Effect of electronic health interventions on metabolic syndrome: a systematic review and meta-analysis

Dandan Chen, Zhihong Ye, Jing Shao, Leiven Tang, Hui Zhang, Xiyi Wang, Ruolin Qiu, Qi Zhang

ABSTRACT
Objective We aimed to examine whether eHealth interventions can effectively improve anthropometric and biochemical indicators of patients with metabolic syndrome (MetS).

Design Systematic review and meta-analysis.

Methods PubMed, the Web of Science, Embase, Medline, CINAHL, PsycINFO, the Cochrane Library, the Chinese National Knowledge Infrastructure, the Wanfang and Weipu databases were comprehensively searched for papers that were published from database inception to May 2019. Articles were included if the participants were metabolic syndrome (MetS) patients, the participants received eHealth interventions, the participants in the control group received usual care or were wait listed, the outcomes included anthropometric and biochemical indicators of MetS, and the study was a randomised controlled trial (RCT) or a controlled clinical trial (CCT). The Quality Assessment Tool for Quantitative Studies was used to assess the methodological quality of the included articles. The meta-analysis was conducted using Review Manager V5.3 software.

Results In our review, seven RCTs and two CCTs comprising 935 MetS participants met the inclusion criteria. The results of the meta-analysis revealed that eHealth interventions resulted in significant improvements in body mass index (standardised mean difference (SMD)=−0.36, 95% CI (−0.61 to −0.10), p<0.01), waist circumference (SMD=−0.47, 95% CI (−0.84 to −0.09), p=0.01) and systolic blood pressure (SMD=−0.35, 95% CI (−0.66 to −0.04), p=0.03) compared with the respective outcomes associated with the usual care or wait-listed groups. Based on the included studies, we found significant effects of the eHealth interventions on body weight. However, we did not find significant positive effects of the eHealth interventions on other metabolic parameters.

Conclusions The results indicated that eHealth interventions were beneficial for improving specific anthropometric outcomes, but did not affect biochemical indicators of MetS. Therefore, whether researchers adopt eHealth interventions should be based on the purpose of the study. More rigorous studies are needed to confirm these findings.

INTRODUCTION
Metabolic syndrome (MetS) represents an important public health problem. MetS has different diagnostic criteria, but it is characterised by at least three of five metabolic risk factors: abdominal obesity, elevated triglycerides (TG), reduced high-density lipoprotein cholesterol (HDL-C), hypertension and impaired glucose tolerance. The prevalence of MetS is increasing and is even likely to reach epidemic proportions, which will result in substantial medical costs and impose a heavy burden on the healthcare system. A previous study indicated that over 20% of the world’s population met the criteria for MetS, and individuals with MetS were three times more likely to develop cardiovascular disease and five times more likely to develop type 2 diabetes mellitus. Moreover, patients with MetS experienced higher cancer risks and worse health-related quality of life than individuals without MetS. In view of the negative outcomes of MetS, it is necessary to identify and control risk factors for MetS. Factors such as older age, female sex, stress, low physical activity, overweight or obesity, high waist circumference (WC), elevated TG, elevated fasting blood glucose (FBG) and high average diastolic blood pressure (DBP) exhibited a close relationship with the progression of
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MetS. Therefore, healthcare professionals should take measures to effectively manage and treat MetS.

Pharmacological therapy and lifestyle interventions are commonly employed to prevent and treat MetS. However, drugs sometimes have adverse effects and are accompanied by limited efficacy. Therefore, researchers pay more attention to lifestyle interventions, which focus on increasing physical activity and improving the diet, and these interventions could reduce MetS risks. In the healthcare system, interest in the application of eHealth devices to conduct lifestyle interventions for patients is growing. eHealth refers to ‘health services and information delivered or enhanced through the internet and related technologies’, which includes internet and computer, mobile phone (the use of text messaging and applications on mobile phones), tele-health, electronic monitors and wireless and Bluetooth enabled devices. eHealth interventions have become increasingly popular due to making treatments more accessible and affordable. They provide benefits for patients with an inconvenient location or commute and unavailable or inflexible times, and patients may receive the required information in a cost-effective way.

The increased use of eHealth devices may create new opportunities to manage MetS in the coming years. A study by Jahangiry et al found that eHealth interventions, such as web-based interventions, could significantly improve physical activity, dietary intake and several dimensions of quality of life among MetS patients. Furthermore, eHealth interventions were promising approaches to reduce health-related stress in MetS patients and could also provide patients with real-time feedback and with tailored interventions according to their needs. Therefore, eHealth interventions may be more convenient, more flexibly fitted to patients’ needs and promote greater treatment adherence.

While the growing benefits of eHealth are evident, researchers have found that the effects of eHealth interventions on anthropometric and biochemical indicators of MetS were not consistent. Although two systematic reviews have reported the positive effects of eHealth interventions on blood pressure and blood glucose, the two studies did not target patients with MetS. Given that a single study cannot disprove the effects of eHealth interventions among MetS patients and none of the systematic reviews based on randomised controlled trials (RCTs) and controlled clinical trials (CCTs), which are associated with rigorous study design, have been conducted to explore the efficacy of eHealth interventions on anthropometric and biochemical indicators of MetS patients, the primary objective of this review is to determine whether eHealth...
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<tr>
<td>Oh et al, 2015&lt;sup&gt;30&lt;/sup&gt;</td>
<td>Aged ≥20</td>
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<td>Mobile phone-based</td>
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<td>C=153</td>
<td>Care</td>
<td>The measured body weight and body care</td>
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<td>Compositions via mobile phone. Health consultations were provided for patients through their phones. Inquiries regarding disease management, health education, and recommended exercise, medication, and proper nutrition.</td>
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<td>Farhangi et al, 2017&lt;sup&gt;36&lt;/sup&gt;</td>
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<td>NCEP-</td>
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<td>Web-based interactive</td>
<td>Participants could download educational materials about diet and exercise</td>
<td>Waiting-list 6 months</td>
<td>Baseline</td>
<td>Weight, BMI, WC, HDL-C, FBG, LDL-C,</td>
<td>12 weeks</td>
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<td>(Tehran)</td>
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<td>BMI, WC, TG, LDL-C</td>
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<td>C=53</td>
<td>Lifestyle modification</td>
<td>Programme</td>
<td>Send personal questions and receive answers on the personal homepage.</td>
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<td>Radhakrishnan et al,</td>
<td>Aged ≥20</td>
<td>IDF</td>
<td>E=33</td>
<td>IT-supported</td>
<td>Participants were sent two personalised mobile texts that carried programme</td>
<td>Exercise</td>
<td>Baseline</td>
<td>BMI, WC, TG, FBG, HDL-C,</td>
<td>12 weeks</td>
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<td>2014&lt;sup&gt;34&lt;/sup&gt;</td>
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<td>Participants visited links to evidence Physical activity on the study Web site</td>
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<td>TC, HDL-C, TG,</td>
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<td>C=10</td>
<td>Activity intervention</td>
<td>Based Web sites, entered daily minutes of activity Web sites, and received the email feedback on</td>
<td>After intervention 6 weeks</td>
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<td>Fappa et al, 2012&lt;sup&gt;32&lt;/sup&gt;</td>
<td>49.0±11.8</td>
<td>NCEP-</td>
<td>E=18</td>
<td>Telephone counselling</td>
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<td>ATP III</td>
<td>C=13</td>
<td>Sessions through seven 20 min,</td>
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<td>Kim et al, 2013&lt;sup&gt;33&lt;/sup&gt;</td>
<td>E=48.6 ± 13.4</td>
<td>NCEP-</td>
<td>E=33</td>
<td>Telephone-delivered</td>
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<td>E=100</td>
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<td>Kim et al, 2015&lt;sup&gt;36&lt;/sup&gt;</td>
<td>39.63±7.31</td>
<td>NCEP-</td>
<td>E=24</td>
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<td>C=24</td>
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**Exercise goals.**

One-to-one sessions, conducted every two

Weeks for the first 2 months, and every

Month thereafter until the end of the

6-month evaluation period by telephone.

Follow-up nutrition education was given

By two telephone counselling by 2 weeks

During the first 4 weeks of trial. Education

Focused on encouraging maintenance of

Dietary changes according to the dietary

Guide and individual personal risk factors.

The form of the Internet, telephone

Follow-up and emails.

Participants received online counselling Standard

And downloaded goals and strategies about care

Diet and physical activity, electronically

Submitted their diaries and were

Encouraged by text messages.

**Continued**
Interventions are effective at improving anthropometric and biochemical indicators of MetS among patients with MetS. This finding would not only answer whether eHealth interventions are effective for MetS patients, but also provide a reference point in healthcare communication and promotion using new information technology.

**METHODS**

The review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses Guidelines. The literature search was performed on PubMed, the Web of Science, Embase, the Cochrane Library, Medline, CINAHL, PsycINFO, the Chinese National Knowledge Infrastructure, the Wanfang and Weipu databases. The search terms were conjunctions of the following terms: "mobile applications" OR "mobile application" OR "mobile apps" OR "mobile app" OR "cell phones" OR "smartphone" OR "text messaging" OR "mobile technology" OR "internet" OR "web" OR "eHealth" OR "online interventions" OR "telehealth" OR "telephone" OR "SMS" OR "short message" and "metabolic syndrome" OR "syndrome, metabolic" OR "MetS". In addition, manual searches of cited references in relevant papers were conducted. An example of the PubMed search terms can be found in online supplemental file 1.

**Study selection**

The inclusion criteria of this review were as follows: (1) participants: patients with a clinical diagnosis of MetS. The diagnosis of MetS was performed using the International Diabetes Federation (IDF) or National Cholesterol Education Program-Adult Treatment Panel III (NCEP ATP III) or criteria closely aligned to these definitions prior to publication of these definitions in 2001; (2) interventions: patients with MetS received eHealth interventions; (3) comparisons: the participants in the control group received usual care or were wait-listed; (4) outcomes: anthropometric and biochemical indicators including body weight, body mass index (BMI), waist circumference (WC), systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting blood glucose (FBG), total cholesterol (TC), high-density lipoprotein-cholesterol (HDL-C), low-density lipoprotein-cholesterol (LDL-C), triglycerides (TG), and fasting insulin; (5) study designs: randomized controlled trials (RCTs) or cluster randomized controlled trials (CCTs). The exclusion criteria were as follows: (1) studies that were not eHealth interventions; (2) studies that did not detail the intervention methods and materials; (3) studies in which the intervention methods were not similar to those in the included studies; (4) studies in which the control group received usual care or were wait-listed; (5) studies that did not report anthropometric or biochemical indicators and (6) publications that were not in English or Chinese.

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<tr>
<td>Kang et al, 2014</td>
<td>37.93</td>
<td>AHA E=29</td>
<td>Web-based health</td>
<td>Participants learnt educational contents</td>
<td>Waiting-list</td>
<td>8 weeks</td>
<td>Baseline</td>
<td>WC, FBG, TG, HDL-C, SBP, DBP,</td>
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<tr>
<td>(Korea)</td>
<td>NHLBI C=27</td>
<td>Promotion programme</td>
<td>On website, were asked to keep a diary</td>
<td>For 8 weeks and could ask any questions</td>
<td>After intervention</td>
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AHA/NHLBI/IAS/IASO/WHF, American Heart Association/National Heart, Lung and Blood Institute/International Atherosclerosis Society/International Association for the Study of Obesity/World Heart Federation; BMI, body mass index; C, control group; CDS, Chinese Diabetes Society; DBP, diastolic blood pressure; E, experiment group; FBG, fast blood glucose; HDL-C, high-density lipoprotein-cholesterol; IDF, International Diabetes Federation; LDL-C, low-density lipoprotein-cholesterol; MetS, metabolic syndrome; NCEP-ATP, National Cholesterol Education Program-Adult Treatment Panel; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; WC, waist circumference.

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</tr>
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<tbody>
<tr>
<td>Kang et al, 2014</td>
<td>37.93</td>
<td>AHA E=29</td>
<td>Web-based health</td>
<td>Participants learnt educational contents</td>
<td>Waiting-list</td>
<td>8 weeks</td>
<td>Baseline</td>
<td>WC, FBG, TG, HDL-C, SBP, DBP,</td>
</tr>
<tr>
<td>(Korea)</td>
<td>NHLBI C=27</td>
<td>Promotion programme</td>
<td>On website, were asked to keep a diary</td>
<td>For 8 weeks and could ask any questions</td>
<td>After intervention</td>
<td>8 weeks</td>
<td>HDL-C, SBP, DBP,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IASO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WHF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AHA/NHLBI/IAS/IASO/WHF, American Heart Association/National Heart, Lung and Blood Institute/International Atherosclerosis Society/International Association for the Study of Obesity/World Heart Federation; BMI, body mass index; C, control group; CDS, Chinese Diabetes Society; DBP, diastolic blood pressure; E, experiment group; FBG, fast blood glucose; HDL-C, high-density lipoprotein-cholesterol; IDF, International Diabetes Federation; LDL-C, low-density lipoprotein-cholesterol; MetS, metabolic syndrome; NCEP-ATP, National Cholesterol Education Program-Adult Treatment Panel; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; WC, waist circumference.
Two authors (DC and JS) independently screened the titles and abstracts of all potentially relevant studies. We ultimately identified the papers that met the above described eligibility criteria and obtained the full text of these articles for this systematic review and meta-analysis. Discussion was used to resolve differences.

**Data extraction**

The data were extracted from the included articles using standardised extraction forms. Data included age, country, diagnostic criteria, the number of participants in the experimental and control groups, intervention methods and details, control details, duration of interventions, follow-ups and outcomes. Two authors (DC and JS) independently extracted data from each study, and inconsistencies were resolved through discussion with a third author (ZY). Authors of these studies were contacted if more data were needed. Data extraction form could be found in online supplemental file 2.

**Quality assessment**

The methodological quality of all studies was measured using the Quality Assessment Tool for Quantitative Studies, developed by the Effective Public Health Practice Project, Canada. This tool could be used for RCTs, quasi-experimental studies and uncontrolled studies. The content and construct validity have been established. Two authors (DC and HZ) independently assessed the quality of the included studies. Studies were assessed based on six criteria: selection bias, study design, confounders, blinding, data collection methods and withdrawals and drop-out. The quality rating for the included studies was ‘strong’, ‘moderate’ or ‘weak’. If the two reviewers disagreed, a third author was available for discussion.

**Statistical analysis**

Rev Man V.5.3 software (The Nordic Cochrane Center, The Cochrane Collaboration) was used to quantify the outcomes of the eHealth interventions. Mean net change was used to generate results for this meta-analysis for continuous variables. Mean net changes were calculated as the differences in the changes (mean value post-intervention minus mean value at baseline) for both the experimental group and the control group. Intervention effects were measured by the standardised mean difference (SMD) or weighted mean difference with 95% CIs of standardised mean net changes between the intervention and control groups. SMD was interpreted based on Cohen’s definitions: 0.2–0.5 is defined as a small effect, 0.5–0.8 is a moderate effect and >0.8 is a large effect. The I^2 statistic was performed to analyse heterogeneity. If I^2 of 25%–50% indicated moderate heterogeneity, and >50% indicated high heterogeneity. Tests of heterogeneity were used to decide which method would be used to obtain the pooled results. When I^2 was >50%, a
random-effect model was used; otherwise, a fixed-effect model was employed. Significance was defined as p<0.05. Where statistical heterogeneity was detected, possible contributing factors were investigated in sensitivity analyses.

**Patient and public involvement**

Patients and the public were not involved in this review.

**RESULTS**

Figure 1 illustrates the selection process. The authors retrieved 2185 articles from the databases at the beginning of the study. A total of 1993 records were screened for inclusion after removing 192 repeated documents. Eleven studies matched the above eligibility criteria for the systematic review. For two trials, Zhang and Wu, and Kang et al based on the criteria of the IDF, Chinese Diabetes Society and American Heart Association/National Heart, Lung and Blood Institute/International Atherosclerosis Society/International Association for the Study of Obesity/World Heart Federation.

**Characteristics of eHealth interventions**

The intervention durations ranged from 6 weeks to 6 months. The types of eHealth interventions were mobile phone-based care interventions (n=2), web-based interactive lifestyle modification programmes (n=5) and telephone-delivered interventions (n=2). In terms of mobile phone-based care interventions, participants in the intervention groups could inquire about health information and immediately receive feedback that provided MetS information via mobile phone. In addition, five studies conducted web-based interventions, and the intervention groups could download educational materials about diet and exercise, send personal questions and receive answers on their personal internet homepage. Moreover, Kim et al. and Fappa et al. tested the feasibility of telephone counselling. Participants received telephone counselling sessions and were encouraged to maintain dietary changes according to the dietary guide and individual personal risk factors.

**Study quality**

Quality assessments are shown in table 2. In terms of study design and data collection methods, the included studies had high methodologic quality. However, blinding of the participants and assessors who delivered the treatment interventions was not feasible because they could easily identify the treatment. In particular, three studies did not report whether there were differences between the eHealth interventions except from Zhang and Wu study on WC.

---

**Figure 3** Forest plot for effect of eHealth interventions on standardised mean net changes of WC. WC, waist circumference.

**Figure 4** Forest plot for effect of eHealth interventions from Zhang and Wu study on WC.
groups at baseline.30 34 36 These factors influenced the quality of the included studies. Overall, over half of the studies were of high methodological quality.

Effectiveness of eHealth Interventions among patients with MetS

Body weight

In our study, three included studies chose body weight as an outcome.19 30 33 Due to the limited number of studies, we chose to describe the results for body weight and did not perform a quantitative summary. Kim et al19 found that there were significant group by time interactions in regard to body weight (p=0.022). In a study by Oh et al,30 participants in the intervention group showed significant improvements in body weight compared with the body weight in the control group (p<0.001). Similarly, Kim et al33 reported that at the end of the trial, the intervention group showed a significantly greater reduction in weight than the other group (p<0.05). Therefore, eHealth interventions may be effective in improving body weight in patients with MetS.

Body mass index

A meta-analysis of six studies with 879 participants found a significant effect on BMI in the experimental group versus the control group (SMD=−0.36, 95% CI (−0.61 to −0.10), p<0.01), with a small effect size pooled across studies. There was substantial evidence of high heterogeneity (p=0.01, I²=65%) (figure 2).

Waist circumference

WC was mentioned as an outcome measurement in seven studies comprising 606 participants. Significant improvements were observed in the experimental groups in comparison with the control groups (SMD=−0.47, 95% CI (−0.84 to −0.09), p=0.01), with a small effect size pooled across studies. There was substantial evidence of high heterogeneity (p=0.0001, I²=79%) (figure 3). Zhang and Wu’s35 study showed the highest effect sizes for WC in the included studies. To explore the source of this considerable heterogeneity, we excluded the Zhang and Wu35 study and found that the heterogeneity decreased (I²=32%), which indicated that the study contributed to the considerable heterogeneity (figure 4).

Triglycerides

The impact of eHealth interventions on TG among patients with MetS has been explored in eight studies. As shown in figure 5, compared with the control groups, the participants who received mHealth and eHealth interventions did not experience significant changes in TG (SMD=−0.22, 95% CI (−0.84 to −0.09), p=0.01). There was substantial evidence of high heterogeneity (p=0.0008, I²=72%) (figure 5).

Total cholesterol

In the five reviewed studies, the results suggested that there were no significant differences between the intervention groups and the control groups in regard to TC (SMD=0.15, 95% CI (−0.20 to 0.50), p=0.39). There was evidence of high heterogeneity (p=0.02, I²=66%) (figure 6).

High-density lipoprotein cholesterol

In our review, seven studies found that eHealth interventions did not cause significant effects on HDL-C compared with the effects in the control groups (SMD=−0.17, 95% CI (−0.36 to 0.02), p=0.09). There was no evidence of high heterogeneity (p=0.68, I²=0%) (figure 7).
Low-density lipoprotein cholesterol
In our study, four reviewed studies reported the LDL-C outcome. Farhangi et al.\textsuperscript{36} found that there were no significant differences in LDL-C between the intervention and control groups. Bosak et al.\textsuperscript{31} reported no significant effect of an internet intervention on LDL-C compared with the effect observed in the control group. In the study by Kim et al.,\textsuperscript{33} the authors did not find statistically significant effects of the intervention on LDL-C. Moreover, Radhakrishnan et al.\textsuperscript{34} did not find a significantly positive effect of the intervention on LDL-C compared with that observed in the usual care group.

Systolic blood pressure
In terms of SBP, six studies found that eHealth interventions had significant effects on SBP (SMD=−0.35, 95% CI (−0.66 to −0.04), p=0.03), with a small effect size pooled across studies. High heterogeneity was detected in the analysis (p=0.01, $\Gamma^2=66\%$) (figure 8).

Diastolic blood pressure
DBP was only evaluated in six studies. Compared with the control groups, improvements in DBP were not observed in the experimental groups (SMD=−0.35, 95% CI (−0.82 to 0.13), p=0.15). High heterogeneity was found in the meta-analysis of DBP (p<0.001, $\Gamma^2=86\%$) (figure 9). After excluding Zhang and Wu\textsuperscript{35} study, the heterogeneity decreased ($\Gamma^2=71\%$), which indicated that the study contributed to the high heterogeneity (figure 10).

Fasting blood glucose
As shown in figure 11, in the seven reviewed studies, there were no significant differences in FBG in the control groups and the intervention groups (SMD=−0.27, 95% CI (−0.72 to 0.19), p=0.25). There was no evidence of high heterogeneity (p<0.001, $\Gamma^2=86\%$) (figure 11). After excluding the Zhang and Wu\textsuperscript{35} study, the heterogeneity decreased ($\Gamma^2=0\%$), which indicated that the study was the origin of the high heterogeneity (figure 12).

Fasting insulin
In the two reviewed studies, Farhangi et al.\textsuperscript{36} found a significant positive effect of the intervention on fasting insulin compared with the effect observed in the usual care group. However, in the study of Kim et al.,\textsuperscript{33} the results showed no significant differences in fasting insulin between the control groups and the intervention groups.

Summary of results
As shown in table 3, this systematic review and meta-analysis demonstrated that eHealth interventions resulted in significant improvements in BMI, WC and SBP. However, we did not find significantly positive effects of the eHealth interventions on TG, TC, HDL-C, DBP or FBG compared with the effects observed in the usual care groups or wait listed groups. Moreover, due to the limited number of studies, we could not quantify body weight, LDL-C or fasting insulin. Through the descriptions of the included studies, we found significant effects of the eHealth interventions on body weight. The effects of the eHealth interventions on fasting insulin were mixed, and the effects on LDL-C were negative in the experimental groups compared with the effects in the control groups.
DISCUSSION

This review is the first to describe and evaluate nine RCTs and CCTs that used eHealth interventions to improve metabolic risk factors among patients with MetS. The current study showed that eHealth interventions resulted in significant improvements in body weight, BMI, WC and SBP compared with the effects of usual care but did not affect TG, TC, HDL-C, LDL-C, FBG or fasting insulin levels. Our results indicated that eHealth interventions were effective as interventions in improving specific anthropometric parameters among individuals with MetS.

Our results showed significant reductions in body weight, BMI and WC, which was in line with the suggested significant benefits of eHealth interventions in regard to body weight, BMI and WC in the two studies.38,39 Weight loss is the cornerstone of MetS management.40 Weight loss has beneficial impacts on MetS.41 The magnitude of weight loss was associated with dose-effect improvements in high blood pressure, hyperglycaemia and hyperlipidaemia.42 In contrast, obesity is a risk factor for MetS.30 The positive effect on weight loss and BMI might be due not only to the intervention contents focusing on healthy diet and regular physical activity in the included studies, which were the most effective methods for managing MetS,43 but also to the fact that the exchange of diet and exercise information through eHealth devices, such as the Internet, was found to be more effective in weight loss and maintenance than traditional methods of self-management.14 Kim et al33 found that counselling by telephone could be effective in providing advice and education for MetS patients who need continuous improvement in health behaviours. Moreover, for healthcare professionals, maintaining frequent contact with participants was critical for participant engagement in interventions and to ensure that participants received an adequate intervention.31 Additionally, the greatest adherence to lifestyle goals was observed in the eHealth intervention group, which could explain the weight reduction result.32 For the WC outcome, a 1 cm increase in WC increases the risk of cardiovascular events by 2%.46 Therefore, WC control is vital for MetS patients. The significant reduction in WC may be attributed to the usefulness of continuous counselling through eHealth devices in the treatment of MetS.33 The eHealth devices provided opportunities for patients and medical personnel to communicate, which helped MetS patients have access to health information and improve compliance with interventions. Therefore, a positive effect was observed for WC.

Moreover, in this study, the greater pooled improvements reached significance for SBP. Our result was consistent with those of the studies by Zha,46 Haas et al47 and Nolan et al,48 which illustrated that eHealth interventions effectively improved the level of SBP. This effect might be because eHealth interventions could be more flexibly fitted to MetS patients’ lives and promote greater adherence to the lifestyle programme.32 In addition, the advantages of eHealth interventions, such as widespread appeal, accessibility, ability to reach large and geographically diverse populations and great compliance at a low cost,49,50 contributed to the beneficial change.

However, it is also important to note that the eHealth interventions do little to nothing to significantly improve TG, TC, DBP, FBG, HDL-C, LDL-C and fasting insulin. The results from this systematic review were similar to those reported in previous systematic reviews.51,52 The reason behind this phenomenon may be the differences in study designs, characteristics of study populations, different technologies used in eHealth interventions and...
duration of the interventions. For instance, the duration of the intervention (6 weeks or 8 weeks) in some studies might not be enough to improve many metabolic parameters. In addition, MetS is characterised by the presence of at least three of five indices. However, these indicators are not homogeneous in patients, as any three of these five indicators are acceptable for the diagnostic criteria of MetS. Therefore, when participants met the inclusion criteria, their normal and abnormal data could be included in the analysis. As a result, the intervention effects may be affected. Additionally, a limited number of studies could explain the nonsignificant changes. We included a total of seven RCTs and two CCTs. More studies should be included to further verify the results.

Limitations

Several limitations should be acknowledged. First, the number of RCTs and CCTs and the overall sample size included in the meta-analysis were small. Therefore, the findings of our review should be interpreted with caution. Second, because of the limited number of papers, we could not reliably assess publication bias of the included studies and have not explored which eHealth type is more effective. Third, we only searched Chinese and English databases. More high-quality articles should be included. Another limitation of the review was that the results of the meta-analysis had high heterogeneity. Possible sources of heterogeneity included differences in diagnostic criteria for MetS and eHealth types. Finally, most studies were conducted in developing countries, and the majority were performed in Asia. Only two studies were conducted in developed countries. In the future, we should include more target populations from different cultural contexts to increase the representativeness and stability of the results.

Implications for Practice and Future Research

EHealth is developing as technology advances and has the potential to provide health communication and promotion. Our study adds value to the current literature as the first systematic review and meta-analysis to provide eHealth interventions for MetS patients. The results indicated that eHealth interventions could be used to improve specific anthropometric and biochemical outcomes among MetS patients, such as body weight, BMI, WC and SBP. However, eHealth interventions could not reduce overall health risks. Due to the limited number of studies, more studies are needed to confirm these results. The eHealth interventions employed a broad range of technologies; however, user satisfaction and adherence to long-term interventions (>6 months) are still unclear. Future studies should focus on user satisfaction with eHealth devices and compliance with long-term interventions, which are important factors affecting the effectiveness of interventions. Additionally, MetS is composed of different components and diverse combination types. However, precise interventions for patients with different metabolic components have not been developed. Therefore, in the future, the optimisation of existing interventions is needed to achieve precise treatment for patients with MetS. This optimisation could be beneficial to healthcare providers trying to recommend an intervention therapy for patients with different characteristics. Moreover, the results of this current study were derived from a small number of RCTs and CCTs, and we believe that more regions and larger sample studies are needed.

Figure 11
Forest plot for effect of eHealth interventions on standardised mean net changes of FBG. FBG, fasting blood glucose.

Figure 12
Forest plot for effect of eHealth interventions except from Zhang and Wu study on FBG. FBG, fasting blood glucose.
CONCLUSION

Our study provides preliminary data for the future development and application of eHealth interventions for patients with MetS. The results from this systematic review and meta-analysis indicated that eHealth interventions have significant effects on body weight, BMI, WC and SBP for individuals with MetS. However, their effectiveness on TG, TC, HDL-C, LDL-C, FBG and fasting insulin is insufficient. Therefore, eHealth interventions are beneficial for improving specific anthropometric outcomes. Researchers should decide whether to use eHealth interventions according to their research objectives. Additional eHealth interventions with rigorous study designs are needed to provide robust evidence in a diverse population in the future.

Acknowledgements  We thank the people who took time to become involved in the study.

Contributors  ZY, DC and JS were responsible for the design of this study. DC and JS designed the search strategies and performed the literature searches. DC, JS and HZ performed the review selection, and DC and HZ assessed the methodological quality of the reviews. DC, JS, LT, XW, RQ and QZ were responsible for the data extraction, analysis, and/or interpretation of the data. ZY and DC drafted this manuscript in cooperation with JS, LT, XW, RQ and QZ. All authors read and approved the manuscript.

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Patient consent for publication  Not required.

Provenance and peer review  Not commissioned; externally peer reviewed.

Data availability statement  All data relevant to the study are included in the article or uploaded as supplementary information. No additional data available.

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REFERENCES


Table 3  Estimations of the SMD or MD of related indicators with 95% CI between the intervention and control groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>No of included</th>
<th>SMD (random effect) or MD (fixed effect)</th>
<th>95% CI</th>
<th>I² (%)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index</td>
<td>Six</td>
<td>−0.36</td>
<td>−0.61 to −0.10</td>
<td>65</td>
<td>0.006*</td>
</tr>
<tr>
<td>Waist circumference</td>
<td>Seven</td>
<td>−0.47</td>
<td>−0.84 to −0.09</td>
<td>79</td>
<td>0.01*</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>Eight</td>
<td>−0.22</td>
<td>−0.53 to 0.10</td>
<td>72</td>
<td>0.18</td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>Five</td>
<td>0.15</td>
<td>−0.25 to 0.50</td>
<td>66</td>
<td>0.39</td>
</tr>
<tr>
<td>High-density lipoprotein cholesterol</td>
<td>Seven</td>
<td>−0.17</td>
<td>−0.36 to 0.02</td>
<td>0</td>
<td>0.09</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>Six</td>
<td>−0.35</td>
<td>−0.66 to −0.04</td>
<td>66</td>
<td>0.03*</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>Six</td>
<td>−0.35</td>
<td>−0.82 to 0.13</td>
<td>86</td>
<td>0.15</td>
</tr>
<tr>
<td>Fasting blood glucose</td>
<td>Seven</td>
<td>−0.27</td>
<td>−0.72 to 0.19</td>
<td>86</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*P<0.05.

MD, mean difference; SMD, standardised mean difference.

before eHealth interventions could be recommended in future guidelines.


Additional file 1: Search strategy

Search terms were combined with ‘OR’ and concepts were combined with ‘AND’ (Pubmed example).

1 metabolic syndrome [MeSH Terms]
2 Metabolic Syndromes [Title/Abstract]
3 Syndrome, Metabolic [Title/Abstract]
4 Syndromes, Metabolic [Title/Abstract]
5 1 or 2 or 3 or 4
6 Mobile applications [MeSH Terms]
7 mobile application [Title/Abstract]
8 Mobile apps [Title/Abstract]
9 mobile app [Title/Abstract]
10 Cell Phones [Title/Abstract]
11 Cell Phone [Title/Abstract]
12 Smartphone [Title/Abstract]
13 Text messaging [Title/Abstract]
14 text message [Title/Abstract]
15 mobile phones [Title/Abstract]
16 mHealth [Title/Abstract]
17 mobile health [Title/Abstract]
18 mobile application [Title/Abstract]
19 Internet [Title/Abstract]
20 web [Title/Abstract]
21 eHealth [Title/Abstract]
22 online interventions [Title/Abstract]
23 telehealth [Title/Abstract]
24 telephone [Title/Abstract]
25 SMS [Title/Abstract]
26 short message [Title/Abstract]
27 mobile technology [Title/Abstract]
28 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 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27
29 5 and 28
## Data extraction form

### Table 1. Study characteristics of randomized controlled trials (RCTs) and controlled clinical trials (CCTs) included in the review.

<table>
<thead>
<tr>
<th>Study (Country)</th>
<th>Age</th>
<th>MetS criteria</th>
<th>Allocation</th>
<th>Intervention types</th>
<th>Intervention details</th>
<th>Control group</th>
<th>Intervention length</th>
<th>Follow-ups</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oh et al., 2015 (Korea)</td>
<td>aged ≥20</td>
<td>NCEP-E ATP III</td>
<td>E = 181</td>
<td>Mobile phone-based care</td>
<td>Participant received feedback based on the measured body weight and body compositions via mobile phone. Health consultations were provided for patients through their phones inquiries concerning disease management, health education, recommended exercise, medication, and proper nutrition.</td>
<td>Standard care</td>
<td>24-week</td>
<td>Baseline, after intervention 12 weeks 24 weeks</td>
<td>Weight (+)</td>
</tr>
<tr>
<td>Farhangi et al., 2017 (Tehran)</td>
<td>aged ≥20</td>
<td>NCEP-E ATP III</td>
<td>E = 64</td>
<td>Web-based interactive lifestyle modification program</td>
<td>Participants could download educational materials about diet and exercise, and send personal questions and receive answers on the personal homepage.</td>
<td>Waiting-list 6-month</td>
<td>Baseline</td>
<td>After intervention 6 months</td>
<td>Weight, BMI, WC, SBP, DBP, TC, TG, HDL-C, FBG, LDL-C, m</td>
</tr>
<tr>
<td>Radhakrishnan., 2014 (India)</td>
<td>- IDCDF</td>
<td>E =33</td>
<td>C =28</td>
<td>IT-supported home-based exercise program</td>
<td>Participants were sent two personalized mobile texts per week that carried metabolic syndrome information. Participants received mobile calls at least once a week to discuss the health and were encouraged to exercise regularly.</td>
<td>Exercise program 12-week</td>
<td>Baseline</td>
<td>After intervention 12 weeks</td>
<td>BMI, WC, TG, FBG, HDL-C, LDL-C, m</td>
</tr>
<tr>
<td>Bosak et al., 2010 (America)</td>
<td>32-66</td>
<td>NCEP-E ATP III</td>
<td>E =12</td>
<td>Internet physical activity intervention</td>
<td>Participants visited links to evidence-based Web sites, entered daily minutes of physical activity on the study Web site, and received the e-mail feedback on the</td>
<td>Usual care 6-week</td>
<td>Baseline</td>
<td>After intervention 6 weeks</td>
<td>TC, HDL-C, TG,</td>
</tr>
</tbody>
</table>
Continued Table 1. Study characteristics of randomized controlled trials (RCTs) and controlled clinical trials (CCTs) included in the review.

<table>
<thead>
<tr>
<th>Study (Country)</th>
<th>Age</th>
<th>MetS criteria</th>
<th>Allocation</th>
<th>Intervention Methods</th>
<th>Intervention Details</th>
<th>Control group</th>
<th>Intervention length</th>
<th>Follow-ups</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fappa et al., 2012 (Greece)</td>
<td>49.0 ±11.8</td>
<td>NCEP-ATP III</td>
<td>E =18 C =13</td>
<td>Telephone counseling</td>
<td>Participant received nutrition counseling sessions through seven twenty-minute, one-to-one sessions, conducted every two weeks for the first 2 months, and every month thereafter until the end of the 6-month evaluation period by telephone.</td>
<td>Usual care</td>
<td>6-month</td>
<td>Baseline</td>
<td>After intervention 6 months</td>
</tr>
<tr>
<td>Kim et al.,2013 (Korea)</td>
<td>E = 48.6 ± 13.4 C =48.1 ± 12.3</td>
<td>NCEP-ATP III</td>
<td>E =33 C =33</td>
<td>Telephone-delivered nutrition education</td>
<td>Follow-up nutrition education was given by two telephone counselling by 2 weeks during the first 4 weeks of trial. Education focused on encouraging maintenance of dietary changes according to the dietary guide and individual personal risk factors.</td>
<td>Initial</td>
<td>3-month</td>
<td>Baseline</td>
<td>After intervention 3-month</td>
</tr>
<tr>
<td>Xiumin Zhang 2011 (China)</td>
<td>38. 97 ± 5. 37</td>
<td>CDS</td>
<td>E =100 C =100</td>
<td>Internet-based intervention</td>
<td>Participant received intervention about diet, exercise, and health education in the form of the Internet, telephone follow-up and e-mails.</td>
<td>Usual care</td>
<td>-</td>
<td>Baseline</td>
<td>After intervention</td>
</tr>
<tr>
<td>Kim Chun Ja, 2015 (Korea)</td>
<td>39.63 ±7.31</td>
<td>NCEP-ATP III</td>
<td>E =24 C =24</td>
<td>Internet-based lifestyle intervention</td>
<td>Participants received online counseling and downloaded goals and strategies about diet and physical activity, electronically submitted their diaries and were encouraged by text messages.</td>
<td>Standard care</td>
<td>16-week</td>
<td>Baseline</td>
<td>After intervention16 weeks</td>
</tr>
</tbody>
</table>
## Continued Table 1. Study characteristics of randomized controlled trials (RCTs) and controlled clinical trials (CCTs) included in the review.

| Study (Country) | Age | MetS criteria | Allocation | Intervention methods, details | Control group | Intervention length | Follow-ups | Outcomes |
|-----------------|-----|---------------|------------|-----------------------------|---------------|---------------------|------------|
| Js Kang, 2014 (Korea) | 37.93 | AHA/E =29 NHLBI/C =27 IAS/IASO/WHF | Web-based health promotion program | Participants learnt educational contents on website, were asked to keep a diary for 8 weeks and could ask any questions about the program by telephone. | Waiting-list 8-week | Baseline | After intervention 8 weeks | WC, FBG, TG, HDL-C, SBP, DBP, |

**Abbreviations:** MetS, metabolic syndrome; E, experiment group; C, control group; WC, Waist circumference; BMI, Body mass index; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; LDL-C, Low-density lipoprotein-cholesterol; HDL-C, High-density lipoprotein-cholesterol; TG, Triglycerides; TC, Total cholesterol; FBG, Fast blood glucose; IDF, International Diabetes Federation; NCEP-ATP, National Cholesterol Education Program-Adult Treatment Panel; CDS, Chinese Diabetes Society; AHA/NHLBI/IAS/IASO/WHF, American Heart Association/National Heart, Lung and Blood Institute/International Atherosclerosis Society/International Association for the Study of Obesity/World Heart Federation.