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Effects of Mobile Applications on Weight-Related, Behavior and Metabolic Outcomes for Adults with Overweight and Obesity: A Systematic Review and Meta-Analysis

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Abstract: The meta-analysis aimed to explore the effects of mobile phone applications on weight-related, behavior, and metabolic outcomes among adults with overweight and obesity. Six databases were searched for relevant randomized controlled trials (RCTs) published between January 1, 2010 and November 7, 2023 in English. Two independent authors conducted study selection, data extraction, quality assessment. The effect size of interventions was calculated using mean difference. A random-effects model was applied for data analysis. A total of 27 studies were included. The results indicated that mobile phone application intervention reduced weight (MD=-1.38 kg, P<0.001, 95% CI -1.97 to -0.80), BMI (MD=-0.44 kg/m2, P<0.001, 95% CI -0.57 to -0.30), WC (MD=-2.13 cm, P=0.004, 95% CI -3.57 to -0.69), fat mass, and DBP (MD=-2.04 mmHg, P=0.01, 95% CI -3.65 to 0.44) with statistical significance. Future studies could consider how to optimize app interventions through behavior change strategies to enhance their overall effectiveness.

Keywords: mobile app, overweight, obesity, mHealth, eHealth, physical activity, diet

1. Introduction

Being overweight and obesity have become public health issues. In 2016, over 1.9 billion adults were overweight, with around 650 million suffering from obesity [1], and this is estimated to affect half of the global population by 2030 [2]. The fundamental approach to addressing overweight and obesity remains to be a multicomponent

behavioral intervention [3]. Lifestyle modifications delivered via mobile devices, especially mobile phones present an opportunity to help people lose weight.

Several meta-analyses have been performed to evaluate the effectiveness of mobile phone apps on weight loss in adults [4-6]. However, current reviews have some limitations. First, most reviews [4-8] have limited their outcomes to weight and BMI, but other than the aforementioned two outcomes, other outcomes such as fat mass, blood pressure, and physical activity have also been reported in original studies and have their clinical significance. Second, with the rapid development of technology in recent years, many RCTs in this regard have emerged [9] and updated evidence is needed. Third, instead of regarding adults with overweight and obesity, with and without other diseases as the target population like other reviews [4,5,7], we focus on individuals classified as overweight and obese without concurrent medical conditions to help this population prevent comorbidities and improve their quality of life. In addition, the elements of mobile application design are related to weight loss rather than disease management.

Therefore, we aim to conduct a meta-analysis to explore the effects of mobile phone applications on weight-related outcomes (weight, BMI, fat mass, body fat percentage), behavior outcomes (physical activity, energy intake), and metabolic outcomes [systolic blood pressure (SBP), diastolic blood pressure (DBP), triglycerides, hemoglobin A1c (HbA1c)] among overweight and obese adults.

2. Methods

This meta-analysis was conducted according to the Preferred Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [10].

2.1 Search strategy

Six databases (i.e., PubMed, Embase, CENTRAL, Web of Science, PsycINFO, and CINAHL) were searched for relevant RCTs published between January 1, 2010 and November 7, 2023 in English. The search strategy was developed according to the principle of PICOS (Participants, Interventions, Comparisons, Outcomes, and Study). In addition, we manually searched through the references of relevant reviews published previously.

2.2 Study eligibility criteria

Studies included for this meta-analysis had to (1) Participants: overweight and obese adults aged≥18 years; (2) Intervention: mobile phone apps used as the major component; (3) Comparisons: usual care without mobile phone app interventions or no intervention; (4) Outcomes: weight-related outcome (i.e., weight, body mass index, waist circumference, fat mass, fat mass percentage), behavior outcomes (i.e., physical activity, energy intake), and metabolic outcomes (i.e., SBP, DBP, triglycerides, HbA1c). (5) Studies: RCTs published in the English language. Studies were excluded if they met the following criteria: (1) participants diagnosed with other diseases except for obesity; (2) conference articles, letters, reviews, commentaries, or protocols; (3) full texts or relevant complete data was unavailable.

2.3 Study selection, data extraction and quality assessment

All titles and abstracts of the studies were downloaded and imported into Endnote X9, and duplicates were removed automatically. Two investigators independently screened the titles and abstracts according to the eligibility criteria. Next, the full texts of potentially relevant studies were downloaded and reviewed to select the included articles, and reasons for the exclusion were recorded. Any disagreement was resolved through consultation with a third author. Data regarding paper characteristics (author, year, country), study design, study population (e.g., average age, sex difference, baseline BMI), intervention content (e.g., behavior theory, intervention duration, brief introduction of intervention), comparison content (e.g., brief interdiction of comparison) and outcomes were extracted in a predesigned Excel by one reviewer and checked by a second reviewer. Other statistics (e.g., 95% CI or standard errors) were converted to standard deviations (SD) if it was not available [11]. If the units of the outcome measure are not uniform, such as triglycerides measured in mg/dL, we converted them to mmol/L to ensure consistency in units. If a study had more than one intervention arm eligible for inclusion in the meta-analysis, the sample size of the shared comparator group was divided by the number of arms included to prevent participants from being counted multiple times [11]. The Cochrane Risk-of-Bias (ROB) tool was used to assess the methodological quality of the included RCTs by two reviewers independently [11].

2.4 Statistical analysis

The meta-analysis was performed to evaluate the effectiveness of mobile application interventions on weight loss among overweight and obese adults. Outcomes were pooled in meta-analysis if change scores from baseline were available, and the number of participants was recorded. The heterogeneity of the data was measured using the I^2 statistic with 25%, 50%, or 75% considered low, modest, and high, respectively 27. Review Manager (version 5.3; Cochrane Collaboration) was used to analyze data. The mean difference (MD) with a 95% confidence interval (CI) was used to express the effectiveness of interventions involving mobile applications. A random-effects model was applied for data analysis because it obtained more conservative results. In all analyses, $P<0.05$ was considered statistically significant.

3. Results

3.1 Study selection

The literature search of six databases generated 7,588 articles and an additional 2 records were added by hand-searching from relevant reviews. After removing the duplicates, titles, and abstracts of 4,762 studies were screened. Subsequently, 106 full texts were reviewed. However, 79 studies were excluded according to eligibility criteria. Finally, A total of 27 studies were included in the systematic review and meta-analysis.

3.2 Risk of bias

The risk of bias evaluation results are presented in Figure 1.

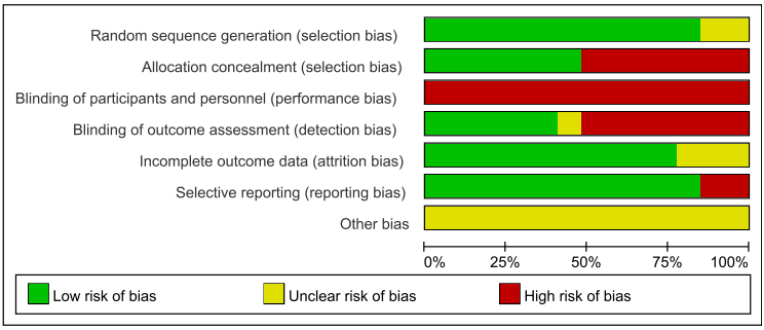

Figure 1. Summary of risk of bias

3.3 Effects of mobile phone application

The review examined the effects of mobile phone application intervention on weight-related outcomes (weight, BMI, WC, fat mass, fat mass percentage), behavior outcomes (MVPA, energy intake), and metabolic outcomes (SBP, DBP, triglycerides, HbA1c). A summary of meta-analyses results was shown in Table 1.

Table 1. A summary of meta-analyses results on each outcome

Outcomes	Studies (n)	Sample size (IG, n)	Sample size (CG, n)	MD (95% CI)	*P* value	I^2 (%)
Weight (kg)	**25**	**1668**	**1537**	**-1.38 (-1.97 to -0.80)**	***P*<0.001**	**55%**
BMI (kg/m^2)	**17**	**1211**	**1189**	**-0.44 (-0.57 to -0.30)**	***P*<0.001**	**0%**
WC (cm)	**11**	**867**	**850**	**-2.13 (-3.57 to -0.69)**	***P*=0.004**	**83%**
Fat mass (kg)	**9**	**507**	**494**	**-1.36 (-1.96 to -0.75)**	***P*<0.001**	**34%**
Fat mass percentage (%)	10	567	556	-0.34 (-1.03 to 0.34)	P=0.33	59%
MVPA (mins/day)	5	416	253	-1.12 (-5.90 to 3.66)	P=0.65	0%
Energy intake (kcal/day)	5	485	468	-100.57 (-226.60 to 25.45)	P=0.12	56%
SBP (mmHg)	9	493	502	-0.14 (-2.66 to 2.37)	P=0.91	66%
DBP (mmHg)	**8**	**460**	**469**	**-2.04 (-3.65 to 0.44)**	**P=0.01**	**55%**
Triglycerides (mmol/L)	5	268	275	0.07 (-0.21 to 0.35)	P=0.61	24%
HbA1c (%)	5	320	284	-0.07 (-0.18 to 0.04)	P=0.22	90%

4. Discussions

4.1 Main findings

A total of 27 RCTs are included in this systematic review and meta-analysis, and 11 outcomes are explored. The results of this review indicated that mobile application intervention reduced weight, BMI, WC, fat mass, and DBP with statistical significance. However, non-significant effects were observed on other outcomes, including fat mass percentage, behavior outcomes (i.e., MVPA, energy intake), and metabolic outcomes (i.e., SBP, triglycerides, and HbA1c).

4.2 Effects of mobile phone application on weight-related outcomes

The meta-analysis suggested that interventions delivered via mobile phone applications could reduce weight among overweight and obese adults significantly,

which is consistent with previous meta-analyses findings[4, 6]. High BMI is related to various conditions, including cardiovascular disease (CVD), certain cancers, and breathing problems [12]. BMI is also decreased with statistical significance in our meta-analysis. WC, a reliable indicator of not only total body fat but also abdominal visceral fat [13], has been demonstrated as an accurate predictor of disease [14]. After combining data from 10 RCTs in the meta-analysis, WC is reduced with statistical significance by using weight loss applications among people with overweight and obese. Our meta-analysis identifies fat mass and fat mass percentage as primary outcomes, revealing a significant reduction in fat mass but not fat mass percentage. This finding suggests that body components other than fat, such as lean muscle mass and bone mass, may have also decreased during the weight loss period.

4.3 Effects of mobile phone application on behavior outcomes

Lifestyle modification including increasing physical activity and restricting calories is considered to be the cornerstone of obesity management [15]. The increase in MVPA is not observed because many weight loss applications are designed to help people self-monitor their physical activity instead of encouraging the performance of physical activity. Energy intake would reduce 100 kcal/day, which may partly explain the effectiveness of weight loss.

4.4 Effects of mobile phone application on metabolic outcomes

In our meta-analysis, the effects on four outcomes (i.e., SBP, DBP, triglycerides, and HbA1c) are explored, and we observed significant reductions only in DBP. Reasons behind this phenomenon is that although weight reduction is statistically significant in our review, weight loss of this extent may fall short of achieving a clinically meaningful reduction in metabolic outcomes [16].

5. Conclusions

This meta-analysis presents findings indicating that mobile phone application interventions significantly reduce weight, BMI, WC, fat mass, and DBP among adults with overweight and obesity. The mobile phone application intervention is a cost-effective intervention that can be applied to a large population. However, the current mobile apps have not achieved clinically significant weight loss, so their effects on SBP, triglycerides, or HbA1c are not observed. Future studies could consider how to optimize app interventions through behavior change strategies to enhance their overall effectiveness.

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