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Effects of technology-based interventions on dietary intake or anthropometrics among adolescents and adults in South Asia – A systematic review of intervention studies☆

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ABSTRACT

Introduction: Mobile technology has been increasingly used as part of dietary interventions, but the effects of such interventions have not been systematically evaluated in the South Asian context. The systematic review aimed to determine the effects of technology-based interventions on dietary intake or anthropometrics among adolescents and adults in South Asia. Methods: Five electronic databases were searched (PubMed, Scopus, Web of Science, Global Health Library and Health Technology Assessment). Studies published in English between 1st January 2011 and 31st December 2021were included. Interventions that evaluated the effects of dietary interventions using technology on dietary outcomes and anthropometrics in adolescents or adults in the age group of 13–44 years (or a broader age group) from South Asia were eligible for inclusion. The risk of bias was assessed using the Cochrane Risk-of-bias 2 tool and ROBINS-I tool. A narrative synthesis was conducted.

Results: Twenty-one studies met the inclusion criteria (20,667 participants). Eleven of the 17 randomised controlled trials (RCTs) had a high overall risk of bias. The four non-randomised intervention studies had a serious or critical overall risk of bias. When including studies with low risk or some concern for bias, the interventions had a beneficial effect on at least one dietary outcome in four of the six RCTs that measured changes in diet, and no effect on the anthropometric outcomes in the six RCTs that measured changes in anthropometric outcomes.

Discussion: Technology-based dietary interventions have had some positive effects on dietary intake, but no effects on anthropometry in South Asia. More evidence is needed as the overall risk of bias was high in a majority of the studies.

Introduction

Globally, the prevalence of diet-related chronic diseases such as obesity, type 2 diabetes, cardiovascular diseases and cancer is on the rise [1,2]. The risks of type 2 diabetes and cardiovascular diseases increase at a lower body mass index (BMI) level in Asian populations than in populations of high-income countries [3,4]. As increasing economic prosperity in South Asia has resulted in higher consumption of animal products and processed foods, South Asia now bears a double burden of existing undernutrition and growth stunting as well as emerging overweight, obesity and related chronic diseases [5,6]. Unhealthy dietary and physical activity habits increase the long-term risk for adverse health outcomes. Preventive interventions to deal with malnutrition are yet insufficient, especially in low-and middle-income countries [7]. Moreover, implementation of these kinds of interventions requires lots of resources. In India, nutrition and lifestyle interventions have improved eating habits, lifestyle practices, and/or anthropometrics among adolescents [8] and adults at increased risk for type 2 diabetes [9]. A review of European studies reported that educational school-based interventions were moderately effective to promote healthy nutrition in adolescents, but their effects on anthropometrics were inconclusive [10].

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Technology-based behavioural interventions with electronic devices (eHealth), including mobile devices (mHealth) [11], have recently been used in chronic diseases management and general motivation for a healthy diet and physical activity, with limited resources and efforts [12,13]. However, a systematic review found no clear evidence on the efficacy of technology-based interventions for improving dietary behaviours, prevention of obesity or achieving sustainable weight reduction among adolescents [14]. Another systematic review reported that eHealth and mHealth interventions were mainly effective in promoting healthy diets among adults in developing countries [15]. An earlier randomised controlled trial (RCT) from India found a lower incidence of type 2 diabetes among men who received mobile phone messages about a healthy lifestyle than among controls [16]. Similarly, another Indian mHealth intervention study reported improvements in dietary habits, physical activity and BMI in an adult population [17]. As adolescents and younger adults account for over half of the Indian population [18], the prevalence of overweight and obesity has increased among them [19], and they usually adopt the use of technical devices more easily than older adults, it is important to study the effects of technology-based behavioural interventions in younger age groups. It is important to promote a healthy lifestyle among adolescents and younger adults, as once they become parents, it will have beneficial effects on the health of the next generation [20,21].

To our knowledge, there are no systematic reviews on the effects of technology-based dietary interventions in South Asia. Although there is diversity in food cultures, circumstances, religions etc. between and within South Asian countries, South Asian countries have many similarities in food culture and lifestyle behaviours and differ from other low-and-middle-income countries in many aspects. Therefore, mHealth interventions conducted in other cultural settings may not be applicable for populations in South Asia. A systematic review focusing on South Asia could guide the planning of effective mHealth interventions for South Asian countries. Thus, in this systematic review, we aim to investigate the effects of technology-based behavioural interventions on dietary intake or anthropometrics among adolescents (13–18 years) and younger adults (up to 44 years) in South Asia.

Methods

This systematic review was conducted based on a pre-determined and registered protocol (Prospero 2019, CRD42019137851) and reported following the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA 2020) [22,23].

Eligibility criteria

Types of studies

Peer-reviewed RCTs, non-randomised intervention studies, and intervention studies with or without a control group were included in the systematic review.

Dietary intervention

Interventions that focused on improving dietary habits, e.g. to prevent overweight or obesity, were included in the review. Studies that included some additional components along with dietary interventions, such as promotion of physical activity or the use of dietary supplements, were also included.

Technology

The interventions had to use mHealth/health technology as a tool. mHealth was defined according to the definition of World Health Organisation Global Observatory [11] as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices”. The definition covers the use of mobile phone’s voice calls, voice messages and short messaging service and the more complex functionalities and applications [11]. *Population included.* Studies conducted in South Asian countries and including 13–44-year-old people were included in the review.

Types of outcome measures

The primary outcome measures were changes in dietary intake (e.g. food, energy, and macro- and micronutrient intakes). Secondary outcomes were changes in anthropometrics (such as body weight, BMI, waist circumference); changes in knowledge or attitudes related to diet; changes in dietary behavioural intentions or norms; and other changes in community conditions, which might support dietary change.

The eligible studies were grouped into RCTs and non-randomised intervention studies for the synthesis. Studies not fulfilling the eligibility criteria were excluded from the systematic review.

Information sources and search strategy

The information sources included electronic databases PubMed, Scopus, Web of Science, Global Health Library and Health Technology Assessment. The included search terms for each database are reported in Appendix A. The search terms were grouped into five broad categories:

1) *Technology:* Telemedicine, mobile health, mHealth, eHealth, mobile technology, telehealth;
2) *Diet and nutrition*: Body weight, diet, dietary assessment, dietary behaviour, dietary habit, eating behaviour, eating habit, feeding behaviour, feeding pattern, food assessment, food habit, healthy diet, healthy lifestyle nutrition, obesity management, obesity, overweight, weight gain;
3) *Geographical area of intervention*: South Asia, India, Pakistan, Bangladesh, Nepal, Afghanistan, Sri Lanka, Bhutan, Maldives;
4) *Study types*: Intervention and randomised controlled trials;
5) *Age criteria*: Studies that included adolescents and adults aged 13–44 years. The studies could also include younger or older age groups.

The reference lists of the publications and grey literature were also searched for any additional eligible studies including reports from organizational websites. The search was restricted to publications from 1st January 2011–31 st December 2021 since smart phones were not commonly used before 2011 (e.g. in India, 4.7% of people had access to a smart phone in 2011 and 60.6% in 2021) [24]. Only English language texts were included as scientific South Asian papers are published in English.

Study selection

Two authors (AC and TIK) conducted the searches with the help of a senior university librarian and imported citations into a reference management software package (RefWorks). Duplicates were removed. Two reviewers (AC, PG) then independently inspected the titles and abstracts of search results to determine if they met the inclusion criteria. Where there was any disagreement, advice from a third member of the research team (TIK) was sought, and a consensus was reached by discussion. AC and TIK reviewed the full texts of potentially eligible papers and agreed on papers eligible for the systematic review.

Data collection process and data items

Information was extracted from studies as reported into a standardised data extraction form, developed in response to the type and quality of studies identified for inclusion. The information included 1) study characteristics (location, year, design, the number of participants in the analyses, funding), 2) participant characteristics (general population or some specific group, mean age or age range), 3) characteristics of the intervention (duration, methods and contents of the intervention, a theoretical model for behavioural change used for implementation of the intervention, details on the technology used, comparison groups), 4) outcome measures (primary outcomes, dietary and anthropometric outcomes, measurement methods, follow-up time), and 5) results related to the effects of the intervention on the dietary and anthropometric outcomes (all measures, time points and analyses). At this stage, two researchers (AC, TIK) independently extracted the data. This was to ensure that the data were accurate and complete, and all elements of the review process were followed. There was no disagreement at this stage between the two independent reviewers and the data were merged with complete consensus.

Risk of bias in individual studies

Cochrane Risk of Bias 2 tool for RCTs [25] and the ROBINS-I tool for assessing the risk of bias in non-randomised intervention studies were closely followed [26,27]. The risk of bias in the measurement of the outcomes was assessed separately for the dietary outcomes and the anthropometric outcomes when applicable [16,17,27–35]. The numbers of missing data were generally the same for both outcomes and were therefore assessed at the study level. Included studies were assessed for risk of bias independently by two reviewers (AC, TIK). However, the two reviewers were unsure of the assessment decisions regarding three of the 21 papers. These three articles [16,36,37] were additionally assessed by the third reviewer (SK), and after discussions, disagreements were resolved, and a consensus was reached.

Effect measures

Differences in means (SD) or percentages, or odds ratios, as well as p-values or 95% confidence intervals (CI) were reported, whenever available.

Synthesis methods

A narrative synthesis of the results from the eligible studies is provided, separately for RCTs and non-randomised intervention studies and by the overall risk of bias. A meta-analysis was not possible due to the heterogeneity of the individual studies. As a majority of the studies had a high risk of bias, the results of a potential meta-analysis would have been likely to be biased as well.

Results

Study selection

The literature search yielded 388 potentially relevant citations (Fig. 1). After eliminating duplicates, 275 peer-reviewed articles remained for further screening and evaluation. A total of 240 studies were found ineligible based on the title and abstract. Of the 35 full-text articles assessed, 19 articles were excluded as they did not meet the inclusion criteria for different reasons (Fig. 1). Four additional eligible studies [31–33,35] were found from the citations of the eligible studies. One of the ineligible studies was a qualitative study [38] that was carried out to explain the findings of an intervention study [39]. That

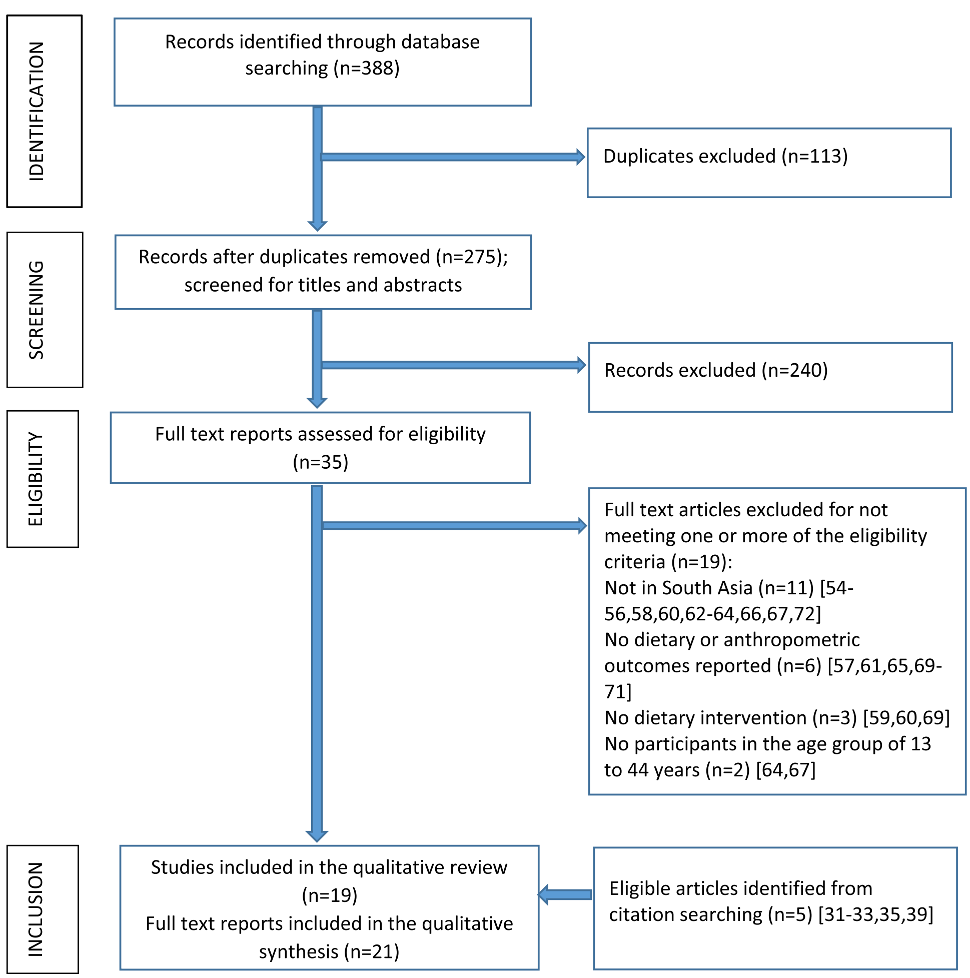

Fig. 1. PRISMA 2020 flow diagram [31-33,35,39] [55-72].

intervention study, even though not identified by the search, was found to be eligible and was included in the present systematic review. Finally, 21 articles were eligible for the final synthesis.

Study characteristics

Table 1 provides a summary of the study characteristics of the 21 articles and a more detailed description is provided in Supplementary Table 1. While all studies aimed at improving dietary and/or anthropometric outcomes, the studies per se are quite heterogeneous in terms of the target audience, methods, and primary outcomes. Seventeen of the articles were reported to be RCTs [16, 28–36,40–45], while the others were non-randomised intervention studies with (n = 3) or without (n = 1) a control group [17,37,46,47]. Fifteen studies [16,17, 28–30,32,34–37,43–47] were from India, four studies [31,39,40,41] were from Bangladesh, and two studies from Pakistan [33,42]. In five studies [16,29,32,34,37], the intervention was based on the trans-theoretical model for behavioural change [48] (Supplementary Table 1). One study [31,49] used two different theoretical models: 1) capability, opportunity, motivation and behaviour, and 2) transtheoretical domains framework. Another study [40] reported that the text messages were based on principles of behavioural change theories, but it did not specify the theories. The other studies did not report having used any theoretical behavioural change model as part of the intervention.

All 21 studies had adult participants and their ages ranged from 18 to 85 years (Supplementary Table 1). Of these studies, 12 studies included people with diabetes or impaired glucose tolerance [16,28–30,32,33,35, 39,40,43–45], three studies included patients with other cardiovascular or metabolic diseases [34,41,42], two studies were conducted among pregnant women [36,47], and four studies were conducted among the general population. [17,31,37,46]. The 15 Indian studies practically included subjects covering the entire country. Among these, seven studies [17,28,32,34,36,44,47] were conducted in a single Indian state each, three studies [16,29,30] in two states, two studies in three states [43,45], one study did not report the location [35] and the remaining studies were conducted across the country [37,46]. The study by Nanditha et al. [32] included participants also from the United Kingdom. The studies by Pawalia et al. [36] and Patnaik et al. [28] were the smallest (n = 36 and n = 55, respectively).

The technology components of the interventions included mobile telephonic consultations with doctors/researchers, mobile text messages (or WhatsApp messaging), voice messages, or videos, which were used as reminders or to give information on healthy dietary and physical activity habits, or a mix of both. Specifically, in the study by Muralidharan et al., the intervention group was asked to use a mobile phone app (mDiab) to track their body weight, diet and physical activity and to watch a weekly video lesson on type 2 diabetes prevention, besides being offered weekly coach calls by a trained nutritionist for 12 weeks [43,45]. The studies by Patnaik et al. [28] and Sharma et al. [17] used both mobile phone calls as well as text messaging during different stages of their interventions. Further, Kaur et al. used both face-to-face consultation on the first visit and phone calls for consulting with the physician during scheduled follow-ups, if needed [44]. Yasmin et al. used interactive, personalised voice calls (10 min) every 10 days to support patients to follow dietary and other advice for diabetes care, besides being offered a possibility to ask for health-related advice from a physician via a 24 h/7d call centre service [39]. One intervention included only phone calls to the participants by the principal investigator [33]. In the study by Paulsamy et al. [47], the MOM programme included a face-to-face educational group session at the first visit, standardised WhatsApp messages every two weeks, and three in-person home visits. The intervention by Manzoor et al. [42] first included individual counselling during the hospital stay, then daily standardised text messages about healthy lifestyle changes, and standard care. The other 12 studies solely used voice messaging [31,34] or text messaging to deliver the mHealth intervention [16,29,30,32,35–37,40,41,46] as part of their design.

There was some variation in the advice given for the control group in these studies. The control group received the usual care in 15 reports [16,29–31,33–36,39, 40, 42–45,47], the same health education as the intervention group but no text messages in two studies [32,41], printed educational materials in one study [28], and nothing in two studies [17, 46]. The study by Ramachandran et al. [37] had no control group.

Regarding dietary outcomes, 17 of the 21 studies assessed the effects of the intervention on dietary habits [16,17,28–35,37,39–42,44,46]. In these studies, the dietary outcomes varied from energy and macronutrient intakes to consumption of different food items, and adherence to the dietary advice in general. Fourteen of the 21 studies reported effects of the intervention on anthropometric outcomes such as body weight, BMI, body fat percentage, waist circumference, hip circumference, waist-hip ratio, gestational weight gain, postpartum weight retention, new-borns birthweight, and crown-heel length [16,17,28–36,43,45,47]. None of the 21 studies reported results on the other secondary outcomes of the present review (changes in knowledge or attitudes related to diet; changes in dietary behavioural intentions or norms; other changes in community conditions, which might support dietary change).

Risk of bias within studies

Of the 17 RCTs, 11 were evaluated to have a high overall risk of bias [28,31,35,36,39,40–45] and five [16,29,30,33,34] had some concerns (Table 2). In the RCT by Nanditha et al. [32], there were some concerns for the dietary outcomes and low risk of bias for the anthropometric outcomes. The risk of bias due to the randomisation process was low in 12 studies [16,29,30–33,35,40–43,45], with some concerns in three [28, 35,44] and high in two studies [36,39]. There were some concerns regarding deviations from intended intervention in five studies [16,28, 29,39,44] and the risk of bias was high for this domain in two studies [31,36]. Eight of the 17 RCTs [28,35,36,39,40,42,43,45] reported a high proportion of loss to follow-up and were rated having a high risk of bias regarding missing outcome data. However, the study by Fottrell et al. [31] selected a different sample of participants for the follow-up measurements, which could not be fully accounted for using the RoB-2 tool. Five studies [28,39,41,42,44] had a high risk of bias and two studies [40,45] had some concerns about the measurement of the outcomes. In seven studies, the risk of bias regarding the measurement of outcome was some concerns (or high) for the dietary outcomes and low for the anthropometric outcomes [16,29,31–35]. Ten studies [28,33–36, 39–42,44] had some concerns about the selection of reported results.

Among the non-randomised intervention studies, three studies [17, 46,47] were assessed to have a serious overall risk of bias and one study [37] a critical overall risk of bias (Table 3). The study by Paulsamy et al. [47] had a serious risk of bias for the confounding domain and a moderate risk of bias for the missing data, measurement of outcomes and reporting of results domains. In the study by Sharma et al., [17] a serious risk of bias arose from the confounding and measurement of the dietary outcome domains, and a moderate risk of bias from reporting results domain, while the risk of bias was low for the other domains. The study by Pfammatter et al. [46] had a serious risk of bias for the confounding and selection of participants domains and a moderate risk of bias for the missing data and reporting results domains. The study by Ramachandran et al. [37] did not include a control group (individuals unexposed to the intervention), due to which this study was rated as being at critical risk of bias for all domains.

Results of individual studies

Changes in dietary outcomes. Among the 14 RCTs that reported dietary outcomes, seven studies [16,29,33,34,39,42,44] had some effect on dietary intake (Table 4). Ram et al. [29] reported that there were significant improvements in the three dietary goals (a decrease in portion size, consumption of oil and consumption of carbohydrates) in the

Table 1
Study characteristics.

First author and year	Study design	Participants	Intervention (dietary intervention, technology)	Dietary and anthropometric outcomes	Number of participants in the analyses
Randomised controlled trials					
Fottrell et al. [31]	A three-arm cluster RCT, villages were randomised	Men and non-pregnant women aged ≥ 30 years. A new random sample was taken for the follow-up measurement, only 25% of participants were the same as at baseline.	**I1, mHealth group**: Twice weekly 1 min long voice messages. The messages included information on T2D etc. Diet was one of the six topic areas. The dietary messages focused on a healthy diet and local resources, and potential strategies to eat more healthily. **I2, community mobilisation group**: Monthly group meetings with various activities. **C**: Usual care (care-seeking in government or private facilities, little or no preventative public health campaigning). **Duration:** 14 months	**D:** fruit and vegetable consumption. **A**: BMI, prevalence of overweight and obesity (BMI≥23 kg/m^2) and abdominal obesity (waist-hip ratio >0.9 for men and >0.85 for women).	11439 (I1: 3812, I2: 3798, C: 3829 in the cross-sectional follow-up survey)
Islam et al. [40]	RCT	Patients with T2D	**I**: Usual care and an automated text message daily (but 90 messages in total). The messages provided health education related to diabetes and 20 of the messages were related to diet. **C**: Usual care. **Duration:** 6 months	**D:** weekly consumption of vegetables and fruits, and weekly sugar consumption (serves of sugar beverages/ week and teaspoons of sugar used in tea and coffee).	163 (I: 90, C: 73)
Jahan et al. [41]	RCT	Patients with hypertension, 35–71 years old	**I**: In-person health education, a health education booklet and text messages to develop awareness and knowledge and to motivate for behavioural changes. The dietary advice was to eat less salt, beef, mutton and junk food, and to eat more fruits and vegetables. Six follow-up meetings, 21 text messages in total. **C**: The same health education and health booklet, but no text messages. **Duration:** 5 months	**D**: vegetable and fruit intake, self-reported salt intake, and measurement of actual salt intake (% of participants who reported improvement in these outcomes).	412 (I: 204, C: 208)
Kaur et al. [44]	RCT	Patients (>18 years) with type 1 or 2 diabetes	**C, Group A**: A follow-up visit to the OPD after 12 weeks. **I1, Group B**: A follow-up visit at the OPD after every 4 weeks. **I2, Group C**: A follow-up visit at the OPD after every 4 weeks. Additionally, advice to contact the concerned doctor at the OPD by phone weekly. Apart from the advised schedule, additional phone calls and OPD visits made by the patients in each group were noted. **Duration:** 12 weeks	**D**: adherence to the dietary advice	120 (I1: 40, I2: 40, C: 40)
Manzoor et al. [42]	RCT	Post-acute coronary syndrome patients	**I**: Usual care and individualised counselling during a hospital stay. Daily standardised text messages about healthy lifestyle changes, and standard care. **C**: Usual care. **Duration:** 6 months	**D**: healthy eating score, restriction of salt intake, preference of healthy diet.	119 (I: 70, C: 49)
Muralidharan et al. [45]	RCT	Individuals at high risk for T2D	**I**: A mobile phone app (mDiab) to track their body weight, diet and physical activity, and to watch a weekly video lesson on T2D prevention. Weekly coach calls by a trained nutritionist.	**A**: body weight change (in kgs and percentage).	561 (I: 271, C: 290)

(continued on next page)

Table 1 (*continued*)

First author and year	Study design	Participants	Intervention (dietary intervention, technology)	Dietary and anthropometric outcomes	Number of participants in the analyses
			C: Usual care. **Duration:** 12 weeks		
Muralidharan et al.[43]	RCT	Individuals at high risk for T2D, 20–65 years old	**I**: A reality-television-based mobile health programme was delivered via videos, text messages and infographics through a smartphone application (mDiab). Weekly health coach calls were made. Focus on weight loss by improving diet (reducing fat intake especially). **C**: Usual care. **Duration:** 12 weeks	**A**: body weight, BMI, body fat percentage, waist circumference.	561 (I: 271, C: 290)
Nanditha et al. [32]	RCT	Employees at public and private organisations, with pre-diabetes, aged 35–55 years	**I**: Structured education on a healthy diet and physical activity at baseline. Additionally, mobile phone text messages 2–3 times per week. The messages provided tips, suggestions, and reinforcement for healthy behaviours. **C**: The same structured education at baseline. **Duration:** 24 months	**D**: energy intake (kcal/day); fat, carbohydrates, protein and fibre intakes (g/day). **A**: body weight, BMI, and waist circumference.	2062 (India: I: 584, C: 587; UK: I: 447, C: 444)
Patnaik et al. [28]	RCT	Patients on treatment for diabetes, age range 30–80 years	**I**: Intensive lifestyle counselling. Printed educational materials and computers were used. A text message containing educational tips for a healthy lifestyle (e.g. diet and physical exercise) was sent weekly. The investigator called each participant by phone every 3 weeks, asked about a healthy lifestyle, and counselled if needed. **C**: Printed educational materials. **Duration:** 3 months	**D**: fried food, starch, sweet, sugar, fish, fruit, vegetables, coffee, soft drinks, water. **A**: BMI, waist-hip-ratio.	55 (I: 34, C: 21))
Pawalia et al. [36]	Reported as an 'RCT', but the women who wanted to participate in an exercise group were randomly assigned either to the exercise group or the exercise and diet group, and the remaining women were in the control group.	Pregnant women > 18 years	**I1, exercise group**: Weekly antenatal exercise sessions at the hospital during pregnancy. **I2, exercise and diet group**: Weekly antenatal exercise sessions at the hospital during pregnancy. Additional regular dietary counselling through mobile text messages, which were reminders, motivational messages, and gave information on guidelines and benefits of maintaining an adequate diet. **C**: Usual care. **Duration:** Not reported	**A**: weight, waist circumference, hip circumference, waist to hip ratio, BMI, gestational weight gain and postpartum weight retention.	36 (I1: 12, I2: 12, C:12)
Ram et al.[29]	RCT	Working men with impaired glucose tolerance aged 35–55 years	**I**: Personalised education and motivation about healthy lifestyle principles (diet, physical activity, body weight), and written information about diet and physical activity at baseline. Additionally, frequent mobile phone messages on healthy dietary habits and physical activity. **C**: Personalised education and motivation about healthy lifestyle principles (diet, physical activity, body weight), and written information about diet and physical activity at	**D**: consumption of carbohydrates and oil, and portion size. **A**: BMI.	517 (I: 261, C: 256)

(*continued on next page*)

Table 1 (*continued*)

First author and year	Study design	Participants	Intervention (dietary intervention, technology)	Dietary and anthropometric outcomes	Number of participants in the analyses
			baseline. **Duration:** 24 months		
Ramachandran et al.[16]	RCT	Working men with impaired glucose tolerance aged 35–55 years	**I:** Personalised education and motivation about healthy lifestyle principles (diet, physical activity, body weight), and written information about diet and physical activity at baseline. Additionally, frequent mobile phone messages on healthy dietary habits and physical activity for two years. **C:** Personalised education and motivation about healthy lifestyle principles (diet, physical activity, body weight), and written information about diet and physical activity at baseline. **Duration:** 24 months	**D:** total dietary energy intake. **A:** BMI, waist circumference.	517 (I: 261, C: 256)
Ramachandran et al.[30]	RCT	Newly diagnosed patients with T2D, age range 20–60 years	**I:** Usual care and customised text messages 2–3 times a week. The message contents were related to a healthy diet, physical activity, diabetes awareness, awareness of complications and medication adherence. **C:** Usual care **Duration:** 24 months	**D:** energy intake, macronutrient intakes, and fibre intake. **A:** body weight and waist circumference.	248 (I: 126, C: 122)
Shahid et al. [33]	RCT	T2D patients, age 18–70 years	**I:** Mobile phone calls by the principal investigator every 15 days (8 in total). The participants were asked about blood glucose self-monitoring, medications, healthy eating and physical activity in each call. **C:** Usual care **Duration:** 4 months	**D:** percentage of participants following the diet plan. **A:** BMI.	440 (I: 220, C: 220)
Sharma et al. [34]	A cluster RCT, villages were randomised	A population-based sample, adults with metabolic syndrome, $\geq$ 20 years old	**I:** Usual care and one voice message per day. The 60 different kinds of messages promoted healthy eating, physical activity and medical treatment etc. **C:** Usual care. **Duration:** 12 months	**D:** healthy diet ($\geq$5 servings/ day of fruit and vegetables). **A:** waist circumference and BMI.	268 (I: 139, C: 129)
Shetty et al.[35]	RCT	Patients with T2D, age range 30–65 years	**I:** A text message every three days to remind them to follow the regime of dietary modification, physical activity and drug schedules. The participants could choose the frequency and content of the messages. **C:** Usual care. **Duration:** 12 months	**D:** Adherence to dietary treatment **A:** BMI	144 (I: 78, C: 66)
Yasmin et al. [39]	Reported as an RCT. Among the first five patients each morning, one patient was randomly selected for each group. Every fifth patient was then allocated to each group.	Patients with T2D	**I:** Interactive, personalised voice calls (10 min) every 10 days to support them to follow dietary and other advice for diabetes care. A possibility to ask for health-related advice from a physician via a 24 h/7d call centre service. **C:** Regular hospital services. **Duration:** Not clearly reported, but approximately 12 months	**D:** adherence to dietary advice (intake within 10% margin of the recommended value for carbohydrate, protein, fat and total energy intake; vegetable intake and fruit intake as recommended). No details on the recommendations were given.	273 (I: 142, C: 131)
Non-randomised intervention studies					
Paulsamy et al. [47]	Reported as ‘a comparative study’, but was classified as a non-randomised	Pregnant women with at least 20 weeks’ gestation	**I:** Routine antenatal care and the MOM programme, which included a single face-to-face	**A:** Maternal: gestational weight gain.	196 (I: 94, C: 102)

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Table 1 (*continued*)

First author and year	Study design	Participants	Intervention (dietary intervention, technology)	Dietary and anthropometric outcomes	Number of participants in the analyses
	intervention study in this review		educational group session at the first visit, focusing on information on healthy, recommended diet. The information was reinforced by standardised WhatsApp messages sent by the research team every two weeks (maximum 8 messages in total). Three in-person home visits were also made. **C**: Routine antenatal care. **Duration:** Not clearly reported but seems that no more than 16 weeks.	New-born: birthweight and crown-heel length.	
Pfammatter et al.[46]	Reported as 'a prospective parallel-group cohort study', but was classified as 'a non-randomised intervention study' in this review	General population > 18 years (intervention group: Nokia mobile phone users, control group: non-Nokia mobile phone users)	**I**: 56 text messages via the mDiabetes programme (mainly twice a week). The messages were designed to motivate improvement in diabetes risk behaviours (diet and physical activity) and increase awareness about diabetes. **C**: Nothing **Duration:** 6 months	**D**: intake of fruit, vegetables and high fat foods.	1243 (I: 611 C: 632)
Ramachandran et al.[37]	Reported as an 'observational study', but was classified as 'an intervention study without a control group' in this review	General population, 86.2% were men with diabetes among 23053 categorised participants	**I**: 90 text messages on healthy living (diet, tobacco use, alcohol use, physical activity, adherence to medication and basics of diabetes/gestational diabetes) on alternate days. **C**: There was no control group. **Duration:** 6 months	**D**: whether the participants followed healthy dietary advice (yes/no).	I: 31725 at baseline. Only 1989 (6.3%) responded to the dietary questions by text messages at 3 or 6 months. A subpopulation of 855 was interviewed by phone at 1-year.
Sharma et al. [17]	Reported as 'a before and after intervention study', but was classified as 'a non-randomised intervention study' in this review	General rural population, age range of 18–64 years	**I**: The participants were called by phone (20 min) once a month to inform them about the importance of modifying behavioural risk factors of non-communicable diseases, to address queries and to provide positive reinforcement. Weekly text messages on the importance of modification of behavioural risk factors. Recommendation to eat at least 5 servings of fruits or vegetables per day and to do physical activity at least for 600 MET-min/week. **C**: Nothing. **Duration:** 8 months	**D**: changes in the percentage of the participants consuming less than 5 servings of fruits or vegetables per day. **A**: changes in BMI.	382 (I: 190, C: 192)

Acronyms: RCT: randomised controlled trial, I: intervention group, C: control/usual care group, D: dietary, A: anthropometric, T2D: type 2 diabetes, BMI: body mass index, OPC: out-patient care

intervention group as compared to the control group. Kaur et al. [44] reported that the patients' adherence to treatment and advice on diet was highest among the phone group compared with the usual care group and the group without phone follow-up service. Shahid et al. [33] reported that the percentage of participants following the diet plan increased in the intervention group (which received mobile phone calls from the investigator) but did not change in the control group. Yasmin et al. [39] demonstrated that adherence to the recommendations on carbohydrate and energy intake, and fruit intake increased in the intervention group from baseline to the follow-up. Mobile phone messaging was associated with a reduced dietary energy intake at follow-up compared with the controls in the study by Ramachandran et al. [16]. Manzoor et al. [42] reported that higher percentages of the intervention group than of the control group had an excellent healthy eating score. The intervention group also preferred a healthy diet and reported that they restricted their salt intake to less than a teaspoon a day more often than the control group. In the study by Sharma et al. [34], the percentage of participants following a healthy diet increased more in the intervention group than in the control group from the baseline to the follow-up. Six studies [28,30–32,40,41] reported no significant differences in the dietary outcomes between the groups at follow-up.

All three non-randomised intervention studies, which reported dietary outcomes, reported effects of the intervention on dietary intake (Table 4). Pfammatter et al. [46] observed that participants receiving text messages increased their consumption of fruits and vegetables, and reduced consumption of high-fat foods compared with the controls. Ramachandran et al. [37] carried out a one-year follow-up among a subgroup of 855 participants and found that 41% of the participants reported following healthy dietary advice at the follow-up (there was no control group in the study). In the study by Sharma et al. [17], the mean number of daily servings of fruits and vegetables increased significantly in both groups, but more in the intervention group than in the control group.

Table 2
Assessment of risk of bias in randomised controlled trials.

	Randomisation process	Deviations from the intended interventions	Missing outcome data	Measurement of outcome	Selection of the reported results	Overall
Fottrell et al. [31]	Low	High	Low	Some concerns / Low**	Low	High
Islam et al.[40]	Low	Low	High	Some concern	Some concern	High
Jahan et al. [41]	Low	Low	Low	High	Some concern	High
Kaur et al. [44]	Some concerns	Some concerns	Low	High	Some concerns	High
Manzoor et al.[42]	Low	Low	High	High	Some concern	High
Muralidharan et al. [45]	Low	Low	High	Some concerns	Low	High
Muralidharan et al. [43]	Low	Low	High	Low	Low	High
Nanditha et al. [32]	Low	Low	Low	Some concerns / Low**	Low	Some concerns / Low**
Patnaik et al.[28]	Some concerns	Some concerns	High	High*	Some concerns	High
Pawalia et al.[36]	High	High	High	Low	Some concerns	High
Ram et al.[29]	Low	Some concerns	Low	Some concerns / Low**	Low	Some concerns
Ramachandran et al. [16]	Low	Some concerns	Low	Some concerns / Low**	Low	Some concerns
Ramachandran et al. [30]	Low	Low	Some concerns	Low***	Low	Some concerns
Shahid et al.[33]	Low	Low	Low	Some concerns / Low**	Some concerns	Some concerns
Sharma et al.[34]	Some concern	Low	Low	Some concerns / Low**	Some concern	Some concern
Shetty et al.[35]	Low	Low	High	High / Low****	Some concern	High
Yasmin et al.[39]	High	Some concerns	High	High	Some concerns	High

* High for the dietary and the anthropometric outcomes
** Some concerns for the dietary outcomes, low for the anthropometric outcomes
*** Low for the dietary and the anthropometric outcomes
**** High for the dietary outcomes, low for the anthropometric outcomes

Table 3
Assessment of risk of bias in non-randomised intervention studies.

	Confounding	Selection of participants into the study	Classification of intervention	Deviations from intended interventions	Missing data	Outcome measurements	Reporting result	Overall bias
Paulsamy et al.[47]	Serious	Low	Low	Low	Moderate	Moderate	Moderate	Serious
Pfammatter et al. [46]	Serious	Serious	Low	Low	Moderate	Low	Moderate	Serious
Ramachandran et al.[37]	Critical	Critical	Critical	Critical	Critical	Critical	Critical	Critical
Sharma et al. [17]	Serious	Low	Low	Low	Low	Serious / Low*	Moderate	Serious

* Serious for the dietary outcomes, low for the anthropometric outcomes

The effects of the interventions on the dietary outcomes were compared by categorising the studies by the overall risk of bias. Of the 14 RCTs reporting dietary outcomes, six studies [16,29,30,32–34] had some concerns for bias and eight studies [28,31,35,39,40–42,44] had a high risk of bias. A higher proportion of the studies with only some concern for bias (4/6 studies) reported that the intervention had an effect on at least one of the dietary outcomes compared with studies with a high risk for bias (3/8 studies). Of the three non-randomised intervention studies which reported dietary outcomes, all had a serious or critical overall risk of bias and reported that the interventions had an effect on at least one dietary outcome.

Changes in anthropometric measures

Among the 12 RCTs that reported anthropometric outcomes, three papers observed beneficial effects of the intervention on changes in anthropometric measures (Table 4). In one of these studies, the mean body weight and the mean waist circumference decreased more in the intervention group than in the control group by 12 weeks' follow-up [43,45]. Another study among pregnant women found that the mean waist circumference increased less in the two intervention groups than in the control group by two months postpartum [36]. The other nine studies [16,28–35] did not find any statistically significant beneficial effects on changes in any anthropometric outcome from baseline to the follow-up.

Of the two non-randomised intervention studies that reported anthropometric outcomes [17,47], both studies reported effects of the intervention on changes in anthropometric measures (Table 4). Sharma et al. [17] showed that among the general rural adult population, the mean BMI reduced slightly but statistically significantly by the follow-up in the intervention group compared with the control group. In the study by Paulsamy et al. [47], the mean birth weight and the mean crown-heel length were higher in the intervention group than in the control group. The maternal outcome, gestational weight gain, was not clearly reported. Based on the reported maternal body weights at baseline (>20 weeks' gestation) and at 36 weeks' gestation (Table 4), the mean gestational weight gain was 1.8 kg in the intervention group and 0.1 kg in the control group (statistical significance of the difference was not reported).

The effects of the interventions on the anthropometric outcomes were also assessed separately for studies with different overall risks of bias. Of the 12 RCTs reporting anthropometric outcomes, one study had a low risk for bias [32], five studies had some concern for bias [16,29,30,

Table 4
Effects of the interventions on the dietary and the anthropometric outcomes.

First author and year	Measurement of the outcomes, follow-up time	Effects on the dietary outcomes	Effects on the anthropometric outcomes
Randomised controlled trials			
Fottrell et al. [31]	The measurement method of the dietary intake was not defined. Height and weight were measured. No information was given on how data on the waist and hip circumference were obtained. The follow-up survey was at 2-years, but for a different sample of participants.	No statistically significant differences were observed in the dietary outcomes between either of the two intervention groups and the control group at the follow-up.	No statistically significant differences were observed in the anthropometric outcomes between either of the two intervention groups and the control group at the follow-up.
Islam et al.[40]	Dietary intake was obtained using a modified WHO STEPS and Indian Migration Study Food Frequency Questionnaire at baseline and at 6 months.	No statistically significant differences were observed in changes in the dietary outcomes between the groups.	Not reported.
Jahan et al.[41]	The participants were asked how much salt they used per day (estimated using spoons). They were asked how many days per week they consumed at least a single piece of fruit or vegetables. The response options were on a Likert-type scale from 1 to 5. The salt concentration of liquid food(s) was measured with a food salinity checker, but no details were given on the selection of the foods.	The intervention had no statistically significant beneficial effect on the dietary outcomes.	Not reported
Kaur et al. [44]	Adherence to the dietary advice was assessed by questioning at the follow-up at 3 months.	The percentages of participants who reported to be adherent to the dietary advice were 20% in Group A, 35% in Group B and 60% in Group C (the statistical significance of the differences was not reported).	Not reported.
Manzoor et al. [42]	Dietary intake was obtained using a 10-item healthy eating assessment questionnaire with questions on the intake of fruits, vegetables, fried foods, snacks, sugar, milk products, and meat. There were additional questions related to salt reduction to less than a teaspoon per day and subjective preference for a healthy diet. All these data were collected at baseline and at 12- and 24-weeks follow-up.	A higher percentage of the intervention group (91.4%) than of the control group (59.2%) were in the 'excellent' category of the healthy eating score ($p < 0.001$) at 24 weeks follow-up. In addition, 92.9% in the intervention group and 81.6% in the control group reported they restricted their salt intake to less than a teaspoon a day ($p = 0.008$), and 95.7% in the intervention group and 81.6% on the control group reported that they preferred healthy diet ($p = 0.012$).	Not reported
Muralidharan et al.[45]	Body weight was measured at baseline and at post-intervention follow-up (at 12 weeks). Height was measured at baseline only.	Not reported.	The intervention group lost 0.8 kg more body weight than the control group by the 12 weeks' follow-up ($p < 0.05$) on average. A total of 15% of the intervention group and 9% of the control group lost more than 5% of their weight ($p > 0.05$).
Muralidharan et al.[43]	Body fat percentage was measured using a body fat analyser (OMRON HBF-306 Body Fat Monitor). Waist circumference was measured using a standard non-stretchable inch tape measure (average of two measurements). Body weight and height were measured, but the methods were not reported. Measurements were performed at baseline and at 12-weeks follow-up.	Not reported	The mean waist circumference was reduced in the intervention group (by 1.8 cm) more than in the control group (by 0.5 cm) ($p = 0.01$). There was no difference in change in body fat percentage in the intervention group (0.7%) and the control group (1.0%) ($p = 0.48$). The intervention group decreased more weight (−1.1 vs. −0.3 kg, $p = 0.01$) and BMI (−0.4 vs. −0.1 kg/m2, $p = 0.002$) than the control group on average.
Nanditha et al. [32]	Dietary intake was obtained using the 24 h recall method, but the number of days at each time point was not reported. Body weight, BMI and waist circumference were measured, but the methods were not	The intervention had no statistically significant effects on the dietary outcomes when using outcome data from all time points (results from India and the UK were combined).	The intervention had no statistically significant effects on the anthropometric outcomes when using outcome data from all time points (results from India and

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Table 4 (*continued*)

First author and year	Measurement of the outcomes, follow-up time	Effects on the dietary outcomes	Effects on the anthropometric outcomes
	reported. The measurements were performed at baseline, 6-months, 12-months and 24-months follow-up.		the UK were combined).
Patnaik et al. [28]	Information on dietary habits was collected by interviewing the participants and using a semi-structured questionnaire. Information on height, weight, BMI, waist circumference and waist-hip ratio were recorded but is not clear if they were measured. All these data were collected at baseline and at the 3-month follow-up.	No statistically significant differences were observed in the dietary outcomes between the groups at the baseline or at the follow-up.	The mean BMI (kg/m^2) was 25.2 (SD 5.3) in the intervention group and 25 (SD 4.7) in the control group at baseline. The respective follow-up values were 25 (SD 4.9) and 24 (SD 2.9). The mean waist-hip ratio was 1.0 (SD 0.2) in the intervention group and 0.97 (SD 0.1) in the control group at baseline. The respective follow-up values were 1 (SD 0.05) in both groups. The statistical significance of the differences was not reported.
Pawalia et al. [36]	Pre-pregnancy weight was self-reported. It is not reported whether the other baseline variables were self-reported or measured in early pregnancy. Weight was measured at the time of delivery. Other outcome variables were measured at 2 months postpartum.	Not reported.	The mean waist circumference increased less in the exercise and diet group (4.08 cm, SD 3.57) and in the exercise group (4.62 cm, SD 4.53) than in the control group (8.25 cm, SD 3.80) by 2 months postpartum (unadjusted, p = 0.031). There were no statistically significant differences in the other outcomes between the groups.
Ram et al. [29]	A 24 h dietary recall at baseline and at follow-up (at 24 months). A trained dietitian conducted the interview. The intakes of carbohydrates, proteins and fat (in grams) were calculated with an in-house dietary analysis programme using the National Institute of Nutrition guidelines for India.	Higher crude percentages of participants in the intervention group improved their dietary habits than in the control group at follow-up: Decreased consumption of carbohydrates (57.1% vs. 47.3%, p = 0.025), decreased consumption of oil (62.1% vs. 48.4%, p = 0.002) and decreased portion size (52.3% vs. 41.8%, p = 0.015), respectively.	There was no difference in the crude percentages of participants with a decrease in BMI of at least 1 unit (kg/m^2) during the follow-up (10.3% in the intervention group vs. 13.3% in the control group, p = 0.301).
Ramachandran et al. [16]	A 24 h dietary recall at baseline and at follow-up (at 24 months). A trained dietitian conducted the interview. The total energy intake (kcal) was calculated with an in-house dietary analysis programme using the National Institute of Nutrition guidelines for India. Body weight and waist circumference were measured at each visit. Height was measured at baseline only.	Total mean energy intake (kcal/day) was lower in the intervention (1998.7, SD 295.4) than in the control group (2042.5, SD 269.8, group difference −43 kcal/day, 95% CI −65.5 to −22.0) at the follow-up. A higher percentage of the intervention group were adherent to the dietary advice than of the control group (unadjusted OR 1.36, 95% CI 1.01–1.83, p = 0.044) at the follow-up.	No statistically significant differences were observed in BMI or waist circumference between the groups at the follow-up.
Ramachandran et al. [30]	A 24 h dietary recall at baseline and at 24 months' follow-up. A trained dietitian conducted the interview. The total energy, macronutrient and fibre intakes were calculated using the National Institute of Nutrition guidelines for India. Anthropometric measurements were made at baseline and at 3-, 6-, 12-, 18- and 24-months follow-ups.	No statistically significant differences were observed between the groups in the dietary outcomes at baseline or at 24 months.	No statistically significant differences were observed between the groups in body weight, BMI or waist circumference at baseline or at 24 months.
Shahid et al. 2015 [33]	The definition or measurement method of the dietary outcome was not reported. Height and weight were measured (no details given). These data were collected at baseline and at 4-months follow-up.	The between-group differences in changes or at follow-up were not tested statistically. The percentage of participants following the diet plan increased from 17.3% to 43.6% (p < 0.001) in the intervention group and did not change in the control group (from 13.6% to 15.9%, p = 0.552).	The between-group differences in changes or at follow-up were not tested statistically. The mean (sd) BMI increased from 27.1 (4.5) to 28.0 (4.7) in the intervention group (p < 0.001) and from 27.6 (3.2) to 28.6 (3.1) in the control group (p < 0.001). The percentage of overweight participants increased from 71.4% to 77.7% in the intervention

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Table 4 (*continued*)

First author and year	Measurement of the outcomes, follow-up time	Effects on the dietary outcomes	Effects on the anthropometric outcomes
			group ($p = 0.001$) and from 77.3% to 91.4% ($p < 0.001$) in the control group.
Sharma et al. [34]	Dietary intake was obtained using a validated 20-item food frequency questionnaire. Measurements were made to obtain body weight (by a spring balance), height and waist circumference (using a non-stretchable measuring tape). These data were collected at baseline and at 12-months follow-up.	The percentage of participants following a healthy diet increased by 20.6% in the intervention group and by 7.9% in the control group from the baseline to the 12-months follow-up (statistically significant, p-value not reported).	There were no statistically significant differences in the percentual changes in BMI or waist circumference between the groups.
Shetty et al. [35]	Adherence to the components of a healthy diet was assessed based on a questionnaire. The participants were asked to record deviations from the prescribed diet in a diary weekly. Body weight was measured. It was not reported whether height was measured or self-reported. These data were collected at baseline and at 12-months follow-up.	No statistically significant differences were observed in the percentage of participants adherent to the dietary treatment at baseline and at follow-up in either group or between the groups at either time point.	The differences in BMI between the groups were not compared. There was no statistically significant change in the percentage of participants with BMI < 25 kg/m^2 from baseline to follow-up in either group.
Yasmin et al. [39]	Self-reported adherence to the dietary recommendations using a structured questionnaire at baseline and at follow-up (at 12–17 months). No details of the questions were reported.	The adherence to the recommendations for carbohydrate intake and energy intake increased in the intervention group from baseline to the follow-up (from 29% to 52% and from 25% to 54%, respectively, $p < 0.001$ for both). Fruit intake increased in the intervention group ($p < 0.001$). No statistically significant changes were observed in the other outcomes in the intervention or the control group.	Not reported.
Non-randomised intervention studies			
Paulsamy et al. [47]	Maternal body weight, height and BMI were obtained at baseline (≥20 weeks'), 28 weeks' and 36 weeks' gestation, but it was not reported whether they were measured or self-reported. Neonatal birthweight and crown-heel length were measured by trained nurses within 72 h of birth.	Not reported.	Gestational weight gain was not clearly reported. At baseline, the mean (sd) maternal weight was 45.8 (4.3) kg in the intervention group and 46.1 (3.9) kg in the control group. At 28 weeks' gestation, the mean (sd) weight was 43.9 (6.2) kg in the intervention group and 41.8 (8.1) kg in the control group. At 36 weeks', the mean (sd) weight was 47.6 (7.4) kg in the intervention group and 46.2 (6.7) kg in the control group. The statistical significances of the differences were not clearly reported. The mean (sd) birth weight was higher in the intervention group (2.78 kg, 0.56) than in the control group (2.56 kg, 0.49, $p = 0.01$). The mean (sd) crown-heel length was higher in the intervention group (47.6 cm, 3.0) than in the control group (46.8 cm, 3.5, $p = 0.001$).
Pfammatter et al. [46]	The data were collected by a phone interview at baseline and at the 6-month follow-up. The dietary questions had categorical response options: 1) the number of fruit servings (0–1, 2–3, 4 or more), 2) the number of vegetable servings (0–1, 2–3, 4 or more), and 3) "Do you consistently avoid eating high-fat food/fried food such as …"? (yes/no).	The intervention group improved their dietary habits compared with the control group at the follow-up: 1) fruit servings OR 1.73, $p < 0.001$, 2) vegetable servings OR 1.75, $p < 0.001$, and 3) high-fat foods OR 1.67, $p = 0.001$), based on logistic regression analyses adjusted for gender, location (urban/rural) and the baseline value of the variable.	Not reported.
Ramachandran et al. [37]	At the 3- and 6-month follow-ups,	Of the 6.3% of the participants who	Not reported.

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Table 4 (*continued*)

First author and year	Measurement of the outcomes, follow-up time	Effects on the dietary outcomes	Effects on the anthropometric outcomes
	the dietary data were collected by eight feedback text messages (contents not reported). Phone interviews were conducted in a subpopulation at the 1-year follow-up, using a structured questionnaire (contents were not reported).	responded to the 3- or 6-month follow-up dietary questions, 57.2% reported that they followed healthy dietary advice. Of the 855 participants at the 1-year follow-up, 41.2% reported that they followed healthy dietary advice.	
Sharma et al. [17]	The dietary data were collected using a semi-structured, validated interview method. The daily number of fruits and vegetable servings was elicited. Body weight, height, and waist and hip circumferences were measured (no details were given). These data were collected at baseline and at the 8-month follow-up.	At baseline, all participants consumed < 5 servings of fruits or vegetables per day. At the follow-up, 94.7% of the intervention group and 97.9% of the control group consumed < 5 servings per day. The mean daily number of servings of fruits or vegetables increased from 1.2 to 2.8 in the intervention group ($p < 0.001$) and from 1.2 to 2.2 in the control group ($p < 0.001$).	The mean BMI reduced from 23.8 (SD 3.6) kg/m^2 to 23.7 (SD 3.5) kg/m^2 ($p = 0.005$) in the intervention group during the follow-up. In the control group, the mean BMI increased from 24.1 (SD 3.8) kg/m^2 to 24.2 (SD 3.5) kg/m^2 ($p = 0.003$) during the follow-up. Changes in the waist and hip circumferences or waist-hip ratio were not reported.

33,34] and six studies [28,31,35,36,43,45] had a high risk of bias. Concerning studies with low risk or some concern for bias, none of the six interventions had a beneficial effect on any of the anthropometric outcomes. Among studies with a high risk of bias, three out of six studies reported that the intervention had effect on at least one anthropometric outcome. Of the two non-randomised intervention studies that reported anthropometric outcomes [17,47], both had a serious risk of bias and reported effects of the intervention on at least one anthropometric outcome.

Discussion

Summary of evidence

This systematic review focused on understanding the effects of technology-based interventions on changes in dietary intake and anthropometrics among adolescents and adults in South Asia. The eligible studies were very heterogeneous in terms of study populations, interventions and outcomes. When including studies with no more than some concerns for bias, the interventions had beneficial effects on at least one dietary outcome in four of the six RCTs that measured changes in diet and no effect on the anthropometric outcomes in the RCTs that measured anthropometric outcomes (see Table 1).

The overall results must be interpreted with caution as 11 of the 17 RCTs had a high overall risk of bias, and all four non-randomised intervention studies had a serious or critical overall risk of bias. The studies with a lower risk of bias had less effective interventions concerning the anthropometric outcomes, but that was not the case concerning the dietary outcomes. It is also challenging to evaluate the effect size or practical significance of the observed changes as the outcomes were very heterogeneous and often measured and reported at a very crude level, e.g. the percentage of participants adherent to the dietary advice, in these studies. Only six of the studies [16,29,31,32,34, 37] specified the behavioural theory that had been used to guide the development of the intervention, which could explain how the intervention helped the participants to change their behaviour.

In the present study, relevant guidelines were closely followed when assessing the risk of bias in the eligible studies [25–27] and reporting the systematic review [22,23]. To our knowledge, this is the first systematic review on the effects of technology-based dietary interventions in South Asia and highlights the research gaps related to this topic. Several other systematic reviews have assessed the effects of various kinds of technology-based dietary interventions, mainly outside of South Asia, and have obtained mixed findings. For example, Müller et al. reported that eight of 11 e- and mHealth interventions had effect on dietary outcomes and 5 of 10 of the interventions had effect on anthropometric outcomes among adults in developing countries [15]. Five of these 11 studies [16,29,33,35,46] were eligible and are also included in the present systematic review. Recently, Ang et al. [50] that the effects of weight-loss interventions including mobile phone apps were small to moderate. The review included 21 studies conducted among any Asian population, but only two of the studies [44,45] were the same as those included in our review. In the following other systematic reviews, most of the included studies were conducted in North America. Based on a meta-analysis of 84 studies, Hutchesson et al. concluded that eHealth interventions were effective for weight loss, but the evidence was insufficient regarding effects on prevention of overweight or obesity [51]. They also found that interventions that included additional face-to-face components were more effective than interventions based on eHealth alone. Goodyear et al. [52] reviewed the effectiveness of social media interventions in 18 studies. They found that many of the interventions had some effect on dietary and anthropometric outcomes based on self-reported data. On the other hand, Chen et al. found no clear evidence on the efficacy of technology-based interventions on dietary or anthropometric outcomes among adolescents in nine studies [14]. Rhodes et al. concluded that exclusively digital interventions had little effect on a healthy diet or gestational weight gain among pregnant women in 11 studies [53]. Techniques such as self-monitoring, goal setting and planning, and feedback and monitoring were reported to be particularly helpful [54]. These systematic reviews [14,15,50–53] used different methods to assess the risk of bias or the quality of the included studies, and the results of the assessment were not taken into account when interpreting the findings of the studies except in the study by Müller et al. [15]. Approximately half of the studies were assessed to have a high risk of bias (or not of good quality) in the reviews by Müller et al., Ang et al., Chen et al. and Rhodes et al. Goodyear et al. classified 33% and Hutchesson et al. only 11% of the studies as having lower quality. Despite many differences in study populations and methodological choices, the findings of these systematic reviews and our systematic review can be summarized as follows: the mHealth interventions have had some effect on self-reported outcomes but less, if any, effect on objectively measured outcomes. Our review adds to the scientific literature by focusing on interventions conducted in South Asian populations and reporting the findings by the risk of bias in the included studies.

Limitations

Study and outcome level

The overall risk of bias was high in 11 of the 17 RCTs and serious or critical in all four non-randomised intervention studies. Among the studies reported as RCTs, the risk of bias due to the randomisation process was high in two studies [36,39] which failed to randomise the participants to the study groups. In the study by Pawalia et al. [36], the pregnant participants could choose whether they will be assigned to the control group with no exercise sessions or to one of the two intervention groups with exercise sessions (and with or without dietary advice). In the study by Yasmin [39], the first patient was randomly selected to the intervention and the control groups among the first five patients each day. From then on, every fifth consenting patient was recruited to each group each day. There were differences in the background characteristics between the intervention and the control groups in both studies which may have affected the findings. The risk of bias due to deviations from the intended interventions was high in two studies [31,36]. In the study by Pawalia et al. [36], the intention-to-treat principle was not followed. Some control participants who started exercising during pregnancy were excluded from the analyses, favouring the intervention groups. In the study by Fottrell et al. [31], a new random sample was taken from the same villages and with the same inclusion criteria for the follow-up measurements. Consequently, only 25% of participants were the same at baseline and in the follow-up, by chance, and the effects of the intervention could not be assessed among the participants starting the intervention at baseline.

The risk of bias due to missing outcome data was high in eight of the 17 RCTs [28,35,36,39,40,42,43,45]. The percentage of or the reasons for loss to follow-up differed between the intervention and the control groups, it was quite likely that missingness in the outcome depended on its true value, the analyses were not corrected for missing data, and drop-out analyses were not provided in these studies. The percentage of missing outcome data was particularly high in the study by Patnaik et al. [28], where 38% of the intervention group and 58% of the control group were lost to follow-up. Pawalia et al. did not even report the number of participants lost to follow-up [36]. The risk of bias in the measurement of the outcomes was high in six studies [28,35,39,41,42,44]. Few of these studies defined the dietary outcomes in detail or reported how the outcomes were assessed (including the anthropometric outcomes in the study by Patnaik et al.). In two studies, the participants were asked to report the amount of salt they used per day (using teaspoons), which is unlikely to be a valid measure of salt intake [41,42]. Although the study by Shahid et al. [33] had only some concerns for bias, the dietary measurement methods were not described, possible drop-outs were not reported and there were errors in the reported numbers for the dietary results.

The non-randomised intervention study by Ramachandran et al. [37] had a critical risk of bias in all domains mainly because there was no control group in the study. Among the three other non-randomised intervention studies [17,46,47], there was a serious risk of bias due to confounding because several potential confounders were not appropriately controlled for in the analyses. The study by Pfammatter et al. [46] had a serious risk of bias in the selection of participants into the study as the selection depended on the availability of the follow-up data, which differed slightly between the groups (62% in the intervention group, 67% in the control group), and was not considered in the analyses. The study by Sharma et al. [17] had a serious risk of bias in the measurement of the dietary outcomes as both the participants and the outcome assessors were aware of the intervention received, which may have affected the quality of the self-reported data.

Review level

This systematic review has some limitations. Firstly, as the eligibility criteria were broad and both RCTs and non-randomised intervention studies were included, the included studies were very heterogeneous in terms of participants, methods and outcomes and it was therefore not possible to carry out a meta-analysis. The inclusion of the non-randomised intervention studies gives a more comprehensive overview of the recent research on the topic in South Asia. However, the non-randomised intervention studies had a clearly higher overall risk for bias than RCTs in this review. Secondly, although the systematic review focused on the age group of 13–44-year-old people (but did not restrict to that age group), only two studies were conducted among this age group and therefore we included studies with a broader age range of participants in this review. Consequently, most of the studies included also older participants and people with type 2 diabetes or impaired glucose tolerance or other chronic diseases. Therefore, the findings may not represent the effects of the interventions among adolescents and younger adults. Another limitation is that the study by Nanditha et al. [32] included participants both from India (57%) and the UK (43%). As the results of the study were not reported separately for participants from each country, the results are not fully comparable to those of the other included South Asian studies. It is also possible that some eligible studies were not identified in the literature search. We may have misinterpreted some information on the included studies as relevant details were not always reported or were unclear and the general quality of reporting was poor in some of the studies. As there were only six studies with no more than some concerns for bias, it was not useful to compare the effects of the interventions by the type of technology used (e.g. text message interventions vs. others). Finally, as 15 out of the 21 included studies were conducted in India, the findings should be generalised to other South Asian countries with caution.

Conclusions

While technology-based dietary interventions have become more common and offer several advantages in terms of effective reach, scalability and follow-up of participants, they need to be used with caution. This systematic review showed that technology-based dietary interventions have had some beneficial effects on self-reported dietary intake, but no effect on anthropometric measures among adolescents and adults in South Asia, especially in India. As the overall risk of bias was high in a majority of the studies, more research is needed widely from South Asian countries before technology-based dietary interventions can be recommended for broader use and public health practice in South Asia.

Future interventions should use a rigorous methodology and the RCT design whenever possible. Relevant guidelines should be followed closely when reporting the methods and findings of the studies. Emphasis should be given to specifying the dietary outcomes and using validated methods to assess changes in dietary intake. The interventions should use effective behavioural change theories and they could examine the use of more advanced mobile phone applications among adolescents and younger adults in different areas in South Asia. There are additional challenges such as suitability and accessibility of the interventions for people with low socio-economic status or low literacy level in South Asia. If proven feasible and effective in different population groups, mobile technology-based dietary interventions could reach a much larger target audience at a lower cost than interventions solely based on face-to-face counselling at health care.

Ethical statement

I have read and have abided by the statement of ethical standards for manuscripts submitted to the Obesity Research & Clinical Practice.Tarja Kinnunen.

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Author’s contributions

SK and TIK had the idea for the systematic review. AC and TIK conducted the literature searches. AC, PG and TIK evaluated whether the identified papers met the inclusion criteria. AC and TIK extracted and summarised the data from the eligible papers. AC, TIK and SK evaluated the risk of bias in the eligible papers. AC and TIK had the primary responsibility for writing the manuscript. All authors participated in writing and revising the manuscript and accepted the final version of it.

Declarations of interest

None.

Data Availability

The data extraction sheets and risk of bias assessment forms are available from the authors.

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Appendix A. The search terms for each database

Search terms for Scopus, Web of Science and Global Health Library databases:

(telemedicine or mobile app* or text messag* or mobile health or mhealth or ehealth or telehealth or mobile technology) AND (healthy diet or healthy lifestyle or feeding behavior eating behavior or nutrition or dietary approaches or dietary behav* or diet or body weight or obesity or overweight or weight gain or weight loss or life style* or obesity management) AND (clinical trial* or trial or intervention* or interventive or interventional or methods) AND (South Asia or India or Pakistan or Afghanistan or Bhutan or Nepal or Bangladesh or Sri Lanka or Maldives).

Search terms for PubMed and HTA databases:

1. ((telemedicine OR mobile applications OR text messaging[MeSH Terms]) OR (telemedicine[Other Term] OR mobile applications [Other Term] OR text messaging[Other Term] OR mobile app* [Other Term] OR mobile health[Other Term] OR mhealth[Other Term] OR ehealth[Other Term] OR telehealth[Other Term] OR text messag*[Other Term] OR mobile technology[Other Term])) OR (telemedicine[Title/Abstract] OR mobile applications[Title/Abstract] OR text messaging[Title/Abstract] OR mobile app*[Title/Abstract] OR mobile health[Title/Abstract] OR mhealth[Title/Abstract] OR ehealth[Title/Abstract] OR telehealth[Title/Abstract] OR text messag*[Title/Abstract] OR mobile technology[Title/Abstract])
2. ((healthy diet OR healthy lifestyle OR feeding behavior OR body weight OR obesity OR diet OR overweight OR weight gain OR weight loss OR life style OR obesity management OR reducing diet[MeSH Terms]) OR (healthy diet[Other Term] OR healthy lifestyle[Other Term] OR feeding behav*[Other Term] OR body weight[Other Term] OR obesity[Other Term] OR diet[Other Term] OR overweight [Other Term] OR weight gain[Other Term] OR weight loss[Other Term] OR life style[Other Term] OR obesity management[Other Term] OR reducing diet[Other Term] OR eating behav*[Other Term] OR nutrition[Other Term] OR dietary approaches[Other Term] OR dietary behav*[Other Term])) OR (healthy diet[Title/Abstract] OR healthy lifestyle[Title/Abstract] OR feeding behav*[Title/Abstract] OR body weight[Title/Abstract] OR obesity[Title/Abstract] OR diet [Title/Abstract] OR overweight[Title/Abstract] OR weight gain [Title/Abstract] OR weight loss[Title/Abstract] OR life style[Title/Abstract] OR obesity management[Title/Abstract] OR reducing diet [Title/Abstract] OR eating behav*[Title/Abstract] OR nutrition [Title/Abstract] OR dietary approaches[Title/Abstract] OR dietary behav*[Title/Abstract])
3. ((clinical trial OR clinical trials as topic OR methods[MeSH Terms]) OR (intervention[Other Term] OR trial[Other Term])) OR (interventions OR intervention OR interventive OR interventional OR methods)
4. ((South Asia OR India OR Pakistan OR Sri Lanka OR Nepal OR Bhutan OR Maldives OR Bangladesh OR Afghanistan[MeSH Terms]) OR (South Asia[Other Term] OR India[Other Term] OR Pakistan [Other Term] OR Sri Lanka[Other Term] OR Nepal[Other Term] OR Bhutan[Other Term] OR Maldives[Other Term] OR Bangladesh [Other Term] OR Afghanistan[Other Term])) OR (South Asia OR India OR Pakistan OR Sri Lanka OR Nepal OR Bhutan OR Maldives OR Bangladesh OR Afghanistan)

Appendix B. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.orcp.2022.06.001.

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