An Overview of the Effectiveness of Digital Apps and Devices in the Management or Prevention of Cardiovascular Diseases

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Contents

Overall summary 3

Apps for diet and weight loss 5

Apps for increasing physical activity 15

Apps for Smoking Cessation 22

Apps for lifestyle/ multiple health behaviours 32

Apps for diabetes control 35

Digital technology for blood pressure control 40

Digital technology & CVD Primary Prevention 48

Digital technology and cardiovascular diseases, secondary prevention/ management 49

References 54

An Overview of the Effectiveness of Digital Apps and Devices in the Management or Prevention of Cardiovascular Diseases

SCOPE: To bring to bear the usefulness of digital apps (mainly mobile health apps) and devices in the management and prevention of cardiovascular diseases and also addressing adverse lifestyle habits in order to empower people to take more responsibility for their health and wellbeing using available mobile technologies as well as provide insight into the application of these technologies for clinician/ patient shared management.

The digital mode reviewed includes mobile health apps, mobile phone text messages, telehealth interventions including tele-monitoring, wearable technologies and sensors, internet-based interventions, digital counselling and video conferencing.

AN OVERALL SUMMARY

Digital apps and devices have been used in the management and prevention of cardiovascular diseases. The systematic reviews discussed herein are assess the influence such technologies have played in the management and prevention of cardiovascular diseases, and reveal different levels of effectiveness for different cardiovascular conditions.

From the meta-analyses and systematic reviews of mobile health apps for diet and weight management, the evidence has shown positive outcomes in the form of reduction in weight and improved nutrition. Mobile app interventions led to weight loss in patients with type 2 diabetes and are worth recommending for weight loss promotion.

Mobile health app interventions have the potential to promote changes in sedentary time and physical activity over the short term. Sensitivity analyses suggested that physical activity programmes with duration of less than 3 months were more effective than apps evaluated across more than 3 months, and that physical activity apps that targeted physical activity in isolation were more effective than apps that targeted physical activity in combination with diet.

Further study is required to evaluate the effectiveness of smoking cessation apps as their low cost, wide availability and absence of side effects may make them useful adjuncts in some populations. The effects of alcohol reduction interventions were inconclusive. Multi-component interventions appear to be more effective than stand-alone app interventions.

There is strong evidence for the efficacy of mobile health apps for lifestyle modification in type 2 diabetes. The use of apps seems to improve lifestyle factors, especially to decrease glycated haemoglobin (HbA1c). More research with long-term follow-up should be performed to assess the effect of mobile health apps for non-communicable diseases other than diabetes.

Interactive mobile health interventions may be a useful tool for improving blood pressure control among adults, especially among those with inadequate blood pressure control. Mobile health apps can be beneficial in terms of improving hypertension self-assessment, treatment and control, being especially useful to help differentiate and manage true and pseudo-resistant hypertension. Digital interventions lower both systolic and diastolic blood pressure compared to usual care. Results suggest these findings can be applied to a wide range of healthcare systems and populations. Evidence suggests that digital interventions can reduce cardiovascular disease outcomes and have a positive impact on risk factors for cardiovascular diseases.

Telehealth interventions yielded positive outcomes in lifestyle changes for secondary prevention of cardiovascular diseases. The impact of the mobile health interventions on all-cause mortality, cardiovascular mortality, heart failure-related hospitalizations, length of stay, New York Heart Association functional class left ventricular ejection fraction, quality of life, and self-care were inconsistent at best. Further research is needed to conclusively determine the impact of mobile health interventions on heart failure outcomes.

With more intense studies and future research, the advancement in technology, especially that of mobile health apps and interventions can be harnessed for the effective prevention and management of cardiovascular diseases.

Apps for diet and weight loss

A meta-analysis by Schippers, M et al[1] concluded that the current body of evidence shows that weight loss interventions delivered via mobile phones produce a modest reduction in body weight when combined with other delivery modes. Delivering interventions with frequent and personal interactions may in particular benefit weight loss results. A meta-analysis to test intervention efficacy was performed, and subgroup analyses were conducted to determine whether interventions' delivery mode(s), inclusion of personal contact, duration and interaction frequency improve efficacy. Pooled body weight reduction (d = -0.23; 95% confidence interval = -0.38, -0.08) was significant. Interventions delivered via other modes in addition to the mobile phone were associated with weight reduction. Personal contact and more frequent interactions in interventions were also associated with greater weight reduction.

Evidence from a systematic review done by Semper, HM et al[2], of the effectiveness of mobile health apps that encourage dietary self-regulatory strategies for weight loss in overweight and obese adults suggests that mobile health apps may be a useful tool for self-regulating diet for weight loss as participants in the mobile health app group in all studies lost at least some bodyweight. However, when compared to other self-monitoring methods, there was no significant difference in the amount of weight lost. Future research needs to be more methodologically rigorous and incorporate measures of whether eating habits become healthier in addition to measuring weight and body mass index.

From 233 potentially relevant publications, 28 studies were included in the assessment of the efficacy, safety and effectiveness of weight control and obesity management mobile health interventions by Puigdomenech P, et al[3]. Of these, 13 (46%) were randomized controlled trials, 11 were single-arm studies (39%), 3 were nonrandomized controlled trials (11%), and 1 study was a cluster randomized trial (4%). The studies were classified as low (15), high (7), and moderate (6) quality according to Scottish intercollegiate guidelines network (SIGN) criteria. All studies focused on efficacy, with only 1 trial mentioning safety and 1 effectiveness. In 11 studies, the apps were used as stand-alone interventions; the others were multicomponent studies that included other tools for support such as sensors or websites. The main management tool included in the apps was feedback messaging (24), followed by goal-setting mechanisms (20) and self-monitoring (19). The majority of studies took weight or body mass index loss as the main outcome (22) followed by changes in physical activity (14) and diet (12). Regarding outputs, usability, adherence, and engagement (17) were the most reported, followed by satisfaction (7) and acceptability. There is a remarkable heterogeneity among these studies and the majority have methodological limitations that leave considerable room for improvement. Further research is required to identify all relevant criteria for assessing the efficacy of mobile health interventions in the management of overweight and obesity.

Wang E et al[4] tried to establish whether mobile technology can improve weight loss in overweight adults via a systematic review. Although the included studies exhibited some design concerns (such as a lack of non-intervention comparator groups) which prevents a definitive conclusion regarding the relative power of mobile apps and wearables over other self-monitoring methods, evidence indicates that mobile technology can be used as integral tools within overarching weight loss strategies recommended in the primary care setting.

Narrative review results by McCarroll et al[5] indicated small positive effects of mobile health interventions on healthy eating (5/8 trials) and weight loss (5/13 trials). Eligible studies were randomized controlled trials (RCTs), published up to 1 July 2016, which examined healthy eating interventions delivered via mobile device. Of 879 articles identified, 84 full text articles were potentially eligible and further assessed, and 23 included. McCarroll et al[5] conclude that the current evidence base is insufficient (studies are of poor quality) to determine conclusive positive effects. More rigorous RCTs with longer-term (>6months) follow-up are warranted to determine if effects are maintained.

A meta-analysis of the eHealth interventions for the prevention and treatment of overweight and obesity in adults done by Hutchesson et al[6], demonstrated significantly greater weight loss (kg) in eHealth weight loss interventions compared with control (MD -2.70 [-3.33,-2.08], P < 0.001) or minimal interventions (MD -1.40 [-1.98,-0.82], P < 0.001), and in eHealth weight loss interventions with extra components or technologies (MD 1.46 [0.80, 2.13], P < 0.001) compared with standard eHealth programmes. The findings support the use of eHealth interventions as a treatment option for obesity, but there is insufficient evidence for the effectiveness of eHealth interventions for weight loss maintenance or weight gain prevention.

Fourteen studies enrolling 2,129 patients with type 2 diabetes were included in the meta-analysis of mobile health app interventions and weight loss in Type 2 Diabetes done by Cai X et al[7]. Mobile health app interventions appeared to significantly reduce body weight (weight mean difference, 0.84 kg; 95% CI: -1.51 to -0.17 kg) and lower waist circumference (-1.35 cm; 95% CI: -2.16 to -0.55 cm) but may not decrease BMI (-0.08 kg/m2; 95% CI: -0.41 to 0.25 kg/m2). The reductions appeared to be more pronounced in patients with obesity or among studies using mobile app interventions combined with other behaviour components. However, weight loss was not moderated by the functionalities of the mobile apps (all P interaction > 0.05) or by the intervention duration (all P > 0.87). Mobile health app interventions lead to weight loss in patients with type 2 diabetes and are worth recommending for weight loss promotion.

Sixteen trials met inclusion criteria for a systematic review of technology- assisted weight loss interventions in primary care done by Levine DM et al[8]. Twelve (75 %) interventions achieved weight loss (range: 0.08 kg - 5.4 kg) compared to controls, while 5-45 % of patients lost at least 5 % of baseline weight. Trial duration and attrition ranged from 3-36 months and 6-80 %, respectively. Ten (63 %) studies reported results after at least 1 year of follow-up. Interventions used various forms of personnel, technology modalities, and behaviour change elements; trials most frequently utilized medical doctors (MDs) (44 %), web-based applications (63 %), and self-monitoring (81 %), respectively. Interventions that included clinician-guiding software or feedback from personnel appeared to promote more weight loss than fully automated interventions. Only two (13 %) studies used publically available technologies. Many studies had fair pragmatism scores (mean: 2.8/4), despite occurring in primary care. Compared to usual care, technology-assisted interventions in the primary care setting can help patients achieve weight loss, offering evidence-based options to primary care providers. However, best practices remain undetermined. Despite occurring in primary care, studies often fall short in utilizing pragmatic methodology and rarely provide publically available technology. Longitudinal, pragmatic, interdisciplinary, and open-source interventions are needed.

A search for the effects of dietary mobile health apps on nutritional outcomes in adults with chronic disease for a systematic review and meta-analysis by Fakih El Khoury et al[9], identified 18,649 articles, and data were extracted from 22 articles. Pooled estimates showed a significantly greater decrease in weight (-2.45 kg, 95% CI -3.33 to -1.58 kg; P<0.001; I2=96.2%, 95% CI 95% to 97%), waist circumference (-2.54 cm, 95% CI -3.34 to -1.73 cm; P<0.001; I2=88.3%, 95% CI 67% to 96%), and energy intake (-149.52 kcal, 95% CI -215.78 to -83.27 kcal; P<0.001; I2=0% CI 0% to 90%) when an app was used compared to control. The findings of this systematic review and meta-analysis indicate that dietary mobile health apps are effective self-monitoring tools, and that their use results in positive effects on measured nutritional outcomes in chronic diseases, especially weight loss.

12 articles were included in a systematic review and meta-analysis done by Flores Mateo et al[10] on mobile health apps that promote weight loss and increased physical activity. Compared with the control group, use of a mobile health app was associated with significant changes in body weight (kg) and body mass index (kg/m(2)) of -1.04 kg (95% CI -1.75 to -0.34; I2 = 41%) and -0.43 kg/m(2) (95% CI -0.74 to -0.13; I2 = 50%), respectively. Moreover, a nonsignificant difference in physical activity was observed between the two groups (standardized mean difference 0.40, 95% CI -0.07 to 0.87; I2 = 93%). These findings were remarkably robust in the sensitivity analysis. No publication bias was shown. Evidence from this study shows that mobile phone app-based interventions may be useful tools for weight loss.

Apps for diet and weight loss-table of main studies

Study	Study type	Type of Apps	Population group	Period of outcome measurement	Outcome	How outcome was measured
Schippers, M et al [1]	Systematic review and Meta-analysis	Mobile phone interventions	16 years and older. All studies included a mix of overweight, obese and morbidly obese participants	Median durat 152 days	Pooled body weight reduction (d= -0.23, 95% CI = -0.38, 0.08) was significant. Intervention delivered via other modes in addition to the mobile phone were associated with weight reduction. Personal contact and more frequent interactions were also associated with greater weight reduction.	Weight BMI
Semper, HM et al [2]	Systematic review	Smart phone apps that encourage dietary selfregulatory strategies	Overweight and obese adults over the age of 18 years and with no long term conditions such as diabetes, cancer, stroke and CVD	6 Months	There was a significant difference in weight loss across time of -1.58kg, $P < 0.001$. however, there was no significant difference in weight across time in the intervention group $p= 0.53$ There was a significant less calories and fat at 6 months period with weight loss of 2.00kg $p< 0.05$	Weight BMI Dietary change
Puigdomenech, PE et al [3]	Systematic review	Mobile health interventions	No restrictions in terms of target population were foreseen	3 weeks to 6 months mainly. One 24 month trial	There was modest evidence for the efficacy of the intervention on weight loss and BMI	Weight BMI

Wang E et al [4]	Systematic review	Mobile apps and wearable devices	Overweight adults 18 years and older excluding those that pertained to other co-morbidities	12 weeks to 2 years	Primary outcomes included weight loss (an average loss ranging from -1.97 kg in 16 weeks to -7.1 kg in 5 weeks) or weight maintenance. Blood glucose reduction (an average decrease of glycated hemoglobin ranging from 0.4% in 10 months to -1.9% in 12 months) .	Weight loss Glycated Haemoglobin
McCarroll R et al [5]	A systematic review	Mobile health interventions delivered via mobile devices	Overweight or obese adults living in highincome countries	<6 months	There was statistically significant weight loss, mean weight loss of 1.35kg over 6 months. 95% CI -2.24, -0.46 P= 0.003. Positive effects of mHealth intervention on healthy eating was demonstrated including vegetable intake, adherence to low fat, vegetarian diet. The validity of the demonstrated effect was not statistically significant.	Weight loss Healthy eating

Hutchesson MJ et al [6]	A systematic review of randomized controlled trials	eHealth interventions which included internet, computers including tablets, email, personal digital assistants, mobile/smart phones, and digital games	Overweight and obese adults >/=18 years	2 to 30 weeks months	There was a significant greater weight loss (kg) in eHealth weight loss intervention when compared with control. d= 2.70 (-3.33, -2.08) P< 0.001 With minimal intervention, d= -1.40 (-1.98, -0.82) P< 0.001 With extra component or technology d= 1.46 (0.80, 2.13) P < 0.001	Weight loss Weight loss maintenance Weight gain prevention

Cai X et al [7]	Meta-analysis	Mobile app interventions	Patients with type 2 Diabetes aged >/= 18 years and mean BMI of 30kg/m^2	3-12 months	Pooled results of mobile app interventions were associated with a reduction in body weight by 0.84kg (95% CI: 1.51 to 0.17 kg), moderate heterogeneity (I 2=49%). Subgroup analysis observed a higher reduction in BW associated with Mobile app interventions in patients with obesity (BMI>30). Non-significant pooled result was obtained for BMI Waist circumference: Mobile app interventions decreased WC by 1.35 cm (95% CI: 2.16 to 0.55 cm; I2 =8%). Subgroup analyses showed that a more pronounced decrease in WC was observed in patients with obesity or in studies using mobile app interventions combined with other behaviour interventions	Body weight BMI Waist circumference
Levine DM et al [8]	A systematic review	Technology-Assisted Interventions	Patients in primary care settings	3 to 36 months	Weight loss range from 0.08 to 5.41kg was observed, 5-45% of patient lost at least 5% of baseline weight.	Body weight

		in primary care			Interventions that included clinically guided software or feedback from personnel appeared to promote more weight loss than fully automated intervention	
Fakih El Khoury et al [9]	A systematic review and meta-analysis	Dietary mobile apps	Adults with chronic diseases	1 to 9 month	There was a significant decrease in weight with an average of 2.45kg 95% CI – 3.33 to -1.58kg, P< 0.001. A significant reduction in waist circumference with an average of 2.54cm, 95% CI -3.34 to 1.73cm P< 0.001. This also reflected in energy intake -149.5kcal, 95% CI 215.78 to – 83.27kcal P< 0.001	Body weight Waist circumference Energy intake
Flores Mateo et al [10]	A systematic review and meta-analysis	Mobile health apps	Populations of children and adults	6 weeks to 9 months	Significant changes in body weight of -1.04kg, 95% CI -1.75 to 0.34, I2 =41%. A reduction in Body mass index -0.43kg/m^2, 95% CI -0.74 to -0.13, I2= 50%. Non-significant difference in physical activity were observed with a mean difference of 0.40, 95% CI 0.07 to 0.87, I2= 93%.	Body weight Body mass index Physical activity

Summary Apps for diet and weight loss

From the above systematic reviews of mobile health apps for diet and weight management, the evidence has shown positive outcomes in the form of reduction in weight and improved nutrition. Personal contact and more frequent interactions in interventions were also associated with greater weight reduction. Evidence indicates that mobile technology can be used as integral tools within overarching weight loss strategies recommended in the primary care setting. Findings also support the use of eHealth interventions as a treatment option for obesity, but there is insufficient evidence for the effectiveness of eHealth interventions for weight loss maintenance or weight gain prevention. Mobile health app interventions led to weight loss in patients with type 2 diabetes and are worth recommending for weight loss promotion. Other findings indicate that dietary mobile apps are effective self-monitoring tools, and that their use results in positive effects on measured nutritional outcomes in chronic diseases, especially weight loss. Further future research is needed to identify all relevant criteria for assessing the efficacy of these mobile health app interventions in the management of obesity and maintenance of a healthy diet.

Apps for increasing physical activity

Following removal of duplicates, a total of 6170 studies were identified from the original database searches in the systematic review and meta-analysis that tries to determine if mobile health apps can increase physical activity, done by Romeo A et al[11]. Of these, 9 studies, involving a total of 1740 participants, met eligibility criteria. Of these, 6 studies could be included in a meta-analysis of the effects of physical activity apps on steps per day. In comparison with the control conditions, mobile health apps produced a nonsignificant (P=.19) increase in participants' average steps per day, with a mean difference of 476.75 steps per day (95% CI -229.57 to 1183.07) between groups. Sensitivity analyses suggested that physical activity programmes with a duration of less than 3 months were more effective than apps evaluated across more than 3 months (P=.01), and that physical activity apps that targeted physical activity in isolation were more effective than apps that targeted physical activity in combination with diet (P=.04). Physical activity app effectiveness did not appear to differ on the basis of target population. This meta-analysis provides modest evidence supporting the effectiveness of mobile health apps to increase physical activity. To date, apps have been most effective in the short term (up to 3 months). Future research is needed to understand the time course of intervention effects and to investigate strategies to sustain intervention effects over time.

Research on the effectiveness of mobile health apps running on smartphones to promote physical activity was carried out by Silva A et al[12]. Pooled effects using the standardized mean difference (SMD) or the weighted mean difference (WMD) were calculated and the overall quality of the evidence was rated using GRADE. Eleven studies were included. In the short term, pooled estimates showed a small and positive effect in the number of steps favouring interventions using a mobile app when compared with no interventions (WMD = 1579.04, 95%CI 454.04 to 2703.38) and with traditional interventions (WMD = 665.96, 95%CI 167.92 to 1164.00). For self-efficacy and at followup, results favoured traditional interventions (WMD = -8.20, 95%CI -14.25 to -2.15). Non-significant results were found for the remaining comparisons. The quality of the evidence ranged from very low to low. There is very low to low quality evidence that interventions using mobile apps running on smartphones, when combined with traditional interventions, are superior to traditional interventions in the short term. Further high-quality studies are required.

Overall, six trials (486 participants, 66.7% [324/486] women; age mean 68 [SD 6] years) were included (five of these trials were included in the meta-analysis) in the systematic review and metaanalysis on the effects of mobile health app interventions on sedentary time, physical activity, and fitness in older adults done by Yerrakalva D et al[13]. Mobile health app interventions may be associated with decreases in sedentary time (SMD=-0.49; 95% CI -1.02 to 0.03), increases in physical activity (506 steps/day; 95% CI -80 to 1092), and increases in fitness (SMD=0.31; 95% CI -0.09 to 0.70) in trials of 3 months or shorter and with increases in physical activity (753 steps/day; 95% CI 147 to 1652) in trials of 6 months or longer. Risk of bias was low for all but one study. The quality of evidence was moderate for physical activity and sedentary time and low for fitness. Mobile health app interventions have the potential to promote changes in sedentary time and physical activity over the short term, but the results did not achieve statistical significance, possibly because studies were underpowered by small participant numbers. Yerrakalva D et al[13] highlight a need for larger trials with longer follow-up to clarify if apps deliver sustained clinically important effects.

The paper by Mathews, J et al[14], reviews the current state of mobile apps for health behavioural change with an emphasis on apps that promote physical activity. The inbuilt persuasive features of mobile health apps were evaluated using the persuasive systems design model. Primary task support, dialogue support, and social support were found to be moderately represented in the selected articles. However, system credibility support was found to have only low levels of representation as a persuasive systems design feature in mobile health apps for supporting physical activity. To ensure that available mobile technology resources are best used to improve the wellbeing of people, it is important that the design principles that influence the effectiveness of persuasive technology be understood.

The meta-analysis by Kim, H et al[15], showed that smartphone-based health interventions significantly affect weight loss and increase physical activity. This study provides modest evidence for using mobile health apps to improve young adults' physical activity, weight control, and body mass index (BMI). Future research is needed to understand long-term effects and the reliability of increasing physical activity through mobile health apps.

A subgroup analysis by Yen H.-Y et al[16], confirmed that wearable technologies were more efficient for weight control in individuals with obesity and chronic diseases. Using wearable technologies for a total of more than or equal to 12 weeks was more effective. Meta-regressions have also revealed that the body weight of individuals who received an additional week of treatment could be reduced by more than 0.37%. Wearable technologies offer innovative platforms of physical activity interventions and an efficient method for weight control

Apps for Increasing Physical Activity-table of main studies

Study	Study type	Type of Apps	Population group	Period of outcome measurement	outcome	How outcome was measured
Romeo A et al [11]	Systematic review and meta-analysis	Smart phone Apps	Adults using smart phone Apps as the primary or sole component of physical activity intervention	8- 12 weeks	There was a non-significant increase (P= 19) in participants' average steps per day (d= 476.75 steps /day 95% CI -229.27 to 1183.07). Sensitivity analysis suggested that physical activity program with duration <3 months were more effective than app evaluated across > 3months P= 01 Physical activity app that targeted physical activity in insolation were more effective than apps that targeted physical activity in combination with diet P= 04 Physical activity app effectiveness did not appear to differ on the basis of target population.	Moderate-Vigorous physical activity (MVPA) per min Steps measured by accelerometer or pedometer

Silva AG et al [12]	Systematic review and meta-analysis	Mobile App based intervention	Adults aged 18-65 years with or without pathology	12-24 weeks	Pooled estimate showed a small and positive effect in the number of steps favouring interventions using a mobile app when compared with no intervention. (WMD= 1579.04, 95% CI 454.04 to 2703.38) and with traditional interventions (WMD = 665.96, 95% CI 167.92 to 1164.00). For self- efficacy and at follow-up, results favoured traditional interventions (WMD = 8.20, 95% CI -14.25 to -2.15) There is low quality evidence that interventions using mobile apps running on smartphones when combined with traditional interventions are superior to traditional interventions in the short term. Pooled effects of mobile app intervention against no intervention in the short term had a non-significant effect on app based intervention (SMD -0.35, 95% CI -0.86, 0.15 $I^2 = 0\%$)	**Primary outcome:** Number of steps Distance covered. Time spent performing an activity. Self-reported physical activity. Energy expenditure **Secondary outcomes** Sedentarism Self-efficacy
Yerrakalva D et al [13]	Systematic Review and meta-analysis	Mobile health App (mHealth)	Adults > 55 years dwelling in community	2-6 months	There is an association between mobile health app intervention and decrease sedentary time. (SMD = -0.49, 95% CI -1.02 to 0.03). Increase physical activity with 506 steps/day, 95% CI -147 to 1652). In trial of 6 months and longer, there was increase in physical activity with 753 steps/day, 95% CI -147 to 1652. Increase in physical fitness (SMD= 0.31, 95% CI 0.09 to 0.70) in trials of 3 months or shorter.	Sedentary time measured by accelerometer. Steps measured by pedometer. Physical fitness Gait steps 6mins walk

Matthews J et al [14]	Systematic Review	Mobile App with inbuilt personalised features	Young adults with mobile app that promote physical activity	3 months	Self-monitoring as a persuasive feature is highly associated with social comparism. There is also a high association between the social comparism and competition. However, there was no significant difference.	Step count Distance travelled Active time Sedentary time
Kim H et al [15]	Systematic review and meta-analysis	Mobile health program	Young adults aged 19-35 years.	12 months	There was a significant increase in physical activity in the intervention groups. (SMD= 2.59, I^2 = 99%, P= 0.001, 95% CI 1.00, 4.18). There was also significant weight loss in the intervention group of 2.80kg (I^2 = 0%, P= 0.002, 95% CI -4.54 to -1.06). No significant difference in BMI -0.14 (I^2 = 41%, P= 0.45, 95% CI -0.51 to 0.23) between smartphone based intervention programs and those without intervention.	Body weight BMI Metabolic Equivalent
					Smartphone-based intervention programs had positive effects on increased physical activity and on weight loss but no effects on BMI was found.	

Yen H et al [16]	Systematic review and Meta-analysis of RCTs	Wearable technologies such as wristbands, smart watches, smartphones with mobile App	Obesity and chronic disease	>/= 12 weeks	Pooled mean effect size was significant which indicated a moderate effect of wearable technologies on body weight. (g= -0.59, 95% CI -0.84 to -0.35, P< 0). Results of homogeneity testing showed Q= 129.18, I^2 = 86.07%. There was a large and significant effect on BMI (g= 0.84, 95% CI -1.29 to -0.39 P<0). Results of homogeneity testing showed Q= 190.56, P< 001 and I^2 = 94.23%. Wearable technology showed a moderate and significant effect on waist circumference. (g= 0.67, 95% CI -1.31 to -0.03, P= 0.4). More weight control in individuals with obesity and chronic diseases. A duration of using wearable technologies for a total of >/= 12 weeks was more effective. Meta-regressions revealed that the body weight of individuals who received an additional week of treatment could be reduced by more than 0.37%.	BMI Body weight Waist circumference

Summary Apps for Physical Activity

These systematic reviews provide modest evidence supporting the effectiveness of mobile health apps to increase physical activity. Sensitivity analyses suggested that physical activity programmes with duration of less than 3 months were more effective than apps evaluated across more than 3 months, and that physical activity apps that targeted physical activity in isolation were more effective than apps that targeted physical activity in combination with diet. To date, apps have been most effective in the short term (up to 3 months). There is very low to low quality evidence that interventions using mobile health apps running on smartphones, when combined with traditional interventions, are superior to traditional interventions in the short term. Mobile health app interventions have the potential to promote changes in sedentary time and physical activity over the short term. Future research is needed to understand the time course of intervention effects and to investigate strategies to sustain intervention effects over time. Wearable technologies offer innovative platforms of physical activity interventions and an efficient method for weight control.

Apps for Smoking Cessation

The review by Whittaker R et al[17], on mobile phone text messages and app-based interventions for smoking cessation included 26 studies (33,849 participants). Overall, 13 studies were judged to be at low risk of bias, three at high risk, and the remainder at unclear risk. Settings and recruitment procedures varied across studies, but most studies were conducted in high-income countries. There was moderate-certainty evidence, limited by inconsistency, that automated text messaging interventions were more effective than minimal smoking cessation support (RR 1.54, 95% CI 1.19 to 2.00; I2 = 71%; 13 studies, 14,133 participants). There was also moderate-certainty evidence, limited by imprecision, that text messaging added to other smoking cessation interventions was more effective than the other smoking cessation interventions alone (RR 1.59, 95% CI 1.09 to 2.33; I2 = 0%, 4 studies, 997 participants). Two studies comparing text messaging with other smoking cessation interventions, and three studies comparing high- and low-intensity messaging, did not show significant differences between groups (RR 0.92 95% CI 0.61 to 1.40; I2 = 27%; 2 studies, 2238 participants; and RR 1.00, 95% CI 0.95 to 1.06; I2 = 0%, 3 studies, 12,985 participants, respectively) but confidence intervals were wide in the former comparison. Five studies compared a smoking cessation mobile app with lower-intensity smoking cessation support (either a lower-intensity app or non-app minimal support). The evidence was pooled and deemed to be of very low certainty due to inconsistency and serious imprecision. It provided no evidence that mobile health apps improved the likelihood of smoking cessation (RR 1.00, 95% CI 0.66 to 1.52; I2 = 59%; 5 studies, 3079 participants). Other mobile health apps tested differed from the apps included in the analysis, as two used contingency management and one combined text messaging with an app, and so they were not pooled. Using complete case data as opposed to using data from all participants randomized did not substantially alter the findings. There is moderate-certainty evidence that automated text messagebased smoking cessation interventions result in greater quit rates than minimal smoking cessation support. There is moderate-certainty evidence of the benefit of text messaging interventions in addition to other smoking cessation support in comparison with that smoking cessation support alone. The evidence comparing mobile health apps with less intensive support was of very low certainty, and more randomized controlled trials are needed to test these interventions.

A meta-analysis of the effectiveness of mobile health apps to aid smoking cessation by Barnett A et al[18] showed that across 8 studies with 3,543 participants there was no statistically significant change in the rate of abstinence compared to usual care (RR 1.15, 95% CI 0.85 to 1.57) and moderate heterogeneity (I2 of 57%). At present there is insufficient evidence to routinely recommend smoking cessation apps for smoking cessation in usual care. Further study is required to evaluate the effectiveness of smoking cessation apps as their low cost, wide availability and absence of side effects may make them useful adjuncts in some populations.

In a systematic review of mobile health apps for smoking cessation by Haskins B L et al[19], Seven articles identified six apps with some level of scientific support, three (50%) were available in at least one app store. Conversely, among the top 50 apps suggested by each of the leading app stores, only two (4%) had any scientific support. While half of the scientifically vetted apps remain available to consumers, they were difficult to find among the many apps that are identified through app store searches.

Apps for Smoking Cessation-table of main studies

Study	Study type	Type of App	Population group	Period of Outcome Measurement	Outcomes	How outcomes was measured

Whittaker R et al (17)	Systematic Review and Meta analysis	Text messages or smartphone apps	Majority of included studies recruited people 18 years and older, but 5 recruited those 16 years and older, and one recruited those 14 years and older (this group were also pregnant). Studies had various ways of defining 'smoker', e.g. self-report or CO monitoring. One study recruited only Torres Strait Islanders, one recruited exclusively from an HIV clinic, and one recruited exclusively men.	6- 12 months	Text messaging versus minimal smoking cessation support: RR of 1.54 (95% CI 1.19 to 2.00; I2 = 71%; 14,133 participants) (analysis of all randomised participants, with those lost to follow-up classified as smokers) Text messaging plus other smoking cessation support versus other smoking cessation support alone: The analysis of all randomised participants, assuming those lost to follow-up were smoking, showed a benefit of adding the text messaging with RR of 1.59 (95% CI 1.09 to 2.33; I2 = 0%; 997 participants). Smartphone app versus minimal non-app smoking cessation support. Data from two studies (Baskerville 2018; Peiris 2019;) showed no evidence	Smoking abstinence at longest follow up (at least 6 months from baseline) selfreported abstinence or biochemically verified abstinence, or both

					of a favourable effect of smartphone apps in comparison with minimal non-app smoking cessation support (RR 0.82, 95% CI 0.56 to 1.18; I2 = n/a as Peiris 2019 had no events). Smartphone app + text messaging versus webbased interventions: evidence for a benefit of the app plus text messaging: RR 1.80, 95% CI 1.32 to 2.45; 1271 participants (one study only)	
Barnett A et al (18)	Meta analysis	Smartphone apps	Adult smokers	2-6 months	Across 8 studies with 3,543 participants there was no statistically significant change in the rate of abstinence compared to usual care (RR 1.15, 95% CI 0.85 to 1.57)	Abstinence at follow up: continuous smoking abstinence/ prevalence smoking abstinence (PPA)
Haskins B L et al (19)	Systematic Review	Smartphone apps	N/A	N/A	A review of 158 articles identified only six apps, 57% of which were supported by low quality evidence. A search of the popular app stores showed	Cross referencing of apps from app store search with evidence from a search of the scientific literature

					that only three (50%) remained available to	
					consumers, with only two ranking among the top 50 popular apps for smoking cessation retrieved via keyword search.	

Palmer M et al (21)	Systematic Review	SMS, voice calls, video message, apps, SMS with web links, Interactive voice response	Mostly adult smokers aged 18 or over. One study recruited adult smokers and recent quitters, six recruited smokers aged 16 years and above, one recruited smokers aged 15 years and above, two recruited HIV positive adults and one recruited pregnant smokers aged 18 or above.		Interventions delivered by SMS: SMS-based smoking cessation interventions providing support for a quit attempt more than doubled biochemically verified continuous smoking abstinence when measured between three and six months. Pooled effect estimate: relative risk [RR] 2.19 [95% CI 1.80–2.68]). Pooled analysis showed smoking cessation interventions providing support for a quit attempt significantly increased biochemically verified 7 day point prevalence of smoking cessation (measured between three and six months) Pooled effect estimate RR 1.51 [95% CI 1.06–2.15]).	Biochemically verified measure of abstinence (salivary-cotinine testing and/or exhaled carbon monoxide testing),
Marcolino, MS et al (26)	Systematic Review of Systematic Reviews	Mobile phoneSMS	Mainly adults 18 years plus, but some recruited young adults, one focused on HIV positive adults.	26 weeks- 6 months	Mobile phone-based cessation interventions increased abstinence rates at 26 weeks (RR 1.67 95% CI	Biochemically verified cessation

					1.46-1.90, 12 RCTs in high income countries, 11,885 participants, GRADE Moderate). Six studies verified quitting biochemically at 6 months (RR 1.83 95% CI 1.54-2.19) SMS-based smoking cessation interventions doubled biochemically verified smoking cessation at 6 months	
Turan, KS et al (43)	Systematic review and meta analysis	Phonecalls/ SMS	Adults in at risk groups, CHD, acute myocardial infarction, angina, ischaemic heart disease, post serious cardiac event	6 months -1 year	Telehealth interventions appear to have had a small effect on enhancing smoking cessation (p = 0.003, OR = 0.456 95% CI 273–0.760) (eight studies, 994 participants, moderate heterogeneity)	Smoking abstinence/ smoking behaviour
Coorey, GM et al (44)	Systematic review and meta synthesis of qual and quant data	Smartphone apps, SMS, mobile monitoring, motivational video, patient lifestyle diary.	Post myocardial infarction patients, post stroke patients.	6 weeks-6 months	Three studies that reported change in participant selfreported smoking status found positive changes but not statistically significant results.	Smoking abstinence/ smoking behaviour

Jin, K et al (53)	Systematic review and meta analysis	Telehealth, phone calls, SMS	CHD patients		There was a significantly lower weighted mean difference (WMD) at medium to long-term follow-up than comparison groups for smoking status (RR=0.77, 95% CI =0.59 to 0.99, p=0.04].	Smoking abstinence/ smoking behaviour

Smoking Cessation in Summary

There is moderate-certainty evidence that automated text message-based smoking cessation interventions result in greater quit rates than minimal smoking cessation support. There is moderate-certainty evidence of the benefit of text messaging interventions in addition to other smoking cessation support in comparison with that smoking cessation support alone. Further study is required to evaluate the effectiveness of smoking cessation apps as their low cost, wide availability and absence of side effects may make them useful adjuncts in some populations.

Apps for lifestyle/ multiple health behaviours

Forty randomized controlled trials were selected to show if evidence supports the use of mobile phone health apps as a driver for promoting healthy lifestyles from a public health perspective. This was done by Covolo L et al[20]. Most of the studies targeted weight management, physical activity and healthy eating (N = 35). A few randomized controlled trials focused on apps designed to encourage sun protection, smoking cessation and responsible alcohol consumption (N = 5). Only 10 randomized controlled trials (25%) found statistical difference between intervention and control groups for all the outcomes measured. Most of the studies had a short follow-up (65%, less than 6 months) and half of them a very small sample size (fewer than 100 subjects). Overall, the evidence so far showed a modest efficacy of mobile apps in health promotion. There is a need to improve the overall quality of intervention studies focused on mobile health apps in order to understand if they could become a valuable tool in support of health professionals and their efforts to promote education and health.

A systematic review of randomized controlled trials was done by Palmer M et al[21] on the effectiveness of smoking cessation, physical activity/diet and alcohol reduction interventions delivered by mobile phones for the prevention of non-communicable diseases. 71 trials were included: smoking cessation (n = 18); physical activity (n = 15), diet (n = 3), physical activity and diet (n = 25); physical activity, diet, and smoking cessation (n = 2); and harmful alcohol consumption (n = 8). 4 trials had low risk of bias. The effect of mobile phone text message-based smoking cessation support on biochemically verified continuous abstinence was pooled relative risk [RR] 2.19 [95% CI 1.80-2.68], I2 = 0%) and on verified 7 day point prevalence of smoking cessation was pooled RR 1.51 [95% CI 1.06-2.15], I2 = 0%, with no reported adverse events. There was no difference in peak oxygen intake at 3 months in a trial of an SMS-based physical activity intervention. The effect of mobile phone text message-based diet and physical activity interventions on incidence of diabetes was pooled RR 0.67 [95% CI 0.49, 0.90], I2 = 0.0%; end-point weight was pooled MD -0.99Kg [95% CI -3.63, 1.64] I2 = 29.4%; % change in weight was pooled MD -3.1 [95%CI -4.86- -1.3] I2 0.3%; and effect on triglyceride levels was pooled MD -0.19mmol/L [95% CI -0.29, -0.08], I2 = 0.0%. The results of other pooled analyses of the effect of mobile phone text message-based diet and physical activity interventions were heterogeneous (I2 59-90%). The effects of alcohol reduction interventions were inconclusive. Smoking cessation support delivered by mobile phone text message increases quitting rates. Trials of physical activity interventions reporting outcomes at 3 months showed no benefits. There were, at best, modest benefits of diet and physical activity interventions. The effects of the most promising mobile phone text message-based smoking, diet and physical activity interventions on morbidity and mortality in high-risk groups should be established in adequately powered randomized controlled trials.

Twenty-seven studies were included in the systematic review of the efficacy of interventions that use mobile health apps to improve diet, physical activity and sedentary behaviour by Schoeppe, S et al[22], most were randomized controlled trials (n = 19; 70%). Twenty-three studies targeted adults (17 showed significant health improvements) and four studies targeted children (two demonstrated significant health improvements). Twenty-one studies targeted physical activity (14 showed significant health improvements), 13 studies targeted diet (seven showed significant health improvements) and five studies targeted sedentary behaviour (two showed significant health improvements). More studies (n = 12; 63%) of those reporting significant effects detected betweengroup improvements in the health behaviour or related health outcomes, whilst fewer studies (n = 8; 42%) reported significant within-group improvements. A larger proportion of multi-component interventions (8 out of 13; 62%) showed significant between-group improvements compared to stand-alone app interventions (5 out of 14; 36%). Eleven studies reported app usage statistics, and three of them demonstrated that higher app usage was associated with improved health outcomes. This review provided modest evidence that app-based interventions to improve diet, physical activity and sedentary behaviours can be effective. Multi-component interventions appear to be more effective than stand-alone app interventions; however, this remains to be confirmed in controlled trials. Future research is needed on the optimal number and combination of app features, behaviour change techniques, and level of participant contact needed to maximise user engagement and intervention efficacy.

A systematic review was done by Milne-Ives, M et al[23] on mobile apps for health behaviour change in physical activity, diet, drug and alcohol use and mental health. A total of 52 randomized controlled trials met the inclusion criteria and were included in the analysis. 37 studies focused on physical activity, diet, or a combination of both, 11 on drug and alcohol use, and 4 on mental health. Participant perceptions were generally positive-only one app was rated as less helpful and satisfactory than the control, and the studies that measured engagement and usability found relatively high study completion rates (mean 83%; n=18, N=39) and ease-of-use ratings (3 significantly better than control, 9/15 rated >70%). However, there was little evidence of changed behaviour or health outcomes. There was no strong evidence in support of the effectiveness of mobile apps in improving health behaviours or outcomes because few studies found significant differences between the app and control groups. Further research is needed to identify the behavioural change techniques that are most effective at promoting behaviour change. Improved reporting is necessary to accurately evaluate mobile health app effectiveness and address the risk of bias.

In order to harness the potential of mobile health apps for behaviour change and health, we need better ways to assess the quality and effectiveness of apps. The review by McKay, FH et al[24] on evaluating mobile health apps for health behaviour change is unable to suggest a single best practice approach to evaluate mobile health apps. Few measures identified in this review included sufficient information or evaluation, leading to potentially incomplete and inaccurate information for consumers seeking the best app for their situation. This is further complicated by a lack of regulation in health promotion generally.

Of a total of 550 publications extracted, 6 studies met the final criteria in the systematic review to find out if there's a benefit to patients using wearable devices such as Fitbit or health apps on mobiles done by Jo, A et al[25]. There was little indication that wearable devices provide a benefit for health outcomes. Of the 6 studies examined, only one study showed a significant reduction for weight loss among participants who used wearable devices. No significant reduction was discovered in cholesterol or blood pressure. Among the 6 studies, only one study examined HbA1c, and it showed a significant reduction in older patients with type 2 diabetes. The current literature evaluating wearable devices indicates little benefit from the devices on chronic disease health outcomes. Wearable devices play a role as a facilitator in motivating and accelerating physical activity, but current data do not suggest other consistent health benefits.

Searches for evidence on the impact of mobile health interventions by Marcolino, MS et al[26], resulted in a total of 10,689 articles. Of these, 23 systematic reviews (371 studies; more than 79,665 patients) were included. Seventeen reviews included studies performed in low- and middle-income countries. The studies used diverse mobile health interventions, most frequently text messaging (short message service, SMS) applied to different purposes (reminder, alert, education, motivation, prevention). Ten reviews were rated as low quality (AMSTAR score 0-4), seven were rated as moderate quality (AMSTAR score 5-8), and six were categorized as high quality (AMSTAR score 9-11). A beneficial impact of mobile health intervention was observed in chronic disease management, showing improvement in symptoms and peak flow variability in asthma patients, reducing hospitalizations and improving forced expiratory volume in 1 second; improving chronic pulmonary diseases symptoms; improving heart failure symptoms, reducing deaths and hospitalization; improving glycaemic control in diabetes patients; improving blood pressure in hypertensive patients; and reducing weight in overweight and obese patients. Studies also showed a positive impact of SMS reminders in improving attendance rates, with a similar impact to phone call reminders at reduced cost, and improved adherence to tuberculosis and human immunodeficiency virus therapy in some scenarios, with evidence of decrease of viral load. Although mobile health intervention is growing in popularity, the evidence for efficacy is still limited. In general, the methodological quality of the studies included in the systematic reviews is low. For some fields, its impact is not evident, the results are mixed, or no long-term studies exist. Exceptions include the moderate quality evidence of improvement in asthma patients, attendance rates, and increased smoking abstinence rates. Most studies were performed in high-income countries, implying that mobile health intervention is still at an early stage of development in low-income countries.

Summary Apps for lifestyle/ multiple health behaviours

Overall, the evidence so far showed modest efficacy of apps in health promotion. There is a need to improve the overall quality of intervention studies focused on mobile health apps in order to understand if they could become a valuable tool in support of health professionals and their efforts to promote education and health. The effects of alcohol reduction interventions were inconclusive. Smoking cessation support delivered by SMS increases quitting rates. Trials of physical activity interventions reporting outcomes at 3 months showed no benefits. There were at best modest benefits of diet and physical activity interventions. Some reviews provided modest evidence that app-based interventions to improve diet, physical activity and sedentary behaviours can be effective. Multi-component interventions appear to be more effective than stand-alone app interventions. There was no strong evidence in support of the effectiveness of mobile health apps in improving health behaviours or outcomes because few studies found significant differences between the app and control groups. The current literature evaluating wearable devices indicates there is little benefit to be gained from the devices on chronic disease health outcomes. Wearable devices play a role as a facilitator in motivating and accelerating physical activity, but current data do not suggest other consistent health benefits.

Apps for diabetes control

There is strong evidence for the efficacy of mobile health apps for lifestyle modification in type 2 diabetes. The evidence is inconclusive for the other diabetes subtypes. This was the conclusion from the systematic review and meta-analysis on the efficacy of mobile health apps for lifestyle modification in Diabetes by Wu X et al[27].

Of the 1588 records examined by Lunde, P et al[28], on the effectiveness of mobile health apps for lifestyle improvement in non-communicable diseases, 9 met the predefined criteria. Seven studies included diabetes patients only, one study included heart patients only, and another study included both diabetes and heart patients. Statistical significant effect was shown in HbA1c in 5 of 8 studies, as well in body weight in one of 5 studies and in waist circumference in one of 3 studies evaluating these outcomes. Seven of the included studies were included in the meta-analyses and demonstrated significant overall effect on HbA1c on a short term (3-6 months; P=.02) with low heterogeneity (I2=41%). In the long term (10-12 months), the overall effect on HbA1c was statistical significant (P=.009) and without heterogeneity (I2=0%). The quality of evidence according to Grading of Recommendations Assessment, Development and Evaluation (GRADE) was low for short term and moderate for long term. The review demonstrated limited research of the use of mobile health apps for non-communicable diseases other than diabetes with a follow-up of at least 3 months. For diabetes, the use of apps seems to improve lifestyle factors, especially to decrease HbA1c. More research with long-term follow-up should be performed to assess the effect of mobile health apps for non-communicable diseases other than diabetes.

Apps for diabetes control-table of main studies

Study	Study type	Type of Apps	Population group	Period of outcome measurement	Outcome	Study
Lunde, P et al (28)	Systematic review and meta-analysis	Mobile phone	18 years and older, diagnosed with any of the following: cardiovascular diseases, cancers, chronic pulmonary diseases, diabetes mellitus	3 months to 12 months	HbA1c: short term effect (3-6 months) mean difference: -0.50 [-0.91, -0.08] HbA1c: long term effect (1012 months) mean difference: -0.24 [-0.43, -0.06] The overall effect on HbA1c was statistical significant (P=.009)	Lunde, P et al (28)

Wu X et al (27)	Systematic review and meta-analysis	Mobile phone	18 years or older, and had one of the following conditions: T1DM, T2DM, GDM, prediabetes	3 months to 12 months	T1 DM, short term effect: estimated overall difference in HbA1c between the app intervention and control groups: –0.09 (95% CI –0.34 to 0.15), which was not significantly different from 0 (P=.18). T2DM, short term estimated overall difference in HbA1c between the app intervention and control groups: –0.48 (95% CI –0.69 to –0.28), which was significantly different from 0 (P<.01). In the long-term effect subgroup, the degree of heterogeneity was acceptable	Wu X et al (27)
					Long term and short term effect subgroups, pooled mean difference: was statistically significant at –0.35 (95% CI –0.48 to –0.21; P<.01).	

Marcolino, MS et al (26)	Systematic Review of Systematic Reviews	Mobile phone, email, phone calls, personal digital assistants, MP3	Youth, adolescents and adults, both T1DM and T2DM	Few minutes24months	HbA1c: A mobile phone-based, home glucose monitoring program study decreased HbA1c from 13.2% to 10.5% after 3-6 months. Text messaging improved HbA1c, with positive results in 6 of 8 studies. Ten of the 13 studies in type 2 diabetes and 4 of 7 studies on type 1 diabetes found mHealth led to HbA1c improvement BP: Educational group sessions for diabetic women via SMS showed higher diastolic blood pressure (+7 mmHg) and less spiritual hope at 6 months.	Marcolino, MS et al (26)
Jo, A et al (25)	Systematic Review	Wearable devices/mobile app	Older adults, T2DM		Results from one study only: reduction in HbA1c	Jo, A et al (25)
Cai X et al (7)	Meta analysis	Mobile phone	Adults ages 18 or over, with T2DM. Mean BMI of 30.0 kg/m2	3-12 months	Body weight pooled results: mobile app interventions were associated with a	Cai X et al (7)

					reduction in BW by 0.84 kg (95% CI: 1.51 to 0.17 kg;), moderate heterogeneity (I 2=49%). Subgroup analysis observed a higher reduction in BW associated with mobile app interventions in patients with obesity (BMI>30). BMI: non-significant pooled result Waist circumference: Mobile app interventions decreased WC by 1.35 cm (95% CI: 2.16 to 0.55 cm; I 2=8%). Subgroup analyses showed that a more pronounced decrease in WC was observed in patients with obesity or in studies using mobile app interventions combined with other behaviour interventions	

Summary Apps for Diabetes

There is strong evidence for the efficacy of mobile health apps for lifestyle modification in type 2 diabetes. The use of apps seems to improve lifestyle factors, especially to decrease HbA1c. More research with long-term follow-up should be performed to assess the effect of mobile health apps for non-communicable diseases other than diabetes.

Digital technology for blood pressure control

There is an emerging trend to empower patients to support hypertension screening and diagnosis, and several studies have shown the benefit of tele-monitoring, particularly when coupled with cointervention, in improving the management of hypertension. Novel technology including smartphones and Bluetooth®-enabled tele-monitoring are evolving as key players in hypertension management and offer particular promise within pregnancy and developing countries. The most pressing need is for these new technologies to be properly assessed and clinically validated prior to widespread implementation in the general population. These are the findings by Kitt, J et al[29], on the new approaches in hypertension management.

The systematic review and meta-analysis of the digital interventions to promote self-management in adults with hypertension McLean G, et al[30] , revealed that four out of seven studies showed a significantly greater reduction for intervention compared to usual care for systolic blood pressure (SBP), with no difference found for three. Overall, digital interventions significantly reduced SBP, with the weighted mean difference being -3.74 mmHg [95% confidence interval (CI) -2.19 to -2.58] with no heterogeneity observed (I-squared = 0.0%, P = 0.990). For diastolic blood pressure (DBP), four out of six studies indicated a greater reduction for intervention compared to controls, with no difference found for two. For DBP, a significant reduction of -2.37 mmHg (95% CI -0.40 to -4.35) was found, but considerable heterogeneity was noted (I-squared = 80.1%, P = <0.001). Digital interventions lower both SBP and DBP compared to usual care. Results suggest these findings can be applied to a wide range of healthcare systems and populations. However, sustainability and longterm clinical effectiveness of these interventions remain uncertain.

For the systematic review and meta-analysis on the effect of remote monitoring of blood pressure of urban hypertensive patients done by Choi, WS et al[31], 1,433 potential references for screening were identified, of which 27 were eligible for review. Substantial heterogeneity was evident for the investigated variables. A significant standardized mean difference (SMD) was observed for remote blood pressure monitoring (RBPM) for systolic blood pressure, but the effect size was small compared to face-to-face care and was clinically irrelevant in avoiding cardiovascular events (0.212, 95% confidence interval 0.148-0.275; p<0.001). For diastolic blood pressure, the SMD between the two groups was small (0.170, p<0.001) and the effect of RBPM was irrelevant in preventing cardiovascular events. The effect on the rate of blood pressure (BP) control was significantly high for the intervention group (relative risk: 1.136; p=0.018). This review demonstrates that RBPM performed on urban hypertensive patients has limited value and seems not to be superior to ordinary care in avoidance of cardiovascular events. Further studies are needed to provide more reliable information about the effectiveness of RBPM in preventing hypertensive cardiovascular complications.
Eleven randomized controlled trials met the inclusion criteria for interactive mobile health intervention and blood pressure management in adults done by Lu, X et al[32], with a total sample size

of 4271 participants. Compared with the control group, mobile health intervention was associated with significant changes in systolic blood pressure and diastolic blood pressure of -3.85 mm Hg; 95% CI, -4.74 to -2.96 and -2.19 mm Hg; 95% CI, -3.16 to -1.23, respectively. Subgroup analyses revealed consistent effects across study duration and intervention intensity subgroups. In addition, participants with inadequate blood pressure control at recruitment might gain more benefits with mobile health intervention. Therefore, interactive mobile health intervention may be a useful tool for improving blood pressure control among adults, especially among those with inadequate blood pressure control.

A total of 24 studies with 8933 participants were included by Li, R et al[33] in the systematic review of the effectiveness of self-management of hypertension in adults using mobile health apps. Of these, 23 studies reported the clinical outcome of blood pressure, 12 of these provided systolic blood pressure (SBP) and diastolic blood pressure (DBP) data, and 16 articles focused on change in selfmanagement behaviour and medication adherence. All 24 studies were included in the narrative synthesis. According to the meta-analysis, a greater reduction in both SBP and DBP was observed in the mobile health intervention groups compared with control groups, -3.78 mm Hg (P<.001; 95% CI 4.67 to -2.89) and -1.57 mm Hg (P<.001; 95% CI -2.28 to -0.86), respectively. Subgroup analyses showed consistent reductions in SBP and DBP across different frequencies of reminders, interactive patterns, intervention functions, and study duration subgroups. A total of 16 studies reported better medication adherence and behavioural change in the intervention groups, while 8 showed no significant change. Six studies included an economic evaluation, which drew inconsistent conclusions. However, potentially long-term financial benefits were mentioned in all economic evaluations. All studies were assessed to be at high risk of bias. This review found that mobile health self-management interventions were effective in blood pressure control. The outcomes of this review showed improvements in self-management behaviour and medication adherence. The most successful mobile health intervention combined the feature of tailored messages, interactive communication, and multifaceted functions. Further research with longer duration and cultural adaptation is necessary. With increasing disease burden from hypertension globally, mobile health intervention offers a potentially effective method for self-management and control of blood pressure. Mobile health can be easily integrated into existing health care systems.

Out of 1032 studies found in the systematic review study done by Jamshidnezhad, A et al[34] on the effects of mobile health apps on patients’ self- care with hypertension, 6 studies were finally reviewed. Out of 6 studies reviewed, three studies confirmed the effect of using mobile health apps on lowering blood pressure. Other studies reported a decline in blood pressure, but statistical significance was not shown. The results showed that mobile health apps have positive potential on improving the self-care behaviour of patients with hypertension, but the evidence presenting their impact are varied. Differing reports of the efficiency of mobile health apps for self-care modification were due to the diverse condition of studies for mobile interventions in patients with hypertension.

Recent research as described by Santo, K et al[35], has shown that mobile health apps can be beneficial in terms of improving hypertension self-assessment, treatment and control, being especially useful to help differentiate and manage true and pseudo-resistant hypertension. However, future research, including large-scale randomized clinical trials with user-centred design, is crucial to further evaluate the potential scalability and effectiveness of such mobile health apps in the resistant hypertension context.

A total of 21 articles including 6320 hypertension patients (internet-based intervention group, n = 3130; control group, n = 3190,) were identified by Zhou, Z et al[36] in a meta-analysis of internet-based interventions in promoting blood pressure control and health related behaviours. Overall, the blood pressure control rate of internet-based interventions group was significantly better than that in control group [(OR = 2.38, 95% CI: 1.77-3.22), P < 0.001]. Internet-based interventions significantly reduced SBP and DBP, with the weighted mean difference being-5.60 mmHg [95% CI-7.25-to-3.96, P < 0.001] and-3.72mmHg [95% CI-5.42-to-2.02, P < 0.001]. Moreover, Internet-based interventions significantly promoted drug compliance [(OR = 2.46 (1.81-3.84), P < 0.001], and regular exercise [OR = 2.01 (1.70-2.38), P < 0.0001], knowledge of hypertension [OR = 2.90 (2.03-4.15), P < 0.001] and drinking control [OR = 1.98 (1.67-2.36), P < 0.0001]. However, it cannot improve tobacco control in hypertension patients [OR = 1.03 (0.83-1.27), P = 0.80]. This study demonstrated that internet-based interventions were effective in promoting blood pressure control and health related behaviours in patients with hypertension. It's worthy of further application and promotion in hypertension management.

Randomized controlled trials of digital counselling for blood pressure reduction in populations with elevated cardiovascular risk factors or cardiovascular disease were extracted by Stogios, N et al[37]. Sixteen trials met inclusion criteria: pooled n = 4,408, 30% female, 89% prescribed antihypertensive medications. SBP reduction was characterized by a low-moderate standardized mean difference (SMD) of 0.39 (95% CI: 0.3, 0.5) between Digital Intervention vs. Control groups, with high-moderate heterogeneity (I2 = 69%). This was equivalent to -8.2 mmHg for digital counselling (95% CI: -7.9 to 8.4) versus -4.2 mmHg for control (95% CI: -4.4 to -3.9), p < 0.0001. Figure 1 illustrates similar lowmoderate treatment effects for SBP outcomes, with high-moderate heterogeneity, among trials with complex interventions of 3-5 treatment components. Therapeutic outcome was optimal for SBP reduction, with a moderate SMD and moderate heterogeneity (I2 = 49%) when the intervention had multiple therapeutic components and was organized by a theoretical framework of behaviour change or counselling. This translated to -4.8 mmHg for digital counselling (95% CI: -5.09 to -4.57) versus -1.4 mmHg (95% CI: -1.89 to -0.99) for Control. Digital health interventions optimize the efficacy of medical therapy for SBP reduction. Therapeutic outcomes are improved with adherence to recommended guidelines for the intervention design, including the use of a clinically organized protocol and multiple therapeutic components in the intervention. Given that digital health apps are projected to grow at an accelerated rate, there is opportunity to promote disruptive change in the design of behavioural counselling interventions for cardiovascular disease risk factor reduction through the synergy of clinical science and digital technology.

Digital technology for blood pressure control-table of main studies

Study	Study type	Type of Apps	Population group	Period of outcome measurement	Outcome	How outcome was measured
Kitt et al. 2019 (29)	Journal article Review	Smartphone apps Telemonitoring	Widespread population as well as specialist groups including the elderly, pregnant patients and those with Atrial fibrillation.		Several studies have shown the benefit of using tele-monitoring, especially when coupled with co-intervention, in reducing BP. It shows particular promise with those with hypertension in pregnancy and in developing countries.	Self monitoring
McLean et al. 2016 (30)	Systematic review with meta-analysis	Mobile phone apps Website, email system, voice responsive system.	Adults over 18 years, with hypertension using interactive digital intervention.	6 weeks to 24 months.	4 out of 7 studies showed significant reduction in SBP, with weighted mean difference -3.74mmHg (-2.19 to -2.58). 4 out of 6 studies showed a reduction in DBP of -2.37mmHg (-0.40to -4.35).	Self-monitoring
Choi et al. 2019 (31)	Systematic review and meta-analysis	Mobile phone apps	Urban population with hypertension		There was a significant standardized mean difference for RBPM for SBP. The effect size was small compared to face-to-face care and was not clinically relevant in reducing cardiovascular events 0.212, (0.148-0.275). The DBP SMD between the two groups was small (0.170) and the effect of RBPM was irrelevant in preventing cardiovascular events. The effect on the rate of BP control was significantly high for the intervention group (RR: 1.136; p = 0.018).	Self monitoring and monitored by a healthcare professional.

Lu et al. 2019 (32)	Systematic review and Meta analysis	Mobile phone apps	Adults with hypertension, articles searched between January 15, 2007 and April 28, 2019.		There were significant changes in SBP 3.85 mm Hg (-4.74 to -2.96) and DBP of -2.19 mm Hg(-3.16 to -1.23). It also showed that patients with inadequate control at the start of the study may gain more benefits with this type of mobile intervention.	Self monitoring
Li et al. 2020 (33)	Systematic review and Meta analysis	Mobile phone/tablet apps	Adults with primary diagnosis of hypertension, using mobile phone/tablet apps.	1.5- 18 months	The meta-analysis showed a greater reduction in both SBP and DBP was seen with mHealth, -3.78 mm Hg (P<.001; 95% CI -4.67 to -2.89) and -1.57 mm Hg (P<.001; 95% CI -2.28 to -0.86). It also showed better medication adherence and behavioural change in 16/24 studies.	Self monitoring and self reported.
Jamshidnezhad et al. 2019 (34)	Systematic review	Mobile phone apps	Adults with hypertension using mobile phone as device for improving self care.	Average 5 months	Three of six studies reviewed confirmed the effect of using mobile applications on lowering blood pressure. Other studies reported a decline in blood pressure but this was not statistically significant. They also show an improvement in self-care behaviour but the evidence is showing this is varied.	Self monitoring
Santo et al 2019 (35)	Journal article review	Mobile phone apps	Adults with resistant hypertension	6 weeks-6 months	This research showed that mobile app interventions can improve hypertension assessment by patients, treatment and control. They can help to distinguish hypertension from pseudo-resistant hypertension.	Self monitoring

Zhou et al. 2018 (36)	Meta-analysis	Internet based interventions	Adults with hypertension		This meta-analysis showed that blood pressure was significantly reduced in the intervention group OR = 2.38, 95% CI: 1.77-3.22), P < 0.001]. The intervention showed a significant reduction in both systolic and diastolic blood pressures, with weighted mean difference of -5.60 mmHg [95% CI-7.25-to3.96, P < 0.001] and-3.72mmHg [95% CI5.42-to-2.02, P < 0.001].	Self monitoring and self reported.
					These types of internet-based health apps significantly encouraged medication compliance [(OR = 2.46 (1.81-3.84), P < 0.001], and regular exercise [OR = 2.01 (1.70-2.38), P < 0.0001], the understanding of hypertension [OR = 2.90 (2.03-4.15), P < 0.001] and their alcohol intake control [OR = 1.98 (1.67-2.36), P < 0.0001]. This study did not show any statistical improvement in tobacco control in this patient group [OR = 1.03 (0.83-1.27), P = 0.80].	

Stogios et al. 2019 (37)	Systematic review and meta-analysis	Internet based interventions accessed through smart phone computer or hand held device.	Adults with increased risk of cardiovascular risk factors or disease	1-12 months	Systolic BP reduction was considered as a low-moderate standardized mean difference (SMD) of 0.39 (95% CI: 0.3, 0.5) between the intervention and control groups, with high-moderate heterogeneity (I2 = 69%). This was equal to -8.2 mmHg for digital counselling (95% CI: -7.9 to -8.4), whereas it was -4.2 mmHg for control (95% CI: -4.4 to -3.9), $p < 0.0001$. There was an optimal reduction in SBP, with a moderate SMD and moderate heterogeneity (I2 = 49%), in cases where there were multiple therapeutic components, which involved counselling or organisation by a theoretical framework for change in behaviour. This was translated to -4.8 mmHg for the intervention group (95% CI: -5.09 to -4.57) compared to the control group which showed -1.4 mmHg (95% CI: -1.89 to 0.99).	Self monitoring with and self reported

Summary Digital technology for blood pressure control

Novel technology including smartphones and Bluetooth®-enabled tele-monitoring are evolving as key players in hypertension management and offer particular promise within pregnancy and developing countries. A review demonstrates that remote blood pressure monitoring performed on urban hypertensive patients has limited value and seems not to be superior to ordinary care in avoidance of cardiovascular events. Interactive mobile health intervention may be a useful tool for improving BP control among adults, especially among those with inadequate BP control. The most successful mobile health intervention combined the feature of tailored messages, interactive communication, and multifaceted functions. The results showed that mobile health apps have positive potential on improving the self-care behaviour of patients with hypertension, but the evidence presenting their impact is varied. Mobile health apps can be beneficial in terms of improving hypertension self-assessment, treatment and control, being especially useful to help differentiate and manage true and pseudo-resistant hypertension. Another study demonstrated that internet-based interventions were effective in promoting blood pressure control and health related behaviours in patients with hypertension. It's worthy of further application and promotion in hypertension management. Digital interventions lower both SBP and DBP compared to usual care. Results suggest these findings can be applied to a wide range of healthcare systems and populations. However, sustainability and long-term clinical effectiveness of these interventions remain uncertain. The most pressing need is for these new technologies to be properly assessed and clinically validated prior to widespread implementation in the general population.

Digital technology & CVD Primary Prevention

Wongvibulsin, S et al[38] showed that initial studies in connected health for cardiovascular disease prevention and management have focused primarily on activity tracking and blood pressure monitoring, but have since expanded to include a full panoply of novel sensors and pioneering mobile health apps with targeted interventions in diet, lipid management and risk assessment, smoking cessation, cardiac rehabilitation, heart failure, and arrhythmias. While outfitting patients with sensors and devices alone is infrequently a lasting solution, monitoring programs that include personalised insights based on patient-level data are more likely to lead to improved outcomes. Advances in this space have been driven by patients and researchers while healthcare systems remain slow to fully integrate and adequately adapt these new technologies into their workflows. Cardiovascular disease prevention and management continue to be key focus areas for clinicians and researchers in the connected health space. Exciting progress has been made though studies continue to suffer from small sample size and limited follow-up. Efforts that combine home patient monitoring, engagement, and personalized feedback are the most promising.

The systematic review and meta-analysis on the digital health interventions for the prevention of cardiovascular disease by Widmer ,RJ[39] found that digital health interventions (DHI) significantly reduced cardiovascular disease outcomes (relative risk, 0.61; 95% CI, 0.46-0.80; P<.001; I(2)=22%). Concomitant reductions in weight (-2.77 lb [95% CI, -4.49 to -1.05 lb]; P<.002; I(2)=97%) and body mass index (-0.17 kg/m(2) [95% CI, -0.32 kg/m(2) to -0.01 kg/m(2)]; P=.03; I(2)=97%) but not blood pressure (-1.18 mm Hg [95% CI, -2.93 mm Hg to 0.57 mm Hg]; P=.19; I(2)=100%) were found in these DHI trials compared with usual care. In the 6 studies reporting Framingham risk score, 10-year risk percentages were also significantly improved (-1.24%; 95% CI, -1.73% to -0.76%; P<.001; I(2)=94%). Results were limited by heterogeneity not fully explained by study population (primary or secondary prevention) or DHI modality. Overall, these aggregations of data provide evidence that digital health interventions can reduce cardiovascular disease outcomes and have a positive impact on risk factors for cardiovascular diseases.

Summary Digital technology & CVD Primary Prevention

Overall, these aggregations of data provide evidence that digital interventions can reduce cardiovascular disease outcomes and have a positive impact on risk factors for cardiovascular diseases. Efforts that combine home patient monitoring, engagement, and personalized health feedback are the most promising.

Digital technology and cardiovascular diseases, secondary prevention/ management

11 trials (n=1189) met eligibility criteria and were included in the review of telehealth exercise-based cardiac rehabilitation (exCR) by Rawstorn, JC et al[40]. Physical activity level was higher following telehealth exCR than after usual care. Compared with centre-based exCR, telehealth exCR was more effective for enhancing physical activity level, exercise adherence, diastolic blood pressure and lowdensity lipoprotein cholesterol. Telehealth and centre-based exCR were comparably effective for improving maximal aerobic exercise capacity and other modifiable cardiovascular risk factors. Telehealth exercise-based cardiac rehabilitation (exCR) appears to be at least as effective as centrebased exCR for improving modifiable cardiovascular risk factors and functional capacity, and could enhance exCR utilisation by providing additional options for patients who cannot attend centrebased exCR. Telehealth exCR must now capitalise on technological advances to provide more comprehensive, responsive and interactive interventions.

Ten articles, representing 9 studies, were included in the review of mobile health-based heart failure interventions Cajita MI, et al [41]. The majority of the studies utilized mobile health technology as part of a heart failure (HF) monitoring system, which typically included a blood pressure-measuring device, weighing scale, and an electrocardiogram recorder. The impact of the mobile health interventions on all-cause mortality, cardiovascular mortality, HF-related hospitalizations, and length of stay, New York Heart Association functional class left ventricular ejection fraction, quality of life, and self-care were inconsistent at best. Further research is needed to conclusively determine the impact of mobile health interventions on HF outcomes. The limitations of the current studies (e.g., inadequate sample size, quasi-experimental design, use of older mobile phone models, etc.) should be taken into account when designing future studies.

Twenty-seven studies with 5165 patients were included in the systematic review of the effect of mobile health interventions on the secondary prevention of cardiovascular disease by Gandhi, S et al[42]. Patients in the mobile health intervention group showed increased adherence to medical therapy (odds ratio [OR], 4.51; $P < 0.00001$), as well as increased adherence to pharmacologic and non-pharmacologic therapy (OR, 3.86; $P < 0.00001$). Patients in the mobile health intervention group showed the ability to meet recommended blood pressure targets (OR, 2.80; $P < 0.001$) with a trend toward the ability to meet exercise goals (OR, 2.55; $P = 0.07$), however, no significant difference in smoking cessation (OR, 1.42; $P = 0.45$) and the ability to meet lipid target levels (OR, 1.16; $P = 0.29$) was found. Patients in the mobile health intervention group did not show a reduction in hospital readmission (OR, 0.93; $P = 0.96$), with a small number of studies showing a reduction in angina (OR, 0.23; $P = 0.005$), and a decrease in transient ischemic attack/stroke recurrence in those with cerebrovascular disease (OR, 0.18; $P < 0.0001$) and a trend toward lower observed mortality rate (OR, 0.19; $P = 0.06$). The mobile health intervention group compared with the usual care group had increased adherence to medical therapy, ability to reach blood pressure targets, exercise goals, and showed less anxiety and increased awareness of diet and exercise. There was no difference in smoking cessation, ability to meet low-density lipoprotein cholesterol targets, and hospital readmission.

The effectiveness of telehealth interventions as a part of secondary prevention in coronary artery disease was studied in a systematic review by Turan, KS et al[43]. Twenty-four studies with a total of 6773 study participants met the inclusion criteria. It was found that telephone call interventions were the most commonly used, text message interventions came second with seven studies, telephone calls in combination with messages were used in four studies and tele-monitoring was used in two studies. Compared to routine care, telehealth interventions had moderate significant effects in reducing waist circumference, total cholesterol and triglyceride, improving medication adherence and physical activity, and had small significant effects in reducing blood pressure and smoking cessation. No significant publication bias was found in the main outcomes. Results showed that the telehealth interventions yielded positive outcomes in lifestyle changes for coronary artery disease. Therefore, telehealth interventions can be used for effective secondary prevention by health professionals who care for individuals with coronary artery disease. Additionally, this study will provide guidance for studies on the development of telehealth intervention.

Ten studies done by Coorey, GM et al[44] of varying designs including 607 patients from five countries were included in the systematic review with meta-synthesis of quantitative and qualitative data on the effectiveness, acceptability and usefulness of mobile health apps for cardiovascular disease selfmanagement. Interventions targeted hypertension, heart failure, stroke and cardiac rehabilitation populations. Factors that improved among app users were rehospitalisation rates, disease-specific knowledge, quality of life, psychosocial well-being, blood pressure, body mass index, waist circumference, cholesterol and exercise capacity. Improved physical activity, medication adherence and smoking cessation were also characteristic of app users. Appealing app features included tracking healthy behaviours, self-monitoring, disease education and personalised, customisable content. Small samples, short duration and selection bias were noted limitations across some studies, as was the relatively low overall scientific quality of evidence. Multiple behaviours and cardiovascular disease risk factors appear modifiable in the shorter term with use of mobile health apps. Evidence for effectiveness requires larger, controlled studies of longer duration, with emphasis on process evaluation data to better understand important system- and patient-level characteristics.

Internet-based interventions for the secondary prevention of coronary heart disease by Devi R et al[45] showed that in general, evidence was of low quality due to lack of blinding, loss to follow-up, and uncertainty around the effect size. Few studies measured clinical events, and of those that did, a very small number of events were reported, and therefore no firm conclusions can be made. Similarly, there was no clear evidence of effect for cardiovascular risk factors, although again the number of studies reporting these was small. There was some evidence for beneficial effects on health related quality of life, dietary outcomes, and physical activity, although firm conclusions cannot yet be made. The effects on healthcare utilisation and cost-effectiveness are also inconclusive, and trials are yet to measure the impact of internet interventions on compliance with medication. The comparison groups differed across trials, and there were insufficient studies with usable data for subgroup analyses. Devi R et al[45] intend to study the intensity of comparison groups in future updates of their review when more evidence is available. The completion of the ongoing trials will add to the evidence base.

Current evidence suggests that mobile health tools can improve medication adherence in patients with cardiovascular diseases. This was found out following a systematic review by Gandapur, Y et al[46]. However, high-quality clinical trials of sufficient size and duration are needed to move the field forward and justify use in routine care.

In the review of the current literature, Kauw, D et al[47]evaluated the effect of various eHealth interventions in patients with congenital heart disease (CHD). Their search resulted in a mere 10 studies, which comprised mostly of children or adolescents with severe congenital heart disease. Home-monitoring of saturation and weight through mobile health intervention was found to be beneficial in patients after palliation procedures, and video conferencing was found to have a positive effect on anxiety and healthcare utilization. Kauw, D et al[47]also note that due to high morbidity and mortality in patients with CHD and the promising results of eHealth interventions, further research is desperately needed.

Seven trials, which included 1321 coronary heart disease patients, were eligible for inclusion in the systematic review of internet-delivered self-management support for improving coronary heart disease and self-management-related outcomes. Palacious, J et al[48] found there was considerable heterogeneity between studies in terms of the intervention content, outcomes measured, and study quality. All 7 of the included studies reported significant positive between-group effects, in particular for lifestyle-related outcomes. Personalization of interventions and provision of support to promote engagement may be associated with improved outcomes, although more data are required to confirm this. The theoretical basis of interventions was poorly developed though evidence-based behaviour change interventions were used. More well-designed randomized controlled trials are needed. These should also explore how interventions work and how to improve participant retention and satisfaction and examine the role of personalization and support within interventions.

The review of mobile health apps to support heart failure self-care management by Athilingam, P et al[49] included studies with low-quality design and sample sizes ranging from 7 to 165 with a total sample size of 847 participants from all 18 studies. Nine studies assessed usability of the newly developed mobile health system. Six of the studies included are randomized controlled trials, and four studies are pilot randomized controlled trials with sample sizes of fewer than 40. There were inconsistencies in the self-care components tested, increasing bias. Thus, risk of bias was assessed using the Cochrane Collaboration's tool for risk of selection, performance, detection, attrition, and reporting biases. Most studies included in this review are underpowered and had high risk of bias across all categories. Three studies failed to provide enough information to allow for a complete assessment of bias, and thus had unknown or unclear risk of bias. This review on the commercially available apps demonstrated many incomplete apps, many apps with bugs, and several apps with low quality. The heterogeneity of study design, sample size, intervention components, and outcomes measured precluded the performance of a systematic review or meta-analysis, thus introducing bias of this review. Although the heart failure-related outcomes reported in this review vary, they demonstrated trends toward making an impact and offer a potentially cost-effective solution with 24/7 access to symptom monitoring as a point of care solution, promoting patient engagement in their own home care.

A systematic review by Hamilton, SJ et al[50] of smartphones in the secondary prevention of cardiovascular disease was as follows: Nine studies described a mix of mobile health interventions for cardiac rehabilitation (CR) (5 studies) and heart failure (4 studies) in the following categories: feasibility, utility and uptake studies; and randomized controlled trials. Studies showed that mobile health delivery for CR and heart failure management is feasible with high rates of participant engagement, acceptance, usage, and adherence. Moreover, mobile health delivery of CR was as effective as traditional centre-based CR (TCR) with significant improvement in quality of life. Hospital utilization for heart failure patients showed inconsistent reductions. There was limited inclusion of rural participants. Mobile health delivery has the potential to improve access to CR and heart failure management for patients unable to attend TCR programs. Feasibility testing of culturally appropriate mobile health delivery for CR and heart failure management is required in rural and remote settings with subsequent implementation and evaluation into local health care services.

The findings of the narrative review done by Li, KHC et al[51] on the current state of mobile health apps for monitoring heart rate (HR), heart rate variability (HRV) and atrial fibrillation (AF) suggest that there is a role for mobile health apps in the diagnosis, monitoring, and screening for arrhythmias and HR. Photo plethysmography and handheld electrocardiograph recorders are the 2 main techniques adopted in monitoring HR, HRV, and AF. A number of studies have demonstrated high accuracy of a number of different mobile devices for the detection of AF. However, further studies are warranted to validate their use for large scale AF screening.

Mobile health solutions are able to provide meaningful clinical information allowing effective and efficient management of chronic diseases, such as heart failure. A variety of data can be collected, such as lifestyle, sensor/biosensor, and health-related information. The analysis of these data empowers patients and the involved ecosystem actors, improves the healthcare delivery, and facilitates the transformation of existing health services. Tripoliti, EE et al[52] suggested from the study of evolution of mobile health solutions for heart failure management.

In total, 32 papers reporting 30 unique trials were identified in the systematic review and metaanalysis of telehealth interventions for the secondary prevention of coronary heart disease done by Jin, K et al[53]. Telehealth was not significantly associated with a lower all-cause mortality than cardiac rehabilitation and/or usual care (risk ratio (RR)=0.60, 95% confidence interval (CI)=0.86 to 1.24, p=0.42). Telehealth was significantly associated with lower rehospitalisation or cardiac events (RR=0.56, 95% CI=0.39 to 0.81, p<0.0001) compared with non-intervention groups. There was a significantly lower weighted mean difference (WMD) at medium to long-term follow-up than comparison groups for total cholesterol (WMD= -0.26mmol/l, 95% CI= -0.4 to -0.11, p <0.001), lowdensity lipoprotein (WMD= -0.28, 95% CI = -0.50 to -0.05, p=0.02) and smoking status (RR=0.77, 95% CI =0.59 to 0.99, p=0.04]. Telehealth interventions with a range of delivery modes could be offered to patients who cannot attend cardiac rehabilitation, or as an adjunct to cardiac rehabilitation for effective secondary prevention.

Summary Digital technology and cardiovascular diseases, secondary prevention/ management

Results showed that the telehealth interventions yielded positive outcomes in lifestyle changes for secondary prevention of cardiovascular diseases. Telehealth and centre-based exercise cardiac rehabilitation were comparably effective for improving maximal aerobic exercise capacity and other modifiable cardiovascular risk factors. Therefore, telehealth interventions can be used for effective secondary prevention by health professionals who care for individuals. The impact of the mobile health interventions on all-cause mortality, cardiovascular mortality, HF-related hospitalizations, and length of stay, New York Heart Association functional class left ventricular ejection fraction, quality of life, and self-care were inconsistent at best. Further research is needed to conclusively determine the impact of mobile health interventions on heart failure outcomes. In another study, the mobile health intervention group compared with the usual care group had increased adherence to medical therapy, ability to reach blood pressure targets, exercise goals, and showed less anxiety and increased awareness of diet and exercise. Current evidence suggests that mobile health intervention tools can improve medication adherence in patients with cardiovascular diseases. Mobile health delivery has the potential to improve access to cardiac rehabilitation and heart failure management for patients unable to attend traditional cardiac rehabilitation programs. A number of studies have demonstrated high accuracy of a number of different mobile devices for the detection of AF. Telehealth interventions with a range of delivery modes could be offered to patients who cannot attend cardiac rehabilitation, or as an adjunct to cardiac rehabilitation for effective secondary prevention.

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