

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

Dandan Chen,<sup>1</sup> Zhihong Ye ,<sup>1</sup> Jing Shao,<sup>2</sup> Leiwen Tang,<sup>1</sup> Hui Zhang,<sup>3</sup> Xiyi Wang ,<sup>1</sup> Ruolin Qiu,<sup>1</sup> Qi Zhang<sup>1</sup>

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<sup>1</sup>Affiliated Sir Run Run Shaw Hospital, Zhejiang University School of Medicine, Hangzhou, China

<sup>2</sup>School of Nursing, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China

<sup>3</sup>Guizhou Provincial People's Hospital, Guiyang, China

## Correspondence to

Dr Zhihong Ye; [yezhang@zju.edu.cn](mailto:yezhang@zju.edu.cn)

## 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 V.5.3 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.

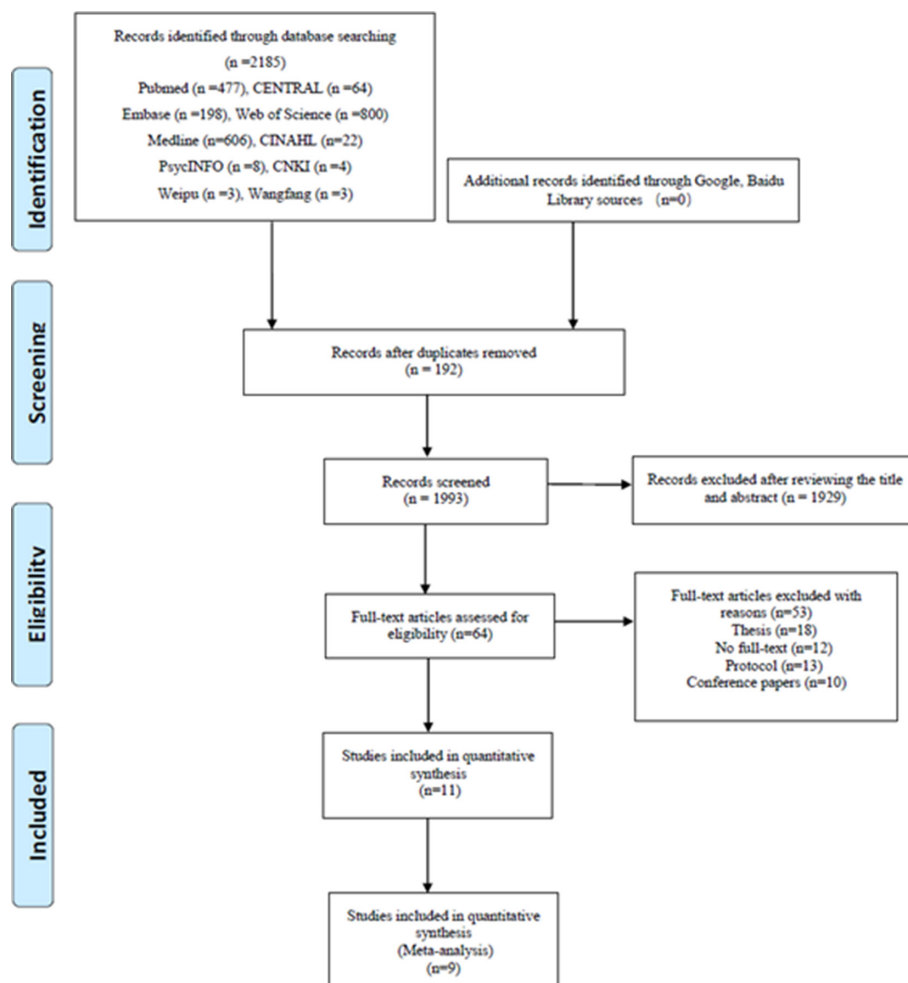
## INTRODUCTION

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

## Strengths and limitations of this study

- To the best of the researchers' knowledge, this is the first systematic review and meta-analysis on eHealth interventions for metabolic syndrome patients.
- The strengths of this review included its adherence to the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines, the comprehensive literature search and the inclusion of eHealth interventions in a predefined patient sample.
- Another strength of this meta-analysis was that randomised controlled trials (RCTs) and controlled clinical trials (CCTs) were included, which are good standards for evidence-based clinical research.
- The number of RCTs and CCTs and the overall sample size included in the meta-analysis were small.
- We only searched the Chinese and English databases. More high-quality articles should be included.

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<sup>1</sup> 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.<sup>2</sup> Moreover, patients with MetS experienced higher cancer risks<sup>3</sup> and worse health-related quality of life<sup>4</sup> 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,<sup>5</sup> stress,<sup>6</sup> low physical activity,<sup>7</sup> overweight or obesity,<sup>8</sup> high waist circumference (WC), elevated TG, elevated fasting blood glucose (FBG) and high average diastolic blood pressure (DBP)<sup>9</sup> exhibited a close relationship with the progression of



**Figure 1** Flow chart of article selection process. CNKI, Chinese National Knowledge Infrastructure.

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.<sup>10</sup> However, drugs sometimes have adverse effects and are accompanied by limited efficacy.<sup>11</sup> 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.<sup>12,13</sup> 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',<sup>14</sup> which includes internet and computer, mobile phone (the use of text messaging and applications on mobile phones), telehealth, electronic monitors and wireless and Bluetooth enabled devices.<sup>15</sup> eHealth interventions have become increasingly popular due to making treatments more accessible and affordable.<sup>16,17</sup> 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.*<sup>18</sup> 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<sup>19</sup> and could also provide patients with real-time feedback and with tailored interventions according to their needs.<sup>20</sup> 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<sup>21</sup> and blood glucose,<sup>22</sup> 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

**Table 1** Study characteristics of randomised controlled trials and controlled clinical trials included in the review

Study (Country)	Age	MetS criteria	Allocation	Intervention types	Intervention details	Control group	Intervention length	Follow-ups	Outcomes
Oh et al, 2015 <sup>30</sup> (Korea)	Aged ≥20	NCEP-ATP III	E=181 C=153	Mobile phone-based Care	Participant received feedback based on The measured body weight and body care Compositions via mobile phone. Health Consultations were provided for patients Through their phones inquiries concerning Disease management, health education Recommended exercise, medication Proper nutrition.	Standard care	24 weeks 24 weeks	Baseline, after intervention 12 weeks 24 weeks	Weight BMI
Farhangi et al, 2017 <sup>36</sup> (Tehran)	aged ≥20	NCEP-ATP III	E=64 C=53	Web-based interactive Lifestyle modification Programme	Participants could download educational Materials about diet and exercise Send personal questions and receive Answers on the personal homepage.	Waiting-list programme	6 months	Baseline After intervention 6 months	Weight, BMI, WC, SBP, DBP, TC, TG, HDL-C, FBG, LDL-C,
Radhakrishnan et al, 2014 <sup>34</sup> (India)	-	IDF	E=33 C=28	IT-supported Home-based Exercise programme	Participants were sent two personalised Mobile texts per week that carried Metabolic syndrome information.	Exercise programme	12 weeks	Baseline After intervention 12 weeks	BMI, WC, TG, FBG, HDL-C, LDL -C,m
Bosak et al, 2010 <sup>31</sup> (America)	32-66	NCEP-ATP III	E=12 C=10	Internet physical Activity intervention	Participants received mobile calls at least Once a week to discuss the health and Were encouraged to exercise regularly Participants visited links to evidence Based Web sites, entered daily minutes Physical activity on the study Web site, And received the email feedback on the	Usual care	6 weeks	Baseline After intervention 6 weeks	TC, HDL-C, TG, Outcomes
<b>Study (Country)</b>	<b>Age</b>	<b>MetS criteria</b>	<b>Allocation</b>	<b>Intervention Methods</b>	<b>Intervention Details</b>	<b>Control group</b>	<b>Intervention length</b>	<b>Follow-ups</b>	<b>Outcomes</b>

Continued

Table 1 Continued

Study (Country)	Age	MetS	Allocation	Intervention	Intervention details	Control	Intervention	Follow-ups	Outcomes
Fappa <i>et al.</i> , 2012 <sup>32</sup> (Greece)	49.0±11.8	NCEP- ATP III	E=18 C=13	Telephone counselling	Participant received nutrition counselling Sessions through seven 20 min, Exercise goals.	Usual care	6 month	Baseline After intervention 6 months	BMI, WC, SBP, DBP TG, HDL-C
Kim <i>et al.</i> , 2013 <sup>33</sup> (Korea)	E=48.6 ± 13.4 C=48.1±12.3	NCEP- ATP III	E=33 C=33	Telephone-delivered Nutrition education	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.	Initial Nutrition Education	3 months	Baseline After intervention 3 months	Weight, BMI, WC, SBP; DBP; FBG TC, LDL -C TG, HDL-C
Zhang and Wu, 2011 <sup>35</sup> (China)	38.97±5.37	CDS	E=100 C=100	Internet-based Intervention	Participant received intervention about Diet, exercise, and health education in The form of the Internet, telephone Follow-up and emails.	Usual care	-	Baseline After intervention	BMI, WC, SBP, FBG, TG, TC, DBP,
Kim <i>et al.</i> , 2015 <sup>19</sup> (Korea)	39.63±7.31	NCEP- ATP III	E=24 C=24	Internet-based lifestyle Intervention	Participants received online counselling And downloaded goals and strategies about Diet and physical activity, electronically Submitted their diaries and were Encouraged by text messages.	Standard care	16 weeks	Baseline After intervention 16 weeks	Weight, WC, TG, HDL-C, FBG SBP, DBP
<b>Study (Country)</b>	<b>Age</b>	<b>MetS</b>	<b>Allocation</b>	<b>Intervention</b>	<b>Intervention</b>	<b>Control</b>	<b>Intervention</b>	<b>Follow-ups</b>	<b>Outcomes</b>

Continued

Table 1 Continued

Study (Country)	Age	MetS	Allocation	Intervention		Intervention details		Control	Intervention	Follow-ups	Outcomes
				Methods,	Details	Group	Length				
Kang <i>et al.</i> , 2014 <sup>37</sup> (Korea)	37.93	AHA	E=29 C=27	Web-based health Promotion programme	Participants learnt educational contents On website, were asked to keep a diary	Waiting-list	8 weeks	Baseline	After intervention 8 weeks	WC, FBG, TG, HDL-C, SBP, DBP,	
		IAS			For 8 weeks and could ask any questions						
		IASO			About the programme by telephone.						
		WHF									

AHA/NHLBI/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; DPB, 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.

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.<sup>23</sup>

### Literature search

PubMed, the Web of Science, Embase, the Cochrane Library, Medline, CINAHL, PsycINFO, the Chinese National Knowledge Infrastructure, the Wanfang and Weipu databases were systematically searched for papers that were published through May 2019. The search terms were conjunctions of the following terms: “mobile applications” OR “mobile application” OR “mobile apps” OR “mobile app” OR “cell phones” OR “cell phone” OR “smartphone” OR “text messaging” OR “text message” OR “mobile phones” OR “mHealth” OR “mobile health” OR “internet” OR “web” OR “eHealth” OR “online interventions” OR “telehealth” OR “telephone” OR “SMS” OR “short message” OR “mobile technology” AND “metabolic syndrome” OR “Metabolic Syndromes” OR “syndrome, metabolic” OR “syndromes, metabolic” OR “MetS”. In addition, manual searches of cited references in relevant papers were conducted if appropriate. Missing relevant articles were obtained by contacting authors. 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) and National Cholesterol Education Programme 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), WC, systolic blood pressure (SBP), DBP, FBG, total cholesterol (TC), HDL-C, low-density lipoprotein cholesterol (LDL-C), TG or fasting insulin and (5) study designs: RCTs or CCTs. The exclusion criteria were as follows: (1) studies that were literature reviews, qualitative studies or protocols; (2) studies in which participants were not patients with MetS; (3) studies in which the intervention methods were not eHealth interventions; (4) studies that did not report anthropometric or biochemical indicators and (5) publications that were not in English or Chinese.

**Table 2** Assessment for the methodological quality of the included studies

Author, Year	Selection bias	Study design	Confounders	Blinding	Data collection	Withdrawals	Global rating
					Methods	And drop-out	
Oh <i>et al</i> , 2015 <sup>30</sup>	Moderate	Strong	Weak	Moderate	Strong	Moderate	Moderate
Farhangi <i>et al</i> , 2017 <sup>36</sup>	Moderate	Strong	Weak	Moderate	Strong	Moderate	Moderate
Radhakrishnan <i>et al</i> , 2014 <sup>34</sup>	Moderate	Strong	Weak	Moderate	Strong	Strong	Moderate
Bosak <i>et al</i> , 2010 <sup>31</sup>	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Fappa <i>et al</i> , 2012 <sup>32</sup>	Strong	Strong	Strong	Moderate	Strong	Weak	Moderate
Kim <i>et al</i> , 2013 <sup>33</sup>	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Zhang and Wu 2011 <sup>35</sup>	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong
Kim <i>et al</i> , 2015 <sup>19</sup>	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Kang <i>et al</i> , 2014 <sup>37</sup>	Strong	Strong	Strong	Moderate	Strong	Strong	Strong

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.

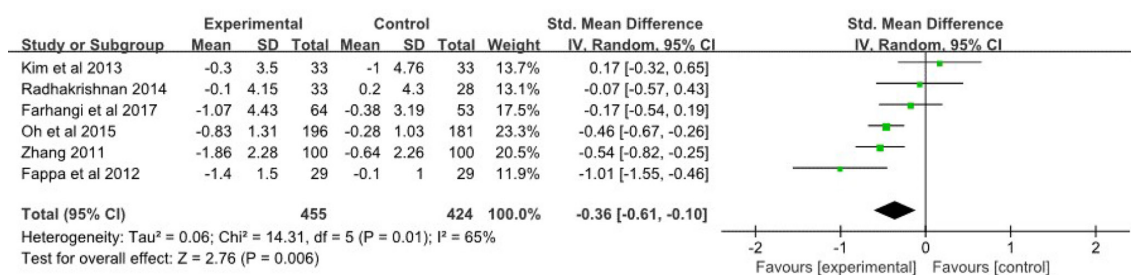
### Quality assessment

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.<sup>24</sup> Two authors (DC and HZ) independently assessed the

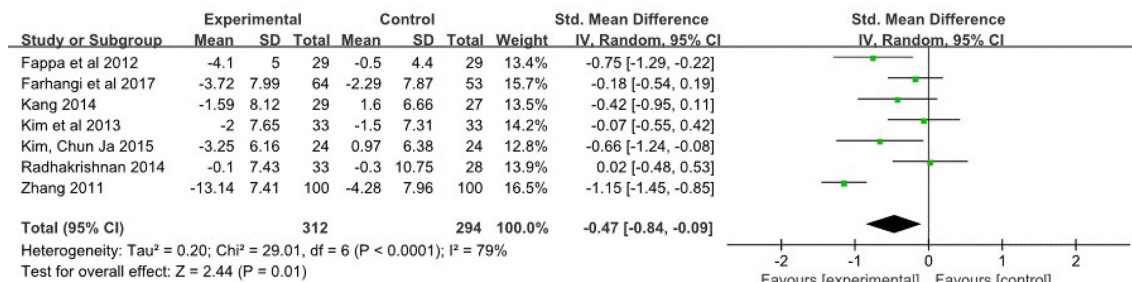
quality of the included studies. Studies were assessed based on six criteria: selection bias, study design, confounders, blinding, data collection methods and withdrawals and drop-out. The quality rating for the included studies was 'strong', 'moderate' or 'weak'. If the two reviewers disagreed, a third 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.<sup>25</sup> 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.<sup>26</sup> The  $I^2$  statistic was performed to analyse heterogeneity. An  $I^2$  of 25%–50% indicated moderate heterogeneity, and >50% indicated high heterogeneity.<sup>27</sup> Tests of heterogeneity were used to decide which method would be used to obtain the pooled results. When  $I^2$  was >50%, a



**Figure 2** Forest plot for effect of eHealth interventions on standardised mean net changes of BMI. BMI, body mass index; IV, inverse variance.



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

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,<sup>28 29</sup> the original data for meta-analysis could not be obtained. Therefore, seven RCTs<sup>30–36</sup> and two CCTs<sup>19 37</sup> fulfilled all inclusion criteria for the meta-analysis.

### Study characteristics

Table 1 summarises the information about the characteristics of the included studies. A total of 935 patients with MetS were included in this study. Nine articles were published from 2010 to 2017. Sample sizes ranged from 22 to 200. Most of the studies were performed in developing countries, such as Korea, Tehran, India and China, and two studies were conducted in developed countries, such as the USA and Greece. Moreover, only Oh *et al*<sup>30</sup> reported more than one follow-up time point. The anthropometric and biochemical indicators were measured using a measuring tape, bioelectrical impedance analysis device, mercury sphygmomanometer and automatic blood analysers. Most studies used the diagnostic criteria of NCEP ATP III,<sup>19 30–33 36</sup> Radhakrishnan

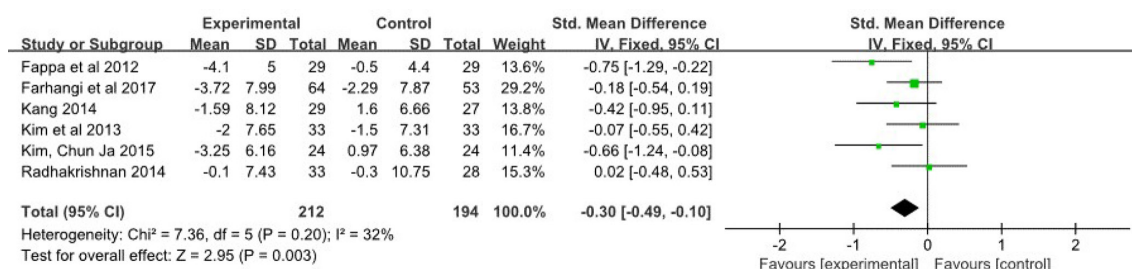
*et al*,<sup>34</sup> Zhang and Wu,<sup>35</sup> and Kang *et al*<sup>37</sup> based on the criteria of the IDF, Chinese Diabetes Society and American Heart Association/National Heart, Lung and Blood Institute/International Atherosclerosis Society/International Association for the Study of Obesity/World Heart Federation.

### Characteristics of eHealth interventions

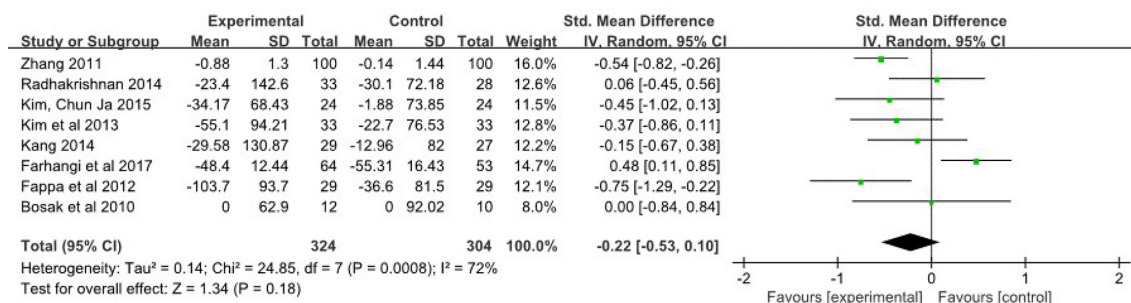
The intervention durations ranged from 6 weeks to 6 months. The types of eHealth interventions were mobile phone-based care interventions ( $n=2$ ),<sup>30 34</sup> web-based interactive lifestyle modification programmes ( $n=5$ )<sup>19 31 35–37</sup> and telephone-delivered interventions ( $n=2$ ).<sup>32 33</sup> 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.<sup>30 34</sup> In addition, five studies<sup>19 31 35–37</sup> 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*,<sup>33</sup> and Fappa *et al*,<sup>32</sup> 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



**Figure 4** Forest plot for effect of eHealth interventions except from Zhang and Wu study on WC. WC, waist circumference.



**Figure 5** Forest plot for effect of eHealth interventions on standardised mean net changes of TG. TG, triglycerides.

groups at baseline.<sup>30 34 36</sup> 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.<sup>19 30 33</sup> 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 al*<sup>19</sup> found that there were significant group by time interactions in regard to body weight ( $p=0.022$ ). In a study by Oh *et al*,<sup>30</sup> 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 al*<sup>33</sup> 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 ( $p=0.01$ ,  $I^2=65%$ ) (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 ( $p<0.0001$ ,  $I^2=79%$ ) (figure 3). Zhang and Wu's<sup>35</sup> 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 Wu's<sup>35</sup> study and found that the heterogeneity decreased ( $I^2=32%$ ), which indicated that the study contributed to the considerable heterogeneity (figure 4).

#### Triglycerides

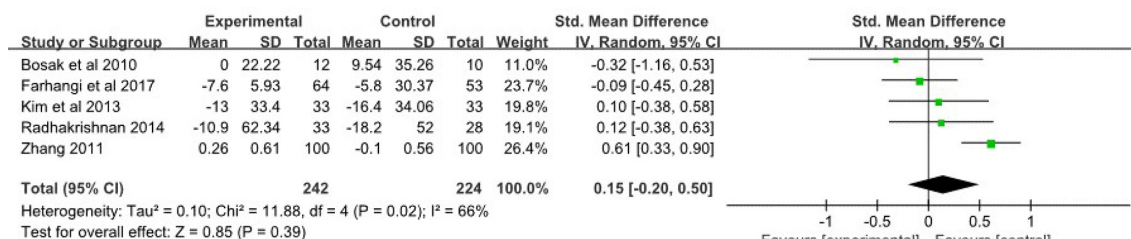
The impact of eHealth interventions on TG among patients with MetS has been explored in eight studies. As shown in figure 5, compared with the control groups, the participants who received mHealth and eHealth interventions did not experience significant changes in TG (SMD=-0.22, 95% CI (-0.53 to 0.10),  $p=0.18$ ). There was substantial evidence of high heterogeneity ( $p=0.0008$ ,  $I^2=72%$ ) (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 ( $p=0.02$ ,  $I^2=66%$ ) (figure 6).

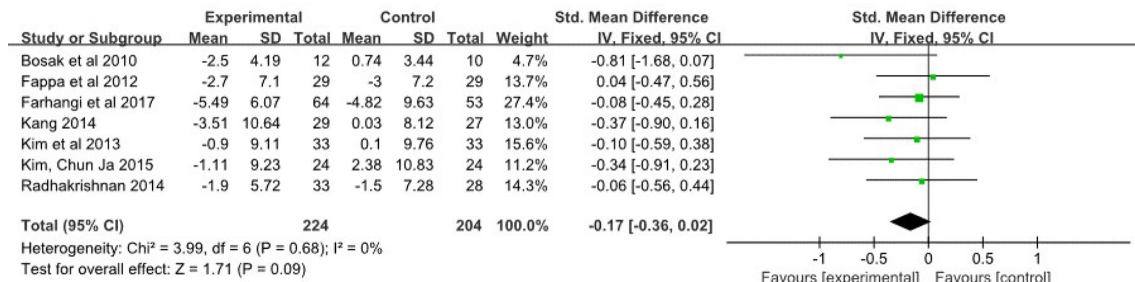
#### High-density lipoprotein cholesterol

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 ( $p=0.68$ ,  $I^2=0%$ ) (figure 7).



**Figure 6** Forest plot for effect of eHealth interventions on standardised mean net changes of TC. TC, total cholesterol.





**Figure 7** Forest plot for effect of eHealth interventions on standardised mean net changes of HDL-C. HDL-C, high-density lipoprotein cholesterol.

### Low-density lipoprotein cholesterol

In our study, four reviewed studies reported the LDL-C outcome.<sup>31 33 34 36</sup> Farhangi *et al*<sup>36</sup> found that there were no significant differences in LDL-C between the intervention and control groups. Bosak *et al*<sup>31</sup> 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*,<sup>33</sup> the authors did not find statistically significant effects of the intervention on LDL-C. Moreover, Radhakrishnan *et al*,<sup>34</sup> did not find a significantly positive effect of the intervention on LDL-C compared with of the effect 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, I<sup>2</sup>=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, I<sup>2</sup>=86%) (figure 9). After excluding Zhang and Wu<sup>35</sup> study, the heterogeneity decreased (I<sup>2</sup>=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

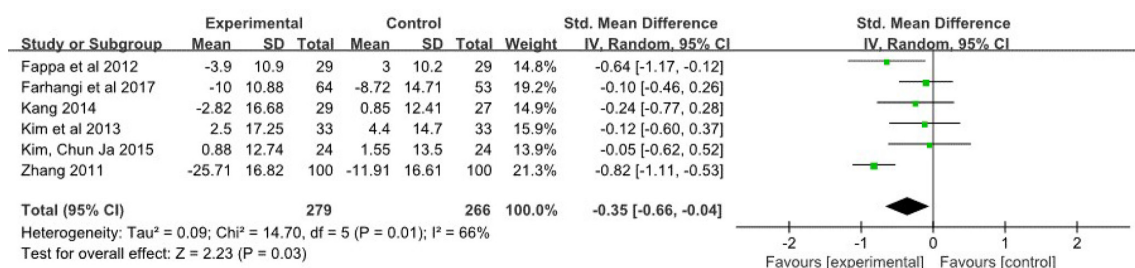
(SMD=-0.27, 95% CI (-0.72 to 0.19), p=0.25). There was no evidence of high heterogeneity (p<0.001, I<sup>2</sup>=86%) (figure 11). After excluding the Zhang and Wu<sup>35</sup> study, the heterogeneity decreased (I<sup>2</sup>=0%), which indicated that the study was the origin of the high heterogeneity (figure 12).

### Fasting insulin

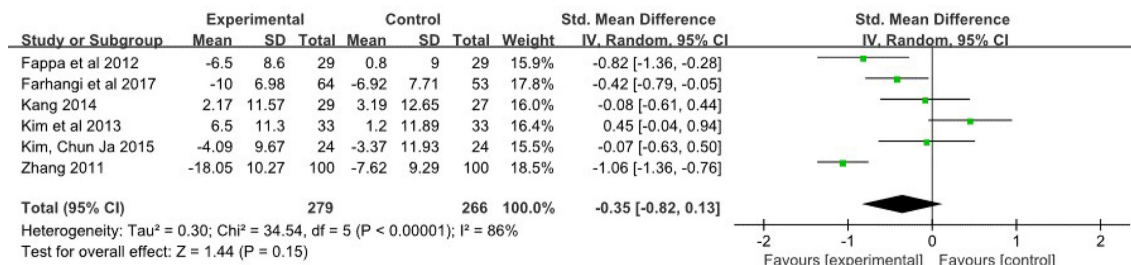
In the two reviewed studies, Farhangi *et al*<sup>36</sup> found a significant positive effect of the intervention on fasting insulin compared with the effect observed in the usual care group. However, in the study of Kim *et al*,<sup>33</sup> the results showed no significant differences in fasting 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.



**Figure 8** Forest plot for effect of eHealth interventions on standardised mean net changes of SBP. SBP, systolic blood pressure.



**Figure 9** Forest plot for effect of eHealth interventions on standardised mean net changes of DBP. DBP, diastolic blood pressure.

## DISCUSSION

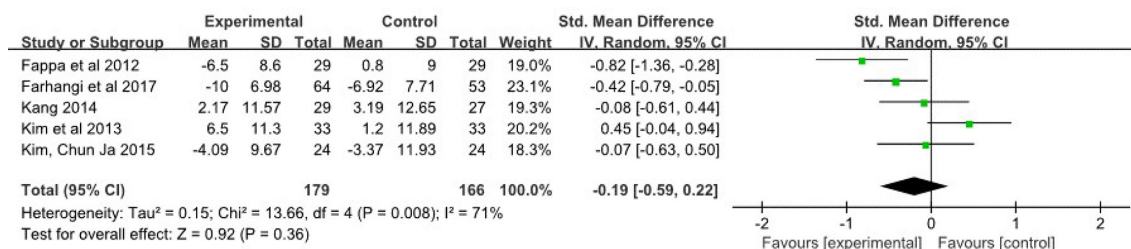
This review is the first to describe and evaluate nine RCTs and CCTs that used eHealth interventions to improve metabolic risk factors among patients with MetS. The current study showed that eHealth interventions resulted in significant improvements in body weight, BMI, WC and SBP compared with the effects 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.<sup>38,39</sup> Weight loss is the cornerstone of MetS management.<sup>40</sup> Weight loss has beneficial impacts on MetS.<sup>41</sup> The magnitude of weight loss was associated with dose-effect improvements in high blood pressure, hyperglycaemia and hyperlipidaemia.<sup>42</sup> In contrast, obesity is a risk factor for MetS.<sup>30</sup> 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,<sup>43</sup> 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.<sup>44</sup> Kim *et al*<sup>33</sup> 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 health-care professionals, maintaining frequent contact with participants was critical for participant engagement in

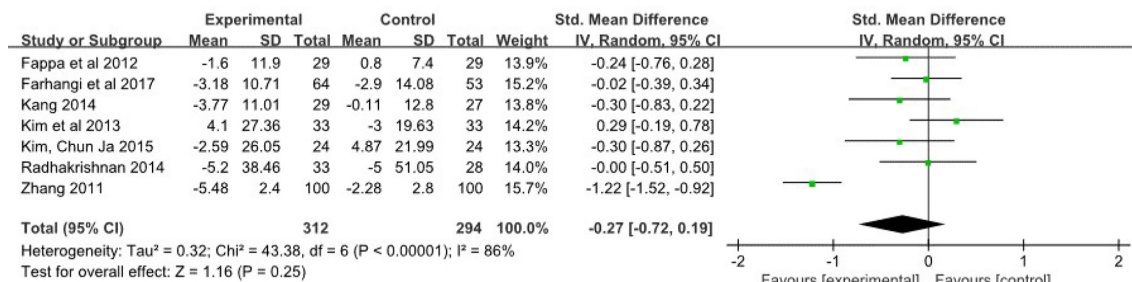
interventions and to ensure that participants received an adequate intervention.<sup>31</sup> Additionally, the greatest adherence to lifestyle goals was observed in the eHealth intervention group, which could explain the weight reduction result.<sup>32</sup> For the WC outcome, a 1 cm increase in WC increases the risk of cardiovascular events by 2%.<sup>45</sup> 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.<sup>33</sup> 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,<sup>46</sup> Haas *et al*<sup>47</sup> and Nolan *et al*,<sup>48</sup> 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.<sup>32</sup> 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,<sup>49,50</sup> 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.<sup>51,52</sup> The reason behind this phenomenon may be the differences in study designs, characteristics of study populations, different technologies used in eHealth interventions and



**Figure 10** Forest plot for effect of eHealth interventions except from Zhang and Wu study on DBP. DBP, diastolic blood pressure.



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

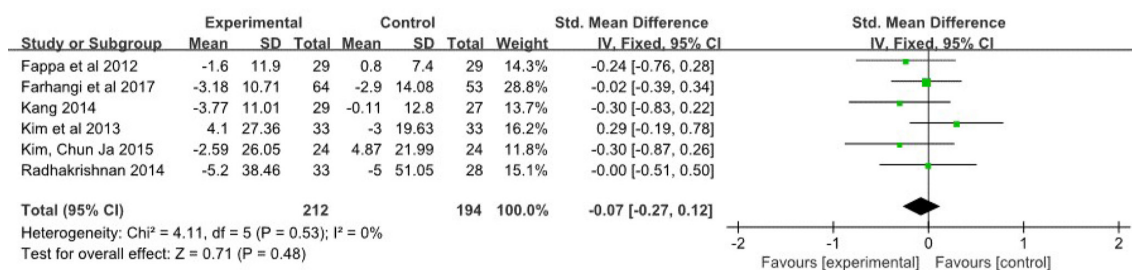
duration of the interventions. For instance, the duration of the intervention (6 weeks or 8 weeks) in some studies might not be enough to improve many metabolic parameters.<sup>37</sup> In addition, MetS is characterised by the presence of at least three of five indices. However, these indicators are 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 12** Forest plot for effect of eHealth interventions except from Zhang and Wu study on FBG. FBG, fasting blood glucose.

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

Variables	No of included	SMD (random effect) or MD (fixed effect)	95% CI	I <sup>2</sup> (%)	P value
Body mass index	Six	-0.36	-0.61 to -0.10	65	0.006*
Waist circumference	Seven	-0.47	-0.84 to -0.09	79	0.01*
Triglycerides	Eight	-0.22	-0.53 to 0.10	72	0.18
Total cholesterol	Five	0.15	-0.25 to 0.50	66	0.39
High-density lipoprotein cholesterol	Seven	-0.17	-0.36 to 0.02	0	0.09
Systolic blood pressure	Six	-0.35	-0.66 to -0.04	66	0.03*
Diastolic blood pressure	Six	-0.35	-0.82 to 0.13	86	0.15
Fasting blood glucose	Seven	-0.27	-0.72 to 0.19	86	0.25

\*P&lt;0.05.

MD, mean difference; SMD, standardised mean difference.

before eHealth interventions could be recommended in future guidelines.

## 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.

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## ORCID iDs

Zhihong Ye <http://orcid.org/0000-0001-6947-3330>

Xiyi Wang <http://orcid.org/0000-0002-6470-8556>

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