activity component ( $p=0.61$ ).



**FIGURE 8** Forest plot showing the effect of e-learning on the mean intake of dietary fibre (g/day).



**FIGURE 9** Forest plot showing the effect of e-learning on the mean energy intake (kcal/day).

## Clinical outcomes

### Body mass index

Thirteen studies<sup>46,53,59,63–66,71,73,77,79,83,84</sup> reported BMI as an outcome, nine<sup>46,59,63,64,66,71,73,77,84</sup> of which reported mean BMI (with SDs; *Figure 10*) and three<sup>53,79,83</sup> of which reported mean change in BMI (with SDs). There was no evidence for heterogeneity in the estimates of effect of e-learning on average BMI ( $p = 0.92$  and  $I^2 = 0\%$ ) and similarly no evidence that smaller studies were associated with larger effects (Egger's test,  $p = 0.66$ ). Random effects meta-analysis of all studies that reported mean BMI showed a WMD of  $-0.1 \text{ kg/m}^2$  (95% CI  $-0.7 \text{ kg/m}^2$  to  $0.4 \text{ kg/m}^2$ ) which was not statistically significant ( $p = 0.69$ ).

There was evidence for heterogeneity in the estimates of difference in mean change in BMI ( $p = 0.039$  and  $I^2 = 69\%$ ). Random effects meta-analysis of the three studies showed no evidence for a difference ( $-0.07 \text{ kg/m}^2$ ; 95% CI  $-0.7 \text{ kg/m}^2$  to  $0.6 \text{ kg/m}^2$ ;  $p = 0.82$ ; *Appendix 7*).

### Subgroups

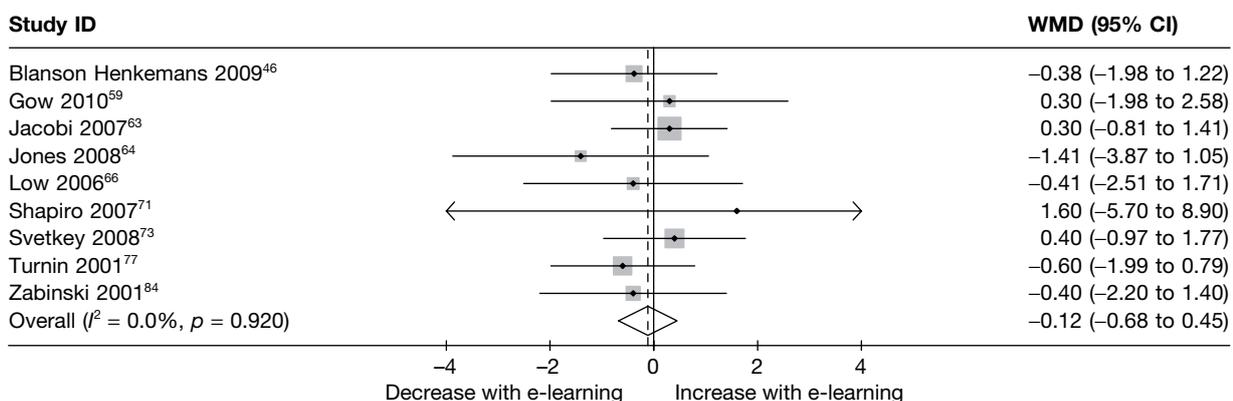
There was no evidence to suggest that estimates of effect on BMI were associated with study quality (EPHPP global rating 'weak' vs 'moderate',  $p = 0.55$ ; level of attrition in studies  $\leq 20\%$  vs  $> 20\%$ ,  $p = 0.29$ ; allocation adequately concealed from investigators 'yes' vs 'unclear',  $p = 0.64$ ). None of the studies measuring average BMI included participants predominantly from low-income groups or with a diagnosed illness.

There was no evidence that estimates of effect differed according to whether or not follow-up was earlier (within 3 months) or later ( $p = 0.59$ ). Effects were not associated with whether or not the included participants were overweight ( $p = 0.58$ ), whether or not the studies aimed to maintain or reduce BMI ( $p = 0.91$ ) or whether or not interventions included a physical activity component ( $p = 0.91$ ).

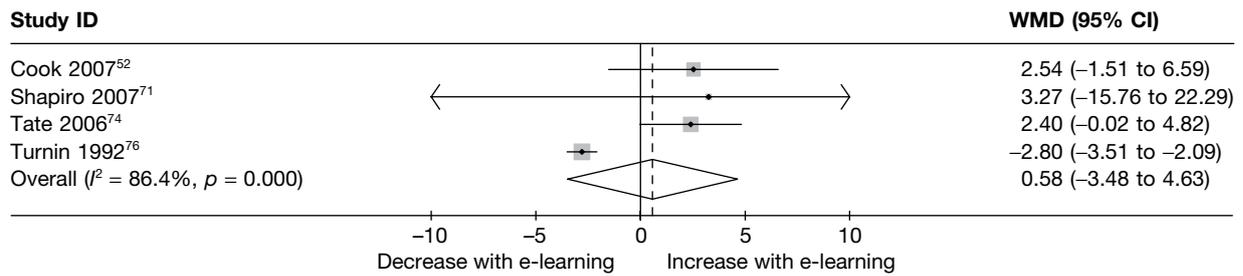
There were two studies that aimed to reduce BMI and did not include a physical activity component.<sup>77,79</sup> At final follow-up, Turnin *et al.*<sup>77</sup> estimated a reduction in BMI of  $-0.6 \text{ kg/m}^2$  (95% CI  $-2.0 \text{ kg/m}^2$  to  $0.8 \text{ kg/m}^2$ ) and Verheijden *et al.*<sup>79</sup> estimated no difference between mean change in the intervention and control groups ( $-0.01 \text{ kg/m}^2$ ; 95% CI  $-1.6 \text{ kg/m}^2$  to  $1.6 \text{ kg/m}^2$ ).

### Weight

Ten studies<sup>42,45,52,53,69,71,73,74,76,83</sup> reported weight as an outcome, four<sup>52,71,74,76</sup> of which reported mean weight (with SDs; *Figure 11*) and three of which reported mean change in weight (with SDs). There was substantial heterogeneity in the trial results ( $p < 0.001$  and  $I^2 = 86\%$ ;  $p < 0.001$



**FIGURE 10** Forest plot showing the effect of e-learning on the mean BMI ( $\text{kg/m}^2$ ).



**FIGURE 11** Forest plot showing the effect of e-learning on the mean weight (kg).

and  $I^2 = 94\%$ , respectively). Random effects meta-analysis of the four studies that reported mean weight found no evidence for effect (0.6 kg; 95% CI -3.5 kg to 4.6 kg;  $p = 0.78$ ).<sup>52,72,74,77</sup>

Random effects meta-analysis of the three studies<sup>53,73,83</sup> that reported mean change in weight found no evidence for effect (-0.07 kg; -1.8 kg to 1.6 kg;  $p = 0.94$ ; *Appendix 7*).

### Subgroups

There was no evidence to suggest that estimates of effect on weight were associated with study quality (EPHPP global rating 'weak' vs 'moderate',  $p = 0.52$ ; level of attrition in studies  $\leq 20\%$  vs  $> 20\%$ ,  $p = 0.82$ ). There was some evidence to suggest that estimates of effect on weight were larger in the single study by Turnin<sup>76</sup> in which the method of allocation concealment used was 'unclear' ( $p = 0.042$ ) and in which participants had a diagnosed illness ( $p = 0.042$ ). None of the studies measuring average weight included participants from low-income groups.

There was no evidence that estimates of effect differed according to whether or not follow-up was earlier (within 3 months) or later ( $p = 0.57$ ). There was no evidence that the estimates of effect differed according to whether or not the included participants were overweight ( $p = 0.52$ ).

### Eating disorders

Four studies<sup>63,64,66,84</sup> evaluated interventions that aimed to prevent eating disorders in high-risk college students. All four studies used the 'STUDENT BODIES program'<sup>90,91</sup> to deliver the intervention. These studies measured a range of eating disorder outcomes: the Eating Disorder Inventory (EDI) scales, the Eating Disorder Examination-Questionnaire (EDE-Q), and Eating Disorder Examination-Body Dissatisfaction (EDI-BD) subscales. A further study<sup>59</sup> used the EDI and EDE-Q to collect data on eating habits. We have not undertaken any analysis of these composite outcomes, as they were not included in our study aims and protocol; only BMI or weight outcomes were used from these studies.

### Further analysis

*Appendix 7* presents further analysis of effectiveness.

*Appendix 8* presents the behavioural change techniques reported to have been used in interventions, tabulated against whether or not the study demonstrated evidence for effect (in the intended direction) on any outcome.

## Chapter 5

# Assessing the cost-effectiveness of e-learning devices for obesity

The aim of this chapter is to assess the cost-effectiveness of e-learning devices for obesity.

### Published economic evaluations

A literature review revealed that no full economic evaluations of e-learning devices based on nutritional activities alone have been published.<sup>83,92-94</sup> However, one UK study that assessed the cost-effectiveness of a web-based support package for people who were obese, in which exercise was also a component, was identified.<sup>93</sup> The study was based on a 12-month RCT of a web-based e-learning device compared with 'standard' dietary advice alone. The results suggested that the dietary advice alone treatment arm was less costly and more effective than the e-learning device. The paper, however, has not been formally reviewed because the underlying RCT was excluded from the clinical review. However, it has been used as a basis to cost a generic 'e-learning device' in this analysis as it is relatively contemporary and UK-based and little other evidence was available.

### The E-Learning Economic Evaluation Model

Because no directly relevant studies have been undertaken, a de novo economic decision model was built, referred to as the E-Learning Economic Evaluation Model (E-LEEM). The first stage in building the E-LEEM model was to examine other decision models for which the primary clinical aim was to promote weight loss or prevent further weight gain. In addition to the results of the clinical review, this process consisted of a non-systematic review of obesity-related studies submitted to the National Institute for Health and Clinical Excellence (NICE), since 2002, as part of either its technology appraisal or clinical guideline programme.

#### The decision problem

##### The (potential) role of e-learning devices

The place of e-learning devices in terms of an overall obesity pathway is somewhat unclear, as discussed already in this report. For example, they have been used to prevent obesity in the first instance and as a means of managing patient groups who are already considered to be (severely) obese (i.e. weight loss). Thus, the aim of intervention could feasibly be to promote weight loss, to prevent obesity in the first instance or both. On the balance of available clinical evidence, the decision was taken to estimate the costs and effects of e-learning devices as a method of promoting weight loss in obese people. All patients were also assumed to be non-smokers with no prior history of either type 2 diabetes (T2D) or CVD, with normal age-adjusted, systolic blood pressure levels, cholesterol ratios and a starting age of 50 years unless otherwise stated. These starting characteristics were varied in a number of sensitivity analyses.

##### Comparator intervention(s)

As most of the RCTs included a 'traditional' dietary advice alone arm, this was taken to represent the baseline treatment. However, in a separate sensitivity analysis, the use of a pharmacological

treatment was also considered. The original intention was to include two NICE-approved treatments, orlistat and sibutramine. However, during the course of writing this report (January 2010), the Medicines and Healthcare products Regulatory Agency removed the marketing authorisation for the latter. Thus, only orlistat has been considered; note, no attempt has been made to use formal methods of performing mixed-treatment comparisons to assess relative treatment effects.

### Description of the technology

Defining what e-learning devices actually consist of (in terms of resources) and how they should be used is difficult because they are idiosyncratic in terms of their design and platform base, not all are commercially available and they and their use were often poorly described in the clinical trials. Thus, for the purpose of the economic evaluation, a single hypothetical/generic package has been defined, largely based on the web-based McConnon *et al.*<sup>93</sup> intervention as previously discussed.

The model consists of a cost–utility analysis, with health outcomes expressed as quality-adjusted life-years (QALYs). Costs were included from a UK NHS perspective and expressed in 2009 prices. In all scenarios, the model was run until all patients died, implying a lifetime horizon for the analysis.

### Heterogeneity versus individual variability

Various publications<sup>95</sup> have suggested that there is a need to separate issues of patient heterogeneity from individual variability (first-order uncertainty) when undertaking economic evaluations to allow treatment costs and effects for individual patient (sub-) groups to be isolated and reported. For this reason, the model was run in the base-case analyses for people with fixed sets of starting characteristics – based broadly on the results of the clinical literature review, but also on clinical opinion of potential candidate patients (*Table 23*). Note, however, that the model can, if required, sample initial patient characteristics (such as age, gender and starting body weight/BMI level) rather than fixing them at the outset.

### Rationale for choice of modelling framework

A number of different modelling approaches were considered: decision trees, Markov models and discrete event simulations. A decision tree approach was discounted because this method is cumbersome when multiple health outcomes are important and events are considered over a relatively long period of time; both issues are important in the context of obesity. The non-systematic examination of associated NICE technology appraisals and clinical guidelines suggested that most obesity-related economic evaluations have been performed using a Markov approach. In a Markov-type analysis, individuals move between a set of pre-defined health states over a *fixed* unit of time according to a set of transition probabilities; they are often referred to as discrete time models for this reason. This is in contrast to discrete *event* simulations (DESS), where a set of possible events is defined (along with associated costs and health outcomes), but

**TABLE 23** Starting characteristics for the base-case analyses

Characteristic	Scenario							
	A	B	C	D	E	F	G	H
BMI (kg/m <sup>2</sup> )	30	30	33	30	33	35	35	30
Gender	Male	Male	Male	Female	Male	Female	Male	Female
Age (years)	50	50	50	50	50	50	50	50
Smoker	No	Yes	No	No	Yes	Yes	Yes	Yes
T2D	No	No	No	No	No	No	Yes	No

the time between each event is variable in a first-order sense. Thus, in effect, the purpose of a DES is to estimate times between events, with the sum of these intervals (typically) representing total life expectancy.

Discrete time and event models are both useful when treatment costs and benefits are likely to accrue over relatively long periods of times, as is likely to be the case herein. However, the limitation with Markov models is that the probability of moving from one health state to another is typically reliant only on an individual's current state of health. Thus, no account is taken of an individual's clinical history. This is arguably problematic in the context of evaluating obesity-related technologies as many issues are interlinked. For example, people who develop T2D are more likely to develop CVD than those who do not. A further limitation with Markov type models is that they become inefficient and demanding in a programming sense if multiple health outcomes are possible, as increasingly more complex sets of health states are required.

A DES potentially overcomes both of these problems; thus, it was judged to be the most appropriate modelling approach. This said, arguably the main limitation with DESs is that although second- and third-order simulations are technically feasible, they add significantly to the complexity of the programming and are computationally expensive. For these reasons, all reported results are based on probabilistic sensitivity analyses (PSA) using 1000 outer (second-order) simulations and 1000 inner (first-order) simulations, but the number of reported sensitivity analysis and expected value of perfect information (EVPI) calculations is limited (see *Discussion* section for more details).

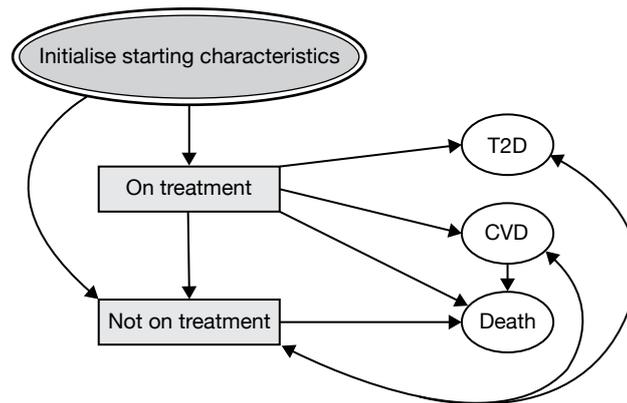
### Discrete event simulation model building considerations

As a basic aim of the evaluation was to link trial evidence to longer-term costs and outcomes, a priori consideration was given to the potential array of quantitative outcomes that relevant RCTs could report. It was suspected that the most useful outcomes would include weight change, percentage weight loss, change in BMI, change in systolic blood pressure and change in cholesterol level. Although a general approach was sought that could potentially incorporate all of these outcomes, the main favoured modelling approach was to link changes in body weight/BMI to changes in the timing of future events. For example, *ceteris paribus* increases in body weight/BMI were assumed to lead to shorter times to CVD, T2D and death. This approach was taken because, on a preliminary scan of the retrieved literature, BMI proved to be a reasonably frequently reported trial outcome. It is an approach which has been used before in other models and because, if required, costs and utilities for various body weight/BMI strata were available.

### Model overview

All patients are assumed to be offered treatment for the first 12 months with either dietary advice alone or dietary advice through an e-learning device (*Figure 12*). Separate consideration was also given to the use of orlistat as an alternative, as previously discussed. During this time, people could experience an event (see *Selecting events of interest*, but including CVD), die or withdraw from treatment (modelled using an attrition rate). Those who experienced any one of these events were assumed to immediately stop treatment. They were also judged to be 'treatment' failures and to have put on weight over this time. On the other hand, patients who completed the 12-month treatment period were assumed to be treatment responders, and to have gained, lost or maintained weight. After the 12-month period, no further treatment is given in the base case, meaning that patients could not lose any further weight. Instead they were assumed to put on weight over time according to a specified function.

All changes in body weight were transformed into increases in BMI, which in turn are linked to changes in the risks of future health-related events and associated activities (increased costs,



**FIGURE 12** Model schematic.

decreased health-related quality of life and increased risk of death). The model terminates only when all people have died.

This modelling approach means that treatment effects can conceptually be incorporated in three individual ways, through an improved attrition rate, lower weight gain for treatment failures or higher weight loss for treatment responders. However, owing to data limitations and the results from the meta-analysis, a decision was taken to include differences in weight gain (or, rather, BMI) only after 12 months in the base case. Other scenarios were explored in the sensitivity analysis.

### Selecting events of interest

Obesity is associated with an increased risk of a number of health-related events. A brief examination of the published cost-effectiveness literature on obesity suggests that most models have focused on CVD, T2D or both. However, at least one model has also considered the costs and outcomes of colon cancer. The case for including both CVD and T2D in the model was clear, as the evidence supporting a relationship between these events and increased body weight is well documented. Moreover, the absolute risk of these conditions in obese patients is arguably high, they are costly to treat and are associated with significant morbidity. The original intention was to also include the possibility of developing colon cancer. However, evidence suggests that the absolute rate of developing disease over 5 years in relatively high-risk European males is approximately 200 cases per 100,000 subjects. Thus, a conservative estimate calculated using an exponential distribution suggests that, on average, relatively high-risk men develop colon cancer once every 2500 years.<sup>96</sup> For this reason, the possibility of developing colon cancer in the model was excluded. In addition to CVD, T2D and death, a BMI increase of 0.1 kg/m<sup>2</sup> was also directly considered to be a possible event in order to model the natural history of the condition.

### The probability of death

The basic method of calculating the probability of all-cause death was using a life-table approach, as outlined by Barton *et al.*<sup>97</sup> A normative age-adjusted data set from the UK's Government Actuaries Department<sup>98</sup> was used to calculate the time to death given current age and gender. In addition to this, 33%<sup>99</sup> of patients who developed CVD were assumed to die immediately once the event had occurred (termed a fatal CVD event), with the likelihood of a CVD happening being partly conditional on whether or not patients had a recorded history of T2D. All deaths from T2D were considered to be attributable to cardiac problems; thus, they were not independently modelled. These approaches were used in the base case to avoid the possibility of double-counting the occurrences of death. However, sensitivity analyses were also run in

which CVD and T2D were assumed to increase the age-related probability of death, by adjusting the life-tables using published BMI-related standardised mortality ratios (SMRs). In effect, this meant that the SMRs associated with CVD and T2D were equal to 1 in the base case, increasing to values > 1 in the sensitivity analyses.

### The probability of developing cardiovascular disease

A number of algorithms with which to predict the timing of future CVD events are available. Perhaps the most frequently cited are the Framingham risk equations,<sup>100</sup> a version of which is currently recommended for use in NICE's lipid-lowering clinical guideline.<sup>101</sup> However, an updated algorithm constructed using UK data has more recently been published, with some evidence to suggest that it more accurately predicts 10-year risks of CVD events (the QRISK<sup>®</sup>2,<sup>102</sup> University of Nottingham, Nottingham and Egton Medical Information Systems Limited, Leeds, UK). As it is UK-based and includes a number of parameters such as BMI that could possibly be reported by trials of e-learning devices and the presence/absence of T2D is included as an independent risk factor, it was chosen as the method of predicting the timing of future CVD events. Note, however, that a limitation of using the QRISK2 for this modelling exercise is that the primary outcome in the original study was the first recorded CVD event (angina, myocardial infarction, stroke or transient ischaemic attack), and individuals with pre-existing CVD were excluded from the study. Therefore, the model does not incorporate any additional risk of having a second (or subsequent) CVD event as a consequence of the original event. In the context of the decision model, this is likely to mean that the overall number of predicted CVD events per unit of time is conservative. Permission to reproduce the QRISK2 algorithm was sought and obtained from the authors.

### The probability of developing type 2 diabetes

A number of risk equations for predicting T2D were identified that included BMI as an independent variable. The preferred algorithm was the UK-based QDScore<sup>®</sup>103 (ClinRisk Ltd, Leeds, UK), which was developed by the authors of the QRISK2 equation, using a similar methodology. However, the underlying algorithm is yet to be validated and published, so it was not possible to use it. None of the alternative algorithms was derived using UK data, and indeed related to North American<sup>104</sup> and Finnish<sup>105</sup> populations. Therefore, the rather arbitrary decision was made to use the Stern equation, but the Lindström model was used as an alternative in a sensitivity analysis.

$$A = -13.415 + (\text{age} \times 0.028) + (\text{gender} \times 0.661) + (\text{Mexican American} \times 0.412) \\ + (\text{fasting glucose} \times 0.079) + (\text{systolic blood pressure} \times 0.018) \\ + (\text{high-density lipid} \times -0.039) + (\text{BMI} \times 0.07) + [\text{family history (of type 2 diabetes)} \times 0.481]$$

Where gender = 0 for males and 1 for females.

$$\text{The probability of developing T2D over 7.5 years} = \frac{\exp(A)}{1 + \exp(A)}$$

### The mean time to gaining body weight

All patients were assumed to put on weight after 12 months of treatment, quitting treatment early or developing either CVD or T2D, whichever occurred first. The 2005 NICE obesity guideline<sup>106</sup> referenced Fine *et al.*,<sup>107</sup> stating that in the studied women, the average weight increase over 4 years was 1 kg per year. The guideline also stated that this finding is consistent with the findings of Heitmann *et al.*,<sup>108</sup> who performed a retrospective semi-longitudinal study to determine the pattern of weight changes over 11 years in a Danish population who became overweight in adulthood. Thus, all patients were assumed to put on an average of 1 kg per year, independent of initial BMI levels.

All weight gains were converted into increased BMIs by assuming that men were on average 1.75 m tall, whereas women were 1.62 m tall. This is equivalent to a 0.33 and a 0.38 unit increase in BMI, respectively, per 1 kg increase in weight [BMI = weight (kg)/height (m)<sup>2</sup>].<sup>109</sup> The mean time to an increased threshold BMI was then calculated on this basis. For example, in the base case the threshold was set equal to a 0.1 unit increase, meaning that, on average, it would take a man 0.30 years (0.1/0.33) for his BMI to increase by this amount.

### Baseline weight change

While on treatment, all body weights were assumed to change (decrease on average) in line with the RCT by McConnon *et al.*<sup>93</sup> kg (N ~ 1.9, 0.63).

### Intervention effectiveness

The base case relative effective of the e-learning devices compared with 'standard care' (i.e. dietary advice alone) was estimated using results from the systematic review and meta-analyses; weighted mean difference BMI (N~ -0.115, 0.29) (see *Chapter 4, Body mass index*). Note, that there was no evidence of heterogeneity between studies for this outcome. The single RCT by Turnin *et al.*<sup>77</sup> was used as the estimate of treatment effect in a sensitivity analysis as it was the only study to use BMI as a primary outcome measure. Few other useful outcomes were reported in terms of being directly importable into the CVD and T2D risk functions, meaning that changes in BMI were the only treatment effect to be incorporated.

The expected costs and effects of orlistat were estimated in single sensitivity analysis. The mean difference (reduction) in body weight between the orlistat and placebo treatment arms (4.36 kg) was taken from Foxcroft,<sup>110</sup> which in turn was based on individual patient-level data from three RCTs.

### The mean time to stopping treatment

High attrition rates appear to be a defining feature of weight loss/preventing weight gain interventions. The Turnin *et al.*<sup>77</sup> RCT was (arbitrarily) used to estimate the base treatment effect. The results showed that 179/557 participants were lost to follow-up over the 12-month period ( $\beta$ ~ 179, 378). Differences in attrition rates between the treatment arms were judged to be negligible and were not included in the model.

### Costs

Costs were broadly divided into two types, those associated with specific events and those relating to the initial 12 months of treatment (*Table 24*). All costs were inflated to 2009 prices using an NHS-specific index. The costs of CVD were taken from Warren *et al.*,<sup>111</sup> and were reported as one-off costs for fatal and non-fatal events, and as an annual cost for survivors. No other costs associated specifically with CVD were included. The annual cost of diagnosed T2D was taken from Ara and Brennan.<sup>112</sup> The cost included two GP visits per year, a specialist nurse visit, drug treatment for high blood pressure, statin therapy and treatment with metformin. The annual costs of 'traditional' dietary advice and those associated with e-learning devices were taken from a UK-based RCT of a web-based support package.<sup>93</sup> The costs for both interventions included resources such as drug costs and health-care visits and slimming clubs. The main difference between the two was that the web-based support package included an additional fixed cost per patient of £854 per annum for the actual web-based support (meaning that this cost was applied per patient irrespective of how long his or her treatment lasted in the base case). In a single scenario analysis, the costs and effects of orlistat were also estimated as a third mutually exclusive treatment option. The yearly cost of orlistat treatment was assumed to be £415 [based on 120-mg treatment three times per day, at a unit price per pill of £0.38 (£32.27/84)], plus the cost of five GP visits (£35 per visit).

**TABLE 24** Description of costs

Description	Mean value	Distribution <sup>a</sup>	Source
CVD fatal event	£3058	Gamma (9, 1/339)	<sup>b</sup> Warren <i>et al.</i> <sup>111</sup>
CVD non-fatal event	£3648	Gamma (9, 1/405)	<sup>b</sup> Warren <i>et al.</i> <sup>111</sup>
Annual cost of non-fatal CVD event	£876	Gamma (9, 1/97)	<sup>b</sup> Warren <i>et al.</i> <sup>111</sup>
Annual cost of T2D	£724	Gamma (9, 1/80)	Ara and Brennan, <sup>112</sup> NICE <sup>b</sup> guideline <sup>106</sup>
Annual cost attributable to orlistat	£715	N/A	<i>British National Formulary</i> , <sup>113</sup> Foxcroft <sup>110</sup>
Annual cost of e-learning device	£140 (SE £234)	Gamma (140 <sup>2</sup> /235 <sup>2</sup> , 140/235 <sup>2</sup> )	<sup>c</sup> McConnon <i>et al.</i> <sup>93</sup>
Fixed cost of e-learning device	£854	N/A	<sup>c</sup> McConnon <i>et al.</i> <sup>93</sup>
Annual cost of dietary advice	£226 (SE £329)	Gamma (226 <sup>2</sup> /329 <sup>2</sup> , 226/329 <sup>2</sup> )	<sup>c</sup> McConnon <i>et al.</i> <sup>93</sup>

N/A, not applicable.

a Parameterised as required in TREEAGE Pro 2009.

b Indicates that mean values were derived from this source, but measures of variance were not reported. In these instances, standard errors were based on one-third of the mean value.

c An extended report relating to the published economic was supplied by the authors.

$\gamma\sim(\alpha, \lambda)$ .

## Utilities

The main source for the evidence relating to utilities was Macran *et al.*<sup>114</sup> This study assessed the relationship between BMI and European Quality of Life-5 Dimensions utility scores in a UK population of approximately 12,000 people. Various statistical models based on ordinary least squares regression techniques are presented, but model F was chosen for the base-case analysis. Although this model related specifically to women, it demonstrated statistically significant differences in preference scores between different BMI strata, age bandings and long-standing illnesses, whereas in the model for men, the long-standing illness component was not significant. Thus, this model was chosen for both men and women; visual inspection of the various models suggests that differences in coefficients across the various models for men and women are arguably small. A maximum of two long-standing illnesses were permitted, representing the possibility of developing CVD and T2D. Note, however, that although these values have been used in the base case, Macran *et al.* are not specific about which long-standing illnesses were reported. The model was expressed as follows (and populated using the data in *Table 25*):

$$\text{Utility} = 0.951 + \text{BMI group} + \text{age group} + \text{number of long-standing illnesses}$$

The report by Macran *et al.*<sup>114</sup> does not report standard errors for the coefficients. Therefore, for the PSA, rather than assume no associated parameter uncertainty, it was assumed that all coefficients could increase or decrease by a maximum of 10% by multiplying all values by a scaling factor that was using a uniformly distributed variable ( $U\sim 0.9, 1.1$ ).

## Discounting

All future costs and benefits were discounted using 3.5% per annum, using the following formulae:

One-off activity:

$$ce^{-\lambda t}$$

where  $c$  is the cost or benefit,  $\lambda = \ln(\text{discount rate})$  and  $t = \text{time of the event in years}$ .

**TABLE 25** Relationship between independent variables and the European Quality of Life-5 Dimensions utility scores, Macran *et al.*<sup>114</sup> model F ( $R^2$ , 0.26)

BMI group (kg/m <sup>2</sup> )	Coefficient	Age group (years)	Coefficient	No. of LSIs	Coefficient
<21	-0.02	18–24	0	0	0
21–25	0	25–34	0.0005	1	-0.115
26–30	-0.02	35–44	-0.01	2	-0.196
31–39	-0.04	45–54	-0.02		
>39	-0.06	55–64	-0.04		
		65–74	-0.04		
		>75	-0.08		

LSI, long-standing illness.

Steady state activity:

$$\frac{ce^{-\lambda t}}{\lambda}(1 - e^{-\lambda s})$$

where  $t$  is the time an event begins in years, over  $s$  years.

### Model verification

A number of efforts were made to ensure that the model was technically correct, i.e. that the programming did exactly what it was intended to do. First, the T2D and CVD risk equations were entered into the TREEAGE PRO 2009 program (TreeAge Software, Inc., Williamstown, MA, USA),<sup>115</sup> run, then reprogrammed separately in Microsoft EXCEL 2007 (Microsoft Corporation) to ensure that the results matched. Results from the CVD risk algorithms were also cross-checked against the published clinical examples to ensure consistency. These processes identified a number of programming errors, which were subsequently corrected. TREEAGE Pro 2009 also contains a facility to output calculations other than the individual total costs and benefits [using the Global( $n$ ) function]. This facility was used to ensure that the internal calculations for each model run looked plausible relative to the outputs so that no unusual events were occurring prior to the model terminating, such as decreases in BMI after the initial 12 months in the base case. The model was also tested to ensure it produced logical results, e.g. that higher starting body weights led to lower life expectancies and higher likelihoods of developing T2D and CVD.

### Modelling software

The DES was built in TREEAGE PRO 2009 using an approach outlined by Barton *et al.*<sup>97</sup> TREEAGE PRO 2009 does not contain an explicit DES facility. Rather, the Markov node function is used as a cycling facility to resample times between possible events instead of indicating a movement between health states over a fixed period of time, which is implicit when using Markov models. Using the Markov function in this manner means that the inbuilt \_stage function now in effect becomes a running total of the number of events that occur per individual rather than an indicator of time, and can no longer be used as a command in any meaningful way.

Other important aspects of the programming included the initiation of a series of tracker variables. Tracker variables are variables whose values can change over time, typically following some event. For example, a person's current body weight was recorded using a tracker variable, as was a variable indicating whether or not a person had developed T2D. A set of tracker variables was also set to act as 'clocks', with each set recording the time between two or more events. For example, clocks were set to record the time from entering the model until death (equivalent to a

person's survival time) and the time between developing T2D and death. The full programming syntax is available on request.

There are a number of ways in which DESs can be run in terms of selecting the next event, as outlined by Barton *et al.*<sup>97</sup> The approach taken in this model was to independently sample times to the competing events using risk equations, mean times to events and a life-table, and to choose the event that was predicted to occur next. The remaining information on the time to the next event was discarded at this point, the tracker variables (including the clocks, total costs and QALYs) updated if required, and the process repeated until each patient had died. In all cases, the time to the next event was modelled assuming an exponential distribution after converting probabilities from the risk equations and life-table to rates, and by calculating the corresponding reciprocal value. These values were then multiplied through by a random draw from an exponential distribution with a lambda value of 1. The random draws were based on TREEAGE's 'distforce' function to ensure that times were resampled each time a new event was expected.

Example: say the predicted probability of developing CVD for a particular individual at a given point in time over 10 years is 0.2, as predicted using the QRISK2 equation. This is equivalent to a hazard rate of 0.022.

$$\frac{-\ln(1-0.2)}{10} = 0.022$$

Converting this to an average time to a CVD event by calculating the reciprocal equals:

$$\frac{1}{0.022} = 44.8 \text{ years}$$

Multiplied by a random draw from an exponential distribution with a lambda value of 1, say 1.6, leads to a predicted time to a CVD event of 71.7 years. The random draw was repeated as many times as required for each of the 1000 hypothetical individuals. In the PSA component of the analysis, the underlying mean values were resampled and a further 1000 first-order simulations run.

## Results

The base-case results are shown in *Table 26* for a number of different patient starting characteristics. Although the absolute costs and QALYs vary across the scenarios, in each instance the incremental health gains were small, as indicated by the fact that very few additional cases of T2D or CVD were averted. The lowest reported incremental cost-effectiveness ratio (ICER) was approximately £102,000 per additional QALY. Scenarios run with women were associated with lower QALYs than those with men (e.g. scenario D compared with A). This was because lower rates and times spent with CVD for women were more than offset by higher rates and time spent with T2D.

The cost-effectiveness acceptability frontier for scenario A is shown in *Figure 13*. It shows that for up to about £200,000 per additional QALY, dietary advice alone is the preferred option. Note, that after this threshold value, e-learning becomes the preferred option, even though at most points the probability that it is the most cost-effective option is barely > 50%. It is, however, preferred because it is associated with the higher expected net benefits at these threshold values.

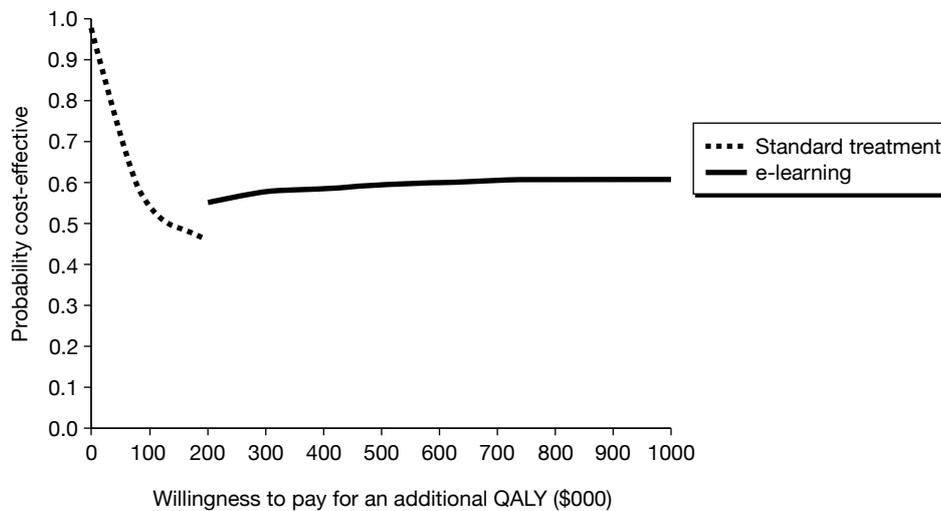
### Sensitivity analysis

A number of one-way sensitivity analyses were performed. Perhaps the most important in terms of large changes to the ICER were the fixed initial cost associated with the e-learning devices, the

**TABLE 26** Base-case results (see Table 23 for starting characteristics)

Scenario	Intervention	TyT2D	TyCVD	P T2D	P CVD	Cost (£)	QALYs	ICER (£)
A	Da	5.372	3.611	0.443	0.559	4884	12.527	
	E-I	5.352	3.608	0.441	0.558	5646	12.534	102,112
B	Da	4.936	4.198	0.444	0.618	5364	12.093	
	E-I	4.921	4.195	0.443	0.617	6129	12.100	121,856
C	Da	6.142	3.709	0.511	0.577	5340	12.196	
	E-I	6.123	3.707	0.510	0.576	6088	12.200	184,962
D	Da	6.587	2.776	0.543	0.475	4035	11.703	
	E-I	6.567	2.774	0.542	0.474	4732	11.708	125,891
E	Da	5.632	4.290	0.494	0.635	5810	11.838	
	E-I	5.615	4.287	0.493	0.634	6566	11.844	150,865
F	Da	7.412	3.645	0.613	0.581	5201	11.209	
	E-I	7.391	3.643	0.612	0.580	5902	11.214	151,142
G	Da	19.745	5.677	1.000	0.786	15,014	10.910	
	E-I	19.748	5.675	1.000	0.786	15,789	10.911	232,911
H	Da	6.031	3.434	0.529	0.553	4469	11.500	
	E-I	6.009	3.431	0.527	0.552	5186	11.506	112,628

Da, dietary advice; E-I, e-learning; P CVD, proportion who develop cardiovascular disease; P T2D, proportion who develop T2D; TyCVD, mean years with cardiovascular disease; TyT2D, mean years with T2D.

**FIGURE 13** Cost-effectiveness acceptability frontier relating to scenario.

relative treatment effect, the rate at which health outcomes were discounted and a longer duration of treatment effect (Table 27).

In a number of scenarios, potentially counterintuitive results were produced. For example, when the costs of T2D and CVD were increased, the ICER associated with e-learning also increased. This is because people treated with e-learning devices on average live longer with these conditions, even though they are less likely to develop them in the first instance. The net result is an increase in the incremental cost and the associated ICER. Such seemingly counterintuitive results were also reported in the NICE obesity guideline,<sup>106</sup> along with a

**TABLE 27** Sensitivity analysis on scenario A patient characteristics

Change	Dietary advice		E-learning		ICER
	Costs (£)	QALYs	Costs (£)	QALYs	
Doubling the time to a BMI increase of 0.1 kg/m <sup>2</sup> after treatment stops	4545	12.972	5302	12.978	122,125
£0 initial cost for e-learning devices	4903	12.475	4845	12.483	Dom
Lindstrom T2D risk equation	4248	12.812	5608	12.818	124,813
Starting age of 60 years	4577	9.749	5347	9.754	118,741
Using estimate of relative treatment effect from Turnin <i>et al.</i> <sup>77</sup> (N~ -0.6, 0.71)	4999	12.802	5704	12.837	20,053 <sup>a</sup>
Doubling all T2D related costs	6819	12.416	7561	12.435	83,306
Doubling all CVD related costs	7704	12.507	8458	12.513	100,480
Standardised mortality ratio of 2 following T2D or a CVD event, or 4 for both events	4307	12.550	5107	12.561	107,122
Doubling the cost of dietary advice	5115	12.482	5706	12.488	86,323
0% discount rate for health benefits	4943	19.325	5699	19.338	58,869
Halving the attrition rate for both treatments	4871	12.799	5662	17.897	84,483
Responders at 12 months continue to receive treatment for a maximum of a further 12 months, all other assumptions held constant	5600	12.806	5719	12.817	64,487
Time to next BMI change based on 0.5 instead of 0.1 kg/m <sup>2</sup>	4936	12.797	5711	12.805	103,627

Dom, e-learning is dominant.

a Fifty-nine per cent probability that e-learning is cost-effective at £30,000 per additional QALY.

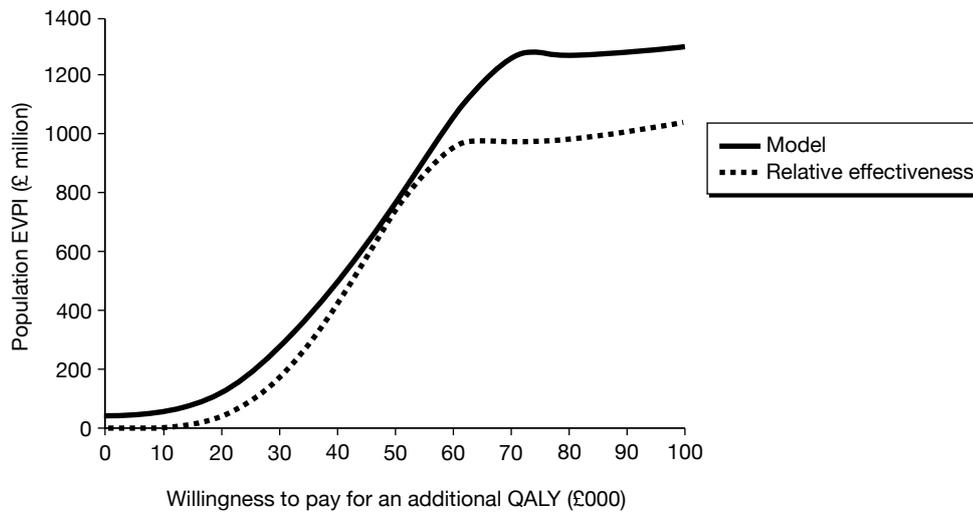
similar explanation. Note, that the ICER increases when the time taken for a BMI increase of 0.1 kg/m<sup>2</sup> is doubled. The main explanation for this is that although mean expected QALYs for all individuals have increased in this scenario, the overall difference in QALYs has slightly reduced. This is because the underlying likelihood of health-related events has also decreased. Thus, the potential impact of e-learning devices has lessened, resulting in fewer additional QALYs and a higher ICER.

When orlistat was included as a compactor, it dominated e-learning (that is, it was less costly and more effective than e-learning). Compared with dietary advice alone, orlistat cost approximately £3000 per additional QALY.

### Expected value of perfect information analysis

The per person model-level EVPI was £13, rising to £453 at willingnesses to pay for an additional QALY of £0 and £100,000, respectively. The number of new obese individuals was difficult to assess, therefore the following assumptions were made. Prevalence data from the 2008 Health Survey for England Report,<sup>109</sup> with obesity being classified as a BMI ≥ 30 kg/m<sup>2</sup>, and by assuming all obese people in 2007 remained obese in 2008, was used to calculate the annual incidence of obesity. Thus, the increase in the number of obese individuals, which was 308,000, is because of new incident cases. Arbitrarily assuming a 10-year lifespan for the technology and a 3.5% discount rate produces *Figure 14* – with arguably large corresponding values at all positive willingnesses to pay.

A single expected value of partial perfect information (EVPPI) analysis was undertaken on the relative treatment effect (WMD) associated with the two treatment options. The results suggest that at a willingness to pay of £20,000–30,000 per additional QALY, the maximum value of conducting a further RCT was between £37M and £170M.



**FIGURE 14** Expected value of perfect information and a single EVPPi analysis based on scenario A assumptions, and an incident obese population of 308,000 people every year for 10 years, discounted at 3.5% per annum.

## Discussion

The aim of this chapter was to assess the cost-effectiveness of e-learning devices, for which the aim was to purely change dietary behaviours. No published economic evaluations on this subject were identified. One evaluation<sup>94</sup> of a device based on a 12-month RCT that included a non-dietary component was, however, identified. In the base case, the results showed that the e-learning device was not cost-effective compared with standard care given the relatively large costs associated with the device. Indeed, although the results were not statistically significant, WMDs in weight loss were lower in the intervention arm and the costs were higher.

Because of the absence of published evidence, an economic model (E-LEEM) was constructed. It aimed to assess the cost-effectiveness of e-learning devices as a method of promoting weight loss in obese people relative to standard care (dietary advice alone). The model was based on a DES approach, and, although data from a number of sources were used to populate the model, the relative impact of the intervention (in terms of a difference in BMI) was based on the systematic review and meta-analysis presented in *Chapter 4*. The review suggested an advantage of e-learning devices compared with standard care; however, the results were not statistically significant and the mean difference is unlikely to suggest clinically significant differences in health. This conclusion is emphasised in the results of the economic evaluation: the differences in QALYs in all scenarios was arguably small. Moreover, because of the fixed initial cost that was assumed in the base case, the intervention was arguably not cost-effective at conventional willingness to pay levels. Only when the fixed cost of e-learning devices was removed, or substantially lowered, did e-learning devices appear to be cost-effective. But even in this circumstance, the probability it was cost-effective did not increase above 75%.

There are undoubtedly a number of (technical) limitations with the E-LEEM model. First, and perhaps most importantly, it was difficult to determine the cost associated with the device(s). This partly reflects the fact that most published clinical evaluations did not report resource/use costs associated with the technology at hand, the heterogeneous nature of the devices and because none appear to be commercially available. Thus, it is difficult to have any real idea how much they are likely to cost, particularly if rolled out for large numbers of patients (i.e. possible economies of scaling up use).

Another limitation was with the use of the QRISK2 risk equation. The equation is designed to assess the probability of developing a first CVD event. Thus, the model takes no account of the fact that individuals who have experienced any events are more likely to experience an additional event. However, given the relatively small difference in weight loss at 12 months derived from the literature review in the base case, it is considered unlikely that such an adjustment would have a significant impact on the results.

A further limitation of the modelling exercise relates to the choice of comparator technologies. The commissioned project scope related to the use of e-learning devices. The systematic review identified 43 RCTs. However, none compared the use of e-learning devices with anything other than (often poorly described) interventions based on other methods of providing 'advice'. Although this is understandable in the context of performing specific trials, it is not helpful in a decision-making sense – there are a myriad of other potential interventions for obese people (for example, interventions based on promoting physical exercise and pharmacological treatments such as orlistat). With respect to the latter, although a formal systematic review and indirect treatment comparison has not been undertaken, a crude and unsystematic look at the evidence would suggest that orlistat could be less costly and more effective in this patient group. Indeed, NICE recommends the use of orlistat as a method of losing weight in obese people.<sup>106</sup> Although it is unclear whether or not this is indeed true in a relative sense, this does serve to emphasise the point that 'cost-effectiveness' is a relative term, and results depend on the choice of comparators. Thus, even if e-learning devices were considered to be cost-effective compared with dietary advice alone, it would remain unclear whether or not they are the optimal method of treating people. It is recommended that future assessments consider a broader project scope.

One particular difficulty was that the RCTs reported a number of different outcomes other than BMI, such as changes in fat and fruit consumption. Whereas it is not inconceivable that changes in these dietary behaviours could result in changes in longer-term health, it was not possible to quantitatively link the two in a robust manner. A related issue is that it is plausible that e-learning devices simultaneously affect more than just BMI levels. For example, NICE's obesity guideline<sup>106</sup> states that orlistat reduces blood pressure levels and BMI. The reviewed trials provided too little information for anything other than changes in BMI to be included in the E-LEEM model, but, clearly, if this is true, the cost-effectiveness of the e-learning devices has been underestimated.

The E-LEEM model was built using a DES approach because patients' clinical histories were considered to be important in terms of predicting future events. The model was programmed to run in TREEAGE PRO 2009. However, it transpired that running basic two-level simulations [i.e. first-order (1000 trials) and second-order (1000 samples) simulations] required almost 2 hours on a high-powered personal computer, meaning that the number of sensitivity analysis that could be run was constrained. It also meant that testing/validating the results was problematic and undertaking a series of EVPPI analyses with any degree of accuracy was impossible. Thus, although the population-level EVPI is arguably high at all positive willingnesses to pay, and the value of undertaking further research to assess the relative effectiveness of the two options is also arguably high, it remains unclear which other parameters are driving the results. At the time of writing this report, the company producing TREEAGE PRO 2009 is beta testing an updated version of the software which can be run using Linux – which gives faster programming speeds. It is hoped to undertake extensive EVPPI when this update becomes available.

The EVPI analysis suggested that the value of further research was arguably large, despite the discouraging clinical results from the systematic review. This is because the incidence of obesity was estimated to be > 300,000 per year and the time horizon was assumed to be 10 years. Clearly, however, if either of these two estimates is believed to be too high, the value of the EVPI estimates will be sharply reduced.

In summary, the E-LEEM model was built to assess the cost-effectiveness of e-learning devices compared with dietary advice alone for people with obesity, as methods of promoting healthier eating and weight loss. The model contains a number of assumptions and necessarily draws on evidence from a number of different sources, although the estimate of relative treatment effect is based on a systematic review. The results from the review suggest only modest differences in outcomes (including BMI) between the approaches, suggesting that, even if statistically significant, clinical differences are likely to be minimal if not non-existent. This conclusion is clearly reflected in the cost-effectiveness results, where differences in QALYs were typically reported at only two decimal places and resulting ICERs were generally unfavourable from a UK NHS perspective. Costing the e-learning devices was difficult because they are idiosyncratic, most do not appear to be commercially available and the clinical studies rarely reported resource use or cost data. In terms of cost-effectiveness, and given the near equivalence of the clinical results, this is important, particularly whether or not there is a fixed initial cost of supplying each device. In the base case, a fixed initial cost of £854 based on the RCT by McConnon *et al.*<sup>93</sup> was assumed. The results showed that e-learning devices were the dominant option if the cost was removed. However, even if this cost was dramatically reduced it would remain unclear whether or not e-learning devices are more cost-effective, as the probability that they were cost-effective was only 59% in this analysis, and no other comparative interventions, such as exercise and pharmacological interventions, were evaluated. It is suggested that future evaluations of these devices consider a wider range of treatment options.

## Chapter 6

### Discussion

#### Explanations of effectiveness

Of the 43 interventions and trials identified, 13<sup>44,51,56,61,68-70,72,75,76,78,82,83</sup> were found to be effective (with the intervention group demonstrating more positive change in the desired behaviour or outcome than the control group), 27<sup>42,43,46-50,52-55,57-60,62-66,71,74,77,79-81,84</sup> showed no difference in effectiveness between the intervention and comparator and, in four trials,<sup>45,51,67,73</sup> participants in the intervention group had less favourable change than those in the control group. In one trial, 51 participants in the intervention group showed a positive effect for one behaviour (reduced fat consumption), but a negative effect for another (increased fruit and vegetable consumption). We analysed the data with a view to determining reasons for the observed variability in effectiveness. We considered that potential reasons could include differences in:

- target populations (low income, overweight, diagnosed illness)
- target behaviours
- intervention content
- theoretical base
- mode of delivery
- 'dose' of intervention (duration × intensity)
- study quality.

#### Target populations

The target populations for the interventions varied: of 23 studies providing inclusion criteria, 10 were aimed at 'healthy' people, 12 aimed at overweight or obese people, one aimed at people with at least one risk factor for CVD, and one aimed at people with diabetes. We might speculate that people with a diagnosed condition (in this case diabetes) may be more motivated to change behaviour than people who consider themselves well; this seems intuitive, but studies included in this review were too weak to provide evidence either way. Although obesity is a clinically defined condition, many people who are obese do not consider themselves ill and may not have been motivated to change.

A defining feature of adaptive e-learning interventions delivered via the internet is that the user controls where, when and how often they use the tool. In view of this, users who are already highly motivated to change may be more likely to use the intervention as well as more likely to achieve change. Being diagnosed with a disease can often trigger a strong emotional reaction leading to a desire to change, which may not be triggered merely by being informed about having a risk factor. In contrast, while opting into an e-learning intervention delivered via mobile technologies requires motivation, ongoing programs may be sent to participants and do not require the ongoing motivation of individuals to seek the intervention. There were only two mobile technology-based interventions in this review. Further research may be warranted to explore whether or not the effects of mobile technology-based interventions are different from those of web-based interventions. One area in which further research may be warranted is exploring whether or not adaptive e-learning tools are better suited for disease management than for health promotion.

### Target behaviours

The statistical meta-analyses demonstrated a small effect of increasing fruit and vegetable consumption, but no effect on reducing fat or energy intake or increasing fibre. It is worth speculating as to why this may be so. One possible reason is that it is easier to eat more of something seen as beneficial (and enjoyable), in this case fruit and vegetables, than to eat less of something seen as harmful. Eating less of something may be viewed as self-denial or self-punitive. Further research into people's views and experiences of dietary change may be useful.

### Intervention content

A comparison of effective and ineffective interventions did not show an association with content (which behaviour change techniques were included in the intervention; see *Appendix 8*). There was unexplained heterogeneity in the effects of intervention on several outcomes, including fruit and vegetable intake, fat intake and weight. However, our original study aim did not include an analysis of the impact of intervention content on statistical heterogeneity. It is possible that unexplained heterogeneity may be related to differences in intervention content, and we are planning further statistical analyses to explore this in a future publication.

### Theoretical base

Of the 43 interventions, 26<sup>43,44,48–50,52,54–56,59,60,62,64–69,71,72,74,75,78–80,83</sup> mentioned one or more behaviour theories and only eight<sup>44,56,68,69,72,75,78,83</sup> of these analysed theoretically predicted mediators. This is of concern, given the importance of investigating not just whether or not interventions work, but also how they work. Understanding the mechanisms of action of interventions is key to developing more effective interventions.<sup>117</sup> Only one-third of interventions that are said to be theory based measure theoretically predicted mediators; without this, the statement that the intervention is theory based has limited scientific value.<sup>118</sup> Of the 13 effective interventions,<sup>44,51,56,61,68–70,72,75,76,78,82,83</sup> eight<sup>44,56,68,69,72,75,78,83</sup> mentioned one or more theories and only two<sup>44,68</sup> of these analysed theoretically predicted mediators. Six studies<sup>56,69,72,75,78,83</sup> measured putative mediators, but did not analyse their mediational role, only changes in the variables over time.

The first mediational analysis was within a trial<sup>44</sup> of a theory-based intervention that included behaviour change techniques of planning and evaluation of goals. These were hypothesised on the basis of social cognitive theory to change self-efficacy and physical and social outcome expectations, which were in turn predicted to change behaviour. The intervention increased consumption of fibre and fruit and vegetables, and decreased fat consumption. This effect was mediated by two of the targeted constructs: self-efficacy and physical outcome expectancies.

The second mediational analysis was within a trial<sup>68</sup> of a tailored information intervention which used theory, the Precaution Adoption Process Model, to select intermediate outcomes to measure. The theory identifies awareness of personal risk behaviour as an important step towards behaviour change. The intervention found no effects on fat or fruit intake and very small effects on vegetable intake and self-rated fat intake. It also found no difference on the theoretically derived mediators – awareness of personal fat, fruit and vegetable intakes. Although not theoretically based, the authors stated that they expected the tailored intervention to be mediated by perceived personal relevance, individualisation and interest: the first two were found to mediate, but on self-rated fat intake only.

Change scores, with no tests of mediation, were found for four of the six studies in which they were measured: self-efficacy to change diet,<sup>72</sup> knowledge,<sup>76</sup> 'stages' of change,<sup>56,72</sup> and self-regulation strategies, although these were not associated with healthy eating.<sup>82</sup>

In conclusion, only one<sup>44</sup> of the 13 effective interventions<sup>45,51,56,61,68–70,72,75,76,78,82,83</sup> drew on theory to identify intervention targets, measured the constructs theoretically hypothesised to bring

about change and conducted a mediational analysis to evaluate whether or not intervention effects occurred as theoretically predicted. The intervention targeted self-efficacy and outcome expectancies and central constructs within social cognitive theory, and changed dietary behaviour at least partly by changing these constructs. We therefore have theoretically informed findings that we can apply to future intervention development from one of the studies reviewed.

### **Mode of delivery**

As described earlier, the most common mode of delivery was the internet, followed by CD-ROM and computer kiosks. Mode of delivery did not appear to be related to effectiveness, with both effective and ineffective interventions delivered by the internet, CD-ROM and computer kiosks.

### **'Dose' of intervention**

The intended duration and intensity of the intervention varied widely, from one-off single sessions lasting 20 minutes<sup>51</sup> to repeated exposures (maximum was 30 minutes monthly for 12 months = 6 hours).<sup>83</sup> Where interventions were delivered over the internet, however, it was often not possible to determine how participants had actually used the intervention. For this reason it was not possible to determine whether or not there was a relationship between 'dose' of the intervention and effectiveness, nor could we even speculate on the nature of any relationship (e.g. threshold effect or linear relationship).

### **Study quality**

According to the EPHPP study assessment method, there were 30 low-quality trials (global rating 'weak')<sup>42,44-49,51-53,55-59,61-64,67,68,70,72,75-78,81,82,84</sup> and 13 medium-quality trials (global rating 'moderate').<sup>43,50,54,60,65,66,69,71,73,74,79,80,83</sup> Only two trials<sup>69,83</sup> reporting a positive effect were of medium quality and 11 were of low quality.<sup>44,51,56,61,68,70,72,75,76,78,82</sup> Of the trials reporting no effect or a negative effect, 11 were of medium quality<sup>43,50,54,60,65,66,71,73,74,79,80</sup> and 20 were of low quality.<sup>42,45-49,51-53,55,57-59,62-64,67,77,81,84</sup> It has previously been established that low trial quality is associated with an overestimation of effects. Specifically, effect estimates have been found to be higher where there is no allocation concealment or no blinding.<sup>118</sup> Further, it has been shown that effect estimates are higher in systematic reviews in which few trials report the same outcome than in systematic reviews in which a high proportion of trials report the same outcomes.<sup>119</sup> This is owing to selective reporting of outcomes in trials in which no statistically significant benefit is found. Our statistical assessment of the evidence suggests that trials with lower methodological quality (i.e. higher risk of bias owing to allocation concealment methods used and 'weak' EPHPP rating of study quality) may overestimate intervention effects.

## **Can e-learning interventions change dietary behaviour?**

There are many factors affecting what foods people eat and why, and an intervention targeted at individual behaviour change can address only a selection of these. An individual's food environment is composed of multiple connected factors acting at the macro level (e.g. national legislation and policy, regulation of food processors and vendors), the physical environment (access to and availability of healthy and unhealthy foods at schools/home/work, in shops, etc.) and the social environment (cultural food practices, social norms, role models).<sup>120</sup>

Factors at all levels play a major role in determining whether or not individuals and populations consume a healthy diet. These factors can easily outweigh attempts by an individual to alter dietary behaviour.

E-learning has not proved itself to be more effective or cost-effective than other behaviour change approaches at an individual level for improving diet, or for preventing or reducing overweight

or obesity. Nor is there any research comparing e-learning approaches with population-level approaches to tackling dietary change or reduce obesity. Some policy and population-level interventions, such as fat taxes or fruit and vegetable subsidies suggest that a carefully targeted tax on unhealthy foods could produce a modest but significant impact on population-level dietary intake and CVD that would be cost-effective.<sup>121</sup> However, a recent systematic review (produced for the World Health Organization) found that few policy and environmental interventions for diet have been properly evaluated in peer-reviewed studies.<sup>122</sup>

## Are e-learning interventions cost-effective to the NHS?

The review did not identify any published economic evaluations that perfectly fitted the project scope. That is, none was identified that assessed the cost-effectiveness of devices that were based purely on changing dietary behaviour. However, one recently published UK RCT-based study<sup>93</sup> was identified that included a non-dietary component (physical exercise). In the base case, the results showed that the e-learning device was not cost-effective compared with standard care given the relatively large costs associated with the device. Indeed, although the results were not statistically significant, WMDs in weight loss were lower in the intervention arm and the costs were higher.

An economic model (E-LEEM) was built to assess the cost-effectiveness of the devices compared with nutritional advice alone delivered using standard approaches as a method of promoting weight loss. The results broadly suggest that the e-learning devices are unlikely to be cost-effective at conventional levels of £20,000–30,000 per QALY gained; the probability they are cost-effective was > 25% at these threshold levels. A result that is perhaps not unsurprising given the relatively modest effects derived from the systematic review and meta-analysis. However, the results were sensitive to the assumptions regarding the initial fixed cost of the devices, lowering this value dramatically increased the cost-effectiveness of the devices.

## What is the potential population health impact of e-learning interventions?

### *To what extent do statistical effects translate into health impact?*

The evidence available suggests that e-learning interventions are not effective in changing dietary behaviours, apart from a possible small effect on increasing fruit and vegetable intake.

#### **Fruit and vegetables**

Dietary recommendations suggest five servings of fruit and vegetables per person per day; currently adults in the UK (aged 19–65 years) are eating on average 4.4 servings,<sup>123</sup> so an increase of a quarter of a serving would still not raise the average intake to meet the guidelines.

#### **Fat**

Dietary recommendations suggest that no more than 35% of calories consumed should come from total fat, and > 11% of calories from saturated fats. Currently, UK adults consume an average of 34–36% of energy from total fat, and 12.8% of energy from saturated fat,<sup>123</sup> so a reduction of 1% would not facilitate achievement of guideline targets.

#### **Fibre**

Recommendations suggest an intake of 18 g of dietary fibre per day, with current intake in UK adults at around 14 g.<sup>123</sup> An increase of 1.5 g would therefore not facilitate achievement of the guideline.

Possible reasons for this lack of effect include that individual behavioural determinants may be relatively unimportant compared with organisational, environmental, economic and sociocultural factors; lack of adequate theoretical underpinning of theory; lack of clarity about potential target audiences; no perceived need for change by users; and high attrition rates leading to ineffective doses.

## Budget impact analysis

If it assumed that e-learning devices are not currently provided by the NHS, then the estimated budget impact is zero, as the clinical and economic evidence suggests that they should not be used.

## Limitations

The limitations of this review include potential reporting bias, incomplete retrieval of completed research studies and data extraction errors. It has been shown that trials showing no, or negative, effects are less likely to be offered for publication, and if offered are less likely to be accepted, resulting in a biased set of data available for review. Although every effort was made to conduct exhaustive electronic searches and to contact authors and researchers for further trials, it is possible that some studies were missed. Furthermore, it is possible that some papers were misclassified as not eligible for inclusion in the review. For some full-text reports that were retrieved it is possible that some data were incorrectly entered onto the review database, although some automatic controls were built into the database and data were double-checked in order to avoid extraction errors.

Further, it has been shown that intervention protocols document more behaviour change tools than are reported in study publications. However, we were unable to obtain the vast majority of intervention protocols. There was unexplained heterogeneity in trial results; our exploration of potential sources of heterogeneity was not exhaustive, owing to a limited number of studies in the review (and hence power). It is possible that individual trials reporting statistically significant results (with intervention effect sizes that would be of public health importance) are genuinely more effective than the pooled estimates of effects. Considering the heterogeneity in interventions, participants and outcomes, it might be considered inappropriate to pool the results of the included studies. In this systematic review, the decision to pool results using random effects meta-analysis was pre-specified in the study protocol. It may have been useful to plan an additional fixed effects meta-analysis, as a sensitivity analysis. However, in this review the use of random effects meta-analysis may be judged reasonable given the presence of substantial statistical heterogeneity among the intervention effects observed in different studies.

One final potential limitation for UK health purposes was that none of the studies were undertaken in the UK, although all were undertaken in similarly developed countries with functioning health systems. The context in which a complex intervention is used can be important, and a change in context may alter its effectiveness. The majority of the included studies were conducted in the USA, but as eating habits in the USA and UK are not dissimilar, it would be reasonable to consider that the overall findings are broadly generalisable to the UK.



# Chapter 7

## Conclusions

### Effectiveness

Despite the availability of several good trials of e-learning interventions for dietary behaviour change, the evidence for effectiveness on dietary behaviours is weak. Although the pooled effects of interventions showed no effects of public health importance, there was high and unexplained heterogeneity in many trial results.

Neither the design nor the targeting of e-learning interventions can yet be informed by available evidence; the implication of these conclusions for policy and practice is that such interventions should not be introduced into routine practice at present. E-learning for dietary behaviour change may, however, have potential as one approach within wider intervention programmes to tackle poor diet and obesity in the population.

### Cost-effectiveness

While the published evidence base was limited, the results from the modelling exercise suggest that e-learning devices to promote dietary behaviour change are unlikely to be cost-effective at conventional UK cost per additional QALY thresholds, unless they are much less costly to provide than assumed in the analysis, particularly the initial (fixed) setup costs. The current clinical and economic evidence base suggests that e-learning devices designed to promote dietary behaviour change will not produce clinically significant changes in dietary behaviour, and are at least as expensive as other individual behaviour change interventions.

### Recommendations for future research

We identified 43 trials of e-learning for dietary behaviour change, and there are many more studies trialling e-learning interventions for altering different health behaviours. Despite the relatively high EVPI results from the cost-effectiveness modelling, we believe the implication for research is that further clinical trials of individual e-learning interventions should not be undertaken until theoretically informed work, which addresses the question of which characteristics of the target population, target behaviour, content and delivery of the intervention are likely to lead to positive results, is completed. This work would include:

- reviews of available behaviour change theoretical frameworks and the empirical data to support each approach
- research in behaviour change techniques (linking theory to techniques) to provide empirical data to help understand which techniques are effective, and under which conditions
- cohort and other study designs which actively map and explore the pathways of change in outcomes among users of the intervention.



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## Contributions of authors

Jody Harris (Research Assistant, Systematic Reviews in Nutrition) undertook screening, reviewing and data extraction, and produced the various tools to be used in the review. She also provided nutrition expertise, co-ordinated the writing of the report and publication of the study protocol.

Lambert Felix (Research Assistant, Systematic Reviews) undertook screening, reviewing and data extraction, and produced the various tools to be used in the review. He also undertook all database searching and contributed to the writing and editing of the review report.

Alec Miners (Lecturer, Health Economics) designed the economic model and undertook the economic analysis. He wrote the chapter on economic evaluation.

Elizabeth Murray (Reader, Primary Care) contributed materially to the design of the conceptual framework and the systematic review methods. She provided clinical expertise and contributed to the writing and editing of the review report.

Susan Michie (Professor, Health Psychology) contributed materially to the design of the conceptual framework and the systematic review methods. She provided expertise and guidance regarding behavioural theories to be investigated, and contributed to the writing and editing of the review report.

Elaine Ferguson (Senior Lecturer, Nutrition) provided expertise and guidance regarding nutrition tools and outcomes. She contributed to the writing and editing of the review report.

Caroline Free (Clinical Lecturer, Public Health and M-Health) contributed materially to the design of the conceptual framework and the systematic review methods.

Karen Lock (Senior Lecturer, Public Health) contributed materially to the design of the conceptual framework and the systematic review methods. She contributed to the writing and editing of the review report.

Jane Landon (Deputy Chief Executive, National Heart Forum) represented user groups in the design of the review and framing of the results.

Phil Edwards (Senior Lecturer, Statistics) managed the project, provided expertise in the design of the systematic review and designed and undertook the statistical analysis. He contributed to the writing and editing of the review report.



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# Appendix 1

## Research protocol

This protocol was previously published in Edwards P, *et al.* Assessing the effectiveness and cost effectiveness of adaptive e-Learning to improve dietary behaviour: protocol for a systematic review. *BMC Public Health* 2010;**10**:200.

### Assessing the effectiveness and cost effectiveness of adaptive e-Learning to improve dietary behaviour: protocol for a systematic review

#### Abstract

##### Background

The composition of habitual diets is associated with adverse or protective effects on aspects of health. Consequently, UK public health policy strongly advocates dietary change for the improvement of population health and emphasises the importance of individual empowerment to improve health. A new and evolving area in the promotion of dietary behavioural change is e-Learning, the use of interactive electronic media to facilitate teaching and learning on a range of issues, including diet and health. The aims of this systematic review are to determine the effectiveness and cost-effectiveness of adaptive e-learning for improving dietary behaviours.

##### Methods/Design

The research will consist of a systematic review and a cost-effectiveness analysis. Studies will be considered for the review if they are randomised controlled trials, involving participants aged 13 or over, which evaluate the effectiveness or efficacy of interactive software programs for improving dietary behaviour. Primary outcome measures will be those related to dietary behaviours, including estimated intakes of energy, nutrients and dietary fibre, or the estimated number of servings per day of foods or food groups. Secondary outcome measures will be objective clinical measures that are likely to respond to changes in dietary behaviours, such as anthropometry or blood biochemistry. Knowledge, self-efficacy, intention and emotion will be examined as mediators of dietary behaviour change in order to explore potential mechanisms of action. Databases will be searched using a comprehensive four-part search strategy, and the results exported to a bibliographic database. Two review authors will independently screen results to identify potentially eligible studies, and will independently extract data from included studies, with any discrepancies at each stage settled by a third author. Standardised forms and criteria will be used.

A descriptive analysis of included studies will describe study design, participants, the intervention, and outcomes. Statistical analyses appropriate to the data extracted, and an economic evaluation using a cost-utility analysis, will be undertaken if sufficient data exist, and effective components of successful interventions will be investigated.

##### Discussion

This review aims to provide comprehensive evidence of the effectiveness and cost-effectiveness of adaptive e-Learning interventions for dietary behaviour change, and explore potential psychological mechanisms of action and the effective components of effective interventions. This can inform policy makers and healthcare commissioners in deciding whether e-Learning should

be part of a comprehensive response to the improvement of dietary behaviour for health, and if so which components should be present for interventions to be effective.

## Background

### The need for improved dietary behaviour

The composition of habitual diets is associated with adverse or protective effects on health [1–3]. Specifically, diets high in saturated fats and sodium have been found to increase risk of cardiovascular diseases, while those high in fruit and vegetables and low in saturated fats have been linked with reductions in a range of diseases including certain cancers, cardiovascular disease and hypertension [4–7]. The WHO reports that the consumption of up to 600 g per day of fruit and vegetables could reduce the total worldwide burden of disease by 1.8%, and reduce the burden of ischaemic heart disease and ischaemic stroke by 31% and 19% respectively [8]. In the UK, the consumption of fruits and vegetables, dietary fibre, iron (pre-menopausal women only) and calcium are well below recommendations, whereas intakes of saturated fats and sodium exceed recommendations in large sections of the population [9]. Consequently, UK public health policy strongly advocates dietary change for the improvement of population health and emphasises the importance of individual empowerment to improve health [7, 10], thereby shifting the focus of the National Health Service from treatment to prevention of illness [11–12].

### Adaptive e-Learning via interactive computerised interventions

A new and evolving area in the promotion of dietary behavioural change is e-Learning, the use of interactive electronic media to facilitate teaching and learning on a range of issues including health (see Additional file 1 for definitions of terms used in e-Learning). E-Learning has grown out of recent developments in information and communication technology, such as the Internet, interactive computer programs, interactive television, and mobile phones [13–17], technologies which are fast becoming more accessible to the general population. (For example, an estimated 70% of the population in the UK has access to the Internet and this percentage is likely to continue to grow [18].) This high level of accessibility with emerging advances in computer processing power, data transmission and data storage makes interactive e-Learning a potentially powerful and cost-effective medium for improving dietary behaviour [19–21]. It also has a number of distinct advantages compared with traditional approaches for the promotion of dietary behaviour change, such as the possibility of tailoring to individual circumstances [22], translating complex information through video, graphics, and audio systems [23], and potential cost savings on face-to-face interventions involving healthcare practitioners. The evidence that individualised, tailored e-Learning approaches are more effective than traditional non-tailored interventions [24] has given them a promising lead in health education [25–27]. E-Learning interventions have been classified into three generations: 1st generation interventions use computers to tailor print materials; 2nd generation interventions use interactive technology delivered on computers; and 3rd generation interventions use portable devices such as mobile phones, for more immediate interaction and feedback [28]. Exploration of the properties of different e-Learning interventions is now required in order to determine possible effective components (with each component comprising both delivery and content – see *Figure 1*). Potential cognitive and emotional mediators of dietary behaviour change should also be explored, in order to elicit potential mechanisms of action (see *Figure 2*).

There is a risk that e-Health and use of new technologies in health care might widen health inequalities on either side of the ‘digital divide’. Experience suggests that there are two dimensions to the digital divide and its impact on health inequalities: *access* (to physical hardware and software) and *accessibility* (or the ability of people with differing literacy/health literacy/IT literacy to use or apply information and support supplied through e-Learning). It has been shown that it is possible to deliver e-health interventions specifically designed for people with low

literacy skills (e.g. Hispanics in Southern USA [29], homeless drug users [30] and single teenage mothers [31]). What remains less clear is the extent to which people with low literacy skills will feel comfortable using a computer, or will be able to act on information or advice provided over the Internet.

Interactive e-Learning programs to promote positive dietary behavioural changes have the potential to benefit population health. However, before e-Learning can be hailed as a dietary behaviour change intervention of the future, the effective components and mechanisms of action of e-Learning programmes must be identified, and its cost-effectiveness established in different contexts.

### Previous reviews

Three systematic reviews have examined the effectiveness of e-Learning for dietary behaviour change. The first [32] was restricted to first-generation interventions for dietary change and did not include any web or Internet-based interventions. The second [33] examined a broad range of second-generation interactive interventions for dietary behaviour change. Both of these reviews reported studies published prior to 2006 that were carried out in a variety of settings. The third review [28] was more recent, reviewing second- and third-generation interventions trialled up to 2008, but only in primary prevention in adults (no participants with diagnosed disease). All reviews were restricted to publications in the English language, and limited their searches to relatively few databases, increasing the potential for publication bias. The conclusions drawn from these systematic reviews were that e-learning shows some promise for dietary behaviour change, although the findings were mixed. Inter-study heterogeneity with respect to study design, participants, measures, and outcomes precluded meta-analysis to estimate pooled intervention effects. Moreover, the cost-effectiveness of e-Learning was not evaluated in any review, nor was there any attempt to identify potential mechanisms of action. The third review assessed internal and external validity of trials, and began to isolate effective components.

Our review will provide a comprehensive and up-to-date account of e-Learning technologies in use for promoting dietary behavioural change, and an evaluation of their effectiveness and cost-effectiveness in improving dietary behaviour as well as clinical outcomes. We will investigate the psychological theories that underlie the process of behaviour change [34–36], and look for key behaviour-change techniques that have been shown to be associated with healthy eating behaviours [37]. Where these have been used to inform intervention design in trials, we will explore potential mediators of behaviour such as knowledge, intention, self-efficacy and emotions with a view to understanding mechanisms of action. We will also explore the different components of trialled interventions, in order to find the effective components of successful e-Learning interventions for dietary change.

We will use a systematic search strategy (described below) to identify relevant studies and to reduce the potential for reporting biases, and use wider inclusion criteria than in previous reviews to enable a wider range of conclusions to be drawn. Preliminary literature searching, including the NHS's Economic Evaluation Database, suggests that the published evidence on cost-effectiveness is extremely limited. Therefore, we will conduct a *de novo* economic evaluation of the intervention studies, looking at cost-effectiveness in England and Wales, if the required clinical effectiveness data are available from the primary trials. We will conclude with policy recommendations and recommendations for future primary research.

### Aims of the review

The aims of this systematic review are to determine the effectiveness and cost-effectiveness of adaptive e-Learning for improving dietary behaviours. The specific objectives are to:

- describe the range of e-Learning technologies in use for promoting dietary behavioural change
- evaluate interactive e-Learning effectiveness in terms of improvement in dietary behaviour and clinical outcomes
- explore the properties of different e-Learning interventions in order to determine possible effective components of successful e-Learning interventions for dietary behaviour change
- investigate potential explanations of dietary behaviour change, and mechanisms of action
- evaluate cost-effectiveness compared with current standard interventions, and likely budget impact in England & Wales.

Final outputs will be a report to the UK National Institutes of Health Research (NIHR) Health Technology Assessment (HTA) programme, and a peer-reviewed paper.

## Methods/Design

### Design

The research will consist of a systematic review and a cost-effectiveness analysis.

### Criteria for considering studies

*Types of study* – We will include randomised controlled trials (RCTs) for evidence of effectiveness, and economic evaluations for evidence of cost-effectiveness.

*Types of population* – Adolescents or adults aged 13 years and above who have participated in a study designed to evaluate the effectiveness of e-Learning to promote dietary behavioural change. We shall include all clinical conditions where dietary advice plays a major part in case management.

*Types of intervention* – Interventions will be included if they are interactive computer software programs that tailor output according to user input (second and third generation interventions). These include those where users enter personal data or make choices about information that alter pathways within programs to produce tailored material and feedback that is personally relevant. Users may interact with the programs as members of a small group, as well as individually. Programs should be available directly to users and allow independent access without the need for any expert facilitation.

Interventions will be excluded if they are: first-generation tailored ‘information only’ (e.g. providing a leaflet or PDF); simple information packages with no interactive elements; non-interactive mass media interventions (such as TV advertisements); interventions designed to be used with others’ help (e.g. teacher or health professional); interventions targeted at health professionals or teachers; computer-mediated delivery of individual health-care advice (e.g. online physicians); or electronic history-taking or risk assessment with no health promotion or interactive elements.

*Outcome measures* – We anticipate that most interventions will be aimed at dietary behaviours, and are unlikely to have followed participants long enough to obtain clinical changes. However, as dietary behaviour tends to be self-reported it is prone to error (e.g. recall bias). Biological outcomes on the other hand are more objective and also more important for modelling purposes. We will therefore use dietary behaviour as our primary outcome, but we will attempt to obtain data that allow us to model the relationship between behaviours and clinical changes.

*Primary outcome measures* – The primary outcome variables will be those related to dietary behaviours. They will include estimated intakes or changes in intake of energy, nutrients, dietary fibre, foods or food groups. The dietary assessment tools or techniques used to estimate dietary behaviour will be critically examined in terms of quality.

*Secondary outcome measures* – Objective measures that are likely to respond to changes in dietary behaviours and are associated with adverse clinical outcomes will be examined, including measurements of anthropometric status and blood biochemistry.

*Other data* – We will also seek data on economic outcomes, including costs of providing the intervention and costs to the individual user; data on unintended adverse consequences of the interventions; and process outcomes (e.g. usage data). Data relating to potential cognitive and emotional mediators of dietary behaviour will also be extracted. These will only be extracted if primary and/or secondary outcome data are available.

## Identification of eligible studies and data extraction

### Search strategy

We have designed a four-part search strategy: firstly, we will search electronic bibliographic databases for published work (see below for databases to be searched). Secondly, we will search the grey literature for unpublished work. Thirdly, we will search trials registers for ongoing and recently completed trials. Finally, we will search reference lists of published studies and contact authors and e-health research groups to check for more trials. All databases will be searched from 1990 (any studies conducted in the 1980s will be identified by searching the reference lists of included studies). There will be no restrictions by language. To ensure the review is reasonably up-to-date at reporting, the searches will be re-run immediately prior to analysis and further studies retrieved for inclusion. The search strategy comprises two concepts: computer/internet-based interventions, and dietary behaviour (see Additional file 2 for full search strategies at [www.biomed.central.com/147-2458/10/200](http://www.biomed.central.com/147-2458/10/200)).

The databases that will be searched are CINAHL, Cochrane Library, Dissertation Abstracts, EMBASE, ERIC, Global Health, HEED, HMIC, MEDLINE, PsychInfo, and Web of Science.

### Screening and review process

All studies identified through the search process will be exported to a bibliographic database (ENDNOTE version X3) for de-duplication and screening. Two review authors will independently examine the titles, abstracts, and keywords of electronic records for eligibility according to the inclusion criteria above. Results of this initial screening will be cross-referenced between the two review authors, and full-texts obtained for all potentially relevant reports of trials. Full-texts of potentially eligible trials will go through a secondary screening by each reviewer using a screening form based on the inclusion criteria (see Additional file 3 at [www.biomed.central.com/147-2458/10/200](http://www.biomed.central.com/147-2458/10/200)) for final inclusion in the review, with disagreements resolved by discussion with a third author. Reference lists of all eligible trials will be searched for further eligible trials.

### Data extraction

Two review authors will independently extract relevant data using a standardised data extraction form (Additional file 4) in conjunction with a data extraction manual (Additional file 5). Trial managers will be contacted directly if the required data are not reported in the published study.

## Analysis

### Descriptive analysis

We will describe all studies that meet the inclusion criteria, including:

1. study design
  - (a) trial design and quality
  - (b) data collection methods, modes, and techniques; validity of tools
  - (c) adherence to protocol (we will attempt to retrieve the protocols of eligible studies to examine the adherence to initial plans)

- (d) statistical and other analyses
- (e) conflict of interest
- 2. participants (intervention and control)
  - (a) socioeconomic and demographic characteristics (e.g. age, ethnicity, education level)
  - (b) health status: diagnosed disease (e.g. diabetes, cardiovascular disease, obesity) versus no diagnosed disease
  - (c) technological literacy and access to technology
  - (d) psychological characteristics (e.g. help seeking)
- 3. intervention
  - (a) setting and recruitment methods
  - (b) components of the intervention, including delivery and content
  - (c) frequency, intensity and duration of the intervention
  - (d) behaviour change theories employed in intervention design
- 4. outcomes
  - (a) primary and secondary outcomes measured
  - (b) information on process (ease of use) and usage (compliance).

Information on how access to the intervention was provided (e.g. free laptops/Internet access); the intended reading age (or other measure of technological literacy/skill required); and the sociodemographic characteristics of the participants will be used to address concerns over the digital divide. Where primary studies have included sub-group analyses of users with low-income or low educational status, we will note these. If sufficient data are provided by the primary studies we will consider undertaking sub-group analyses of intervention effects in low-income and low educational status users.

### Statistical analysis

We will use statistical software (STATA version 11) for data synthesis. In the presence of sufficient homogeneity (i.e. comparable population, interventions and outcomes) we will pool the results of RCTs using a random-effects model, with standardised mean differences (SMDs) for continuous outcomes and odd ratios for binary outcomes, and calculate 95% confidence intervals and two sided *p*-values for each outcome. In studies where the effects of clustering have not been taken into account, we will adjust the SDs by the design effect, using intra-class coefficients if given in papers, or using external estimates obtained from similar studies [38]. In the absence of sufficient homogeneity, we will present tables of the quantitative results.

We will assess selection bias using Egger's weighted regression method and Begg's rank correlation test. Heterogeneity among the trials' odds ratios will be assessed by using both  $\chi^2$  test at a 5% significance level and the  $I^2$  statistic, the percentage of among-study variability that is due to true differences between studies (heterogeneity) rather than to sampling error. We will consider an  $I^2$  value greater than 50% to reflect substantial heterogeneity. We will conduct sensitivity analyses in order to investigate possible sources of heterogeneity including study quality (adequate vs inadequate allocation concealment; low vs high attrition) and sociodemographic factors that could act as effect modifiers (for example age, gender, sexuality and socioeconomic status). Details of each e-Learning program will be presented in a table of study characteristics, and we will conduct exploratory, descriptive analyses of data available on effective components and mechanisms of action.

### Economic evaluation

A decision-analytic model will be built to assess cost-effectiveness, so that intervention effects identified by the systematic review can be extrapolated beyond the observed trial periods [39]. The aim of the evaluation will be to compare the cost-effectiveness of adaptive e-learning technologies against other dietary interventions available in England and Wales. We will

combine the results of the systematic review with expert advice to identify the relevant e-learning technologies and appropriate comparators (e.g. group learning, individual contact with a dietitian) and model the costs associated with each.

The primary form of economic evaluation will be a cost-utility analysis, where health outcomes are expressed as quality-adjusted life-years (QALYs). The base case analysis will be performed from a NHS cost perspective. Future costs and health benefits will be discounted at 3.5% per annum. Results will be presented as expected costs, expected QALYs, incremental cost-effectiveness ratios, net benefit statistics and cost-effectiveness acceptability curves.

The model structure will be informed by: (i) reviewing previously published decision models where the immediate objective has been to evaluate technologies designed to help people change dietary behaviour and (ii) the results of the systematic review with respect to the recorded outcomes. For example, if the trials report changes in BMI, then a Markov model could be constructed, with the health states defined in terms of BMI groupings. Intervention costs [40] and effects could then be simulated by movements through these health states, with higher BMI being associated with increased health care costs (including costs of health outcomes such as cardiovascular disease, type 2 diabetes and cancer) and increased probabilities of all-cause mortality from sources such as the British Regional Heart Study [41].

Depending on the chosen model structure, other literature reviews will also be performed to identify evidence for other parameters, such as the increased costs and the dis-utility associated with increasing levels of obesity. Other variables for which additional searches might be required could include evidence linking increases in fruit or vegetable intake with weight loss and the reduction in the likelihood of cardiovascular disease following weight loss. Other important issues to incorporate in the model structure are likely to include attrition from the intervention, non-compliance and the need to retain a degree of flexibility as clinical studies are likely to report different outcomes (e.g. changes in behavioural and clinical outcomes).

If the primary systematic review identifies a 'network' of relevant RCTs, consideration will be given to performing formal mixed- or indirect-treatment comparisons to allow cost-effectiveness comparisons to be made across all programmes [42].

### **Stakeholder involvement**

Involvement of non- governmental organisations who represent a range of potential user groups has been an important part of the project development. Jane Landon, Deputy Chief Executive of the National Heart Forum, is a member of the investigative team, attends steering group meetings with the other co-investigators, and contributes to decisions made as the study progresses. The National Heart Forum (NHF) is an alliance of over 60 national organisations representing professional, academic, consumer, charity and public sector organisations throughout the UK, and therefore represents a large population of potential users of e-Learning for dietary behaviour change. In our experience, user input is particularly valuable in considering outcomes of interest to users, and methods of disseminating results to user communities, thus contributing to public involvement in science.

### **Discussion**

#### **Strengths and limitations of the review**

Strengths of this review include unambiguous definitions and inclusion criteria, and a clear and systematic approach to searching, screening and reviewing studies and extracting data using standardised forms and duplicating all stages. Our search area is large enough and our inclusion criteria broad enough to encompass the broadest range of interactive e-Learning interventions and dietary, clinical and behavioural outcomes, and so has the best chance of identifying effective

components of effective interventions for translation into policy or further research. Our review will also pinpoint potential mechanisms of action in terms of psychological theories of behaviour change employed in interventions, which will further inform the future development of e-learning interventions. The final report to the HTA will allow for a comprehensive statistical, economic and subgroup analyses, as well as descriptive analysis not usually available given the limited space available in academic journals.

Although every effort will be made to locate unpublished trials our findings may still be vulnerable to selective reporting, and despite a pre-defined and systematic approach to screening and reviewing the study will still involve judgments made by review authors, either of which may lead to bias. This review will not look at cohort or other observational study designs, and therefore may not be able to evaluate acceptability or preference of e-Learning interventions.

### **Implications for policy and healthcare commissioning**

This review aims to provide comprehensive evidence of the effectiveness and cost-effectiveness of adaptive e-Learning interventions for dietary behaviour change, and explore potential psychological mechanisms of action and the effective components of effective interventions. This can inform policy makers and healthcare commissioners in deciding whether e-Learning should be part of a comprehensive response to the improvement of dietary behaviour for health, and if so which components should be present for interventions to be effective.

Competing interests: none.

### **Authors' contributions**

PE will manage the project, and provided expertise in the design of the systematic review and statistical analysis; LF and JH will undertake screening, reviewing, and data extraction, and produced the various tools to be used in the review; LF will also undertake all database searching; JH will also provide nutrition expertise and coordinate writing and publication; EF provided expertise and guidance regarding nutritional outcomes to be investigated; CF, EM, SM and KL contributed materially to the design of the conceptual framework and the systematic review methods; SM also provided expertise and guidance regarding behavioural theories to be investigated; AM designed and will undertake the cost-effectiveness analysis; JL represented user groups in the design of the review. All authors contributed to the writing or editing of the protocol for publication, and will contribute to the final report and paper.

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## Appendix 2

### Search strategies

**N**umbers in brackets indicate number of database hits.

#### MEDLINE

##### *Dietary (A)*

1. exp food/or exp beverages/ (892,524)
2. exp Diet/ (155,154)
3. exp nutrition processes/or exp nutritional requirements/or exp nutritional status/or exp nutritive value/ (160,564)
4. exp Nutrition Therapy/ (67,396)
5. exp nutrition assessment/ (17,368)
6. exp Body Weight/ (279,095)
7. exp Nutrition Disorders/ (197,372)
8. food\$.ab,ti. (191,554)
9. nutri\$.ab,ti. (177,742)
10. diet\$.ab,ti. (288,751)
11. weigh\$.ab,ti. (542,082)
12. (diet\$adj3 behav\$).ab,ti. (2698)
13. (eat\$adj3 behav\$).ab,ti. (4135)
14. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 12 or 12 or 13 (A) – **1,950,164**

##### *E (B)*

15. exp Electronics/ (18,202)
16. exp cybernetics/or exp reminder systems/or exp communications media/or exp computing methodologies/or computers/or exp informatics/ (635,512)
17. exp Audiovisual Aids/ (74,190)
18. exp Technology/ (219,462)
19. exp decision support techniques/ (43,790)
20. online.ab,ti. (14,628)
21. computer\$.ab,ti. (178,320)
22. internet.ab,ti. (16,721)
23. (World wide web or world-wide-web or world-wide web or website\$or internet\$).ab,ti. (21,646)
24. (chat room\$or chatroom\$).ab,ti. (163)
25. (email or e-mail or electronic messag\$).ab,ti. (3377)
26. (blog\$or web-blog\$or weblog\$).ab,ti. (196)
27. (bulletin board\$or bulletinboard\$or message board\$or message board\$).ab,ti. (291)
28. (DVD or dvd).ab,ti. (378)
29. (CD-ROM or cd-rom or CDROM or cdrom).ab,ti. (966)
30. interactive health communicat\$.ab,ti. (36)
31. interactive televis\$.ab,ti. (72)
32. interactive video\$.ab,ti. (404)
33. interactive technolog\$.ab,ti. (63)
34. interactive multimedia.ab,ti. (214)

35. (E-health or ehealth or electronic health).ab,ti. (2078)
36. (surf or surf\$or browse or brows\$).ab,ti. (534,484)
37. (iphone or i-phone).ab,ti. (5)
38. (ipod or i-pod).ab,ti. (37)
39. (information kiosks or inform\$kiosk\$).ab,ti. (10)
40. (short messaging service or sms or text message or text\$message or txt).ab,ti. (2181)
41. (multimedia messaging service or mms).ab,ti. (2549)
42. virtual reality.ab,ti. (2419)
43. 15 or 16 or 17or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37or 38 or 39 or 40 or 41 or 42 (B) – **1,398,010**

### **Study design (C)**

44. Randomi#ed controlled trial.pt. (290,249)
45. controlled clinical trial.pt. (82,860)
46. Randomi#ed.ab. (233,631)
47. placebo.ab. (119,558)
48. clinical trials as topic.sh. (149,962)
49. randomly.ab. (140,912)
50. trial.ti. (85,200)
51. 44 or 45 or 46 or 47 or 48 or 49 or 50 (683,732)
52. (animals not (humans and animals)).sh,ti. (3,414,928)
53. 51 not 52 (C) – **634,766**

### **Publication year (D)**

54. (199\$or 200\$).yr. (D) – **10,151,288**

### **A+B+C+D**

55. **14 (A) + 43(B) + 53 (C) + 54 (D) = 5483**

## **CINAHL (Cumulative Index to Nursing and Allied Health Literature)**

### **DIETARY (A)**

1. (MH "Diet+") (33,062)
2. (MH "Diet Records") (3304)
3. (MH "Diet Therapy+") (10,432)
4. (MH "Nutrition+") or (MH "Nutrition Disorders+") or (MH "Nutrition Services+") or (MH "Nutritional Assessment") or (MH "Nutritional Counseling") or (MH "Nutritional Requirements+") or (MH "Nutritional Status") (80,466)
5. (MH "Nutrition Education") (3603)
6. (MH "Eating Behaviour+") (9299)
7. TI diet\* (16,159)
8. AB diet\* (20,894)
9. TI food\* (11,959)
10. AB food\* (15,241)
11. TI nutri\* (18,746)
12. AB nutri\* (21,060)
13. TI weigh\* (12,948)
14. AB weigh\* (36,173)
15. TI diet\* N3 behavio?r (43)
16. AB diet\* N3 behavio?r (89)

17. TI eat\* N3 behavio?r (51)
18. AB eat\* N3 behavio?r (126)
19. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18  
(A) – 157,321

### E (B)

20. (MH “Informatics+”) (256,420)
21. (MH “Telecommunications+”) (41,066)
22. (MH “Communications Media+”) (199,431)
23. (MH “Information Technology+”) (7671)
24. (MH “Educational Technology”) (542)
25. (MH “Access to Information+”) (8277)
26. Cybernetics (9)
27. (MH “Blogs”) (323)
28. (MH “Information Retrieval+”) (4719)
29. (MH “Digital Divide”) (28)
30. TI online (6176)
31. AB online (5278)
32. TI computer\* (9875)
33. AB computer\* (15,217)
34. TI world-wide-web or TI website\* (2051)
35. AB world-wide-web or AB website\* (2235)
36. TI blog\* or TI web-blog\* or TI weblog\* (401)
37. AB blog\* or AB web-blog\* or AB weblog\* (164)
38. TI bulletin board\* or TI bulletinboard\* or TI message board\* (939)
39. AB bulletin board\* or AB bulletinboard\* or AB message board\* (126)
40. TI interactive health communicat\* (9)
41. AB interactive health communicat\* (10)
42. TI interactive televis\* (30)
43. AB interactive televis\* (42)
44. TI interactive video (93)
45. AB interactive video\*–181)
46. TI interactive multimedia (62)
47. AB interactive multimedia (71)
48. TI surf\* or TI brows\* (3317)
49. AB surf\* or AB brows\* (13,219)
50. TI e-health or TI electronic –health (778)
51. AB e-health or AB electronic –health (538)
52. TI i-pod or TI i-phone (1)
53. TI inform\* kiosk\* (5)
54. AB inform\* kiosk\* (4)
55. TI short messaging service or TI sms or TI text message or TI txt message or TI txt (72)
56. AB short messaging service or AB sms or AB text message or AB txt message or AB txt (124)
57. TI multimedia messaging service or TI mms (9)
58. AB multimedia messaging service or AB mms (51)
59. 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or  
36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or  
52 or 53 or 54 or 55 or 56 or 57 or 58 (B) – 407,762
60. 19 (A) and 59 (B) – 33,791

### Study design (C)

61. (MH “Clinical Trials+”) (90,999)

62. (MH "Experimental Studies+") (112,471)
63. PT Clinical trial (51,222)
64. TX Randomized control\* trial\* (37,433)
65. AB randomly (20,411)
66. AB random assignment (387)
67. TX random\* allocat\* (335)
68. TX Placebo\* (38,380)
69. TX Allocat\* random\* (195)
70. 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 (C) – **162,068**
71. 60 (A + B) and 70 (C) – **6415**

### **Publication year (D)**

72. **A + B + C + D = 6409**

MH = exact subject heading; TI = title; AB = abstract; TX = all text; PT = publication type.

## **PsycINFO**

### **Dietary (A)**

1. exp nutrition/or exp "beverages (nonalcoholic)"/or exp diets/or exp food/or exp food additives/ (14,533)
2. exp eating behaviour/or exp binge eating/or exp eating attitudes/or exp eating disorders/or exp food intake/or exp mealtimes/ (32,159)
3. ((diet\* or eat\*) adj3 behav\*).ti,ab. (5469)
4. "nutri\*.ti,ab. (11,209)
5. "food\*.ti,ab. (41,203)
6. "diet\*.ti,ab. (18,939)
7. "weigh\*.ti,ab. (49,146)
8. **6 or 1 or 4 or 3 or 7 or 2 or 5 (117,495)**

### **E (B)**

9. exp internet/or exp communication systems/or exp information systems/or exp automated information processing/or exp computer applications/or exp computer mediated communication/or exp electronic communication/or exp online therapy/or exp telecommunications media/or exp telemedicine/or exp websites/or exp internet usage/ (62,091)
10. exp computer applications/or exp decision support systems/or exp electronic communication/or exp expert systems/or exp information science/or exp information technology/or exp intelligent agents/or exp knowledge management/or exp learning management systems/ (47,389)
11. exp human computer interaction/or exp virtual classrooms/or exp virtual teams/ (6943)
12. exp educational television/or exp educational audiovisual aids/or exp televised instruction/ (929)
13. exp computers/or exp artificial intelligence/or exp computer assisted design/or exp computer assisted therapy/or exp cybernetics/or exp databases/ (24,493)
14. exp computer games/or exp computer simulation/ (13,154)
15. exp communications media/ (29,968)
16. exp hypermedia/ (539)
17. computer\*.ti,ab. (51,993)
18. (email or e-mail).ti,ab. (2466)
19. online.ti,ab. (9993)

20. (World wide web or world-wide-web or world-wide web or website\* or www).ti,ab. (3291)
21. (E-health or ehealth or electronic health).ti,ab. (281)
22. "interactive health communicat\*".ti,ab. (28)
23. "interactive televis\*".ti,ab. (73)
24. "interactive video\*".ti,ab. (357)
25. "interactive technology\*".ti,ab. (48)
26. interactive multimedia.ti,ab. (182)
27. (surf or surf\* or browse or brows\*).ti,ab. (16,665)
28. (chat room\* or chatroom\*).ti,ab. (356)
29. (blog\* or web-blog\* or weblog\*).ti,ab. (301)
30. (bulletin board\* or bulletinboard\* or message board\* or message board\*).ti,ab. (329)
31. (DVD or dvd).ti,ab. (284)
32. (CD-ROM or cd-rom or CDROM or cdrom).ti,ab. (499)
33. (i-phone or iphone).ti,ab. (3)
34. (i-pod or ipod).ti,ab. (25)
35. (information kiosks or inform\*kiosk\*).ti,ab. (5)
36. (short messaging service or sms or text message or text\* message or txt).ti,ab. (453)
37. (multimedia messaging service or mms).ti,ab. (196)
38. virtual reality.ti,ab. (1451)
39. **35 or 11 or 32 or 33 or 21 or 26 or 17 or 22 or 18 or 30 or 13 or 16 or 23 or 29 or 27 or 25 or 28 or 36 or 9 or 12 or 14 or 15 or 20 or 34 or 37 or 24 or 10 or 19 or 31 or 37 or 38 (144,714)**
40. **8 (A) and 38 (B) (4991)**

### Study design (C)

41. exp placebo/ (2403)
42. exp treatment effectiveness evaluation/ (10,902)
43. exp experimental design/ (40,065)
44. exp prospective studies/ (302)
45. "clinical trial\*".ti,ab. (10815)
46. controlled clinical trial.ti,ab. (608)
47. randomi?ed controlled trial.ti,ab. (4094)
48. randomi?ed.ti,ab. (23,653)
49. placebo.ab. (22,179)
50. randomly.ab. (35,218)
51. trial.ti. (9995)
52. ((singl\* or doubl\* or trebl\* or tripl\*) adj3 (blind\* or dummy or mask\*)).ti,ab. (14,208)
53. ((crossover or clin\* or control\* or compar\* or evaluat\* or prospectiv\*) adj3 (trial\* or studi\* or study)).ti,ab. (106,973)
54. "exp\*".ti,ab. (1,062,801)
55. 50 or 53 or 51 or 41 or 47 or 48 or 42 or 52 or 49 or 46 or 45 or 43 or 44 or 54 (1,194,568)
56. exp animals/ (207,822)
57. exp human females/ (86,263)
58. exp human males/ (27,625)
59. 57 or 58 (107,294)
60. 56 not (57 and 58) (487)
61. **55 not 50 (1,194,324)**
62. **61 (C) and 40 (A+B) (2669)**

### Publication year (D)

63. ("1990" or "1991" or "1992" or "1993" or "1994" or "1995" or "1996" or "1997" or "1998" or "1999").yr. (629,371)

64. "200\*".yr. (977,563)
65. 63 or 64 (1,606,828)

### **A+B+C+D**

66. **62 (A+B+C) and 65 (D) = 2376**

## **EMBASE**

### **Dietary (A)**

1. exp food/or exp nutrition/ (1,182,412)
2. food\$.ti,ab. (174,537)
3. diet\$.ti,ab. (283,160)
4. nutri\$.ti,ab. (161,807)
5. weigh\$.ti,ab. (538,793)
6. (diet\$adj3 behav\$).ti,ab. (2185)
7. (eat\$adj3 behav\$).ti,ab. (3827)
8. (feed\$adj3 behav\$).ti,ab. (4802)
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 (A) – **1,782,850**

### **Electronics (B)**

10. exp information system/ (38,399)
11. exp computer/ (58,488)
12. exp internet/or exp mass communication/ (129,648)
13. exp cybernetics/ (772)
14. exp educational technology/ (1107)
15. exp audiovisual equipment/ (35,989)
16. exp information processing/ (448,408)
17. computer\$.ti,ab. (156,790)
18. online.ti,ab. (11,955)
19. (email or e-mail or electronic messag\$).ti,ab. (4055)
20. (World wide web or world-wide-web or world-wide web or website\$or www or internet connect\$).ti,ab. (5821)
21. interactive health communicat\$.ti,ab. (24)
22. interactive televis\$.ti,ab. (23)
23. interactive video\$.ti,ab. (207)
24. interactive technolog\$.ti,ab. (37)
25. interactive multimedia\$.ti,ab. (124)
26. (surf or surf\$or browse or brows\$).ti,ab. (535,139)
27. (chat room\$or chatroom\$).ti,ab. (140)
28. (blog\$or web-blog\$or weblog\$).ti,ab. (142)
29. (bulletin board\$or bulletinboard\$or message board\$or message board\$).ti,ab. (197)
30. (DVD or dvd or video disk\$).ti,ab. (336)
31. (CD-ROM or cd-rom or CDROM or cdrom).ti,ab. (677)
32. (iphone or i-phone).ti,ab. (5)
33. (ipod or i-pod).ti,ab. (32)
34. smartphone\$.ti,ab. (26)
35. inform\$kiosk\$.ti,ab. (4)
36. (short messaging service or sms or text message or text\$message or txt).ti,ab. (1978)
37. (multimedia messaging service or mms).ti,ab. (2318)
38. virtual reality.ti,ab. (1883)
39. second life.ti,ab. (40)

40. 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 37 (B) – 1,170,334
41. 9 (A) and 40 (B) – 120,361

### Study design (C)

42. exp clinical trial/ (583,349)
43. exp randomized controlled trial/ (178,474)
44. exp randomization/ (27,376)
45. exp single blind procedure/ (8733)
46. exp double blind procedure/ (79,416)
47. exp crossover procedure/ (22,265)
48. exp placebo/ (150,812)
49. randomi?ed controlled trial.ti,ab. (21,141)
50. rct.ti,ab. (3141)
51. random allocation.ti,ab. (729)
52. Randomly allocated.ti,ab. (10,942)
53. (allocated adj2 random).ti,ab. (723)
54. Single blind\$.ti,ab. (8123)
55. double blind\$.ti,ab. (97,446)
56. ((treble or triple) adj blind\$.ti,ab. (187)
57. placebo\$.ti,ab. (123,895)
58. exp prospective study/ (88391)
59. 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 (774,721)
60. exp case study/ (15,716)
61. case report.ti,ab. (150,170)
62. (abstract report or letter).mp. [mp = title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer name] (545,008)
63. 60 or 61 or 62 (708,316)
64. 59 not 63 (C) – 747,554

### Publication year (D)

65. (199\$or 200\$).yr. (9,112,286)

### A+B+C+D

66. 9(A) + 40(B) + 64(C) + 65(D) = 7843

## The Cochrane Library

### Dietary (A)

1. MeSH descriptor **Food and Beverages** explode all trees (16,529)
2. MeSH descriptor **Feeding Behaviour** explode tree 2 (2995)
3. MeSH descriptor **Nutrition Assessment** explode all trees (453)
4. MeSH descriptor **Food Labelling** explode all trees (21)
5. MeSH descriptor **Nutritional Requirements** explode all trees (408)
6. MeSH descriptor **Nutritional Status** explode all trees (1129)
7. diet\* or food\* nutri\* (25,028)
8. eat\* behavio?r (337)
9. weigh\* (35,289)
10. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 (A) – 57,374

**E (B)**

11. MeSH descriptor **Computing Methodologies** explode all trees (8032)
12. MeSH descriptor **Telecommunications** explode all trees (1969)
13. MeSH descriptor **Cybernetics** explode all trees (772)
14. MeSH descriptor **Informatics** explode all trees (49)
15. MeSH descriptor **Medical Informatics** explode all trees (6778)
16. MeSH descriptor **Educational Technology** explode all trees (1712)
17. MeSH descriptor **Audiovisual Aids** explode all trees (1697)
18. Computer\* (14,503)
19. email or e-mail (3660)
20. DVD or dvd (55)
21. online (7582)
22. "World wide web" (153)
23. website\* (1368)
24. "chat room\*" (5)
25. "chatroom\*" (2)
26. blog\* (44)
27. weblog\* (2)
28. "bulletin board\*" (15)
29. "bulletinboard\*" (2)
30. "message board\*" (5)
31. "interactive health communicat\*" (1)
32. "interactive television" (4)
33. "interactive video\*" (35)
34. "interactive technology" (11)
35. "interactive multimedia" (59)
36. "E-health" (149)
37. ehealth (30)
38. "electronic health" (39)
39. surf (18)
40. surf\* (10,603)
41. browse (263)
42. brows\* (285)
43. ipod (2)
44. i-pod (1)
45. "information kiosks" (2)
46. "short messaging service" (8)
47. sms (130)
48. "text message" (11)
49. "text\* message" (11)
50. txt (26)
51. MMS (93)
52. 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 **(B) – 41,997**

**A+B**

53. 10 (A) and 52 (B) – 8279

**Study design (C)**

54. (randomly):ab or (trial):ti or (randomized controlled trial):pt or (controlled clinical trial):pt or (randomized):ab (329,582)

55. (placebo):ab (74,750)
56. clinical trial as topic (20,978)
57. (animals not (humans and animals)):ti (131)
58. (56 or 57 or 58) (338,150)
59. 60 and not 59 (C) – **338,069**

### A+B+C

60. **10 (A) + 52 (B) + 59 (C) = 6448**

## Global health

### Dietary (A)

1. exp foods/ (96,400)
2. exp diet/or exp dietary guidelines/ (32,241)
3. exp nutrition/or exp nutrition information/or exp nutrition knowledge/or exp nutrition labeling/or exp nutrition planning/or exp nutrition research/or exp nutritional intervention/ (41,394)
4. “food\*”.ab,ti. (188,659)
5. “diet\*”.ab,ti. (229,658)
6. “nutri\*”.ab,ti. (137,958)
7. (diet adj3 behavio#r).ab,ti. (200)
8. (eat adj3 behavio#r).ab,ti. (5)
9. “weigh\*”.ab,ti. (173,600)
10. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 (A) – **566,683**

### E (B)

11. exp computers/or exp computer analysis/or exp computer assisted instruction/or exp computer graphics/or exp computer simulation/or exp computer software/or exp computer techniques/or exp electronics/or exp information systems/or exp information technology/ (6511)
12. exp telecommunications/ (1653)
13. exp mass media/ (1934)
14. exp information science/or exp information/or exp information needs/or exp information processing/or exp information services/ (33,902)
15. exp computer games/ (51)
16. exp cybernetics/ (5)
17. exp multimedia instruction/ (34)
18. exp educational technology/or exp educational innovation/or exp educational television/ (47)
19. (email or e-mail).ab,ti. (342)
20. “computer\*”.ab,ti. (9723)
21. online.ab,ti. (1308)
22. (World wide web or world-wide-web or world-wide web or website\$or internet\$).ab,ti. (2714)
23. (E-health or ehealth or electronic health).ab,ti. (110)
24. “interactive health communicat\*”.ab,ti. (3)
25. “interactive televis\*”.ab,ti. (3)
26. “interactive video\*”.ab,ti. (17)
27. “interactive tech\*”.ab,ti. (11)
28. “interactive multimedia\*”.ab,ti. (29)
29. (surf or surf\* or browse or brows\*).ab,ti. (66,004)

30. (chat room\* or chatroom\*).ab,ti. (32)
31. (blog\* or web-blog\* or weblog\*).ab,ti. (13)
32. (bulletin board\* or bulletinboard\* or message board\* or message board\*).ab,ti. (27)
33. (DVD or dvd).ab,ti. (37)
34. (CD-ROM or cd-rom or CDROM or cdrom).ab,ti. (165)
35. (i-pod or ipod).ab,ti. (1)
36. (information kiosks or inform\$kiosk\$).ab,ti. (1)
37. (short messaging service or sms or text message or text\$message or txt).ab,ti. (160)
38. (multimedia messaging service or mms).ab,ti. (99)
39. virtual reality.ab,ti. (24)
40. 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 **(B) – 116,166**
41. 10 (A) and 40 (B) – 25,317

### Study design (C)

42. exp trials/or exp experimental design/or exp experiments/or exp feasibility studies/ (19,683)
43. “clinical trial\*”.ab,ti. (14,110)
44. controlled clinical trial.ab,ti. (944)
45. randomi#ed controlled trial.ab,ti. (3778)
46. randomi#ed.ab,ti. (28,951)
47. trial.ti. (11,764)
48. ((crossover or clin\* or control\* or compar\* or evaluat\* or prospectiv\*) adj3 (trial\* or studi\* or study)).ab,ti. (127,130)
49. 42 or 46 or 45 or 43 or 44 or 47 or 48 **(C) – 146,517**
50. 41(A+B) and 49 (C) – 1742

### Publication year (D)

51. (199\* or 200\*).yr. (1,147,042)
52. **50 (A+B+C) and 51 (D) = 1447**

## Health Management Information Consortium

### Diet (A)

1. exp food/ (2267)
2. exp diet/or exp diet therapy/or exp dietary advice/or exp dietary intake studies/or exp meals/ or exp nutrients/or exp nutrition/or exp nutritional requirements/or exp nutritional value/ (2252)
3. diet\$.ab,ti. (1841)
4. food\$.ab,ti. (3322)
5. nutri\$.ab,ti. (1528)
6. weigh\$.ab,ti. (2463)
7. (eat\$adj3 behav\$).ab,ti. (56)
8. (diet\$adj3 behav\$).ab,ti. (72)
9. (eat\$adj3 habit\$).ab,ti. (68)
10. food habit\$.ab,ti. (6)
11. (eat\$adj3 disorder).ab,ti. (47)
12. **6 or 11 or 3 or 7 or 9 or 2 or 8 or 1 or 4 or 10 or 5 (9261)**

**E (B)**

13. exp information technology/or exp computer science/or exp computers/or exp expert systems/or exp information systems/or exp video discs/ (10,776)
14. exp telecommunications/or exp communication networks/ (1963)
15. exp communication media/ (859)
16. exp computer networks/ (1489)
17. exp online systems/ (332)
18. exp educational technology/ (13)
19. exp computer programs/ (127)
20. exp internet websites/ (536)
21. "computer\*".ab,ti. (4782)
22. (email or e-mail).ab,ti. (248)
23. online.ab,ti. (597)
24. (World wide web or world-wide-web or world-wide web or website\$or internet\$).ab,ti. (1723)
25. (E-health or ehealth or electronic health).ab,ti. (262)
26. interactive health communicat\$.ab,ti. (4)
27. interactive televis\$.ab,ti. (21)
28. interactive video\$.ab,ti. (31)
29. interactive technolog\$.ab,ti. (2)
30. interactive multimedia.ab,ti. (20)
31. (surf or surf\$or browse or brows\$).ab,ti. (449)
32. (chat room\$or chatroom\$).ab,ti. (10)
33. (blog\$or web-blog\$or weblog\$).ab,ti. (9)
34. (bulletin board\$or bulletinboard\$or message board\$or message board\$).ab,ti. (22)
35. (DVD or dvd).ab,ti. (14)
36. (CD-ROM or cd-rom or CDROM or cdrom).ab,ti. (123)
37. (information kiosks or inform\$kiosk\$).ab,ti. (16)
38. (short messaging service or sms or text message or text\$message or txt).ab,ti. (64)
39. (multimedia messaging service or mms).ab,ti. (3)
40. virtual reality.ab,ti. (34)
41. **35 or 32 or 33 or 21 or 26 or 17 or 22 or 18 or 30 or 13 or 16 or 23 or 29 or 27 or 25 or 39 or 28 or 40 or 36 or 14 or 15 or 20 or 38 or 34 or 24 or 37 or 19 or 31 (16,076)**
42. **12 (A) and 41 (B) = 281**

**Web of Science**

Search field	Diet (A)	Electronics (B)	Study design (C)	A+B+C
Title	diet* or nutri* or food* or diet* intake or food intake or diet* behavior?r or eat* behavior?r or weigh* or food habit* or eat* habit* or eat* disorder or obesity or overweight	computer* or internet* or online or 'e-health' or ehealth or web* or interactive* or 'communication systems' or 'information systems' or 'automated information processing' or 'computer applications' or 'computer mediated communication' or 'electronic communication' or 'online therapy' or 'educational audiovisual aids' or 'televised instruction' or 'artificial intelligence' or 'computer assisted design' or 'computer assisted therapy' or cybernetics or 'computer games' or 'computer simulation' or 'communications media' or hypermedia or multimedia	experiment* or trial* or randomi\$ed or evaluat* or prospect* or comparat* or crossover or random* or 'clinical trial'	222

## Health Economic Evaluations Database

Search field	Diet (A)	Electronics (B)	A + B
<b>Abstract</b>	diet* or nutri* or food* or 'diet intake' within 3 or 'food intake' or 'diet behaviour' within 3 or 'eat behaviour' within 3 or weigh* or 'food habit' or 'eat habit' within 3 or 'eat disorder' within 3 or obesity or overweight	computer* or internet* or online or 'e-health' or ehealth or web* or interactive* or 'communication systems' or 'information systems' or 'online therapy' or 'televised instruction' or 'artificial intelligence' or cybernetics or 'computer games' within 4 or 'computer simulation' within 4 or 'communications media' or hypermedia or multimedia	18

## Education Resources Information Centre (1990–2009)

Search field	Diet (A)	Electronics (B)	Study design (C)	A + B + C
<b>Thesaurus descriptors</b>	'Nutrition' OR 'Nutrition Instruction' OR food OR 'food habits'	computer OR internet OR online		2990
<b>Title</b>	food* OR nutri* OR weigh*	e-health OR ehealth OR 'electronic health' OR surf OR surf* OR browse OR brows* OR ipod OR i-pod OR 'information kiosks' OR 'short messaging service' OR sms OR 'educational technology' OR 'audiovisual aids' OR email OR e-mail OR 'interactive health communication' OR 'interactive video' OR 'web based' OR website OR 'world wide web' OR 'interactive television' OR 'interactive multimedia' OR computer* OR Internet OR online	'experimental design' OR 'prospective studies' OR 'clinical trial' OR 'controlled clinical trial' OR 'randomised controlled trial' OR 'randomised controlled trial' OR random* OR trial OR 'crossover trial' OR 'comparative trial' OR 'comparative study' OR 'evaluative trial' OR 'evaluative study' OR 'prospective trial' OR 'prospective study'	

## Dissertation abstracts

Diet (A)	Electronics (B)	Study design I (C1)	Study design II (C2)	A + B + C1	A + B + C2
diet or nutrition or food or diet* or eat* or nutri* or weigh*	computer* or online or internet or telecommunications or cybernetics or medical informatics	(experimental design OR prospective studies OR clinical trial* OR (controlled clinical trial) OR (randomi?ed controlled trial) OR randomi?ed OR random* OR trial)	((crossover or clin* or control* or compar* or evaluat* or prospectiv*) W/3 (trial* or studi* or study))	659	303
	e-health or ehealth or 'electronic health' or surf or surf* or browse or brows*			561	489
	ipod or i-pod or 'information kiosks' or 'short messaging service' or sms			27	11
	'educational technology' or 'audiovisual aids' or email or e-mail or DVD or CD-ROM or chatroom or blog or weblog*			17	16
	'interactive health communicat*' or 'interactive video*' OR interactive television or interactive multimedia			8	2
	web-based or website or 'world wide web'			25	18
TOTAL				1296	839
TOTAL = (A + B + C1) + (A + B + C2)				2136	

# Appendix 3

## Screening form

### 1. Design

Is this a randomised controlled trial, evaluating the effectiveness of an intervention?	No	Yes	?
	Go to 5	Go to 2	Go to 2

*Note: Exclude (but read for background and check reference list) any systematic or non-systematic reviews of interventions, and any non-RCT evaluations of e-learning interventions.*

### 2. Participants

Are participants adults or adolescents aged 13 years and above?	No	Yes	?
	Go to 5	Go to 3	Go to 3

*Note: Interventions may be targeted to populations as a preventative measure, or to populations with clinical conditions for management of these conditions. Interventions may be targeted to individuals or their carers.*

### 3. Intervention(s)

Does the intervention seek to change behaviour through interactive software programs, delivered through electronic media, which tailor output according to user input?	No	Yes	?
	Go to 5	Go to 4	Go to 4

*Note: Users may interact with the programme as members of a group or as individuals, but may not require expert facilitation. Multi-component interventions including other outcomes (e.g. physical activity) will be included only if the dietary component can be isolated.*

### 4. Outcomes

Does the study include any of the following as outcomes: dietary behaviour; food consumption; energy intake; nutrient or dietary fibre consumption; BMI; blood lipid levels; plasma vitamin or mineral levels or biomarkers of these; or a combination of these outcomes?	No	Yes	?
	Go to 5	Go to 5	Go to 5

## 5. Decisions

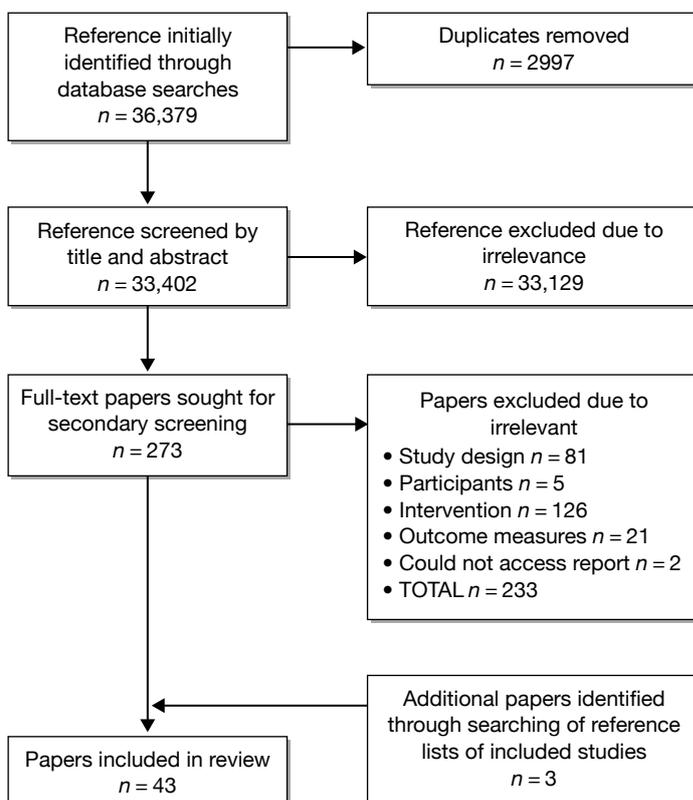
If all 1–4 'Yes'	Paper to be included. Data extraction form to be completed. Paper and form to be filed on computer.
If any 1–4 'No'	Paper to be excluded. Reasons for exclusion to be entered on 'exclusion' database. Paper to be filed on computer.
If any 1–4 '?'	Reviewer 1 and 2 (and if necessary 3) to reach consensus; include/exclude as above.
Possible background papers	Reference lists to be checked. Paper to be filed on computer for reference.

## 6. References

Reference list checked?	Yes	No
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## Appendix 4

### PRISMA flow diagram





## Appendix 5

### Bibliography of included studies

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4. Beasley JM, Riley WT, Davis A, Singh J. Evaluation of a PDA-based dietary assessment and intervention program: a randomized controlled trial. *J Am Coll Nutr* 2008;**27**:280–6.
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## Appendix 6

### List of excluded studies

**TABLE 28** Reasons for exclusion of potentially eligible studies

Author and year	Not an RCT evaluation of an intervention <sup>a</sup>	Participants not adults or adolescents > 13 years old	Intervention does not seek to change behaviour exclusively through adaptive e-learning <sup>b</sup>	Study does not include dietary behaviour outcomes	<sup>a</sup> Data reported elsewhere (this is a dissertation or earlier paper)	<sup>b</sup> E-learning intervention, but involves significant contact with a therapist	Could not access the report
Abood 2008			✓				
Adachi 2004	✓						
Adachi 2007			✓				
Adachi 2009	✓						
Adams 2002	✓				✓		
Anhoj 2004	✓						
Armitage 2001			✓				
Arsand 2008	✓						
Artal 2007			✓				
Ashfield-Watt 2002			✓				
Atienza 2008			✓				
Ayala 2002			✓				
Ayala 2006			✓				
Babazono 2007			✓				
Balas 1997	✓						
Bara-Carril 2004	✓						
Baranowski 2003		✓					
Baranowski 2003		✓					
Barkley 2003			✓				
Bauer 2009	✓						
Bechtel-Blackwell 2002			✓				
Bemelmans 2000			✓				
Bennett 2000	✓						
Bergh 2002			✓				
Biagioli 2007	✓						
Blissmer 2006			✓				
Block 2004	✓						
Block 2008				✓			
Bobroff 2003			✓				
Boeckner 1999	✓						
Bond 2007			✓				
Booth 2008			✓				
Booth 2008			✓				

*continued*

**TABLE 28** Reasons for exclusion of potentially eligible studies (*continued*)

Author and year	Not an RCT evaluation of an intervention <sup>a</sup>	Participants not adults or adolescents > 13 years old	Intervention does not seek to change behaviour exclusively through adaptive e-learning <sup>b</sup>	Study does not include dietary behaviour outcomes	<sup>a</sup> Data reported elsewhere (this is a dissertation or earlier paper)	<sup>b</sup> E-learning intervention, but involves significant contact with a therapist	Could not access the report
Brantley 2008	✓						
Brotherton 2007	✓						
Brown 1995			✓				
Brown 1997				✓			
Brug 1996			✓				
Brug 1998			✓				
Brug 1999	✓						
Brug 1999	✓						
Bruning Brown 2004			✓				
Burden 2000			✓				
Burgess-Champouit 2007	✓						
Burnett 1992	✓						
Calfas 2002			✓				
Campbell 1992	✓				✓		
Campbell 1994			✓				
Campbell 1999			✓				
Campbell 1999			✓				
Campbell 1999	✓						
Campbell 2002			✓				
Campbell 2004	✓						
Carlton 2000	✓						
Carpenter 2004			✓				
Carroll 1996	✓						
Carroll 2007			✓				
Casazza 2006	✓						
Casazza 2007	✓						
Celio 2000			✓				
Celio 2002	✓						
Celio 2005	✓						
Cheskin 2008	✓						
Christian 2008			✓				
Clark 1997			✓			✓	
Consoli 1994			✓				
Consoli 1995			✓				
Cook 2007			✓				
Cousineau 2005	✓						
Cousineau 2008	✓						
Coü 1998			✓				
Cullen 2008	✓						
Dalziel 2007	✓						
Dayton 2008			✓				
De Bar 2006			✓				

**TABLE 28** Reasons for exclusion of potentially eligible studies (*continued*)

Author and year	Not an RCT evaluation of an intervention <sup>a</sup>	Participants not adults or adolescents > 13 years old	Intervention does not seek to change behaviour exclusively through adaptive e-learning <sup>b</sup>	Study does not include dietary behaviour outcomes	<sup>a</sup> Data reported elsewhere (this is a dissertation or earlier paper)	<sup>b</sup> E-learning intervention, but involves significant contact with a therapist	Could not access the report
De Bar 2009	✓				✓		
Dennison 1996	✓						
de Vet 2008			✓				
de Vries 2008			✓				
Dolhanty 2006			✓			✓	
Doyle 2008			✓				
Dutton 1995	✓				✓		
Dzator 2004			✓				
Dzator 2005	✓				✓		
Eakin 2008	✓						
Eck 2005	✓						
Estabrooks 2005			✓			✓	
Estabrooks 2008			✓				
Estabrooks 2009	✓						
Evers 2007	✓						
Ezendam 2007	✓						
Fernandez-Aranada 2009			✓			✓	
Fitzgibbon 1995							✓
Franko 2005			✓				
Frenn 2005	✓						
Friedman 1998	✓						
Gabriele 2009			✓			✓	
Gadd 2000				✓			
Gans 2009			✓				
Glanz 2006	✓						
Glasgow 1995			✓			✓	
Glasgow 1996			✓			✓	
Glasgow 1997			✓			✓	
Glasgow 2002			✓				
Glasgow 2003			✓				
Glasgow 2006			✓				
Glasgow 2006			✓				
Glasgow 2007	✓						
Gold 2007			✓			✓	
Gollings 2006			✓				
Gould 2000	✓						
Goulis 2004			✓				
Greene 2008			✓				
Greenway 2005			✓				
Haerans 2006			✓				
Haerens 2006			✓				

*continued*

**TABLE 28** Reasons for exclusion of potentially eligible studies (*continued*)

Author and year	Not an RCT evaluation of an intervention <sup>a</sup>	Participants not adults or adolescents > 13 years old	Intervention does not seek to change behaviour exclusively through adaptive e-learning <sup>b</sup>	Study does not include dietary behaviour outcomes	<sup>a</sup> Data reported elsewhere (this is a dissertation or earlier paper)	<sup>b</sup> E-learning intervention, but involves significant contact with a therapist	Could not access the report
Haerens 2007			✓				
Haerens 2007			✓				
Harvard Health Letter	✓						
Harvey Berino 2002			✓			✓	
Harvey-Berino 1998			✓				
Harvey-Berino 2004			✓			✓	
Havas 1998			✓				
Heidal 2006	✓						
Heinicke 2007			✓			✓	
Herrejon 2009				✓			
Horowitz 2005	✓						
Hung 2008	✓						
Hunter 2005	✓				✓		
Hunter 2008			✓			✓	
Jacobi 2005							✓
Jacobi 2008	✓						
Jacobs 2002			✓				
Johnson 2008			✓				
Jones 2002			✓				
Kalten 2000	✓						
Kelders 2009	✓						
Kennedy 2008			✓				
Kerksick 2009			✓				
Kershaw 2001	✓						
Kim 2005			✓				
Kirk 2003	✓						
Kroeze 2008			✓				
Kroeze 2008	✓						
Kuhlmann 2008	✓						
Kypri 2005	✓						
Leefeldt 2007				✓			
Lindsay 2008			✓				
Lindsay 2009			✓				
Ljotsson 2007			✓				
Lutz 1996			✓				
Maddison 2009	✓						
McConnon 2007			✓				
McDoniel 2008			✓				
McDoniel 2009			✓				
McHugh 2008	✓						
McKay 2002			✓				
McVey 2009			✓				
Meyer 2004				✓			

**TABLE 28** Reasons for exclusion of potentially eligible studies (*continued*)

Author and year	Not an RCT evaluation of an intervention <sup>a</sup>	Participants not adults or adolescents > 13 years old	Intervention does not seek to change behaviour exclusively through adaptive e-learning <sup>b</sup>	Study does not include dietary behaviour outcomes	<sup>a</sup> Data reported elsewhere (this is a dissertation or earlier paper)	<sup>b</sup> E-learning intervention, but involves significant contact with a therapist	Could not access the report
Mhurchu 2007			✓				
Micco 2007			✓			✓	
Miller 2007	✓						
Mitchell 2003	✓						
Mitchell 2008			✓			✓	
Mobley 2006			✓			✓	
Moore 2009		✓					
Morgan 2009			✓			✓	
Murdy 2003			✓			✓	
Nevonen 2006			✓			✓	
Oenema 2003				✓			
Park 2008				✓			
Park 2009	✓						
Paūton 2007			✓			✓	
Peng 2009				✓			
Plotnikoff 2005			✓				
Polzien 2005			✓			✓	
Polzien 2007			✓			✓	
Prochaska 2002		✓					
Prochaska 2004			✓			✓	
Prochaska 2005				✓			
Pullen 2008			✓				
Raats 1999			✓				
Robertson 2007	✓						
Rubens 2006			✓			✓	
Rubens 2006			✓			✓	
Ruiter 2006				✓			
Schinke 1994				✓			
Schmidt 2006			✓				
Schmidt 2008			✓				
Schulz 2009	✓						
Shapiro 2008		✓					
Sheldon 1996	✓						
Sigrist 2004				✓			
Silk 2008				✓			
Smeets 2007				✓			
Stevens 2002			✓			✓	
Stevens 2008	✓						
Struempfer 2002	✓						
Tate 2001			✓			✓	
Tate 2003			✓				
Tate 2003	✓						

*continued*

**TABLE 28** Reasons for exclusion of potentially eligible studies (*continued*)

Author and year	Not an RCT evaluation of an intervention <sup>a</sup>	Participants not adults or adolescents > 13 years old	Intervention does not seek to change behaviour exclusively through adaptive e-learning <sup>b</sup>	Study does not include dietary behaviour outcomes	<sup>a</sup> Data reported elsewhere (this is a dissertation or earlier paper)	<sup>b</sup> E-learning intervention, but involves significant contact with a therapist	Could not access the report
Taylor 1991			✓				
Trepka 2008				✓			
Tsang 2001			✓				
Tsorbazoudis 2005			✓				
Turner-McGrievy 2009			✓				
Turner-McGrievy 2009			✓				
Turnin 1994	✓						
Turnin 1995	✓						
Ueki 2009			✓			✓	
Ueland 2009			✓				
van Assema 2006	✓						
Vandelanotte 2004	✓				✓		
Vandelanotte 2005	✓				✓		
Vandelanotte 2008	✓				✓		
Volker 2008	✓						
Wangberg 2007				✓			
Webber 2008	✓						
White 2003	✓				✓		
White 2004			✓			✓	
Williamson 2003			✓				
Williamson 2005			✓			✓	
Williamson 2006			✓			✓	
Winett 1999	✓						
Wing 2006			✓				
Winzelberg 1998			✓			✓	
Winzelberg 1999			✓				
Winzelberg 2000				✓			
Womble 2004			✓				
Yang 2004			✓			✓	
Zabinski 2001				✓			
Zabinski 2004			✓			✓	
Zabinski 2008	✓						
<b>TOTAL</b>	<b>81</b>	<b>5</b>	<b>126</b>	<b>19</b>	<b>10</b>	<b>34</b>	<b>2</b>

## Appendix 7

### Additional analysis of effectiveness

This appendix includes additional analyses of outcomes, including assessment of evidence for publication bias and evidence for subgroup effects.

Table 29 presents an assessment of statistical heterogeneity in the results for outcomes reported in the included studies. The chi-squared test  $p$ -value quantifies the evidence against the null hypothesis of homogeneity (similarity) of effects estimated by the trials.  $I$ -squared (derived from the chi-squared statistic and degrees of freedom) quantifies the percentage of total variation

**TABLE 29** Heterogeneity in effects on outcomes

Outcomes	Studies	Difference in means		Difference in mean change	
		$\chi^2$ $Q$ (df), $p$ -value	$I^2$	$\chi^2$ $Q$ (df), $p$ -value	$I^2$
<b><i>Fruit and vegetables</i></b>					
Fruit and vegetables (servings per day)	15	66.3 (11), $p < 0.001$	83.4%	–	–
Fruit (servings per day)	4	2.8 (1), $p = 0.09$	64.9%	–	–
Vegetables (servings per day)	4	1.6 (1), $p = 0.20$	38.0%	–	–
<b><i>Fats</i></b>					
Total fat (g/day)	14	15.2 (11), $p = 0.18$	27.5%	–	–
Saturated fat (g/day)	7	18.3 (4), $p = 0.001$	78.1%	–	–
% energy from fat	13	39.4 (9), $p < 0.001$	77.2%	5.9 (1), $p = 0.015$	83.1%
% energy from saturated fat	2	2.2 (1), $p = 0.13$	55.6%	–	–
Whole-fat dairy (g/day)	2	<i>No SD</i>	–	<i>No SD</i>	–
% body fat	1	–	–	–	–
Poly-unsaturated fatty acid (g/day)	1	–	–	–	–
Mono-unsaturated fatty acid (g/day)	1	–	–	–	–
Trans fats (unsaturated fat) (g/day)	1	–	–	–	–
<b><i>Fibre, proteins, sugars</i></b>					
Dietary fibre (g/day)	5	2.49 (1), $p = 0.11$	59.9%	–	–
Wholegrain cereals (g/day)	3	<i>No SD</i>	–	<i>No SD</i>	–
Red/processed meat (servings per day)	1	<i>No SD</i>	–	<i>No SD</i>	–
Protein (% of caloric intake)	2	0.21 (1), $p = 0.64$	0.0%	–	–
Carbohydrate (% of caloric intake)	2	11.8 (1), $p = 0.001$	91.5%	–	–
Saccharose (%)	1	–	–	–	–
Added sugars (g/day)	1	–	–	–	–
Glucose (mmol/l)	1	–	–	–	–
Fructosamine (%)	1	–	–	–	–
<b><i>Energy</i></b>					
Energy (kcal)	9	4.6 (4), $p = 0.33$	12.8%	19.7 (2), $p < 0.001$	89.9%
Caloric excess (kcal)	1	–	–	–	–

*continued*

**TABLE 29** Heterogeneity in effects on outcomes (*continued*)

Outcomes	Studies	Difference in means		Difference in mean change	
		$\chi^2$ Q (df), p-value	$I^2$	$\chi^2$ Q (df), p-value	$I^2$
<b>Weight</b>					
BMI (kg/m <sup>2</sup> )	12	3.2 (8), $p=0.92$	0.0%	6.5 (2), $p=0.039$	69.2%
BMI z-score	1	–	–	–	–
Weight (kg)	9	22.1 (3), $p<0.001$	86.4%	30.8 (2), $p<0.001$	93.5%
% of baseline weight loss	1	–	–	–	–
Waist circumference (cm)	1	–	–	–	–
<b>Blood pressure</b>					
Systolic blood pressure (mmHg)	2	–	–	2.3 (1), $p=0.13$	57.1%
Diastolic blood pressure (mmHg)	2	–	–	0.36 (1), $p=0.55$	0.0%
<b>Lipids, lipoproteins, etc.</b>					
LDL (mmol/l)	3	–	–	0.14 (1), $p=0.70$	0.0%
HDL (mmol/l)	3	–	–	0.02 (1), $p=0.89$	0.0%
HDL2 (mmol/l)	1	–	–	–	–
Total cholesterol (mmol/l)	3	–	–	8.1 (1), $p=0.004$	87.6%
Triglycerides (mmol/l)	3	–	–	0.03 (1), $p=0.87$	0.0%
HbA <sub>1c</sub> (%)	1	–	–	–	–
Insulin ( $\mu$ U/ml)	1	–	–	–	–

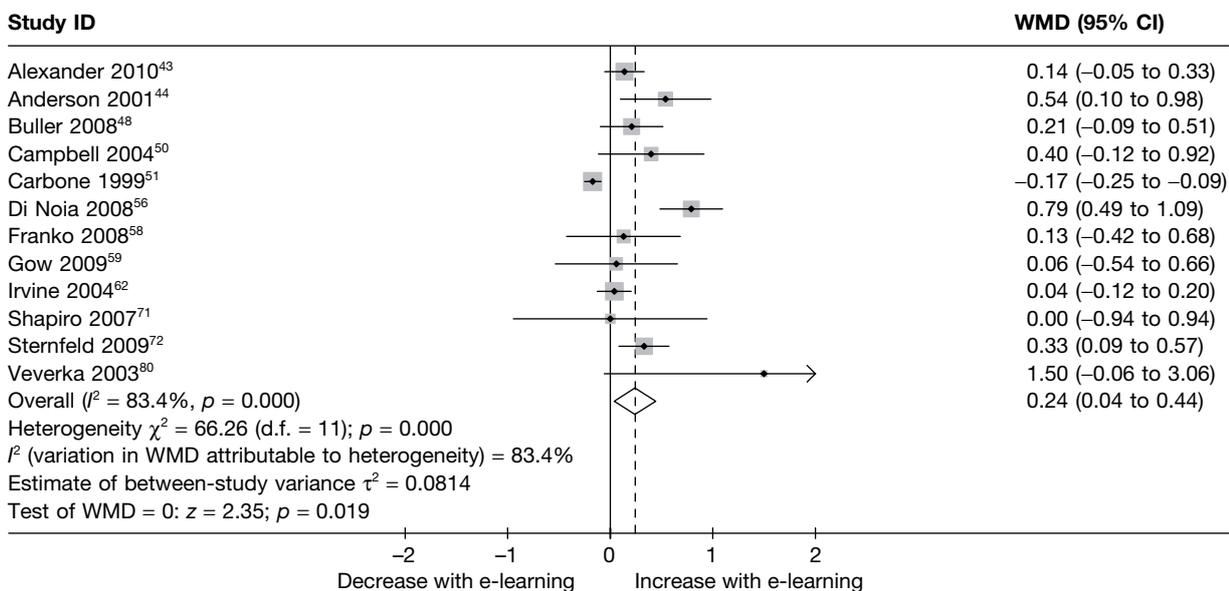
df, degrees of freedom; HbA<sub>1c</sub>, glycated haemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

in effects attributable to heterogeneity. The assessment of heterogeneity is shown in separate columns according to whether or not outcome measures were reported as means or as a mean change. Heterogeneity is not quantified for some outcomes for which the study reports did not provide SDs (and it was not possible to obtain these from authors), and for which an outcome was reported by a single study only.

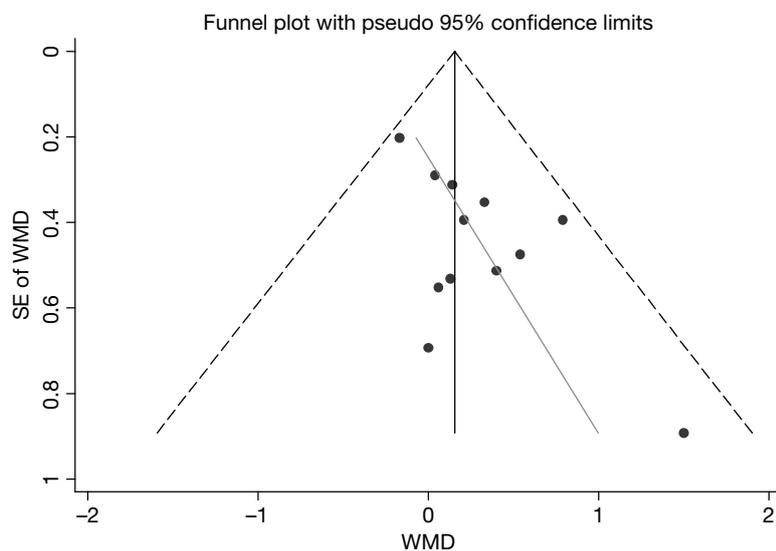
There was substantial heterogeneity (i.e.  $I^2 > 50\%$ ) in the estimates of effect of e-learning interventions on many reported outcomes. There was relatively little evidence for heterogeneity in the estimates of effect of e-learning on total fat intake per day ( $p=0.18$  and  $I^2=28\%$ ), energy intake per day ( $p=0.33$  and  $I^2=13\%$ ) and BMI ( $p=0.92$  and  $I^2=0\%$ ).

## Fruit and vegetables

Figures 15–18 show analyses of estimates of effect on fruit and vegetables, fruit only and vegetables only.



**FIGURE 15** Forest plot showing the effect of e-learning on the mean intake of fruit and vegetables (servings per day).



**FIGURE 16** Funnel plot showing estimates of the effect of e-learning on the mean intake of fruit and vegetables (servings per day).

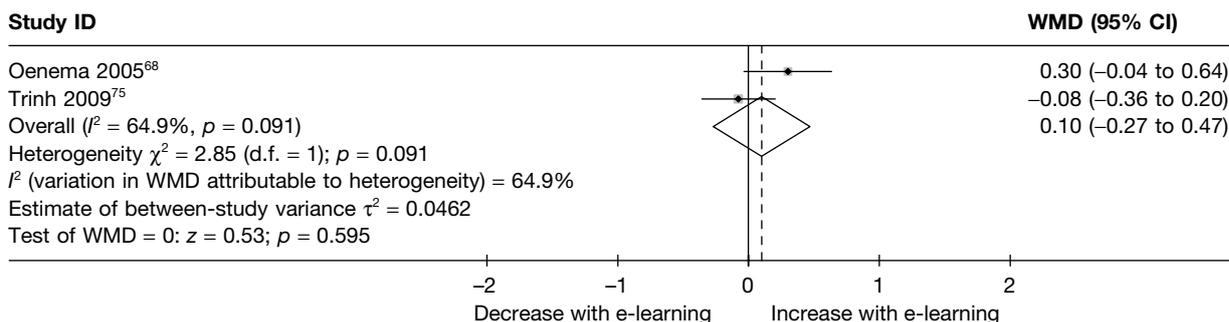


FIGURE 17 Forest plot showing the effect of e-learning on the mean intake of fruit (servings per day).

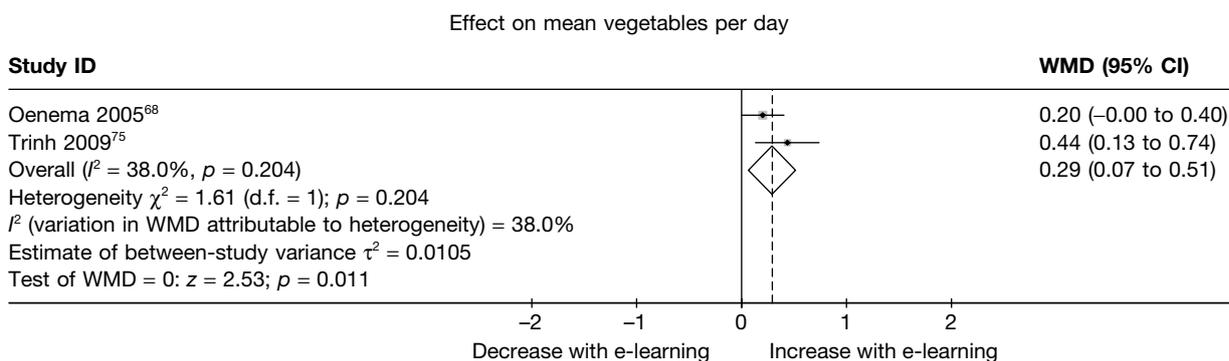


FIGURE 18 Forest plot showing the effect of e-learning on the mean intake of vegetables (servings per day).

Egger’s test for small-study effects:

Number of studies = 12, root MSE = 1.781

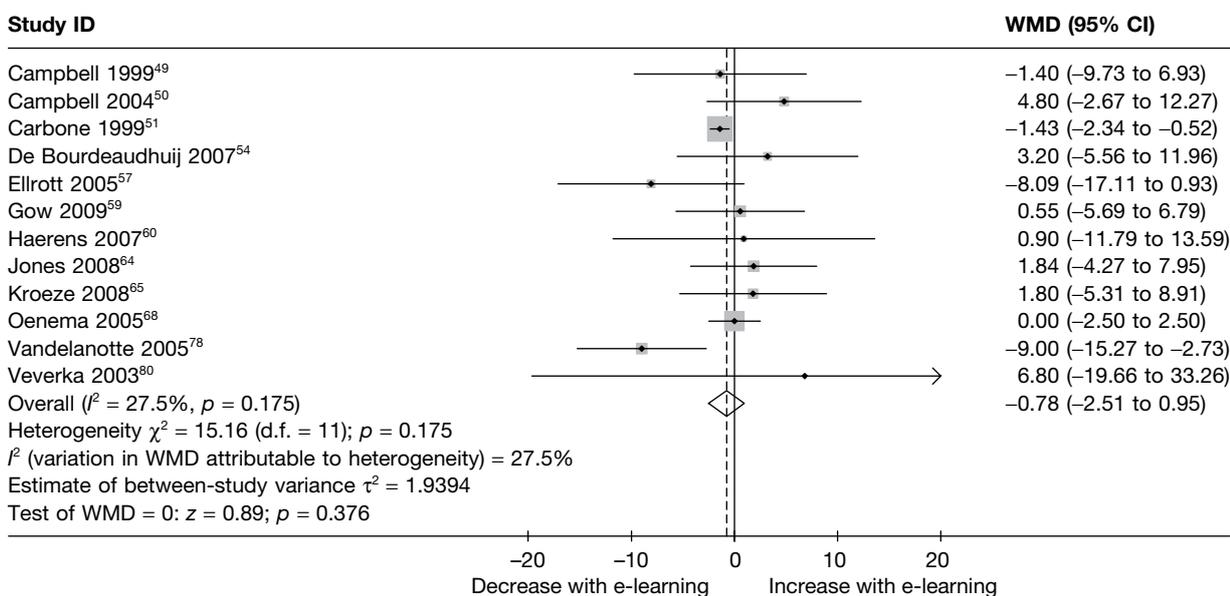
Std_Eff	Coef.	SE	t	p >  t	(95% CI)	
Slope	-.2111621	.0847431	-2.49	0.032	-.3999816	-.0223426
Bias	2.616964	.7948991	3.29	0.008	.8458188	4.38811

H0, null hypothesis; MSE, mean squared error.  
 Test of H0: no small-study effects  $p = 0.008$ .

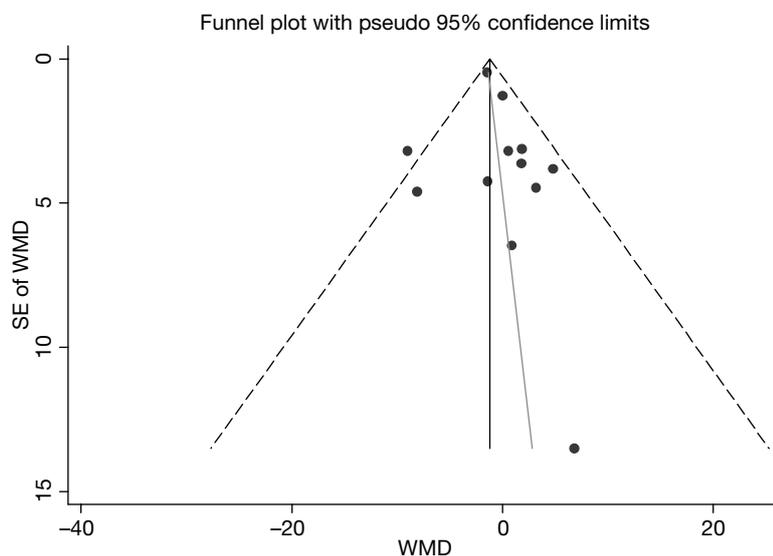
Figure 16 shows the estimates of effect of e-learning on mean intake of fruit and vegetables (servings per day) plotted against their standard errors. Smaller studies are associated with a larger treatment effect (i.e. larger increase in servings of fruit and vegetables per day,  $p = 0.008$ ).

## Fats

Figures 19–26 show analyses of estimates of effect on total fat, saturated fat and percentage of energy from fat.



**FIGURE 19** Forest plot showing the effect of e-learning on the mean intake of fat (g/day).



**FIGURE 20** Funnel plot showing estimates of the effect of e-learning on the mean intake of fat (g/day).

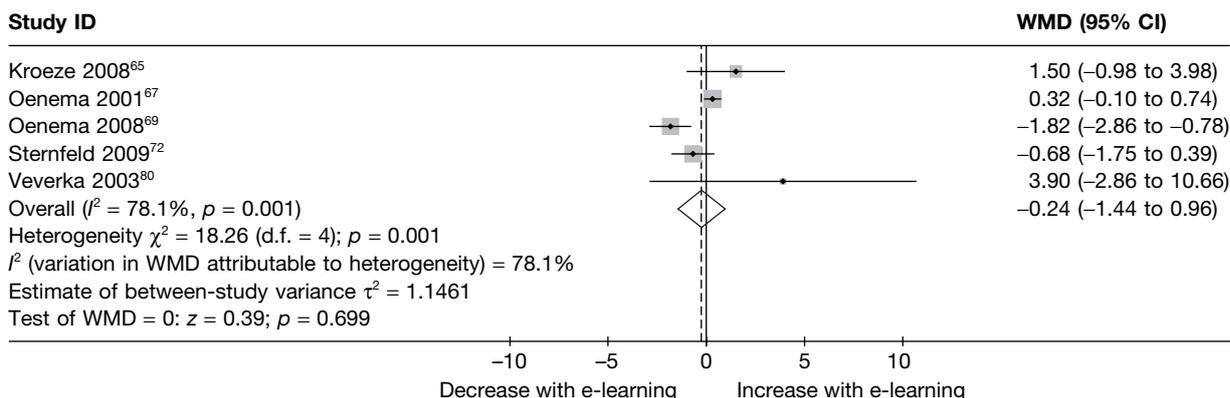


FIGURE 21 Forest plot showing the effect of e-learning on the mean intake of saturated fat (g/day).

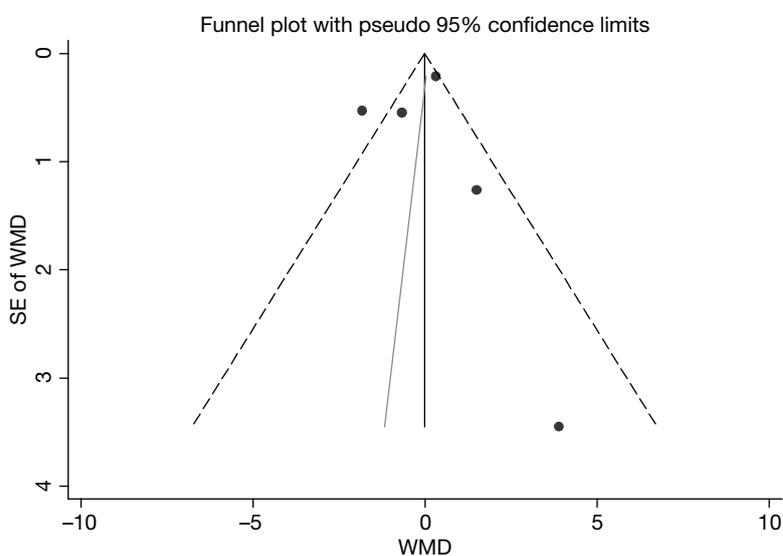


FIGURE 22 Funnel plot showing estimates of the effect of e-learning on the mean intake of saturated fat (g/day).

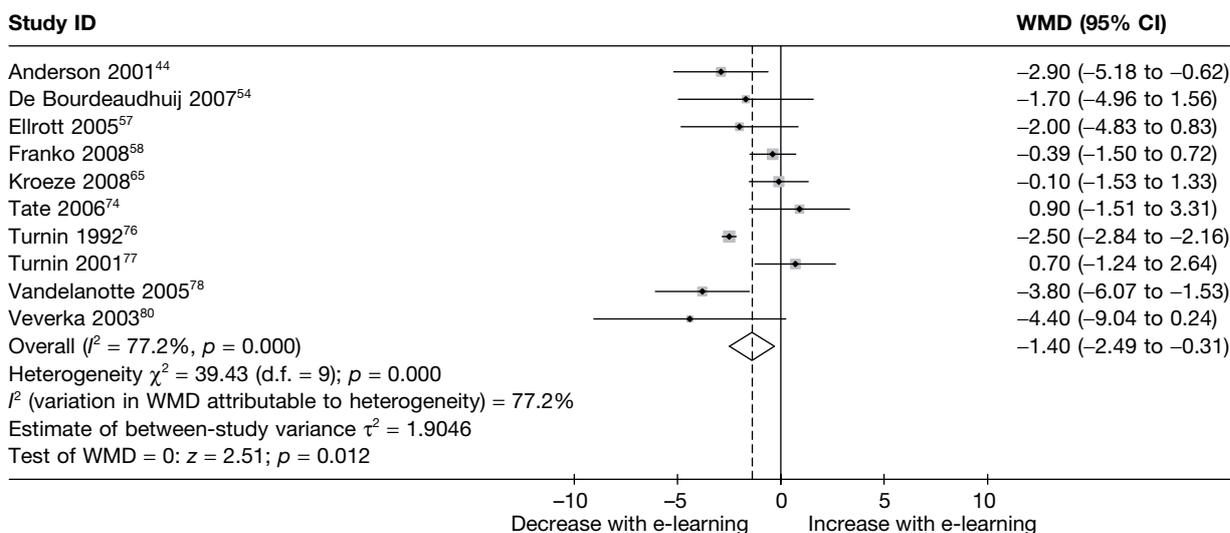
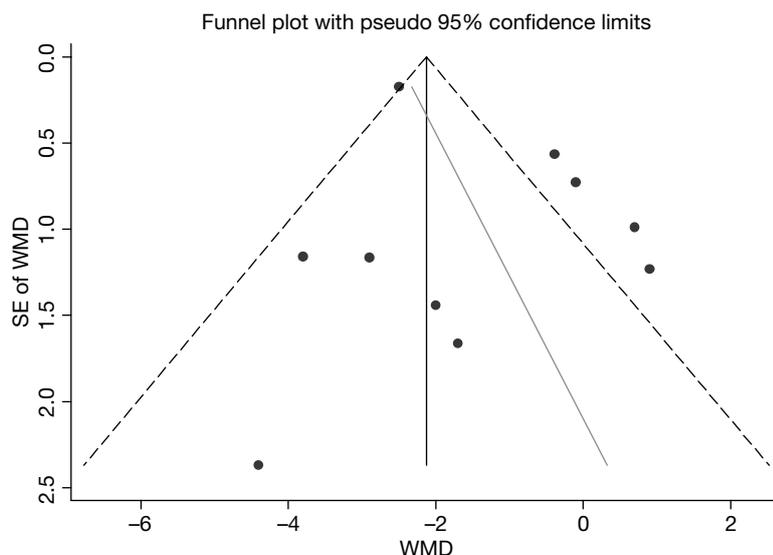
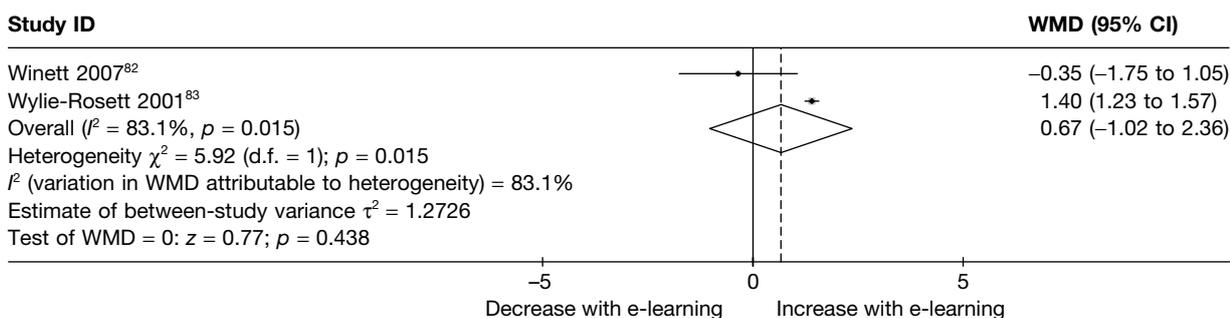


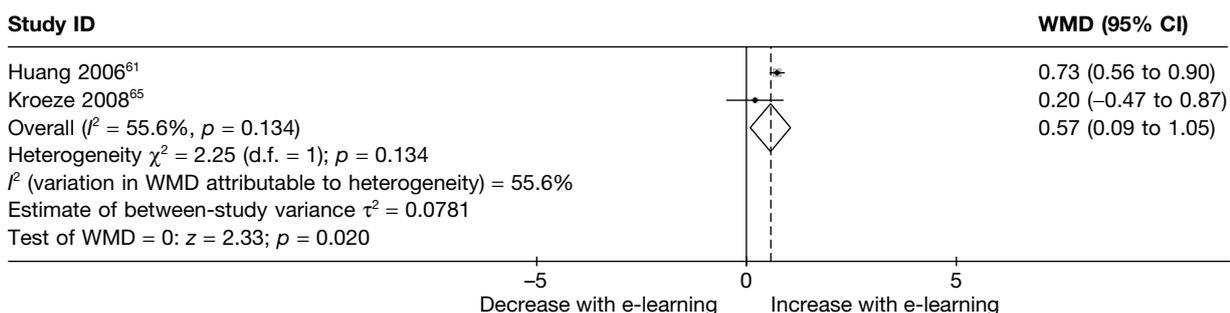
FIGURE 23 Forest plot showing effect of e-learning on mean percentage of energy from fat (%).



**FIGURE 24** Funnel plot showing estimates of the effect of e-learning on the mean percentage of energy from fat.



**FIGURE 25** Forest plot showing the effect of e-learning on the mean change in percentage of energy from fat (%).



**FIGURE 26** Forest plot showing the effect of e-learning on the mean percentage of energy from saturated fat (%).

## Egger's test for small-study effects:

Regress standard normal deviate of intervention

Effect estimate against its SE

Number of studies = 12, root MSE = 1.202

Std_Eff	Coef.	SE	t	p> t	(95% CI)	
Slope	-1.485873	.6410574	-2.32	0.043	-2.914238	-.0575083
Bias	.3176107	.4487315	0.71	0.495	-.6822255	1.317447

HO, null hypothesis; MSE, mean squared error.

Test of HO: no small-study effects  $p=0.495$ .

Figure 20 shows the estimates of effect of e-learning on mean intake of fat (g/day) plotted against their standard errors. There was no evidence that smaller studies are associated with a larger or smaller treatment effect ( $p=0.495$ ).

## Egger's test for small-study effects:

Regress standard normal deviate of intervention

Effect estimate against its SE

Number of studies = 5, root MSE = 2.449

Std_Eff	Coef.	SE	t	p> t	(95% CI)	
Slope	.1064684	.7148023	0.15	0.891	-2.168352	2.381288
Bias	-.3716999	1.744761	-0.21	0.845	-5.924307	5.180907

HO, null hypothesis; MSE, mean squared error.

Test of HO: no small-study effects  $p=0.845$ .

Figure 22 shows the estimates of effect of e-learning on the mean intake of saturated fat (g/day) plotted against their standard errors. There was no evidence that smaller studies are associated with a larger or smaller treatment effect ( $p=0.84$ ).

## Egger's test for small-study effects:

Regress standard normal deviate of intervention

Effect estimate against its SE

Number of studies = 10, root MSE = 1.994

Std_Eff	Coef.	SE	t	p> t	(95% CI)	
Slope	-2.535416	.4271861	-5.94	0.000	-3.520509	-1.550323
Bias	1.207866	.8719168	1.39	0.203	-.8027776	3.21851

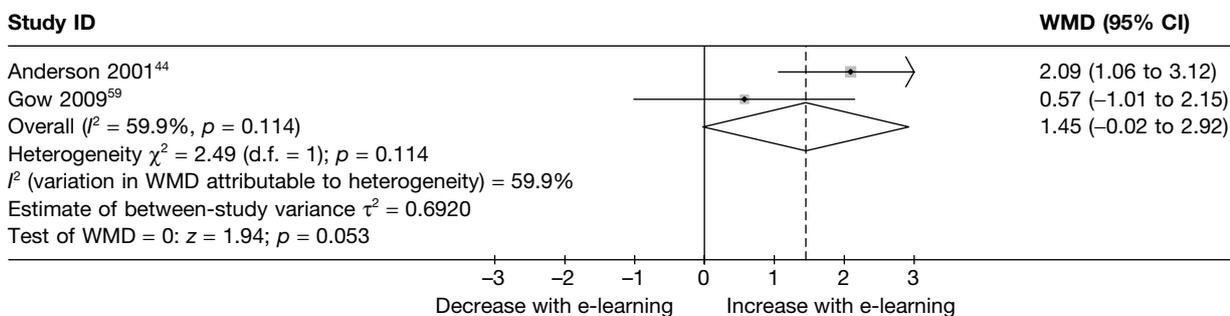
HO, null hypothesis; MSE, mean squared error.

Test of HO: no small-study effects  $p=0.203$ .

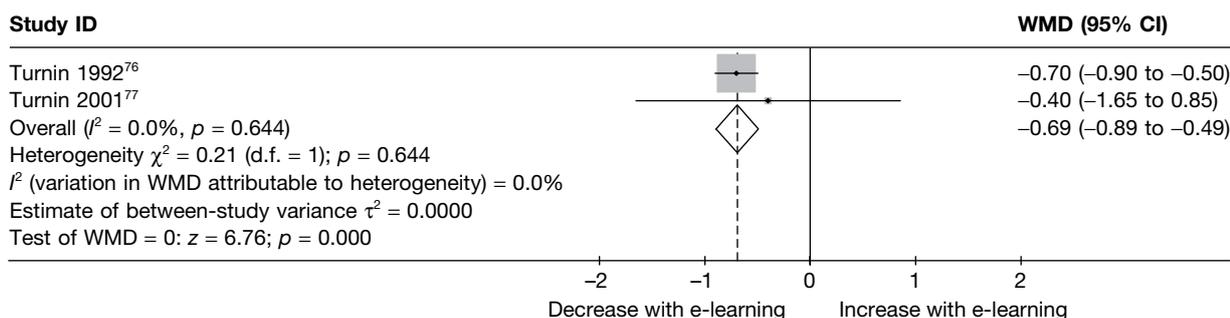
Figure 24 shows the estimates of effect of e-learning on mean percentage of energy from fat plotted against their standard errors. There was no evidence that smaller studies are associated with a larger or smaller treatment effects ( $p=0.203$ ).

## Fibre, proteins, sugars

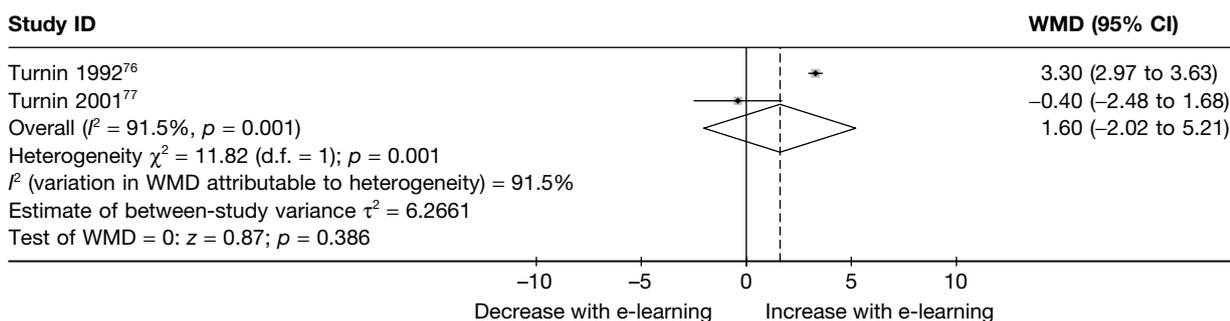
Figures 27–29 show analyses of the estimates of effect on dietary fibre, percentage of energy from protein, and percentage of energy from carbohydrate.



**FIGURE 27** Forest plot showing the effect of e-learning on the mean intake of dietary fibre (g/day).



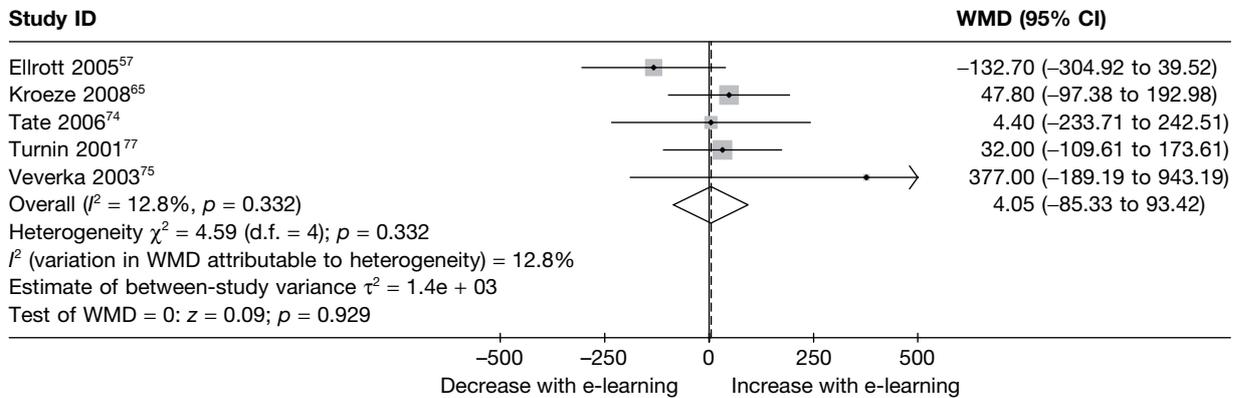
**FIGURE 28** Forest plot showing the effect of e-learning on the mean percentage of energy from protein (%).



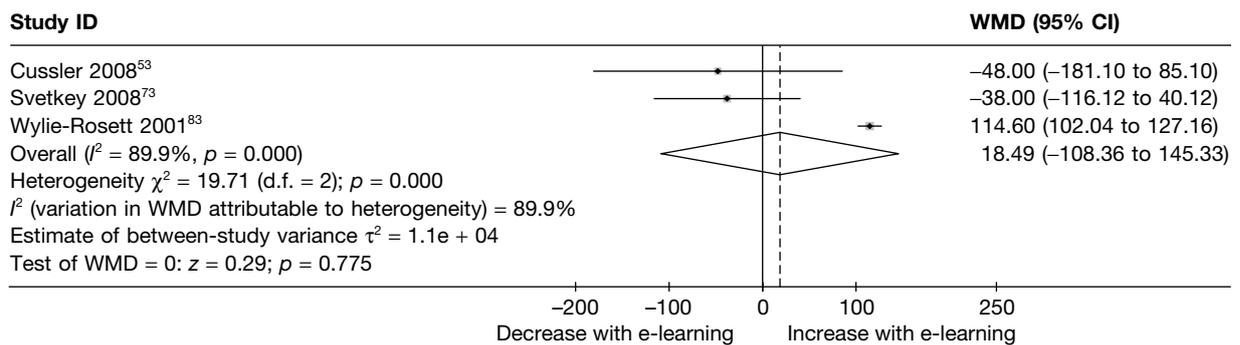
**FIGURE 29** Forest plot showing the effect of e-learning on the mean percentage of energy from carbohydrate (%).

## Energy

Figures 30 and 31 show analyses of estimates of effect on energy intake.



**FIGURE 30** Forest plot showing the effect of e-learning on the mean energy intake (kcal/day).



**FIGURE 31** Forest plot showing the effect of e-learning on the mean change in energy intake (kcal/day).

## Body mass index/weight

Figures 32–36 show analyses of estimates of effect on BMI and weight.

Egger's test for small-study effects:

Regress standard normal deviate of intervention  
Effect estimate against its SE  
Number of studies = 9, root MSE = .6681

Std_Eff	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)
Slope	.1203499	.5400326	0.22	0.830	-1.156624 1.397324
Bias	-.2923767	.6274486	-0.47	0.655	-1.776057 1.191303

H<sub>0</sub>, null hypothesis; MSE, mean squared error.  
Test of H<sub>0</sub>: no small-study effects  $p = 0.655$

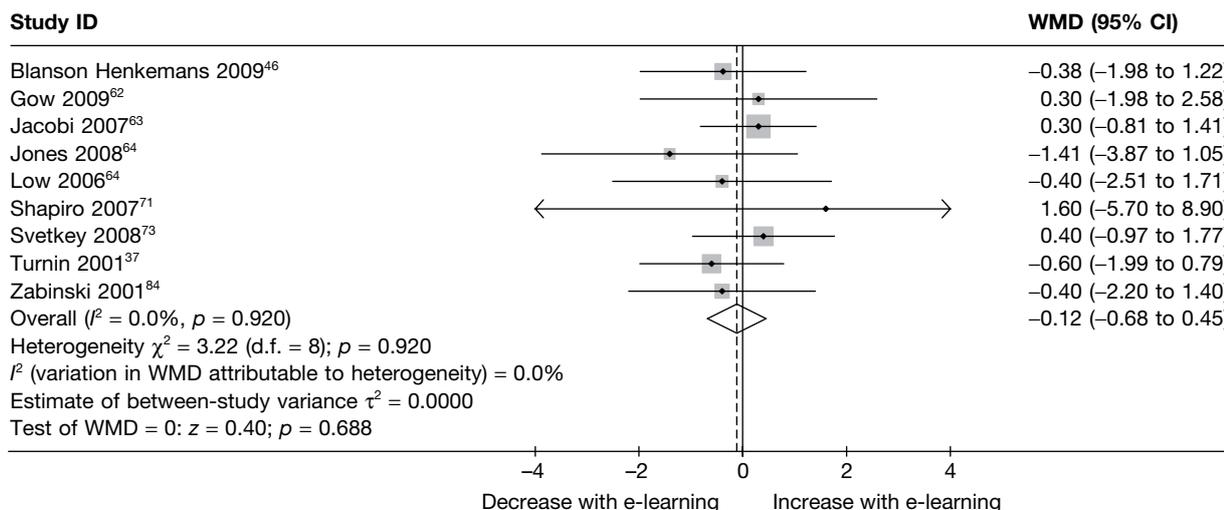


FIGURE 32 Forest plot showing the effect of e-learning on the mean BMI (kg/m<sup>2</sup>).

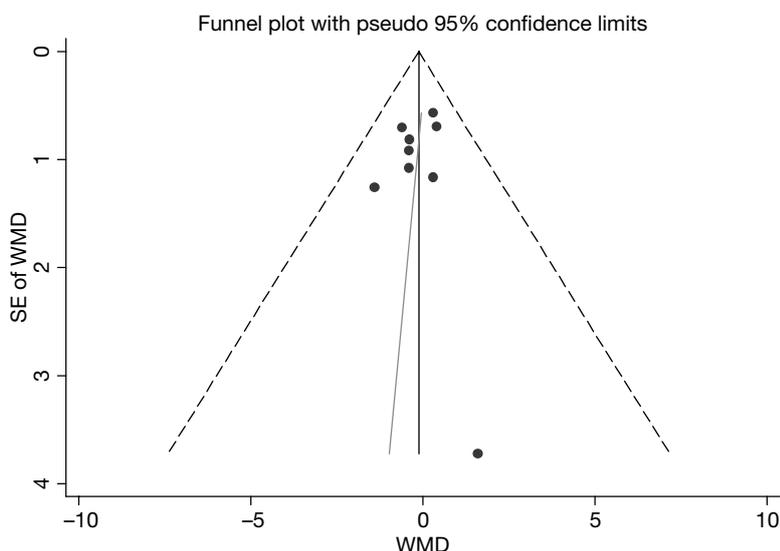


FIGURE 33 Funnel plot showing estimates of the effect of e-learning on the mean BMI (kg/m<sup>2</sup>).

Figure 33 shows estimates of effect of e-learning on mean BMI plotted against their standard errors. There was no evidence that smaller studies are associated with larger treatment effects (i.e. larger decrease in BMI,  $p = 0.66$ ).

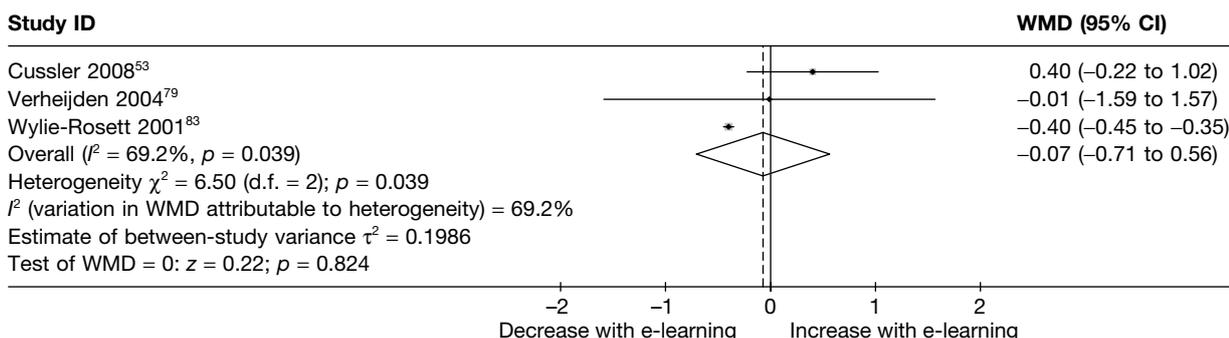
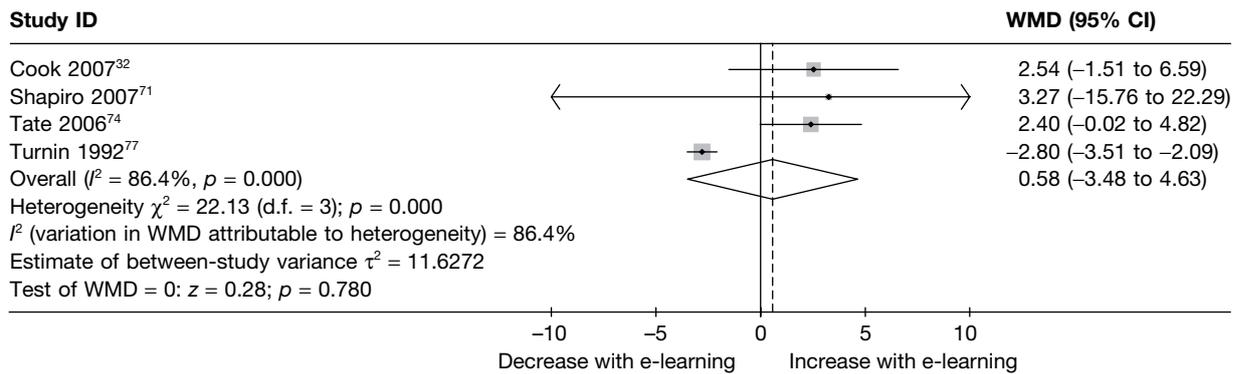
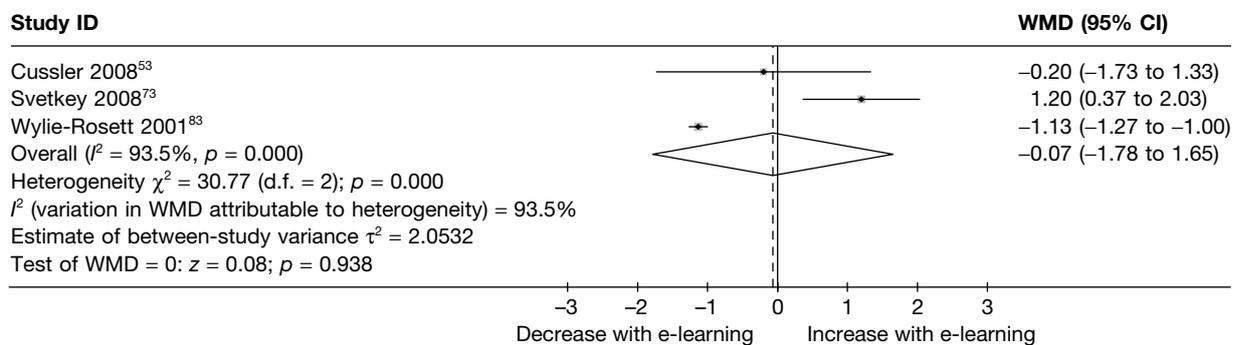


FIGURE 34 Forest plot showing the effect of e-learning on the mean change in BMI (kg/m<sup>2</sup>).



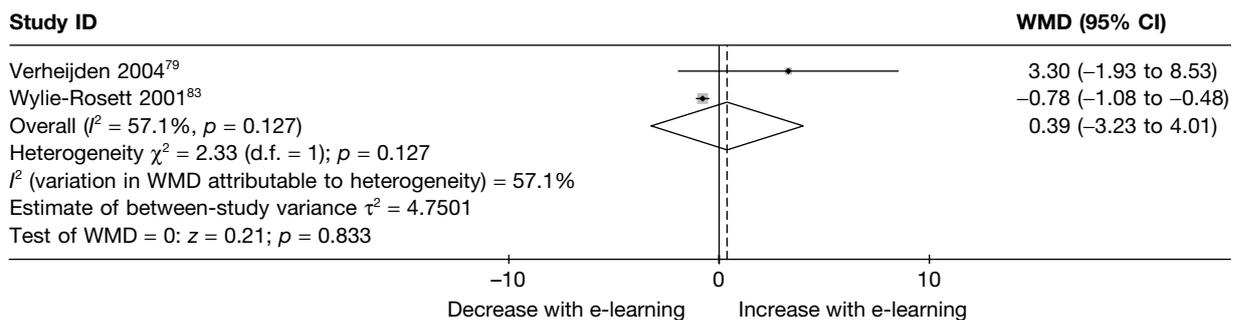
**FIGURE 35** Forest plot showing the effect of e-learning on the mean weight (kg).



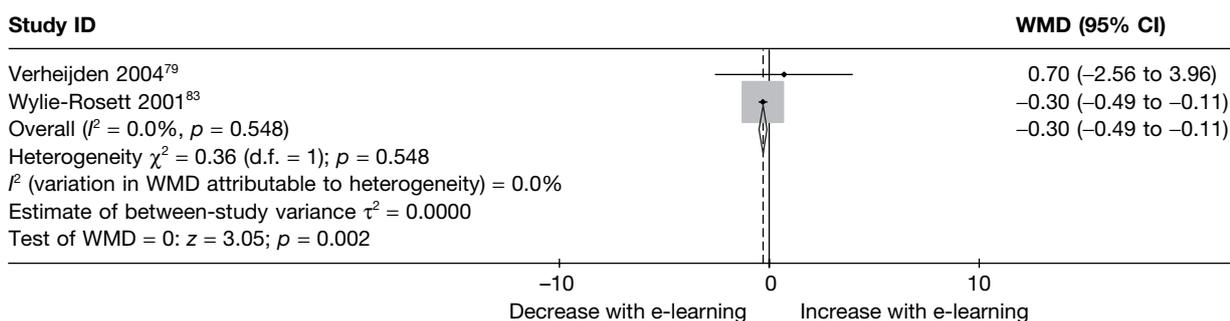
**FIGURE 36** Forest plot showing the effect of e-learning on the mean change in weight (kg).

## Blood pressure

Figures 37 and 38 show analyses of the estimates of effect on systolic and diastolic blood pressure.



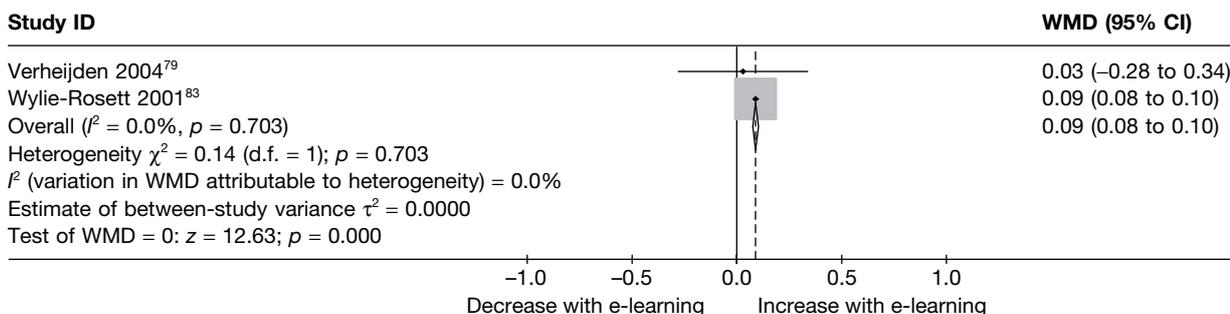
**FIGURE 37** Forest plot showing the effect of e-learning on the mean change in systolic blood pressure (mmHg).



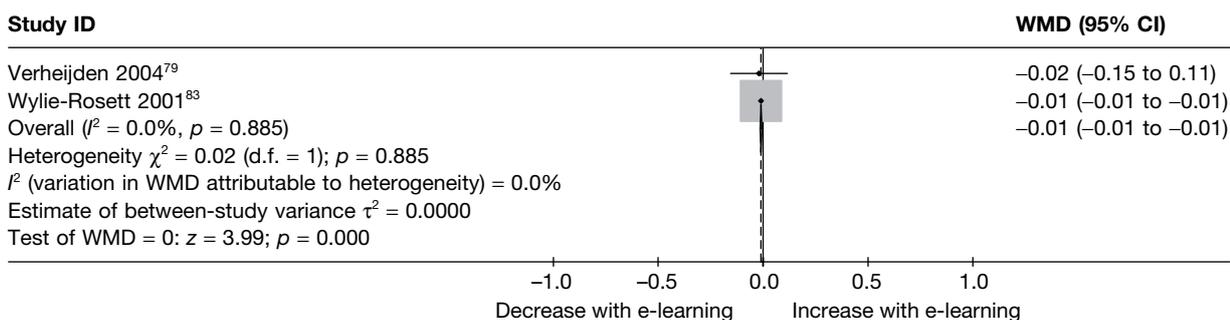
**FIGURE 38** Forest plot showing the effect of e-learning on the mean change in diastolic blood pressure (mmHg).

## Lipids and lipoproteins

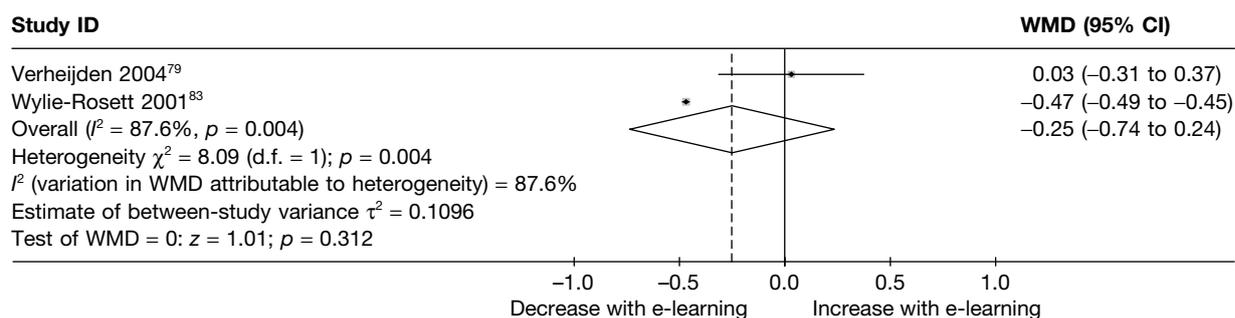
Figures 39–42 show analyses of estimates of effect on low-density lipids, high-density lipids, total cholesterol and triglycerides.



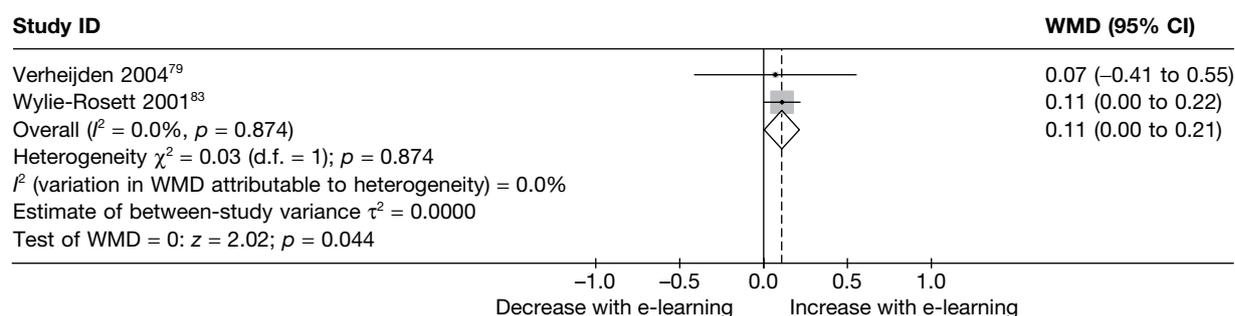
**FIGURE 39** Forest plot showing the effect of e-learning on the mean change in low-density lipids (mmol/l).



**FIGURE 40** Forest plot showing the effect of e-learning on the mean change in high-density lipids (mmol/l).



**FIGURE 41** Forest plot showing the effect of e-learning on the mean change in total cholesterol (mmol/l).



**FIGURE 42** Forest plot showing the effect of e-learning on the mean change in triglycerides (mmol/l).

## Subgroup analysis for selected outcomes

Our published study protocol stated that in order to investigate possible sources of heterogeneity we would conduct sensitivity analysis by study quality and by SES of participants. Subgroup analysis has been conducted where outcomes were reported by five or more studies. Subgroups were also investigated for our secondary outcomes of BMI and weight, according to whether or not studies aimed to maintain or reduce BMI (or weight), and whether or not studies included a physical activity component.

The STATA output is shown for each subgroup and an interpretation provided.

### 1. Study quality (EPHPP assessment) Fruit and vegetables

Meta-regression number of studies = 12

Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (10 d.f.) = 61.4446

$p > Q = 0.000$

Proportion of variation due to heterogeneity  $I^2 = 0.837$

Moment-based estimate of between-study variance:  $\tau^2 = 0.0936$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)
_lephpp_2	-.0587248	.2545131	-0.23	0.822	-.6258154 .5083657
_cons	.2898408	.2220584	1.31	0.221	-.2049361 .7846178

There was no evidence to suggest that estimates of effect on servings of fruit and vegetables were associated with EPHPP global rating.

## Total fat

. xi: metareg wmd i.ephpp, wsse(se) mm  
 i.ephpp \_lephpp\_1-2 (\_lephpp\_1 for ephpp==MODERATE omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 10.9395  
 $p > Q = 0.362$   
 Proportion of variation due to heterogeneity  $I^2 = 0.086$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.4840$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lephpp_2	-4.414625	2.273575	-1.94	0.081	-9.480465	.6512156
_cons	3.059523	2.172567	1.41	0.189	-1.781259	7.900304

There was weak evidence to suggest that studies with 'weak' EPHPP global rating on average found larger reductions on fat intake ( $p = 0.081$ ).

## Percentage energy from fat

. xi: metareg wmd i.ephpp, wsse(se) mm  
 i.ephpp \_lephpp\_1-2 (\_lephpp\_1 for ephpp==MODERATE omitted)  
 Meta-regression number of studies = 10  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (8 d.f.) = 28.5597  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.720$   
 Moment-based estimate of between-study variance:  $\tau^2 = 1.6222$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lephpp_2	-1.075684	1.170951	-0.92	0.385	-3.775902	1.624534
_cons	-.6570533	.9659334	-0.68	0.516	-2.8845	1.570393

There was no evidence to suggest that estimates of effect on percentage of energy fat were associated with the EPHPP global rating.

## Energy

. xi: metareg wmd i.ephpp, wsse(se) mm  
 i.ephpp \_lephpp\_1-2 (\_lephpp\_1 for ephpp==MODERATE omitted)  
 Meta-regression number of studies = 5  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (3 d.f.) = 3.51876  
 $p > Q = 0.318$   
 Proportion of variation due to heterogeneity  $I^2 = 0.147$   
 Moment-based estimate of between-study variance:  $\tau^2 = 1.9e+03$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lephpp_2   -91.91838	94.49451	-0.97	0.402	-392.6421	208.8053	
_cons	53.8557	69.5182	0.77	0.495	-167.3822	275.0936

There was no evidence to suggest that estimates of effect on total energy intake were associated with EPHPP global rating.

### Body mass index

. xi: metareg wmd i.ephpp, wsse(se) mm  
 i.ephpp \_lephpp\_1-2 (\_lephpp\_1 for ephpp == MODERATE omitted)  
 Meta-regression number of studies = 9  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (7 d.f.) = 2.83317  
 $p > Q = 0.900$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lephpp_2	-.4149028	.6658704	-0.62	0.553	-1.989436	1.15963
_cons	.1978034	.5780817	0.34	0.742	-1.169143	1.564749

There was no evidence to suggest that estimates of effect on BMI were associated with the EPHPP global rating.

### Weight

. xi: metareg wmd i.ephpp, wsse(se) mm  
 i.ephpp \_lephpp\_1-2 (\_lephpp\_1 for ephpp == MODERATE omitted)  
 Meta-regression number of studies = 4  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (2 d.f.) = 6.48674  
 $p > Q = 0.039$   
 Proportion of variation due to heterogeneity  $I^2 = 0.692$   
 Moment-based estimate of between-study variance:  $\tau^2 = 9.4399$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lephpp_2	-3.087439	3.944292	-0.78	0.516	-20.05836	13.88348
_cons	2.48286	3.149766	0.79	0.513	-11.06949	16.03521

There was no evidence to suggest that estimates of effect on weight were associated with the EPHPP global rating.

## 2. Low attrition (0–20%) versus high attrition (>20%) Fruit and vegetables

. xi: metareg wmd i.CompleteEPHPP, wsse(se) mm  
 i.CompleteEPHPP \_ICompleteE\_1-2 (\_ICompleteE\_1 for Com~P == 60–79% omitted)  
 Meta-regression number of studies = 11  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (9 d.f.) = 25.0174  
 $p > Q = 0.003$   
 Proportion of variation due to heterogeneity  $I^2 = 0.640$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0577$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IComplete~2	.1077183	.2054918	0.52	0.613	-.3571365	.572573
_cons	.2602589	.1213245	2.15	0.061	-.0141961	.5347139

There was no evidence to suggest that estimates of effect on daily servings of fruit and vegetables were associated with the level of attrition in studies.

### Total fat

```
. xi: metareg wmd i.CompleteEPHPP, wsse(se) mm
i.CompleteEPHPP _ICompleteE_1-2 (_ICompleteE_1 for Com~P==60-79% omitted)
Meta-regression number of studies=11
Fit of model without heterogeneity ( $\tau^2=0$ ): Q (9 d.f.)=13.4312
p > Q=0.144
Proportion of variation due to heterogeneity  $I^2=0.330$ 
Moment-based estimate of between-study variance:  $\tau^2=5.4695$ 
```

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IComplete~2	2.718195	3.868409	0.70	0.500	-6.032753	11.46914
_cons	-.8227567	1.432562	-0.57	0.580	-4.063436	2.417923

There was no evidence to suggest that estimates of effect on total fat intake were associated with the level of attrition in studies.

### Percentage energy from fat

```
. xi: metareg wmd i.CompleteEPHPP, wsse(se) mm
i.CompleteEPHPP _ICompleteE_1-2 (_ICompleteE_1 for Com~P==60-79% omitted)
Meta-regression number of studies=10
Fit of model without heterogeneity ( $\tau^2=0$ ): Q (8 d.f.)=38.8865
p > Q=0.000
Proportion of variation due to heterogeneity  $I^2=0.794$ 
Moment-based estimate of between-study variance:  $\tau^2=2.3678$ 
```

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IComplete~2	.8740884	1.206316	0.72	0.489	-1.907681	3.655858
_cons	-1.890358	.8921099	-2.12	0.067	-3.947567	.1668514

There was no evidence to suggest that estimates of effect on percentage energy from fat were associated with the level of attrition in studies.

## Energy

. xi: metareg wmd i.CompleteEPHPP, wsse(se) mm  
 i.CompleteEPHPP \_JCompleteE\_1-2 (\_JCompleteE\_1 for Com~P==60-79% omitted)  
 Meta-regression number of studies = 5  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (3 d.f.) = 3.51876  
 $p > Q = 0.318$   
 Proportion of variation due to heterogeneity  $I^2 = 0.147$   
 Moment-based estimate of between-study variance:  $\tau^2 = 1.9e+03$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_JComplete~2	91.91838	94.49451	0.97	0.402	-208.8053	392.6421
_cons	-38.06268	64.00337	-0.59	0.594	-241.75	165.6246

There was no evidence to suggest that estimates of effect on energy intake were associated with the level of attrition in studies.

## Body mass index

. xi: metareg wmd i.CompleteEPHPP, wsse(se) mm  
 i.CompleteEPHPP \_JCompleteE\_1-2 (\_JCompleteE\_1 for Com~P==60-79% omitted)  
 Meta-regression number of studies = 8  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (6 d.f.) = 1.76955  
 $p > Q = 0.940$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_JComplete~2	.7038533	.6068578	1.16	0.290	-.7810744	2.188781
_cons	-.4702745	.4494989	-1.05	0.336	-1.570159	.6296096

There was no evidence to suggest that estimates of effect on BMI were associated with the level of attrition in studies.

## Weight

. xi: metareg wmd i.CompleteEPHPP, wsse(se) mm  
 i.CompleteEPHPP \_JCompleteE\_1-2 (\_JCompleteE\_1 for Com~P==60-79% omitted)  
 Meta-regression number of studies = 4  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (2 d.f.) = 21.7976  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.908$   
 Moment-based estimate of between-study variance:  $\tau^2 = 12.1802$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_JComplete~2	-2.791344	10.5395	-0.26	0.816	-48.13913	42.55644
_cons	3.266	10.31643	0.32	0.782	-41.122	47.654

There was no evidence to suggest that estimates of effect on weight were associated with the level of attrition in studies.

### 3. Allocation concealment (Cochrane 'low risk of bias' vs other) Fruit and vegetables

. xi: metareg wmd i.allocationconcealcoch, wsse(se) mm  
 i.allocationc~h \_lallocatio\_1-2 (\_lallocatio\_1 for all~h == Unclear omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 52.3053  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.809$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0819$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lallocati~2	-.0546828	.206455	-0.26	0.796	-.5146931	.4053276
_cons	.2688521	.1447394	1.86	0.093	-.0536475	.5913517

There was no evidence to suggest that estimates of effect on daily servings of fruit and vegetables were associated with whether or not allocation was adequately concealed from investigators or was unclear.

#### Total fat

. xi: metareg wmd i.allocationconcealcoch, wsse(se) mm  
 i.allocationc~h \_lallocatio\_1-2 (\_lallocatio\_1 for all~h == Unclear omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 15.1604  
 $p > Q = 0.126$   
 Proportion of variation due to heterogeneity  $I^2 = 0.340$   
 Moment-based estimate of between-study variance:  $\tau^2 = 2.8665$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lallocati~2	-.3916092	2.275972	-0.17	0.867	-5.46279	4.679572
_cons	-.6184049	1.251933	-0.49	0.632	-3.407885	2.171075

There was no evidence to suggest that estimates of effect on total fat intake were associated with whether or not allocation was adequately concealed from investigators or was unclear.

#### Percentage energy from fat

. xi: metareg wmd i.allocationconcealcoch, wsse(se) mm  
 i.allocationc~h \_lallocatio\_1-2 (\_lallocatio\_1 for all~h == Unclear omitted)  
 Meta-regression number of studies = 10  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (8 d.f.) = 32.524  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.754$   
 Moment-based estimate of between-study variance:  $\tau^2 = 1.9619$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lallocati~2	.669468	1.224406	0.55	0.599	-2.154018	3.492954
_cons	-1.609689	.6854733	-2.35	0.047	-3.190393	-.0289842

There was no evidence to suggest that estimates of effect on percentage of energy from fat were associated with whether or not allocation was adequately concealed from investigators or was unclear.

### Energy

. xi: metareg wmd i.allocationconcealcoch, wsse(se) mm  
 i.allocationc~h \_lallocatio\_1-2 (\_lallocatio\_1 for all~h==Unclear omitted)  
 Meta-regression number of studies = 5  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (3 d.f.) = 4.14494  
 $p > Q = 0.246$   
 Proportion of variation due to heterogeneity  $I^2 = 0.276$   
 Moment-based estimate of between-study variance:  $\tau^2 = 4.2e+03$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lallocati~2	50.12752	110.4682	0.45	0.681	-301.4315	401.6866
_cons	-17.01646	72.97764	-0.23	0.831	-249.2639	215.231

There was no evidence to suggest that estimates of effect on total energy intake were associated with whether or not allocation was adequately concealed from investigators or was unclear.

### Body mass index

. xi: metareg wmd i.allocationconcealcoch, wsse(se) mm  
 i.allocationc~h \_lallocatio\_1-2 (\_lallocatio\_1 for all~h==Unclear omitted)  
 Meta-regression number of studies = 9  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (7 d.f.) = 2.98302  
 $p > Q = 0.887$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lallocati~2	.2828604	.5793218	0.49	0.640	-1.087018	1.652739
_cons	-.2368358	.3803496	-0.62	0.553	-1.13622	.662548

There was no evidence to suggest that estimates of effect on BMI were associated with whether or not allocation was adequately concealed from investigators or was unclear.

### Weight

. xi: metareg wmd i.allocationconcealcoch, wsse(se) mm  
 i.allocationc~h \_lallocatio\_1-2 (\_lallocatio\_1 for all~h==Unclear omitted)  
 Meta-regression number of studies = 4  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (2 d.f.) = .010586  
 $p > Q = 0.995$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lallocati~2	5.246741	1.115829	4.70	0.042	.4457161	10.04777
_cons	-2.8	.3627551	-7.72	0.016	-4.360809	-1.239191

There was some evidence to suggest that estimates of effect on weight were larger in studies in which allocation was adequately concealed from investigators ( $p=0.042$ ). (Note: this analysis does not account for whether or not studies aimed to reduce or maintain weight.)

#### 4. Low income group versus other Fruit and vegetables

. xi: metareg wmd i.Low\_Inc, wsse(se) mm  
 i.Low\_Inc \_lLow\_Inc\_0-1 (naturally coded; \_lLow\_Inc\_0 omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q(10 \text{ d.f.})=38.2686$   
 $p > Q=0.000$   
 Proportion of variation due to heterogeneity  $I^2=0.739$   
 Moment-based estimate of between-study variance:  $\tau^2=0.0453$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lLow_Inc_1	.4975182	.2271436	2.19	0.053	-.0085892	1.003626
_cons	.1452362	.0912218	1.59	0.142	-.0580186	.348491

There was some evidence to suggest that estimates of effect on daily servings of fruit and vegetables were larger in studies with participants predominantly from low-income groups ( $p=0.053$ ).

#### Total fat

. xi: metareg wmd i.Low\_Inc, wsse(se) mm  
 i.Low\_Inc \_lLow\_Inc\_0-1 (naturally coded; \_lLow\_Inc\_0 omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q(10 \text{ d.f.})=13.8384$   
 $p > Q=0.180$   
 Proportion of variation due to heterogeneity  $I^2=0.277$   
 Moment-based estimate of between-study variance:  $\tau^2=1.9142$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_lLow_Inc_1	3.042827	3.369411	0.90	0.388	-4.464689	10.55034
_cons	-1.041848	.9845122	-1.06	0.315	-3.235478	1.151781

There was no evidence to suggest that estimates of effect on total fat intake were associated with studies including participants predominantly from low-income groups.

#### Percentage energy from fat

None of the studies measuring percentage energy from fat included participants predominantly from low-income groups.

### Energy

None of the studies measuring energy intake included participants predominantly from low-income groups.

### Body mass index

None of the studies measuring BMI included participants predominantly from low-income groups.

### Weight

None of the studies measuring weight included participants predominantly from low-income groups.

## 5. Early outcome (<3 months) versus later outcome (≥3 months) Fruit and vegetables

. xi: metareg wmd i.FU, wsse(se) mm  
i.FU \_IFU\_0–1 (naturally coded; \_IFU\_0 omitted)  
Meta-regression number of studies = 12  
Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (10 d.f.) = 47.6783  
 $p > Q = 0.000$   
Proportion of variation due to heterogeneity  $I^2 = 0.790$   
Moment-based estimate of between-study variance:  $\tau^2 = 0.0732$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IFU_1	.1187708	.1980919	0.60	0.562	–.3226053	.560147
_cons	.1813987	.1381617	1.31	0.219	–.1264447	.4892421

There was no evidence that estimates of effect on servings of fruit and vegetables differed according to time to follow-up.

### Total fat

i.FU \_IFU\_0–1 (naturally coded; \_IFU\_0 omitted)  
Meta-regression number of studies = 12  
Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (10 d.f.) = 15.159  
 $p > Q = 0.126$   
Proportion of variation due to heterogeneity  $I^2 = 0.340$   
Moment-based estimate of between-study variance:  $\tau^2 = 2.7992$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IFU_1	–.2754214	2.40662	–0.11	0.911	–5.637705	5.086862
_cons	–.6704323	1.204002	–0.56	0.590	–3.353117	2.012252

There was no evidence that estimates of effect on total fat intake differed according to time to follow-up.

### Percentage energy from fat

. xi: metareg wmd i.FU, wsse(se) mm  
 i.FU \_IFU\_0-1 (naturally coded; \_IFU\_0 omitted)  
 Meta-regression number of studies = 10  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (8 d.f.) = 39.4114  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.797$   
 Moment-based estimate of between-study variance:  $\tau^2 = 2.0669$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IFU_1	.6480017	2.137268	0.30	0.769	-4.280546	5.576549
_cons	-2	2.05116	-0.98	0.358	-6.729982	2.729982

There was no evidence that estimates of effect percentage of energy from fat differed according to time to follow-up.

### Energy

. xi: metareg wmd i.FU, wsse(se) mm  
 i.FU \_IFU\_0-1 (naturally coded; \_IFU\_0 omitted)  
 Meta-regression number of studies = 5  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (3 d.f.) = 1.46516  
 $p > Q = 0.690$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IFU_1	176.0411	99.62481	1.77	0.175	-141.0095	493.0917
_cons	-132.7	87.86581	-1.51	0.228	-412.3282	146.9282

There was no evidence that estimates of effect on energy intake differed according to time to follow-up.

### Body mass index

. xi: metareg wmd i.FU, wsse(se) mm  
 i.FU \_IFU\_0-1 (naturally coded; \_IFU\_0 omitted)  
 Meta-regression number of studies = 9  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (7 d.f.) = 2.90451  
 $p > Q = 0.894$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IFU_1	-.324209	.5759164	-0.56	0.591	-1.686035	1.037617
_cons	.0332676	.3893472	0.09	0.934	-.8873923	.9539275

There was no evidence that estimates of effect on BMI differed according to time to follow-up.

## Weight

. xi: metareg wmd i.FU, wsse(se) mm  
 i.FU \_IFU\_0-1 (naturally coded; \_IFU\_0 omitted)  
 Meta-regression number of studies = 4  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (2 d.f.) = 16.2713  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.877$   
 Moment-based estimate of between-study variance:  $\tau^2 = 11.6652$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IFU_1	-2.9805	4.481034	-0.67	0.574	-22.26083	16.29983
_cons	2.634944	3.721698	0.71	0.552	-13.37823	18.64812

There was no evidence that estimates of effect on weight differed according to time to follow-up.

## 6. Overweight (BMI >25kg/m<sup>2</sup>) versus not overweight Fruit and vegetables

. xi: metareg wmd i.Overweight, wsse(se) mm  
 i.Overweight \_IOverweigh\_0-1 (naturally coded; \_IOverweigh\_0 omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 66.0638  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.849$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0835$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IOverweigh~1	-.2510207	.5715148	-0.44	0.670	-1.524435	1.022394
_cons	.2510207	.1057554	2.37	0.039	.015383	.4866585

There was no evidence that estimates of effect on servings of fruit and vegetables differed according to whether or not included participants were overweight.

## Total fat

. xi: metareg wmd i.Overweight, wsse(se) mm  
 i.Overweight \_IOverweigh\_0-1 (naturally coded; \_IOverweigh\_0 omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 15.1632  
 $p > Q = 0.126$   
 Proportion of variation due to heterogeneity  $I^2 = 0.341$   
 Moment-based estimate of between-study variance:  $\tau^2 = 2.6260$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IOverweigh~1	-.9068454	3.274809	-0.28	0.787	-8.203574	6.389883
_cons	-.6454614	1.091058	-0.59	0.567	-3.076491	1.785568

There was no evidence that estimates of effect on total fat intake differed according to whether or not included participants were overweight.

### Percentage energy from fat

. xi: metareg wmd i.Overweight, wsse(se) mm  
 i.Overweight \_IOverweigh\_0-1 (naturally coded; \_IOverweigh\_0 omitted)  
 Meta-regression number of studies = 10  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (8 d.f.) = 27.5027  
 $p > Q = 0.001$   
 Proportion of variation due to heterogeneity  $I^2 = 0.709$   
 Moment-based estimate of between-study variance:  $\tau^2 = 1.4112$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IOverweigh~1	1.918306	1.140995	1.68	0.131	-.7128328	4.549444
_cons	-1.891834	.5879203	-3.22	0.012	-3.247581	-.5360873

There was no evidence that estimates of effect on percentage of energy from fat differed according to whether or not included participants were overweight.

### Energy

. xi: metareg wmd i.Overweight, wsse(se) mm  
 i.Overweight \_IOverweigh\_0-1 (naturally coded; \_IOverweigh\_0 omitted)  
 Meta-regression number of studies = 5  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (3 d.f.) = 3.39924  
 $p > Q = 0.334$   
 Proportion of variation due to heterogeneity  $I^2 = 0.117$   
 Moment-based estimate of between-study variance:  $\tau^2 = 1.5e+03$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IOverweigh~1	-102.272	98.09153	-1.04	0.374	-414.443	209.899
_cons	72.89176	80.47466	0.91	0.432	-183.2145	328.9981

There was no evidence that estimates of effect on total energy intake differed according to whether or not included participants were overweight.

### Body mass index

. xi: metareg wmd i.Overweight, wsse(se) mm  
 i.Overweight \_IOverweigh\_0-1 (naturally coded; \_IOverweigh\_0 omitted)  
 Meta-regression number of studies = 9  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (7 d.f.) = 2.88748  
 $p > Q = 0.895$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IOverweigh~1	-.3317409	.5740735	-0.58	0.581	-1.689209	1.025727
_cons	.0562025	.4122949	0.14	0.895	-.9187199	1.031125

There was no evidence that estimates of effect on BMI differed according to whether or not included participants were overweight.

### Weight

. xi: metareg wmd i.Overweight, wsse(se) mm  
 i.Overweight \_IOverweigh\_0-1 (naturally coded; \_IOverweigh\_0 omitted)  
 Meta-regression number of studies = 4  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (2 d.f.) = 6.48674  
 $p > Q = 0.039$   
 Proportion of variation due to heterogeneity  $I^2 = 0.692$   
 Moment-based estimate of between-study variance:  $\tau^2 = 9.4399$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IOverweig~1	3.087439	3.944292	0.78	0.516	-13.88348	20.05836
_cons	-.6045792	2.374113	-0.25	0.823	-10.81956	9.610406

There was no evidence that estimates of effect on weight differed according to whether or not included participants were overweight.

## 7. Primary prevention versus diagnosed illness

### Fruit and vegetables

None of the studies measuring daily servings of fruit and vegetables included participants with a diagnosed illness.

### Total fat

None of the studies measuring total fat intake included participants with a diagnosed illness.

### Percentage energy from fat

. xi: metareg wmd i.Secondary, wsse(se) mm  
 i.Secondary \_ISecondar\_0-1 (naturally coded; \_ISecondar\_0 omitted)  
 Meta-regression number of studies = 10  
 Fit of model without heterogeneity ( $\tau^2 = 0$ ):  $Q$  (8 d.f.) = 18.9136  
 $p > Q = 0.015$   
 Proportion of variation due to heterogeneity  $I^2 = 0.577$   
 Moment-based estimate of between-study variance:  $\tau^2 = 1.4700$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_ISecondar~1	-1.350213	1.431508	-0.94	0.373	-4.651275	1.95085
_cons	-1.149787	.5965762	-1.93	0.090	-2.525494	.2259199

There was no evidence that estimates of effect on percentage of energy from fat differed according to whether or not participants had a diagnosed illness.

### Energy

None of the studies measuring energy intake included participants with a diagnosed illness.

### BMI

None of the studies measuring BMI included participants with a diagnosed illness.

## Weight

. xi: metareg wmd i.Secondary, wsse(se) mm  
 i.Secondary \_ISecondary\_0-1 (naturally coded; \_ISecondary\_0 omitted)  
 Meta-regression number of studies = 4  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (2 d.f.) = .010586  
 $p > Q = 0.995$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_ISecondar~1	-5.246741	1.115829	-4.70	0.042	-10.04777	- .4457161
_cons	2.446741	1.055217	2.32	0.146	-2.093492	6.986975

There was some evidence to suggest that estimates of effect on weight were larger in studies with participants with a diagnosed illness ( $p = 0.042$ ). (Note: this analysis does not account for whether or not studies aimed to reduce or maintain weight.)

## 8. Aimed to reduce versus maintain body mass index/weight Fruit and vegetables

. xi: metareg wmd i.BMI\_down, wsse(se) mm  
 i.BMI\_down \_IBMI\_down\_0-1 (naturally coded; \_IBMI\_down\_0 omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 66.0638  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.849$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0835$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IBMI_down_1	-.2510207	.5715148	-0.44	0.670	-1.524435	1.022394
_cons	.2510207	.1057554	2.37	0.039	.015383	.4866585

There was no evidence that estimates of effect on servings of fruit and vegetables differed according whether or not studies aimed to maintain or reduce BMI.

## Total fat

. xi: metareg wmd i.BMI\_down, wsse(se) mm  
 i.BMI\_down \_IBMI\_down\_0-1 (naturally coded; \_IBMI\_down\_0 omitted)  
 Meta-regression number of studies = 12  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 15.0849  
 $p > Q = 0.129$   
 Proportion of variation due to heterogeneity  $I^2 = 0.337$   
 Moment-based estimate of between-study variance:  $\tau^2 = 2.5378$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IBMI_down_1	-1.535807	3.487471	-0.44	0.669	-9.306377	6.234762
_cons	-.6056245	1.06856	-0.57	0.583	-2.986523	1.775275

There was no evidence that estimates of effect on total fat intake differed according whether or not studies aimed to maintain or reduce BMI.

### Percentage energy from fat

. xi: metareg wmd i.BMI\_down, wsse(se) mm  
 i.BMI\_down \_IBMI\_down\_0-1 (naturally coded; \_IBMI\_down\_0 omitted)  
 Meta-regression number of studies = 10  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (8 d.f.) = 36.9256  
 $p > Q = 0.000$   
 Proportion of variation due to heterogeneity  $I^2 = 0.783$   
 Moment-based estimate of between-study variance:  $\tau^2 = 2.7521$

WMD	Coef.	SE	t	p >  t	(95% CI)	
_IBMI_down_1	1.642182	1.275113	1.29	0.234	-1.298234	4.582598
_cons	-2.32978	.9474181	-2.46	0.039	-4.51453	-.1450303

There was no evidence that estimates of effect on percentage of energy from fat differed according whether or not studies aimed to maintain or reduce BMI.

### Energy

. xi: metareg wmd i.BMI\_down, wsse(se) mm  
 i.BMI\_down \_IBMI\_down\_0-1 (naturally coded; \_IBMI\_down\_0 omitted)  
 Meta-regression number of studies = 5  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (3 d.f.) = 2.88746  
 $p > Q = 0.409$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	t	p >  t	(95% CI)	
_IBMI_down_1	-380.5853	291.8849	-1.30	0.283	-1309.493	548.3226
_cons	377	288.8699	1.31	0.283	-542.313	1296.313

There was no evidence that estimates of effect on energy intake differed according whether or not studies aimed to maintain or reduce BMI.

### Body mass index

. xi: metareg wmd i.BMI\_down, wsse(se) mm  
 i.BMI\_down \_IBMI\_down\_0-1 (naturally coded; \_IBMI\_down\_0 omitted)  
 Meta-regression number of studies = 9  
 Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (7 d.f.) = 3.20983  
 $p > Q = 0.865$   
 Proportion of variation due to heterogeneity  $I^2 = 0.000$   
 Moment-based estimate of between-study variance:  $\tau^2 = 0.0000$

WMD	Coef.	SE	t	p >  t	(95% CI)	
_IBMI_down_1	-.0619419	.5753033	-0.11	0.917	-1.422318	1.298434
_cons	-.0861856	.391764	-0.22	0.832	-1.01256	.840189

There was no evidence that estimates of effect on BMI differed according whether or not studies aimed to maintain or reduce BMI.

### Weight

All studies that estimated mean weight as an outcome aimed to reduce weight.

## 9. Physical activity component in intervention versus none Fruit and vegetables

. xi: metareg wmd i.PA, wsse(se) mm  
i.PA \_IPA\_0-1 (naturally coded; \_IPA\_0 omitted)  
Meta-regression number of studies = 12  
Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 57.6919  
 $p > Q = 0.000$   
Proportion of variation due to heterogeneity  $I^2 = 0.827$   
Moment-based estimate of between-study variance:  $\tau^2 = 0.0800$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IPA_1	.1512111	.2807434	0.54	0.602	-.4743242	.7767464
_cons	.2175574	.1114721	1.95	0.080	-.0308179	.4659328

There was no evidence that estimates of effect on servings of fruit and vegetables differed according to whether or not interventions included a physical activity component.

### Total fat

. xi: metareg wmd i.PA, wsse(se) mm  
i.PA \_IPA\_0-1 (naturally coded; \_IPA\_0 omitted)  
Meta-regression number of studies = 12  
Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (10 d.f.) = 10.0671  
 $p > Q = 0.435$   
Proportion of variation due to heterogeneity  $I^2 = 0.007$   
Moment-based estimate of between-study variance:  $\tau^2 = 0.0337$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IPA_1	-7.125047	3.147323	-2.26	0.047	-14.13772	-.1123749
_cons	-1.033167	.4412864	-2.34	0.041	-2.016414	-.0499195

There was some evidence to suggest that estimates of effect on total fat intake were larger in studies in which interventions also included a physical activity component ( $p = 0.047$ ).

### Percentage energy from fat

. xi: metareg wmd i.PA, wsse(se) mm  
i.PA \_IPA\_0-1 (naturally coded; \_IPA\_0 omitted)  
Meta-regression number of studies = 10  
Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (8 d.f.) = 17.1085  
 $p > Q = 0.029$   
Proportion of variation due to heterogeneity  $I^2 = 0.532$   
Moment-based estimate of between-study variance:  $\tau^2 = 1.0507$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IPA_1	-1.43327	1.032209	-1.39	0.202	-3.813548	.9470078
_cons	-.8038327	.6508597	-1.24	0.252	-2.304718	.6970525

There was no evidence that estimates of effect on percentage of energy from fat differed according to whether or not interventions included a physical activity component.

### Energy

. xi: metareg wmd i.PA, wsse(se) mm  
i.PA \_IPA\_0-1 (naturally coded; \_IPA\_0 omitted)  
Meta-regression number of studies=5  
Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (3 d.f.)=4.29626  
 $p > Q=0.231$   
Proportion of variation due to heterogeneity  $I^2=0.302$   
Moment-based estimate of between-study variance:  $\tau^2=3.7e+03$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IPA_1	78.65628	140.2495	0.56	0.614	-367.6804	524.9929
_cons	-9.159267	58.73057	-0.16	0.886	-196.0662	177.7476

There was no evidence that estimates of effect on total energy intake differed according to whether or not interventions included a physical activity component.

### Body mass index

. xi: metareg wmd i.PA, wsse(se) mm  
i.PA \_IPA\_0-1 (naturally coded; \_IPA\_0 omitted)  
Meta-regression number of studies=9  
Fit of model without heterogeneity ( $\tau^2=0$ ):  $Q$  (7 d.f.)=3.20835  
 $p > Q=0.865$   
Proportion of variation due to heterogeneity  $I^2=0.000$   
Moment-based estimate of between-study variance:  $\tau^2=0.0000$

WMD	Coef.	SE	<i>t</i>	<i>p</i> >   <i>t</i>	(95% CI)	
_IPA_1	.06573	.5749834	0.11	0.912	-1.29389	1.42535
_cons	-.145655	.3932479	-0.37	0.722	-1.075538	.7842284

There was no evidence that estimates of effect on BMI differed according to whether or not interventions included a physical activity component.

### Weight

All studies that estimated mean weight as an outcome included a physical activity component.

## Appendix 8

# Behaviour change techniques and effectiveness

	Behaviour change technique	Effective <i>n</i> = 13 <sup>a</sup>	Ineffective <i>n</i> = 26 <sup>b</sup>	Not clear <i>n</i> = 4 <sup>c</sup>	Total <i>n</i> = 43 <sup>d</sup>
1	Provide information on consequences of behaviour in general	6	7	1	14
2	Provide information on consequences of behaviour to the individual	5	6		11
3	Provide information about others' approval		1		1
4	Provide normative information about others' behaviour		4		4
5	Goal setting (behaviour)	4	8	2	14
6	Goal setting (outcome)	1		1	2
7	Action planning	3	1	1	5
8	Barrier identification/problem solving	5	7	1	13
9	Set graded tasks	2		1	3
10	Prompt review of behavioural goals	5	5	1	11
11	Prompt review of outcome goals		1	1	2
12	Provide rewards contingent on effort or progress towards behaviour		2	1	3
13	Provide rewards contingent on successful behaviour	2			2
14	Shaping			1	1
15	Prompting generalisation of a target behaviour		1		1
16	Prompt self-monitoring of behaviour	4	8		12
17	Prompt self-monitoring of behavioural outcome	1	3		4
18	Prompting focus on past success			1	1
19	Provide feedback on performance	7	6	1	14
20	Provide information on where and when to perform the behaviour	1	2		3
21	Provide instruction on how to perform the behaviour	4	7	1	12
22	Model/demonstrate the behaviour	1	5		6
23	Teach to use prompts/cues	3	3	1	7
24	Environmental restructuring		1		1
25	Agree behavioural contract				0
26	Prompt practice				0
27	Use of follow up prompts		1		1
28	Facilitate social comparison	1	2		3
29	Plan social support/social change	3	7		10
30	Prompt identification as role model/position advocate		1		1
31	Prompt anticipated regret				0
32	Fear arousal	3	3		6
33	Prompt self-talk				0
34	Prompt use of imagery				0
35	Relapse prevention/coping planning		1		1
36	Stress management				0
37	Emotional control training		1		1
38	Motivational interviewing		1	1	2
39	Time management				0
40	General communication skills training				0

		Effective <i>n</i> = 13 <sup>a</sup>	Ineffective <i>n</i> = 26 <sup>b</sup>	Not clear <i>n</i> = 4 <sup>c</sup>	Total <i>n</i> = 43 <sup>d</sup>
41	Stimulate anticipation of future rewards				0
42	General planning	1	1		2
43	Tailoring <sup>e</sup>	13	26	4	43

a Effective = statistical significance, in the intended direction, comparing final follow-up time-point between intervention and control groups (change from baseline not assessed).

b Includes those studies in which statistically significant effect was found in the opposite direction to that intended.

c Four studies<sup>42,47,55,81</sup> did not provide a measure of variation (such as SD), and could not therefore be assessed for statistical significance.

d One study<sup>63</sup> did not specify any details about the intervention and therefore no behaviour change techniques could be entered.

e Tailoring should have been used in all studies, as it is a requirement for inclusion in the review.

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***We look forward to hearing from you.***