Lifestyle modification with mobile apps in chronic liver disease-related conditions: A systematic review and meta-analysis

Eri Asakura, David Brain, Sameera Senanayake, Adrian Barnett

Submitted to: JMIR mHealth and uHealth
on: June 05, 2024

Table of Contents

Lifestyle modification with mobile apps in chronic liver disease-related conditions: A systematic review and meta-analysis

Eri Asakura[1] MPH; David Brain[1] PhD; Sameera Senanayake[1, 2, 3] PhD; Adrian Barnett[1] PhD

[1]Australian Centre for Health Services Innovation and Centre for Healthcare Transformation School of Public Health and Social Work, Faculty of Health Queensland University of Technology Brisbane AU
[2]Health Services and Systems Research Duke-NUS Medical School Singapore SG
[3]National Heart Research Institute Singapore National Heart Centre Singapore SG

Corresponding Author:
Eri Asakura MPH
Australian Centre for Health Services Innovation and Centre for Healthcare Transformation
School of Public Health and Social Work, Faculty of Health
Queensland University of Technology
60 Musk Avenue
Kelvin Grove
Brisbane
AU

Abstract

Background: The importance of self-management of chronic condition has been highlighted during the COVID-19 pandemic, including the management of chronic liver disease. The use of technology in disease self-management could assist task-shifting, which involves the delegation of tasks from highly qualified healthcare workers to healthcare workers with fewer qualifications or technology, where appropriate. This can optimise the allocation of human resources in healthcare as well as patients' disease self-management and health.

Objective: Our systematic review with meta-analyses aimed to summarise characteristics of mobile app-based interventions with a focus on resource use among patients with underlying conditions related to chronic liver disease and explore the possibility of task-shifting using mobile apps in liver disease management.

Methods: The six databases MEDLINE, CINAHL, Web of Science, Embase, PsycInfo, and Cochrane Library were searched for randomised controlled trials about mobile app-based interventions in patients with four chronic liver disease-related conditions: overweight and obesity, type 2 diabetes, metabolic abnormalities, and risky alcohol drinking. The Cochrane Risk of Bias assessment tool was used. Random-effects nested meta-analyses of the intervention effectiveness were performed with unadjusted results, unadjusted intention-to-treat results, and adjusted results for each of the four outcomes: HbA1c, weight, body mass index, and waist circumference when available.

Results: Twenty-two articles were included in the systematic review. Nine key intervention characteristics were identified including self-monitoring platform, education, and data sharing with intervention providers. Eighteen studies were considered to be at 'high risk' of bias mainly due to excluding randomised participants from the analysis and insufficient description on dealing with missing outcome data. Unadjusted pooled mean differences showed that app-based interventions could have small benefits on reducing HbA1c (Mean difference [MD]=-0.28, 95% Confidence Interval [95% CI]: -0.55 to -0.02), weight (MD=-1.44 kg, 95% CI: -2.39 to -0.49), body mass index (MD=-0.48, 95% CI: -0.85 to -0.12), and waist circumference (MD=-1.88 cm, 95 %CI: -3.04 to -0.72).

Conclusions: The available evidence was suboptimal due to high rates of lost to follow-up and lack of intention-to-treat analysis. The following three considerations may be required for the implementation of task-shifting in the management of chronic liver disease: careful deliberations for intervention designs; matching each stakeholder's needs; accumulation of evidence. Further research on stakeholders' preference on app characteristics is needed for the successful implementation of app-based interventions as the task-shifting approach. Clinical Trial: Not applicable.

(JMIR Preprints 05/06/2024:62883)
DOI: https://doi.org/10.2196/preprints.62883

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Review

Eri Asakura[1], MPH; David Brain[1], PhD; Sameera Senanayake[1,2,3], PhD; Adrian Barnett[1], PhD

1. Australian Centre for Health Services Innovation and Centre for Healthcare Transformation, School of Public Health and Social Work, Faculty of Health, Queensland University of Technology, Australia
2. Health Services and Systems Research, Duke-NUS Medical School, Singapore
3. National Heart Research Institute Singapore, National Heart Centre, Singapore

Correspondence and request to:

Ms Eri Asakura

Australian Centre for Health Services Innovation and Centre for Healthcare Transformation, School of Public Health and Social Work, Faculty of Health, Queensland University of Technology, Brisbane, QLD, 4001, Australia

Email: eri.asakura@hdr.qut.edu.au

Lifestyle modification with mobile apps in chronic liver disease-related conditions: A systematic review and meta-analysis

Abstract

Background: The importance of self-management of chronic condition has been highlighted during the COVID-19 pandemic, including the management of chronic liver disease. The use of technology in disease self-management could assist task-shifting, which involves the delegation of tasks from highly qualified healthcare workers to healthcare workers with fewer qualifications or technology, where appropriate. This can optimise the allocation of human resources in healthcare as well as patients' disease self-management and health.

Objective: Our systematic review with meta-analyses aimed to summarise characteristics of mobile app-based interventions with a focus on resource use among patients with underlying conditions related to chronic liver disease and explore the possibility of task-shifting using mobile apps in liver disease management.

Methods: The six databases MEDLINE, CINAHL, Web of Science, Embase, PsycInfo, and Cochrane

Library were searched for randomised controlled trials about mobile app-based interventions in patients with four chronic liver disease-related conditions: overweight and obesity, type 2 diabetes, metabolic abnormalities, and risky alcohol drinking. The Cochrane Risk of Bias assessment tool was used. Random-effects nested meta-analyses of the intervention effectiveness were performed with unadjusted results, unadjusted intention-to-treat results, and adjusted results for each of the four outcomes: HbA1c, weight, body mass index, and waist circumference when available.

Results: Twenty-two articles were included in the systematic review. Nine key intervention characteristics were identified including self-monitoring platform, education, and data sharing with intervention providers. Eighteen studies were considered to be at ‘high risk’ of bias mainly due to excluding randomised participants from the analysis and insufficient description on dealing with missing outcome data. Unadjusted pooled mean differences showed that app-based interventions could have small benefits on reducing HbA1c (Mean difference [MD]=-0.28, 95% Confidence Interval [95% CI]: -0.55 to -0.02), weight (MD=-1.44 kg, 95% CI: -2.39 to -0.49), body mass index (MD=-0.48, 95% CI: -0.85 to -0.12), and waist circumference (MD=-1.88 cm, 95 %CI: -3.04 to -0.72).

Conclusion: The available evidence was suboptimal due to high rates of lost to follow-up and lack of intention-to-treat analysis. The following three considerations may be required for the implementation of task-shifting in the management of chronic liver disease: careful deliberations for intervention designs; matching each stakeholder’s needs; accumulation of evidence. Further research on stakeholders’ preference on app characteristics is needed for the successful implementation of app-based interventions as the task-shifting approach.

Keywords

mHealth; digital health; chronic liver disease; lifestyle modification; mobile apps; task-shifting; health system efficiency; resource allocation

Introduction

Chronic liver disease is an urgent public health issue in many countries. Unhealthy diet, physical inactivity, and risky alcohol drinking can lead to lifestyle diseases such as obesity, and metabolic abnormalities. A recent review estimated that in the overweight population the global prevalence of non-alcoholic fatty liver disease was 70% and non-alcoholic steatohepatitis 34%[1]. The global prevalence of alcoholic related liver disease in the general population was estimated as 4.8%[2]. As liver disease is usually asymptomatic, it is likely to be widely underdiagnosed[3]. Untreated or poorly controlled fatty liver can lead to advanced liver disease such as cirrhosis and hepatocellular carcinoma, which can incur extra costs and resource use in the health system. Since fatty liver has no approved pharmacotherapy, the first-line treatment for fatty liver is modifying lifestyle risk factors to have a healthier lifestyle[3], which requires long-term efforts and motivation from patients.

The importance of self-management of chronic conditions has been highlighted during the COVID-19 pandemic, when people experienced medication and medication-related problems due to doctors' offices being closed for in-person visits and a worsening of their chronic conditions[4]. Furthermore, healthcare resources are generally scarce, the optimal allocation of health resources is essential to maintain financially stable health systems. For these reasons, the use of technology such as mobile applications can be a solution for achieving self-management goals, improved patients' outcomes, and improved health system efficiency.

The World Health Organization first published the guidelines for task-shifting to help to address the shortages of health workers in 2007, with a main focus on scaling up HIV/AIDS treatment in resource-poor settings in African countries to improve health system efficiency by improving healthcare resource allocation[5]. More recently, a paper suggested shifting tasks to machines or technology[6], which goes beyond the traditional human-to-human task-shifting. During the COVID-19 pandemic the task-shifting approach gained attention as a feasible way to maintain essential healthcare[7]. Task-shifting involves the delegation of tasks from highly qualified healthcare workers to healthcare workers with fewer qualifications, where appropriate.

Mobile app-based interventions for lifestyle modification could potentially be as effective as, but possibly cheaper and hence cost-effective, compared to usual care. It is hypothesised that implementation of task-shifting using a mobile app could improve

patients' health and healthcare resource allocation in the management of chronic liver disease. This study aims to systematically review the evidence on mobile app-based interventions with a focus on resource use, and evaluate the effectiveness of interventions among patients with underlying conditions related to chronic liver disease.

METHODS

Eligibility Criteria

A Prospective Register of Systematic Reviews (PROSPERO) protocol was published (CRD42022333553). Studies were eligible if they were individually randomised controlled trials (RCTs) that met the following inclusion criteria concerning their study design, population, intervention, and outcome:

(1) RCTs that evaluated the effectiveness or efficacy of mobile app-based interventions.
(2) RCTs that were conducted in patients with underlying conditions related to chronic liver disease defined as: overweight and obesity, type 2 diabetes, metabolic syndrome, and risky alcohol consumption.
(3) RCTs that had at least one arm that compared a mobile app-based intervention to usual care.
(4) RCTs that reported clinical measurement as a primary outcome (such as weight or HbA1c).
(5) RCTs that were undertaken for any follow-up duration.
(6) RCTs with full-text articles published in English.

Studies were excluded if they:

(1) were not RCTs;
(2) were RCTs but were pilot or feasibility studies for which the power calculation for the sample size was not performed, or were secondary analysis of a RCT;
(3) were RCTs and had a mobile app intervention but did not compare the effectiveness to usual care; and
(4) were RCTs and had a mobile app intervention but the app was not the main intervention (for example, the app was used only to collect data).

Search Strategy and Study Selection

Six databases were searched: MEDLINE, CINAHL, Web of Science, Embase, PsycInfo, Cochrane Library. The search strategy was developed with an experienced librarian, consisting of terms related to the intervention (i.e., mobile application) and population (i.e., patients with underlying conditions related to chronic liver disease) (Supplementary Table 1 in the Multimedia Appendix 1).

The titles and abstracts of all articles retrieved from electronic searching were screened for eligibility (by EA, DB). Any uncertainties regarding study eligibility were resolved through discussion with two other reviewers (SS, AB) until a consensus was reached.

Data collection

The following data were extracted for each included trial:

(1) Study and participant characteristics

(2) Interventions' characteristics

(3) The effectiveness of the interventions

In order to extract data on the interventions' characteristics and assess the intervention descriptions in a standardised manner, we used a modified version of the Template for Intervention Description and Replication (TIDieR) checklist[8]. The TIDieR checklist was developed to help authors write a better quality of their intervention as many studies do not adequately describe their intervention[8]. Where the individual components of mobile-app interventions were missing or described in insufficient detail, attempts were made to locate this information in related publications such as study protocols[8].

For the effectiveness data, if multiple intervention arms were compared with usual care within a single study, each arm was considered a separate intervention and data were extracted accordingly. If results at multiple times were reported then all times were extracted.

Risk of Bias Assessment

The quality assessment of each trial was assessed using the Cochrane Risk of Bias (RoB2) Tool[9]. The RoB2 Tool is structured with five domains, and each domain has

five to seven signalling questions. The five domains are: Randomisation process (Domain 1); Deviations from the intended interventions (Domain 2); Missing outcome data (Domain 3); Measurement of the outcome (Domain 4); and Selection of the reported results (Domain 5)[9].

We assessed imbalance in baseline characteristics between groups using a Bayesian model to estimate the probability that the trial is under- or over-dispersed using the baseline table of summary statistics[10,11]. We flagged a likely baseline imbalance the probability of under- and over-dispersion was greater than 95%.

As trial publications do not always provide information about protocol deviations, we assumed that it was not probable that any non-protocol interventions occurred unless they were specified or discussed. If reasons for withdrawal and loss to follow-up were not provided in sufficient detail, we inferred that missingness may depend on the true value and were not missing at random.

Statistical Analysis

Meta-analyses were performed to obtain an estimated pooled effectiveness of the mobile app-based interventions for each outcome compared to usual care. The pooled effectiveness was presented as the standardised mean difference with 95% confidence intervals (CIs), and we included 95% prediction intervals.

Meta-analyses were conducted in R (version 4.2.2, The R Foundation[12]) with the random-effects model using studies that had clinical outcomes selected below after consultation with clinical experts. Either as a primary or secondary outcome.

1. HbA1c (%)
2. Weight (kg)
3. Body mass index in weight (kg/m^2)
4. Waist circumference (cm)

Details can be found in the Multimedia Appendix 1. Briefly, we extracted data on the group sample size, means, and standard deviations. We pre-calculated standard deviations if results were reported with confidence intervals.

If a study had multiple data collection times such as weight at 3 and 6 months post-randomisation, these data were included in the meta-analysis to increase the statistical power to detect the pooled effectiveness of the interventions. Similarly, if a trial had multiple intervention arms, then all arms were included in the meta-analysis. We

performed nested meta-analysis to account for using potentially correlated data from the same trial[13]. The percentage of total variability due to between-study heterogeneity was assessed using I^2 values.

We performed the following meta-analyses:

1. With trial results unadjusted for baseline
2. With trial results adjusted for baseline
3. With trial results from any intention-to-treat analysis

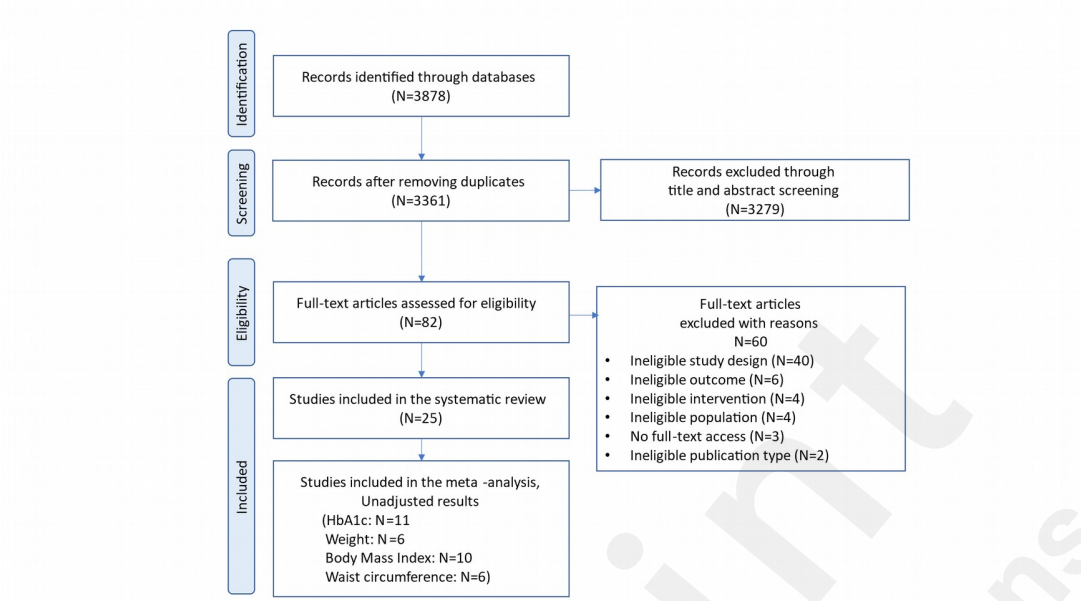
We planned to undertake meta-analysis on patient-reported outcomes such as health-related quality of life as secondary outcomes. However, due to the wide variety of reporting formats used among studies summarised in Supplementary Table 2 in the Multimedia Appendix 1, we were not able to combine the study estimates on patient-reported outcomes.

RESULTS

Study Selection

Peer-reviewed articles that were published in the last 10 years were searched on the 1st of July 2022. A total of 3878 articles were identified in the initial database search, with 3361 left after removing duplicates. Eighty-two full-text articles were assessed for eligibility. Twenty-two studies were eligible for inclusion in the systematic review (Figure 1).

Figure 1. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Flow diagram



Study Characteristics

The included 22 studies have nine about type 2 diabetes[14-22], five about overweight and obesity[23-27], seven about metabolic abnormalities[28-34], and two about risky alcohol drinking[35,36] . Participants of the studies in metabolic abnormalities were overweight or obese in combination with being prediabetic or with cardiometabolic conditions such as hypertension, diabetes, hyperlipidaemia, or non-alcoholic fatty liver disease.

Study characteristics are summarised in Table 1. Due to the nature of the intervention, participants of all studies were unblinded. Most studies observed higher rates of loss to follow-up than planned; although studies calculated sample sizes with around 15 to 20% planned loss to follow-up, the actual losses ranged from zero to 40%.

Table 1. Characteristics of included studies

Author (year)	Country	Follow-up	Participants randomised	Mean age (years)	Outcome	Comparator
Type 2 diabetes						
Agarwal (2019)[14]	Canada	3 and 6 months	240	52	HbA1c	Usual diabetes care
Anzaldo-Campos (2016)[15]	Mexico	4 and 10 months	301	C 53 PD: 51 PD-TE: 52	HbA1c	Standard care outlined by the Mexican Institute of Social Security guidelines
Boels (2019)[16]	Netherland	6 months	230	I: 59 C: 60	HbA1c	Care as usual
Gong (2020)[17]	Australia	6 and 12 months	187	57	HbA1c	Routine diabetes self-care, including access to health care services and resources

Author (year)	Country	Follow-up	Participants randomised	Mean age (years)	Outcome	Comparator
Hilmarsdóttir (2021)[18]	Iceland	2, 4, and 6 months	37	I: 51 C: 52	HbA1c	Not specified
Kim (2022)[19]	South Korea	8 weeks	68	55	HbA1c	A book entitled Diabetes Management Guide, which is generally provided to patients with diabetes in the clinic.
Kleinman (2017)[20]	India	3 and 6 months	91	48	HbA1c	Manage diabetes as usual
Lee (2018)[21]	South Korea	3 and 6 months	148	I: 53 C: 51	HbA1c	Usual diabetes care
Yu (2019)[22]	China	12 and 24 weeks	185	53	HbA1c	Usual treatment once a month
Overweight and obesity						
Apinaniz (2019)[23]	Spain	1, 3 and 6 months	110	39	Weight	Motivational advice including recommendations on diet and physical exercise.
Duncan (2020)[37]	Australia	6 and 12 months	116	45	Weight	Waitlist control: asked to maintain current weight, physical activity, dietary intake and behaviours and sleep health.
Laing (2014)[25]	United States	3 and 6 months	212	43	Weight	Usual primary care (Not specified)
Vaz (2021)[26]	United States	3 and 6 months	28	43	Weight	Waitlist control
Zhou (2021)[27]	China	45 and 90 days	750	70	Weight	Followed their lifestyle as before, a book on reasonable diet was given
Metabolic abnormalities						
Bennet (2018)[28]	United States	6 and 12 months	351	51	Weight	Current standard of care.
Block (2015)[29 b]	United States	6 months	399	55	HbA1c	Wait-list usual-care control group (not specified)
Lim (2020)[30 c]	Singapore	3 and 6 months	108	I: 47 C: 46	5% of weight loss	Usual standard care (advice on dietary and physical activity modification as per American Heart Association guidelines)
Muralidharan (2019)[38 d]	India	12 weeks	714	I: 38 C: 38	5% of weight loss[31]	Usual care for patients with prediabetes or obesity: on-off meeting with a dietitian, handouts about diabetes prevention[31]
Plotnikoff (2017)[33 e]	Australia	10 and 20 weeks	84	45	Aerobic fitness (VO_2Max)	Waitlist control group
Tanaka (2018)[34f]	Japan	8 and 12 weeks	112	I: 46 C: 48	Weight	Did not receive any intervention
Risky alcohol drinking						
Gustafson (2014)[35]	United States	4, 8 and 12 months	349	I: 38 C: 38	Risky drinking days	Treatment as usual, varied across programs.

Author (year)	Country	Follow-up	Participants randomised	Mean age (years)	Outcome	Comparator
Mellentin (2019)[36]	Denmark	6 months	164	I_{app}: 48 I_{group}: 48 C: 45	Sensible drinking	Aftercare as usual: one follow-up session with cognitive behavioural therapy

[a] *Patients with obesity and hypertension, diabetes, and hyperlipidaemia*
[b] *Participants with prediabetes*
[c] *Patients with non-alcoholic fatty liver disease*
[d] *Participants with prediabetes and/or obesity*
[e] *Participants with or at risk of type 2 diabetes*
[f] *Participants who were overweight and had at least one of the cardiometabolic risk factors*

Intervention characteristics

Mobile app-based interventions were classified into two categories: mobile app stand-alone or a combination of a mobile app and co-interventions provided by healthcare professionals. Only four studies out of 22, two each for type 2 diabetes[14,16] and overweight/obesity[23,25], had mobile app stand-alone interventions. Three studies used mobile phones with pre-installed apps.[14,15,35]

The following nine key intervention characteristics are identified including two features for healthcare workers which are sharing participants' data and sending alert about participants' out-of-range blood glucose levels.

1. Goal setting
2. Self-monitoring
3. Information
4. Feedback
5. Reminder
6. Social support
7. Data sharing with intervention/healthcare providers
8. Alert for providers
9. Other features

These functions were carried out either automatically by mobile apps or manually by healthcare workers. Some interventions used other devices/materials such as cellular connected weight scales or test strips for blood glucose to support self-monitoring. Table 2 briefly summarises mobile app characteristics and healthcare resources such as healthcare professionals involved, and devices and materials used other than mobile apps. The full table can be found in Multimedia Appendix 1.

Table 2. Mobile app characteristics of the included studies

Authors (Year)	Self-monitoring 1. Diet 2. Physical activity 3. Clinical outcome 4. Behaviour	Information 1. Diet 2. Physical activity 3. Clinical outcome 4. Behaviour	Feedback	Reminder	Social support	Data sharing with providers	Alert for providers
Type 2 diabetes							
Agarwal (2019)[14]	App (1,2,3)	NA	App	NA	NA	App	NA
Anzaldo-Campos (2016)[15]	App (3)	App (1,2,3,4), HCW: In person	NA	App	NA	App	App
Boels (2019)[16]	NA	App (1,2,3,4)	NA	App	NA	NA	NA
Gong (2020)[17]	App (3)	App (1,2,3,4) HCW: Online, Telephone	App	NA	HCW: Online	NA	App, HCW: Online, Telephone
Hilmarsdóttir (2021)[18]	App (1,2,3,4)	App (1,2,4)	HCW: Online	NA	App	App, HCW: Online	NA
Kim (2022)[19]	App (1,2,3,4)	App (4), HCW: In-person	HCW: via App	HCW: App	HCW: via App	App, HCW: Online	NA
Kleinman (2017)[20]	App (3)	App (4), HCW: In-person	NA	App	HCW: via App	App, HCW: Online	HCW: Online
Lee (2018)[21]	App (1,2,3,4)	HCW: Online	HCW: Online	HCW: Online	HCW: via App	App, HCW: Online	NA
Yu (2019)[22] (MPA group)	App (1,2,3,4)	App (1,2,3,4)	NA	NA	HCW: via App	App	App
Yu (2019)[22] (MPA + SMBG group)	App (1,2,3,4)	App (1,2,3,4)	NA	NA	HCW: via App	App	App
Overweight and obesity							
Apinaniz (2019)[23]	App (1,2)	App (1,2,4)	NA	NA	NA	NA	NA
Duncan (2020)[37] Traditional group	App (1,2,3)	App (1,2), HCW: In-person	HCW: email, SMS, in-person	HCW: email	NA	NA	NA
Duncan (2020)[37] Enhanced group (Traditional + sleep components)	App (1,2,3,4)	App (1,2), HCW: In-person	HCW: email, SMS, in-person	HCW: email	NA	NA	NA
Laing (2014)[25]	App (1,2,3)	NA	App	App	App	NA	NA
Vaz (2021)[26]	App (1,2,3)	App (1), HCW: In-person, text message	App, HCW: via App or text message	App, HCW: not specified	App, HCW: via App	App, HCW: Data monitoring	NA
Zhou (2021)[27]	App (1,2,3)	HCW: Online	HCW: via text message or telephone	NA	HCW: not specified	App, HCW: Data reviewing online	NA
Metabolic abnormalities							
Bennet (2018)[28 a]	App (1,2,3,4), HCW: Review data[39]	HCW: Telephone	App, HCW: In-person	NA	HCW: Telephone	App, Other: Progress report	NA
Block (2015)[29 b]	App (1,2,3)	App (4)	Other: Interactive voice response	App	App	NA	NA
Lim (2020)[30 c]	App (1,2,3), HCW: In-person	App (Not specified)	App, HCW: via the app automated response system	App	App	App, HCW: via App	NA
Muralidharan (2019)[38 d]	App (1,2,3)	App (1,2,3,4) HCW: Telephone	App, HCW: Email	App	App, HCW: Not specified	App, Other: Progress report	NA

[a] *Patients with obesity and hypertension, diabetes, and hyperlipidaemia*
[b] *Participants with prediabetes*
[c] *Patients with non-alcoholic fatty liver disease*
[d] *Participants with prediabetes and/or obesity*
[e] *Participants with or at risk of type 2 diabetes*
[f] *Participants who were overweight and had at least one of the cardiometabolic risk factors*
Note. Clinical outcomes can include any parameters such as weight, blood glucose level, or blood pressure. 'Behaviour' includes topics about disease self-management other than diet and physical activity such as healthy lifestyle, prevention of complication, medication, motivation and stress management.
Abbreviations. HCW: Healthcare workers, NA: Not applicable, MPA: Mobile phone applications, SMBG: Self-monitor blood glucose

1. Goal setting

The terms 'goal setting' and 'recommendations' are considered to be interchangeable in this review. Common goals are observed in most studies, with risky alcohol drinking as a rarer target.

Goals can be directly towards either final outcomes such as 'weight loss' or 'improved HbA1c', or focused on specific behavioural change targets such as having at least 400 g of fruit and vegetables[23], avoiding sugary drinks and junk food or snacks late in the day[18,29], and weekly 150 minutes of moderate-to-vigorous intensity physical activity[23,29,37]. As lifestyle approaches for weight loss can be focused on creating an energy deficit[40], goal setting for daily energy deficit of 2000 kj[37] could also make a weight loss target more realistic for patients. Goals were updated regularly such as weekly[30] or bimonthly[28] or as soon as the initial target was achieved[25], by apps using participants' data[28,29].

2. Self-monitoring

Self-monitoring features, in line with goal settings, were also common among three chronic conditions except for risky alcohol drinking. About half of included studies used either a Bluetooth/cellular/USB-connected weight scale[26,27,30,37], blood glucose reader[15,19-22,27], or activity tracker[26,27,33,37] that transferred data into the apps, which likely made it easier for participants to record their daily data.

Logging data on diet was performed either manually, using an app built-in barcode scanner for store-bought foods[25], selecting food items from in-app food databases[25,38], or uploading meal photos into the app[26,27,34]. Sleep was also self-monitored[37].

Other than blood glucose reading, disease-specific parameters included medication[19,21], stress management[18] for type 2 diabetes, blood pressure[18,21,22] for metabolic abnormalities. Patients in the alcohol study self-monitored protective and risky items related to drinking such as lifestyle balance, quality of sleep, negative effects, and recent substance use[35].

3. Information

The most common information provided to participants were about diet and physical activity. Some apps also gave explanations on: the benefits of exercise[23], the risks of a sedentary lifestyle[23], affirmational content to encourage sustained behaviour changes[14], the importance of a healthy diet[23], and details about how behaviours related to weight loss[37]. One study provided meal plans to select from low glycaemic index, low fat, low carbohydrate, or Mediterranean style[26].

Some studies included visual instructions such as in-app short video clips and photos[15,22,30,33]. One study focused on physical activity in the outdoor environment and provided park locations of a standardised 3 km course for walking or running[33]. Other information concerned behavioural skill training and disease-specific content such as diabetes care, foot care, and medication taking, prevention of hypoglycaemia, and glucose control[16].

Information was provided in a various ways such as via apps, via email and/or short message services, via a website for discussion forums, by healthcare professionals at the in-person counselling[19,28], phone counselling[19,28], or peer educator-led educational classes[15]. Frequency of information provision could be higher in the first few months, such as daily, and decreased towards the end, such as twice a week[15,23]. Information provided in the alcohol studies included the importance of reducing cue-induced cravings[36] and audio-guided relaxation[35].

4. Feedback

We included any individualised comments on participants' progress as feedback. Feedback was delivered either by the app itself[14,17,27], automated response system[29,30], text message[28], by healthcare providers via the apps[18,26,34], via a website[21], by email[37], by text message or phone call[14,27], or in-person counselling[37]. Individualised feedback ranged from short encouragement messages such as 'Can be better' or 'Good, keep it up' [18] to recommendations based on clinical practice recommendations by professional coaches[21].

5. Reminder

The purpose of reminders were to open or re-engage with the app[37], to motivate participants to meet the target for diet or exercise[26], for logging information (meal intake[25,30], weigh-in[30]), and for times (meal, exercise, blood glucose measurement, and

medication)[19]. Reminders were sent either via the app or short message services.

6. Social support

This function aimed to provide motivation and encouragement via two-way communication between other study participants. For example, participants posted their meal photos or achievement to the in-app social networking platform, and other participants gave positive reactions to motivate others; participants motivated and encouraged each other on the platform[22,25]. Healthcare professionals were involved in the communications[19,22]. Some variations were found such as adding competitions and rewards[18,26,29], and allowing participants to invite their family and friends to the peer support channel[30].

Another example of social support is that participants were allowed to ask healthcare providers questions via the app, and healthcare workers responded to participants in a timely manner[22,38].

7. Data sharing with intervention/healthcare providers

Participants' data were shared either via their app[14,15,18], the healthcare worker's app[22], study database[19,26], or web portal/dashboard[20,21,27,30]. Progress reports were generated using the data recorded in the app and used for counselling[28,38].

8. Alert for providers

An app in type 2 diabetes [15,22] sent alerts to healthcare providers to notify the out-of-range blood glucose levels and an app for alcohol sent alerts for risky drinking[35]. A web portal highlighted participants who needed attention and clinical information that required review[20].

9. Other features

Other built-in features of apps included generating summary reports on logged data for participants to check their progress[25,29,37], rewards for healthy behaviours[29] that resulted in charitable donations as an extra rewards[18], and competition with other participants[18,29]. An alcohol study used GPS to alert participants who were at a high-risk location such as a bar and asked them if they wanted to be there[35].

Usual Care

Reported usual care groups were: routine diabetes self-care including access to health services[14], diabetes management guide published by the national diabetes

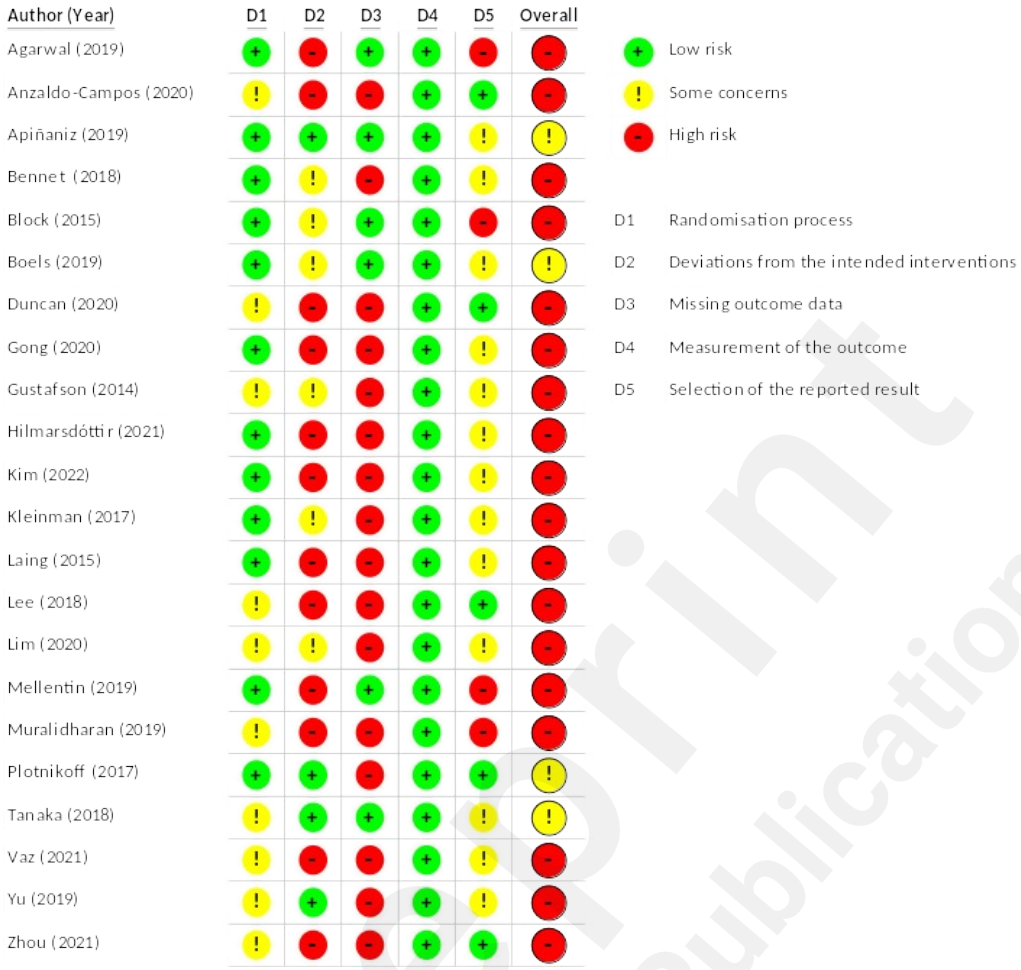
association[19], motivational advice including recommendations on diet and physical exercise[23,38], publicly available self-help materials[28], or waitlist controls. One study did not use standardised usual care due to a pragmatic study design[14].

Risk of Bias Assessment

Details are in the Multimedia Appendix 1. Overall, four studies had ‘some concerns’ about risk of bias and 18 studies are at ‘high risk’ of bias (Figure 2). Excluding randomised participants from the analysis (Domain 2) and insufficient description on dealing with missing outcome data (Domain 3) are the primary reasons for studies being at high risk of bias.

A tool that estimates the probability of under- or over-dispersed imbalance in baseline characteristics between randomised groups detected a high probability of over-dispersion (99.1%) in one study[22] that self-reported statistically significant differences in age (p=0.02), diastolic blood pressure (p=0.005), and total cholesterol (p=0.015). We excluded this study from the meta-analysis because there were large differences between the randomised groups at baseline that were not explained, and the trial registration number provided had no match in the clinical trials registry.

Figure 2. Risk of bias assessment



Effectiveness of Interventions

There were three formats for reporting estimates:

1. Change from baseline (within-group change)
2. Post-intervention values (values at follow-up visits)
3. Reported between-group mean difference

These could be either adjusted or unadjusted for other variables. When results were presented in multiple formats, we selected them using the above ordering.

Bennet et al[28] reported a mean of -0.2, which was the outside of the associated confidence interval of -0.04 to -0.001. We assumed the lower value of -0.04 was a typo due to adding an extra zero and used -0.4 in our meta-analysis. A study by Anzaldo-Campos enrolled patients without current insulin use started the insulin therapy during the intervention[15].

The effectiveness of the interventions on each of the four outcomes by analysis methods are summarised in Table 3 and Figure 3.

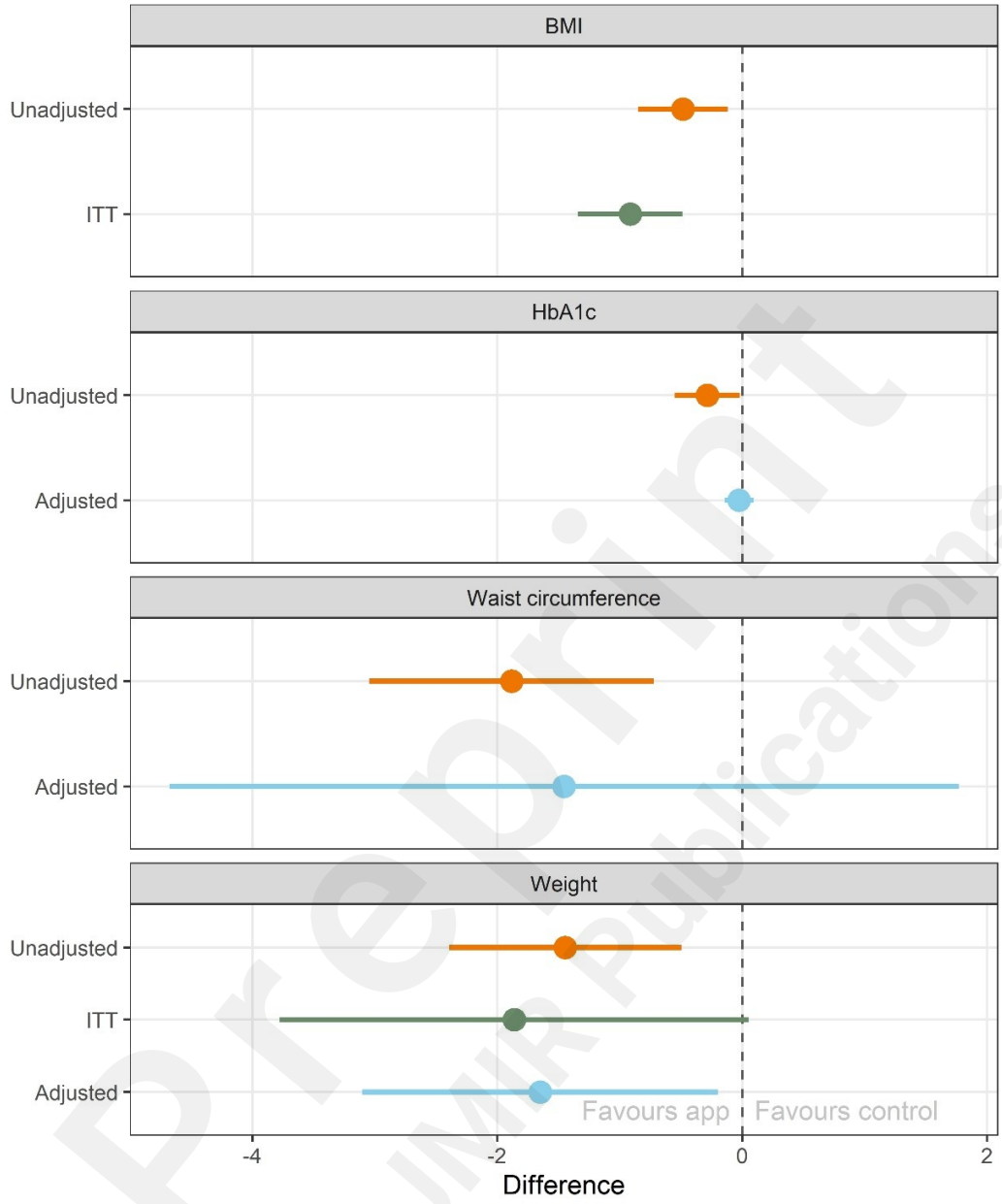
The unadjusted pooled mean difference showed that the mobile app could have some benefits on reducing weight (mean difference [95% CI]: -1.44 kg [-2.39 to -0.49]), HbA1c (mean difference [95% CI]: -0.22 [-0.42 to -0.02]), BMI (mean difference [95% CI]: -0.48 [-0.85 to -0.12]), and waist circumference (mean difference [95% CI]: -1.88 cm [-3.04 to -0.72]). However, since study participants were obese and/or with a high HbA1c level, clinically meaningful benefits of the interventions might be limited (Figure 4-7).

Table 3. Effectiveness of the interventions on outcomes by analysis methods

	HbA1c			**Weight**			**Body mass index**			**Waist circumference**		
	Studies (arms)	Mean difference [95% CI]	I^2	Studies (arms)	Mean difference [95% CI]	I^2	Studies (arms)	Mean difference [95% CI]	I^2	Studies (arms)	Mean difference [95% CI]	I^2
Unadjusted	11 (19)	-0.28 [-0.55 to -0.02]	95%	6 (14)	-1.44 [-2.39 to -0.49]	53%	10 (20)	-0.48 [-0.85 to -0.12]	93%	6 (13)	-1.88 [-3.04 to -0.72]	24%
Adjusted	5 (9)	-0.02 [-0.14 to 0.10]	46%	3 (5)	-1.65 [-3.10 to -0.20]	66%	NA	NA	NA	2 (6)	-1.45 [-4.68 to 1.77]	77%
ITT	NA	NA	NA	2 (4)	-1.86 [-3.78 to 0.06]	74%	2 (4)	-0.91 [-1.34 to -0.49]	0%	NA	NA	NA

Abbreviations. CI: Confidence interval, ITT: Intention-to-treat analysis, I^2: Total variability due to between-study heterogeneity, NA: Not applicable

Figure 3. Summary plot of the effectiveness of the interventions on outcomes by analysis methods



Abbreviations. ITT: Intention-to-treat analysis

Figure 4. Forest plot of the unadjusted pooled effectiveness on BMI

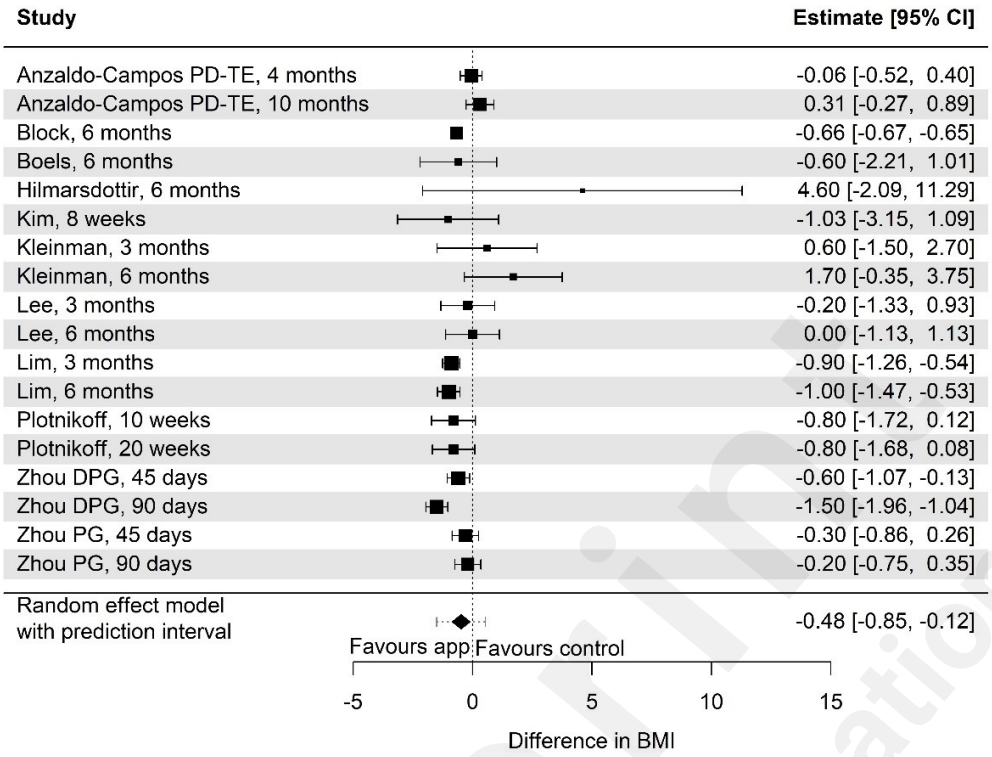


Figure 5. Forest plot of the unadjusted pooled effectiveness on HbA1c

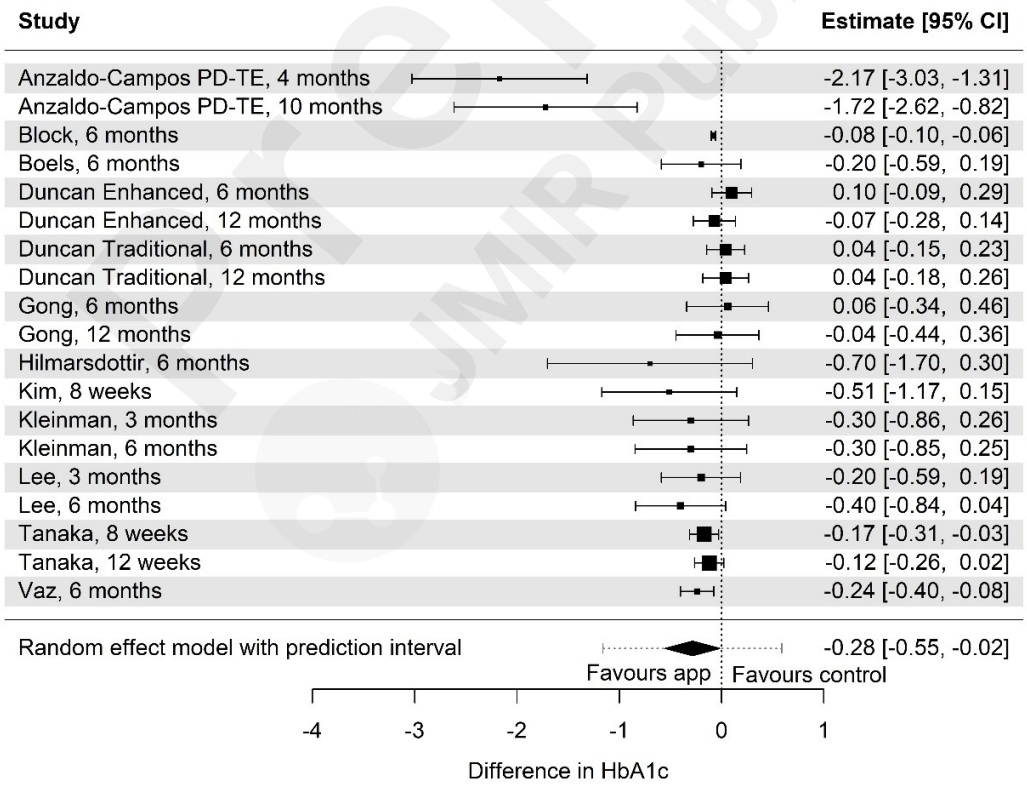


Figure 6. Forest plot of the unadjusted pooled effectiveness on waist circumference

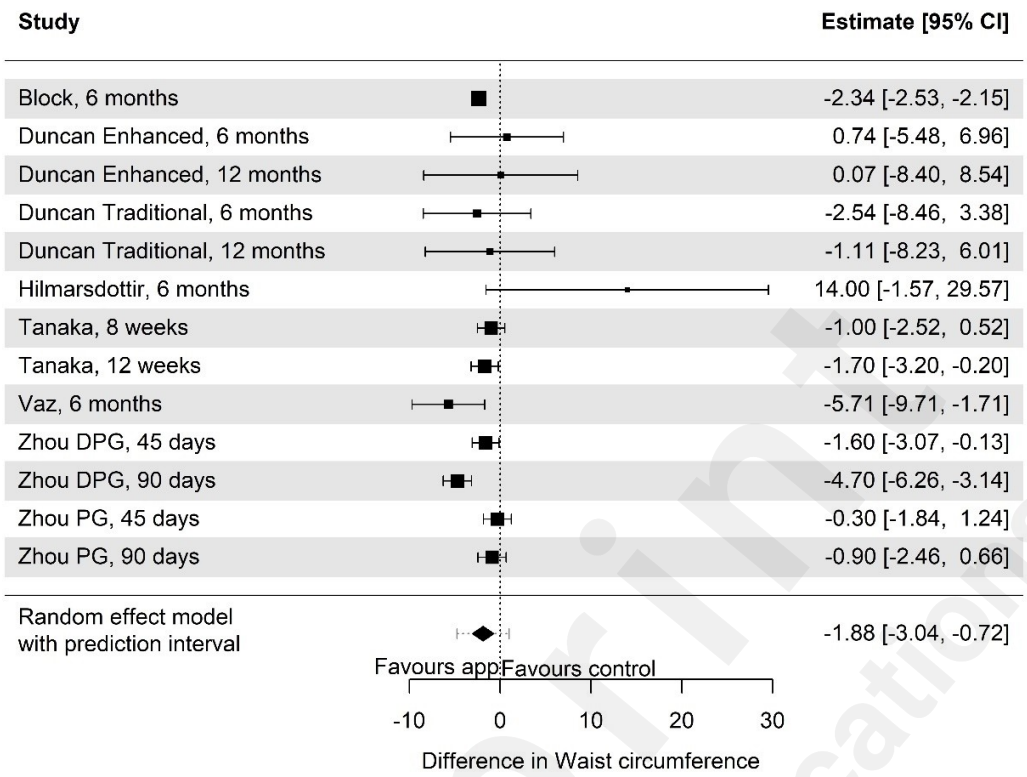
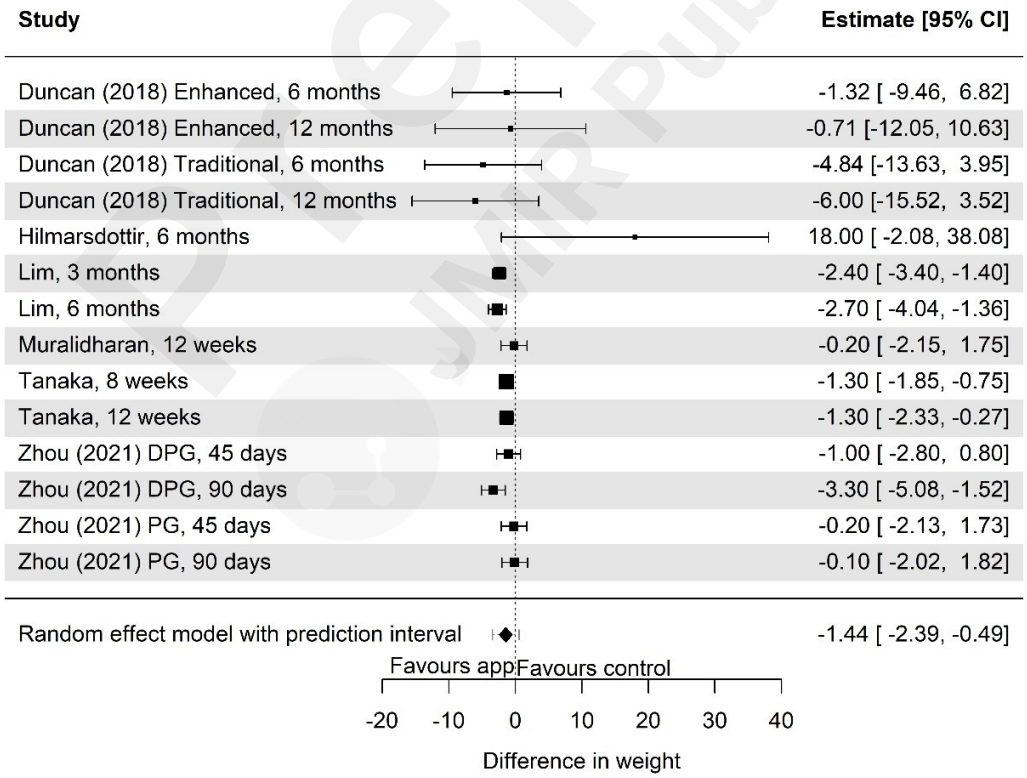


Figure 7. Forest plot of the unadjusted pooled effectiveness on weight



The adjusted pooled mean differences showed similar results to the unadjusted mean

differences on HbA1c, weight and waist circumference; no adjusted study was found for BMI. The unadjusted pooled mean differences from intention-to-treat results also showed similar results to the unadjusted results; no study was found for waist circumference (Table 3, Figure 3). The forest plots of these analyses are in the Multimedia Appendix 1.

DISCUSSION

Principal findings

This study systematically reviewed the evidence on the effectiveness of mobile app-based interventions on four conditions related to chronic liver disease. We examined mobile-app characteristics with a particular interest in human and non-human resource use.

The systematic review identified nine key features of mobile app interventions for lifestyle modification and highlighted the significant involvement of human-led activities and other devices and materials other than the mobile app in the included studies.

The meta-analyses showed some benefits of app-based interventions for reducing the HbA1c level, weight, BMI and waist circumference. In reporting of randomised controlled trials, the adjusted estimates for baseline outcome measurements are considered to be the most precise estimates of the intervention effects[41]. Yet not all the studies reported adjusted results, resulting in the inclusion of small number of studies in the analysis of the pooled adjusted effect. Similarly, though intention-to-treat analysis is the most appropriate approach for giving a realistic estimate of an intervention's effect in practice, only a few studies used this method. Therefore, we should be cautious about interpreting all these meta-analysis results.

Comparison with Prior Work

A previous meta-analysis that included 54 studies with randomised designs among patients with type 1 or type 2 diabetes showed the favourable effect of mobile app interventions on HbA1c (the pooled mean difference: -0.36, 95%CI: -0.46 to -0.26)[42], which was slightly larger than the effect we detected. The previous study also found that the improvements in HbA1c were associated with self-monitoring behaviour and the focus on taking medication as a target behaviour[42]. They pointed out the necessity

of advancement in the evidence generation process; the methodological quality issues of the randomised controlled trials, specifically, trials being at high risk of bias, and the provision of the standardised interventions to all participants, rather than personalised features, could be limitations of the trial designs[42]. Likewise, this systematic review and meta-analysis also supported the importance of the careful considerations on the intervention designs, stakeholders' needs, and accumulation of evidence, which will be discussed further in the next section.

Possibility of Task-Shifting in the Management of Chronic Liver Disease

The mobile apps used in the included trials were developed to support patients' disease self-management. As summarised in Table 2, mobile apps, healthcare professionals, and other devices shared their roles in the interventions. Some apps performed tasks that are usually performed by healthcare professionals such as provision of educational information and feedback. This suggests that mobile apps could replace some healthcare providers' tasks as 'task-shifting'. Apps can also provide extra support such as platforms for tracking weight trends with visualisation, reminders for logging, and transferring data to treating clinicians. These advantages could facilitate implementing task-shifting using mobile apps in the management of chronic liver disease.

Apps are not 'one-size-fits-all' and can only ever augment professional healthcare. Thus, the task-shifting approach can be introduced only when it is justified; certain tasks can only be provided by healthcare professionals such as careful assessment of patients' health status, medical history, comorbidities and other health-related risks as well as their needs, skills, and knowledge and development of individually tailored disease management. Considering the prevalence of chronic liver disease in older people, barriers and enablers such as patient preferences for the task-shifting approach and user friendliness of app features will also need to be carefully examined.

The following three considerations may be required for the implementation of task-shifting in the management of chronic liver disease according to our review.

1. Careful deliberations for intervention designs

App designers should ensure that mobile app features are suitable for the target population. Considerations that should be considered are age, medical history and

disease severity, and readiness for lifestyle change.

Age can have a big impact on design. For example, physical activity ability and eHealth literacy will vary between ages. Although having regular exercise and healthy diet are key to lifestyle modification, Zhou, who undertook a study among overweight or obese patients aged 60 to 80 pointed out the limited ability to be physically active and feasibility of dietary intervention among the elderly[27]. In addition, levels of eHealth literacy, or ability to use digital technologies for healthcare such as having difficulty in using apps were discussed in included studies[17,19,27].

Levels of support or required skills and knowledge may differ between medical history and disease severity; populations who have had a disease for a long time but are still not well-controlled and/or with a more severe disease may need extra support. Australian clinical guidance suggested active management for the obese population, with standard care for those who are overweight[43]. However, only one study[28] out of 10 studies that had a BMI eligibility criterion clearly targeted obese people (BMI ranged from 30.0 to 44.9). With regards to type 2 diabetes, required support will likely differ among those with and without insulin use, or those treated in primary care or receiving specialist care. However, of nine studies with a HbA1c eligibility criterion, four studies[14,15,19,20,29] had a criterion for the use of insulin or diabetic medications. Patients with comorbidities may also have different preferences for support.

Regarding patients' readiness for lifestyle change, the importance of internal motivation, specifically, readiness for investing the time and putting in the necessary work to self-monitoring was discussed in many studies[14,25,28,30,34]. A study among overweight and obesity patients in urban areas found that participants were busy with work and had little time for the intervention[38]; conversely self-management and easy access to their coach via app may be a solution for time and constraints, and may be more easily adopted by populations such as full-time workers and students[34].

Researchers aiming to get the most conclusive evidence need to carefully consider the eligibility criteria, including patients' readiness for lifestyle modification, and app designs suitable for the target population during the trial planning, although stricter eligibility criteria will make trial recruitment harder and reduce generalisability. Subgroup analysis by obesity classifications, comorbidities, medication status may be informative to evaluate the intervention's effectiveness.

2. Matching each stakeholders' needs

The involvement of healthcare workers seems to be inevitable in the app-based disease management, and thus, not only patients' needs but also providers' needs should be considered to perform task-shifting.

The use of an unsuitable app can lead to reduced user's confidence in achieving lifestyle modification goals. Laing discussed how setting weight loss goals by participants may have increased awareness of whether or not they achieved their goals, which could have decreased users' confidence [25]. Tanaka pointed out the need of strict goals for clinically meaningful weight loss[34].

Kleinman[20] used a provider satisfaction measurement with a focus on the intervention's acceptability, impact on the practice, and impact on patients among diabetic patients and reported positive responses. Sharing patients' self-monitoring data with providers may be helpful to better understand patients' disease self-management, which can facilitate more effective communication and stronger relationships with patients[30]. It is difficult for healthcare providers to give effective advice if patients' data are under-reported[25]. In other words, the more self-monitoring data healthcare providers obtain, the more personalised, meaningful advice they can provide to patients, which can lead to more positive impact on patients in practice. The promise of better feedback could encourage patients to engage with self-monitoring with an app.

3. Accumulation of evidence

Accumulation of evidence on the effectiveness of app interventions, healthcare workers' tasks that can be shifted to apps, and patient preferences for services provided by apps instead of healthcare workers is required for successful implementation of task-shifting.

A recommendation by physicians to use an app for patients' self-management could accelerate task-shifting by encouraging patients to better manage their disease. However, the lack of high-quality evidence on the effectiveness of mobile app-based interventions due to the often high risk of bias in previous trials makes it difficult for physicians to prescribe apps[23]. We identified the roles of mobile apps in the management of chronic conditions related to chronic liver disease. However, we also need to know all healthcare workers' tasks to justify which of these can be task-shifted. Furthermore, there must be a gap between what apps can do and what patients would like apps to do instead of healthcare workers in disease self-management.

Strengths

To our best knowledge, this is the first systematic review of evidence and meta-analysis of the effectiveness of mobile applications for lifestyle modification with a focus on chronic liver disease. We searched six databases regarding four conditions related to chronic liver disease. Regarding the risk of bias assessment, we did not consider so-called 'modified intention-to-treat' analysis as the appropriate analysis, which may be stricter than the Cochrane Risk of Bias assessment guidance[9]. We used the novel tool to assess baseline imbalance[11] in addition to the Cochrane Risk of Bias assessment. We focused on resource use in the app-based interventions. The summary of the co-interventions provided by healthcare professional provided valuable insights for evaluating effectiveness and cost-effectiveness of the mobile app interventions for future studies.

Limitations

We have several limitations. First, since we included randomised controlled trials that studied the effectiveness of a mobile application compared to usual care, studies that compared the effectiveness to other interventions such as paper-based food logs were excluded. Also, usual care varied across studies, which increased the between-study heterogeneity. Although we included two studies for risky alcohol drinking, the populations were those who had already had access to treatment, and general population who drink heavily were not included in this review. As risky alcohol drinking may be considered as an addiction, rather than chronic condition, the nature of this condition and its treatment goals are different to other three chronic conditions and may not be comparable. Second, since RCTs often strictly restricted participants in terms of eligibility, the participants may not represent the wider target population who might benefit from the intervention. For example, younger populations with underlying conditions might be more familiar with the use of smartphones and likely to engage with an app-based intervention, and thus an intervention could have had larger effect size among such group of people. Third, not all the studies clearly presented the number of participants included in the analysis for each group in the result tables, which might have created errors in data extraction. Lastly, as our primary focus was on the impact of mobile app interventions on clinical outcomes that was of interest to clinicians in practice, we did not evaluate how the interventions affected behavioural change. Further research is anticipated to investigate how mobile

app interventions consider treatment guidelines and behaviour change targets and how these targets are evaluated.

CONCLUSION

We identified mobile app-based interventions among patients with underlying conditions related to chronic liver disease. The available evidence was suboptimal due to high rates of loss to follow-up and lack of evidence from intention-to-treat analysis. Most studies included substantial involvement of healthcare workers. We identified some tasks that were provided either by healthcare workers or mobile apps such as the provision of education, which could suggest potential of task-shifting from healthcare workers to mobile apps. Such task-shifting approach could improve allocation of human resource in healthcare and be cost-effective if it is proven as effective as usual care. However, implementation of task-shifting may require careful deliberations for intervention designs, matching each stakeholders' needs, and accumulation of evidence on the effectiveness of app interventions. Further research is needed particularly on the stakeholders' preferences on implementation of task-shifting in management of chronic liver disease.

Acknowledgements

The thank James O'Beirne (Hepatologist, Sunshine Coast University Hospital, QLD, Australia) for the consultation on chronic conditions related to chronic liver disease and Cameron Rutter (Librarian, Queensland University of Technology, QLD, Australia) for the assistance with developing search strategies for this study.

Conflicts of Interest

None declared.

References

1. Quek J, Chan KE, Wong ZY, et al. Global prevalence of non-alcoholic fatty liver disease and non-alcoholic steatohepatitis in the overweight and obese population: a systematic review and meta-analysis. *Lancet Gastroenterol Hepatol*. Jan 2023;8(1):20-30. doi:10.1016/s2468-1253(22)00317-x
2. Niu X, Zhu L, Xu Y, et al. Global prevalence, incidence, and outcomes of alcohol related liver diseases: a systematic review and meta-analysis. *BMC Public Health*. May 11 2023;23(1):859. doi:10.1186/s12889-023-15749-x
3. Lazarus JV, Mark HE, Anstee QM, et al. Advancing the global public health agenda for NAFLD: a consensus statement. *Nature Reviews Gastroenterology & Hepatology*. 2022/01/01 2022;19(1):60-78. doi:10.1038/s41575-021-00523-4
4. Ismail H, Marshall VD, Patel M, Tariq M, Mohammad RA. The impact of the COVID-19 pandemic on medical conditions and medication adherence in people with chronic diseases. *J Am Pharm Assoc (2003)*. May-Jun 2022;62(3):834-839.e1. doi:10.1016/j.japh.2021.11.013
5. World Health Organization, Unaids P. Task shifting : rational redistribution of tasks among health workforce teams : global recommendations and guidelines. Geneva: World Health Organization; 2007.
6. van Schalkwyk MCI, Bourek A, Kringos DS, et al. The best person (or machine) for the job: Rethinking task shifting in healthcare. *Health Policy*. 2020/12/01/ 2020;124(12):1379-1386. doi:https://doi.org/10.1016/j.healthpol.2020.08.008
7. Centers for Disease Control and Prevention. https://stacks.cdc.gov/view/cdc/95317. Centers for Disease Control and Prevention, . 20 March, 2022. Accessed 20 March, 2022. https://www.cdc.gov/coronavirus/2019-ncov/global-covid-19/task-sharing.html
8. CONSORT. TIDieR. CONSORT. Accessed 18 December, 2022. http://www.consort-statement.org/resources/tidier-2
9. MRC Network of Hubs for Trials Methodology Research. Rob 2 tool - A revised tool to assess risk of bias in randomized trials. Accessed 18 December, 2022. https://www.riskofbias.info/welcome/rob-2-0-tool
10. Barnett A. Automated detection of over- and under-dispersion in baseline tables in randomised controlled trials [version 1; peer review: 1 approved, 1 approved with reservations]. *F1000Research*. 2022;11(783)doi:10.12688/f1000research.123002.1
11. Barnett A. Detecting under- or over-dispersion in a baseline table from a randomised controlled trial. Accessed 4 January, 2024.
12. Foundation TR. The R Project for Statistical Computing. The R Foundation. Accessed 03 June, 2022.
13. Harrer M, Cuijpers P, Furukawa TA, Ebert DD. *Doing Meta-Analysis With R: A Hands-On Guide*. 1st ed. Chapman & Hall/CRC Press; 2021.
14. Agarwal P, Mukerji G, Desveaux L, et al. Mobile App for Improved Self-Management of Type 2 Diabetes: Multicenter Pragmatic Randomized Controlled Trial. *JMIR Mhealth Uhealth*. Jan 10 2019;7(1):e10321. doi:10.2196/10321
15. Anzaldo-Campos MC, Contreras S, Vargas-Ojeda A, Menchaca-Díaz R, Fortmann A, Philis-Tsimikas A. Dulce Wireless Tijuana: A Randomized Control Trial Evaluating the Impact of Project Dulce and Short-Term Mobile Technology on Glycemic Control in a Family Medicine Clinic in Northern Mexico. *Diabetes Technol Ther*. Apr 2016;18(4):240-51. doi:10.1089/dia.2015.0283
16. Boels AM, Vos RC, Dijkhorst-Oei LT, Rutten G. *Effectiveness of diabetes self-management education and support via a smartphone application in insulin-treated patients with type 2 diabetes: results of a randomized controlled trial (TRIGGER study)*. BMJ Open Diabetes Res Care. 2019 Dec 30;7(1):e000981. doi: 10.1136/bmjdrc-2019-000981. eCollection 2019.; 2019.
17. Gong E, Baptista S, Russell A, et al. My Diabetes Coach, a Mobile App-Based Interactive Conversational Agent to Support Type 2 Diabetes Self-Management: Randomized Effectiveness-Implementation Trial. *J Med Internet Res*. Nov 5 2020;22(11):e20322. doi:10.2196/20322
18. Hilmarsdóttir E, Sigurðardóttir Á K, Arnardóttir RH. A Digital Lifestyle Program in Outpatient Treatment of Type 2 Diabetes: A Randomized Controlled Study. *J Diabetes Sci Technol*. Sep 2021;15(5):1134-1141. doi:10.1177/1932296820942286
19. Kim Y, Lee H, Seo JM. Integrated Diabetes Self-Management Program Using Smartphone Application: A Randomized Controlled Trial. *West J Nurs Res*. Apr 2022;44(4):383-394. doi:10.1177/0193945921994912
20. Kleinman NJ, Shah A, Shah S, Phatak S, Viswanathan V. Improved Medication Adherence and Frequency of Blood Glucose Self-Testing Using an m-Health Platform Versus Usual Care in a Multisite Randomized Clinical Trial Among People with Type 2 Diabetes in India. *Telemed J E Health*. Sep 2017;23(9):733-740. doi:10.1089/tmj.2016.0265
21. Lee DY, Park J, Choi D, Ahn HY, Park SW, Park CY. The effectiveness, reproducibility, and durability

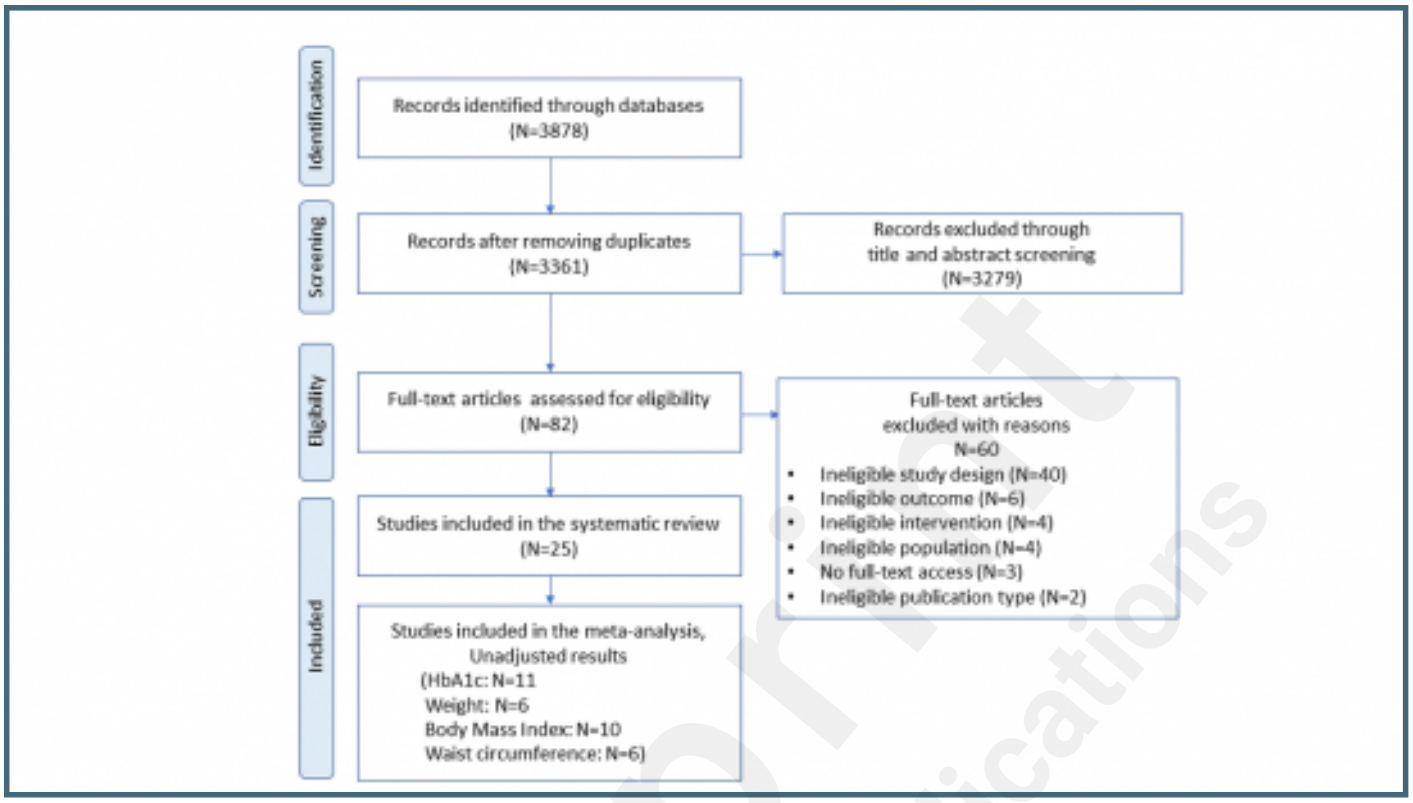
of tailored mobile coaching on diabetes management in policyholders: A randomized, controlled, open-label study. *Sci Rep*. Feb 26 2018;8(1):3642. doi:10.1038/s41598-018-22034-0
22. Yu Y, Yan Q, Li H, et al. Effects of mobile phone application combined with or without self-monitoring of blood glucose on glycemic control in patients with diabetes: A randomized controlled trial. *J Diabetes Investig*. Sep 2019;10(5):1365-1371. doi:10.1111/jdi.13031
23. Apiñaniz A, Cobos-Campos R, Sáez de Lafuente-Moríñigo A, et al. Effectiveness of randomized controlled trial of a mobile app to promote healthy lifestyle in obese and overweight patients. *Fam Pract*. Nov 18 2019;36(6):699-705. doi:10.1093/fampra/cmz020
24. Duncan MJ, Brown WJ, Burrows TL, et al. Examining the efficacy of a multicomponent m-Health physical activity, diet and sleep intervention for weight loss in overweight and obese adults: randomised controlled trial protocol. *BMJ Open*. Oct 30 2018;8(10):e026179. doi:10.1136/bmjopen-2018-026179
25. Laing BY, Mangione CM, Tseng CH, et al. Effectiveness of a smartphone application for weight loss compared with usual care in overweight primary care patients: a randomized, controlled trial. *Ann Intern Med*. Nov 18 2014;161(10 Suppl):S5-12. doi:10.7326/m13-3005
26. Vaz CL, Carnes N, Pousti B, Zhao H, Williams KJ. A randomized controlled trial of an innovative, user-friendly, interactive smartphone app-based lifestyle intervention for weight loss. *Obes Sci Pract*. Oct 2021;7(5):555-568. doi:10.1002/osp4.503
27. Zhou M, Zhang N, Zhang Y, et al. Effect of Mobile-Based Lifestyle Intervention on Weight Loss among the Overweight and Obese Elderly Population in China: A Randomized Controlled Trial. *Int J Environ Res Public Health*. Aug 21 2021;18(16)doi:10.3390/ijerph18168825
28. Bennett GG, Steinberg D, Askew S, et al. Effectiveness of an App and Provider Counseling for Obesity Treatment in Primary Care. *Am J Prev Med*. Dec 2018;55(6):777-786. doi:10.1016/j.amepre.2018.07.005
29. Block G, Azar KM, Romanelli RJ, et al. Diabetes Prevention and Weight Loss with a Fully Automated Behavioral Intervention by Email, Web, and Mobile Phone: A Randomized Controlled Trial Among Persons with Prediabetes. *J Med Internet Res*. Oct 23 2015;17(10):e240. doi:10.2196/jmir.4897
30. Lim SL, Johal J, Ong KW, et al. Lifestyle Intervention Enabled by Mobile Technology on Weight Loss in Patients With Nonalcoholic Fatty Liver Disease: Randomized Controlled Trial. *JMIR Mhealth Uhealth*. Apr 13 2020;8(4):e14802. doi:10.2196/14802
31. Muralidharan S, Mohan V, Anjana RM, et al. Mobile Health Technology (mDiab) for the Prevention of Type 2 Diabetes: Protocol for a Randomized Controlled Trial. *JMIR Res Protoc*. Dec 12 2017;6(12):e242. doi:10.2196/resprot.8644
32. Or CK, Liu K, So MKP, et al. Improving Self-Care in Patients With Coexisting Type 2 Diabetes and Hypertension by Technological Surrogate Nursing: Randomized Controlled Trial. *J Med Internet Res*. Mar 27 2020;22(3):e16769. doi:10.2196/16769
33. Plotnikoff RC, Wilczynska M, Cohen KE, Smith JJ, Lubans DR. Integrating smartphone technology, social support and the outdoor physical environment to improve fitness among adults at risk of, or diagnosed with, Type 2 Diabetes: Findings from the 'eCoFit' randomized controlled trial. *Prev Med*. Dec 2017;105:404-411. doi:10.1016/j.ypmed.2017.08.027
34. Tanaka K, Sasai H, Wakaba K, et al. Professional dietary coaching within a group chat using a smartphone application for weight loss: a randomized controlled trial. *J Multidiscip Healthc*. 2018;11:339-347. doi:10.2147/jmdh.S165422
35. Gustafson DH, McTavish FM, Chih MY, et al. A smartphone application to support recovery from alcoholism: a randomized clinical trial. *JAMA Psychiatry*. May 2014;71(5):566-72. doi:10.1001/jamapsychiatry.2013.4642
36. Mellentin AI, Nielsen B, Nielsen AS, et al. A Mobile Phone App Featuring Cue Exposure Therapy As Aftercare for Alcohol Use Disorders: An Investigator-Blinded Randomized Controlled Trial. *JMIR Mhealth Uhealth*. Aug 16 2019;7(8):e13793. doi:10.2196/13793
37. Duncan MJ, Fenton S, Brown WJ, et al. Efficacy of a Multi-component m-Health Weight-loss Intervention in Overweight and Obese Adults: A Randomised Controlled Trial. *Int J Environ Res Public Health*. Aug 26 2020;17(17)doi:10.3390/ijerph17176200
38. Muralidharan S, Ranjani H, Mohan Anjana R, et al. Engagement and Weight Loss: Results from the Mobile Health and Diabetes Trial. *Diabetes Technol Ther*. Sep 2019;21(9):507-513. doi:10.1089/dia.2019.0134
39. Foley P, Steinberg D, Levine E, et al. Track: A randomized controlled trial of a digital health obesity treatment intervention for medically vulnerable primary care patients. *Contemp Clin Trials*. May 2016;48:12-20. doi:10.1016/j.cct.2016.03.006
40. National Health and Medical Research Council. *Australian guidelines to reduce health risks from drinking alcohol*. 2020. https://www.nhmrc.gov.au/about-us/publications/australian-guidelines-reduce-health-risks-drinking-alcohol#block-views-block-file-attachments-content-block-1
41. Higgins JPT, Thomas J, Chandler J, et al. *Cochrane Handbook for Systematic Reviews of Interventions version 6.4 (updated August 2023)*. Cochrane; 2023. www.training.cochrane.org/handbook

42. Tarricone R, Petracca F, Svae L, Cucciniello M, Ciani O. Which behaviour change techniques work best for diabetes self-management mobile apps? Results from a systematic review and meta-analysis of randomised controlled trials. *eBioMedicine*. 2024/05/01/ 2024;103:105091. doi:https://doi.org/10.1016/j.ebiom.2024.105091
43. National Health and Medical Research Council. *Clinical practice guidelines for the management of overweight and obesity in adults, adolescents and children in Australia*. National Health and Medical Research Council; 2013. https://www.nhmrc.gov.au/about-us/publications/clinical-practice-guidelines-management-overweight-and-obesity

Supplementary Files

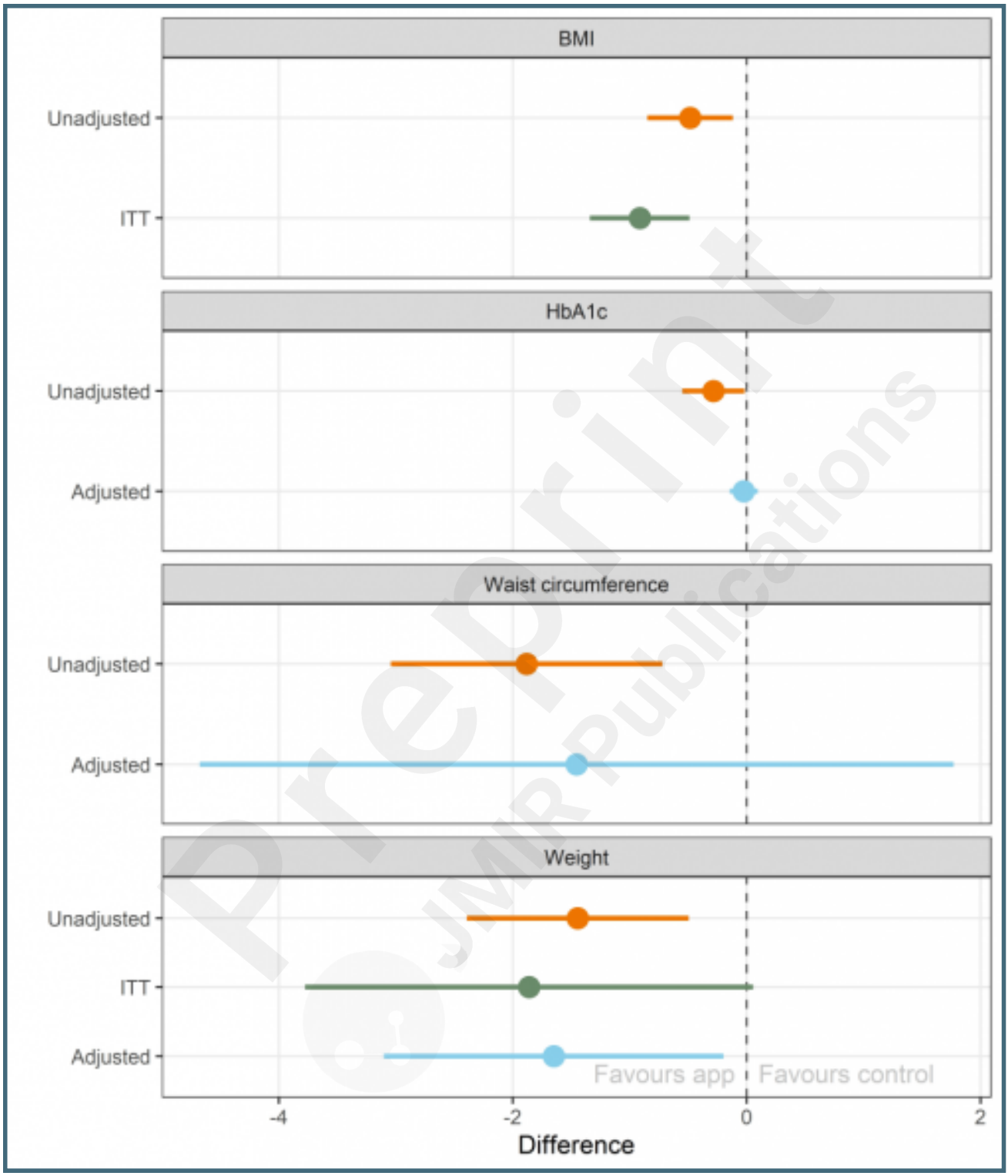
Figures

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Flow diagram.

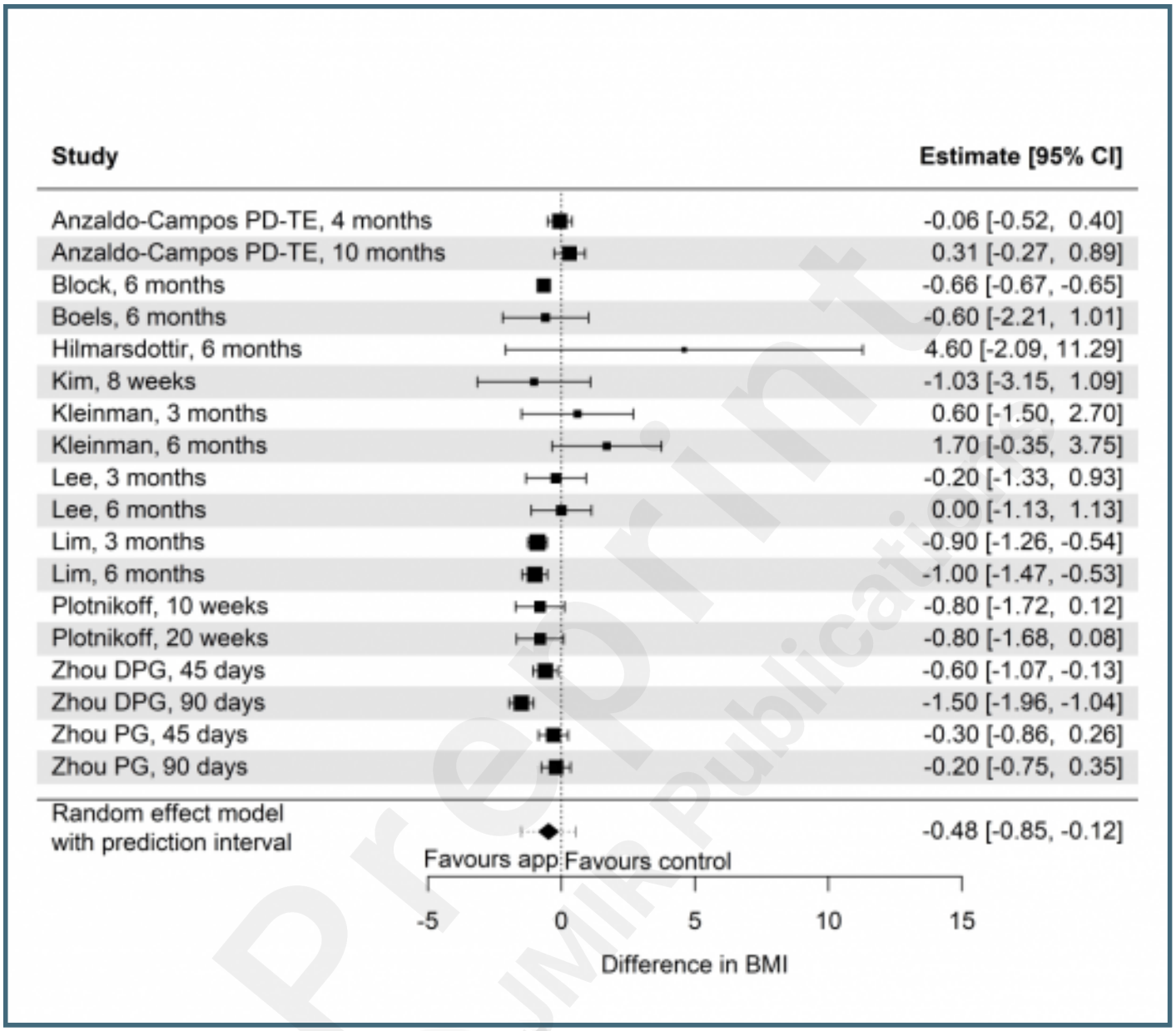


Risk of bias assessment.

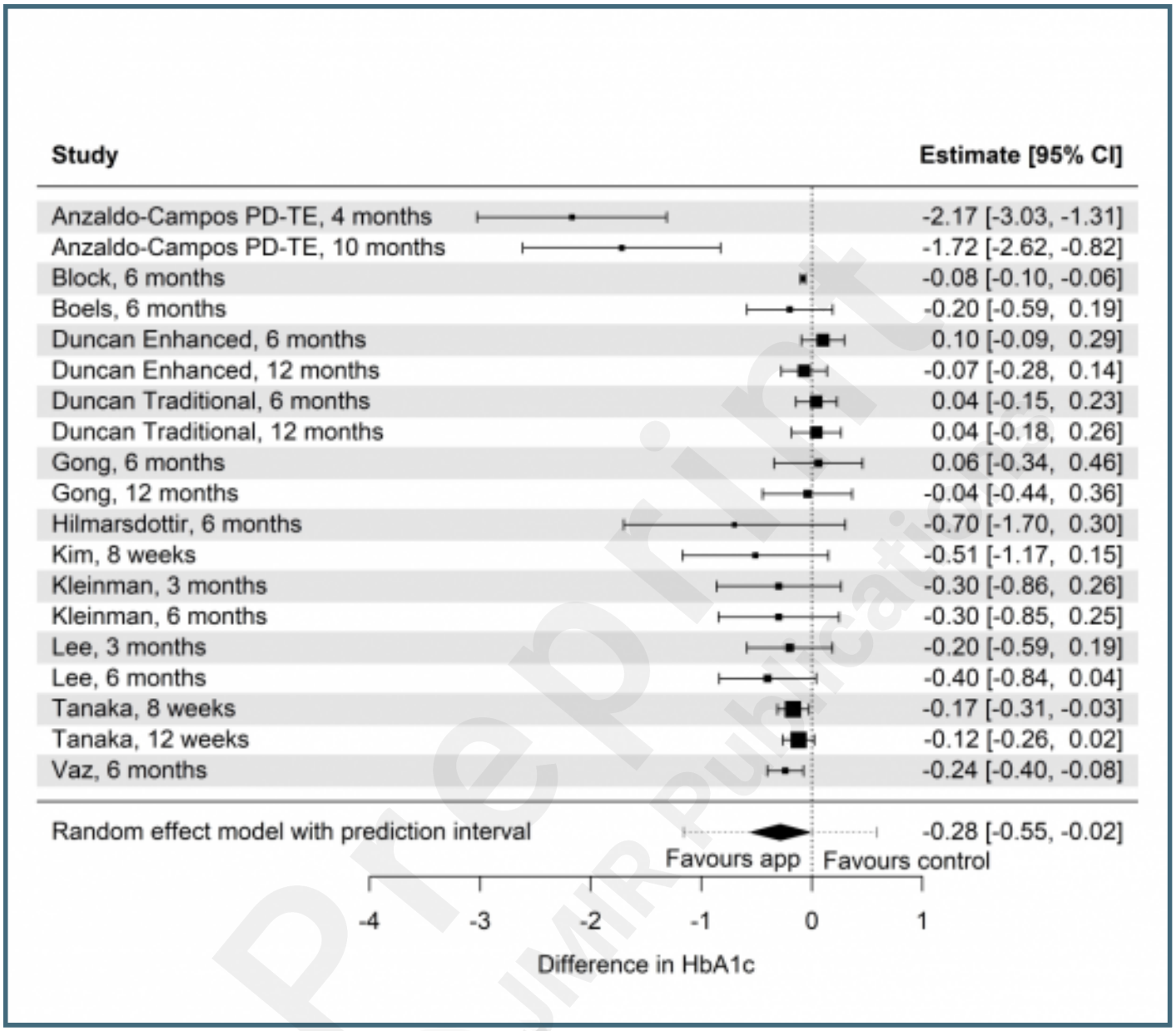
Summary plot of the effectiveness of the interventions on outcomes by analysis methods.



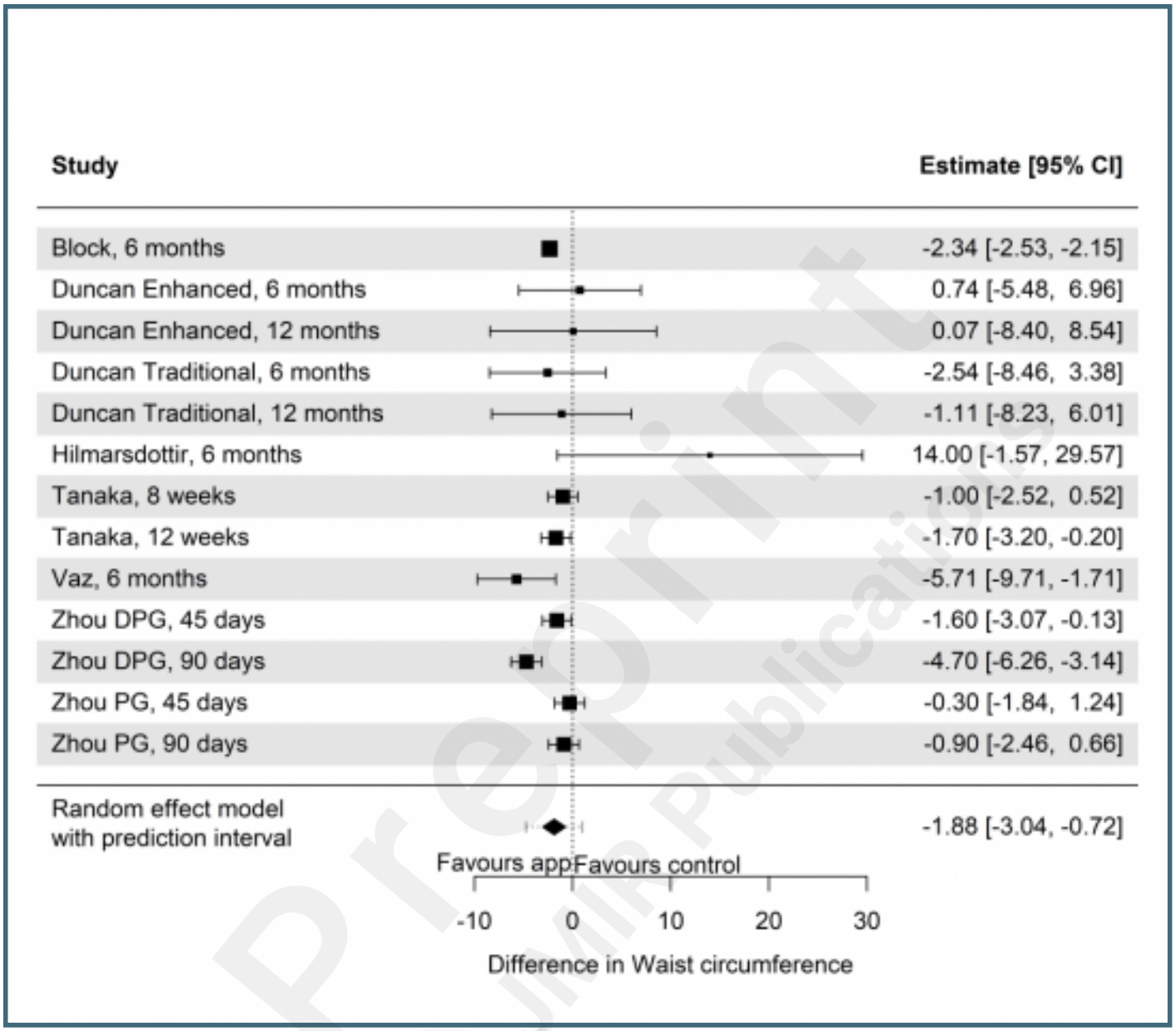
Forest plot of the unadjusted pooled effectiveness on BMI.



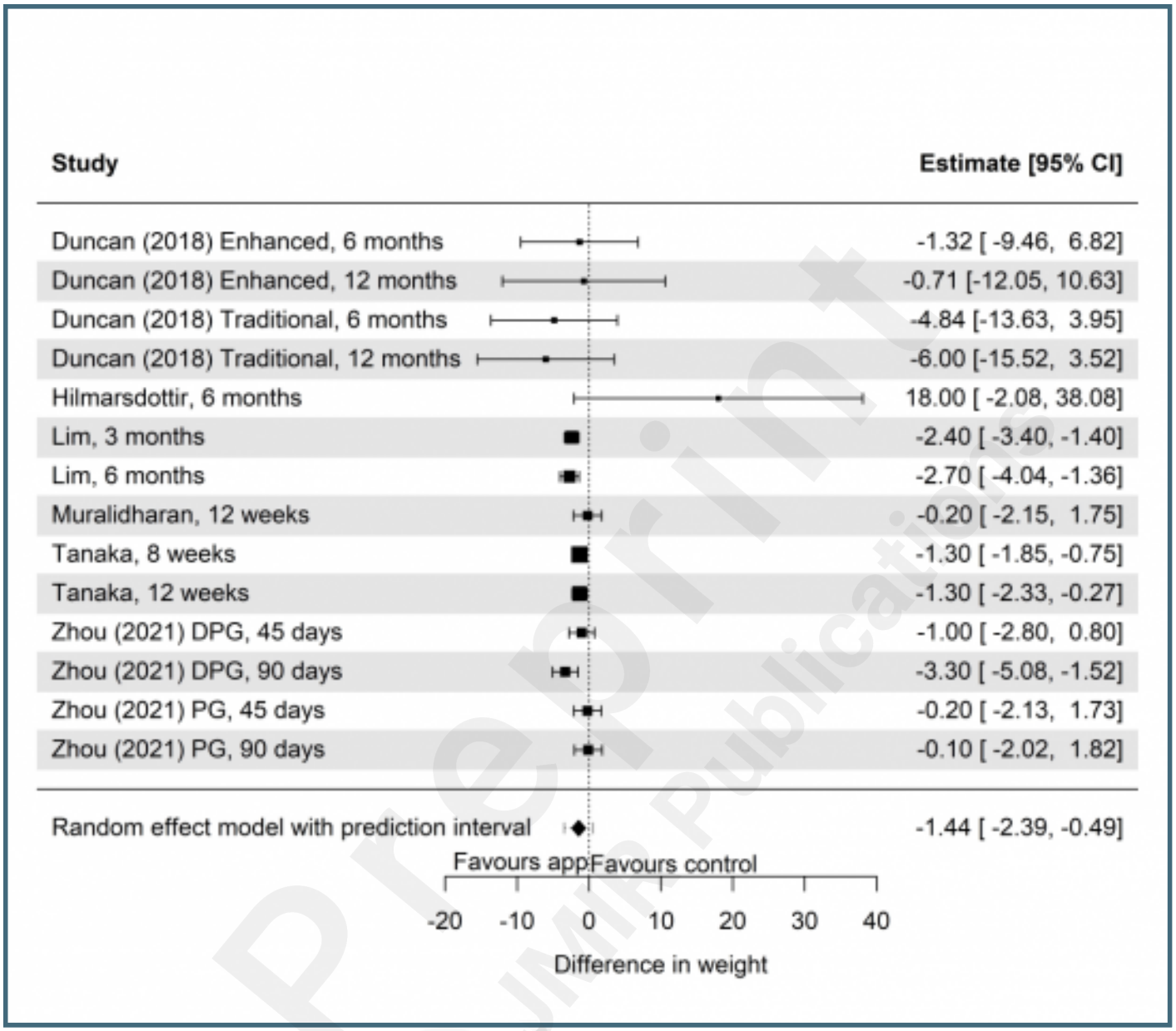
Forest plot of the unadjusted pooled effectiveness on HbA1c.



Forest plot of the unadjusted pooled effectiveness on waist circumference.



Forest plot of the unadjusted pooled effectiveness on weight.



Multimedia Appendixes

Online Supplementary material that provides additional information about the study.
URL: http://asset.jmir.pub/assets/56b5cd3da4797351c7285aadb7a09358.docx