Applications of Mobile Health Technologies to Address Cardiometabolic Health Disparities in the United States: A Systematic Review

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Introduction: Black and Hispanic adults are disproportionately burdened by cardiometabolic disorders. The aim of this systematic review was to examine the effectiveness of mobile health technologies to promote disease prevention and self-management among US adults in diverse communities.

Methods: Potential studies were identified using a comprehensive search of the PubMed and EMBASE databases for recent studies published from December 2018 through 2021. Keywords and search strategies were established to focus on health disparity populations and the application of mobile health technology for cardiovascular disease risk reduction. Titles and abstracts were assessed and, if a study was eligible, 2 independent reviewers completed a full-length review with extraction in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Results: A total of 13 studies met our inclusion criteria. Study sample sizes ranged from 8 to 533 baseline participants. Studies were conducted in diverse communities (eg, North Carolina and California). Most studies used mobile applications (n=11) and a majority used accelerometers or similar technologies (eg, smartwatches) to assess changes in dietary behavior, blood pressure control, and physical activity. Overall, studies reported positive associations between mobile technology use and risk factor reduction actions and behaviors. Long-term adherence varied across studies. Those that prioritized culturally tailored approaches reported more significant impacts than those that did not.

Conclusions: Evidence suggests that mobile technology may be useful in promoting disease self-management and risk reduction among populations at higher risk of cardiometabolic diseases. The use of mobile health technologies, particularly when tailored to target populations, may be a practical approach to advancing population health equity. *Ethn Dis.* 2023;33(4):180–193; doi:10.18865/ed.33.4.180

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Introduction

As the leading cardiometabolic disorder, heart disease is responsible for 23% of total deaths in the United States.[1] Cardiometabolic diseases, such as heart disease, encompass various cardiovascular (CVD) conditions, including coronary artery disease and stroke.[2] Appropriate self-management of cardiometabolic disease risk factors may help reduce its incidence and prevalence.[3,4] These include managing blood pressure (BP), obesity, physical activity, and dietary behavior.[5] Despite the benefits of self-management, racially/ethnically minoritized populations may be disproportionately susceptible to heart disease due to structural and psychosocial barriers.[6,7] Mobile health technology (mHealth) may help achieve desired outcomes by improving patient self-management, particularly in populations experiencing health disparities.

Evidence supports that mHealth interventions have been successful at improving chronic disease self-management.[8] This technology may be particularly useful for further engaging with disproportionally affected groups. However, further evidence is needed to better understand feasibility and long-term efficacy of various mHealth interventional strategies. This systematic review aims to synthesize published evidence on the use of various mobile health technologies (eg, smartphones, smartwatches, pedometers, accelerometers) used by minoritized populations to address cardiometabolic risk factors and decrease health disparities in the US.

Methods

This systematic review used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[9] to report findings. The following subsections provide further details.

Search Strategy

Studies were collected from the PubMed and EMBASE databases. Three sets of search strings were built based on the following concepts: (1) mobile health technology, (2) health disparity populations, and (3) cardiometabolic risk reduction factors. For instance, standardized search terms for African American, Hispanic, and Asian communities were constructed to define target health disparity populations. Appropriate subpopulations were included (eg, Mexican American, Filipino). These categories were composed of key terms and Medical Subject Headings. The search terms were modified to fit each database and appropriate filters were applied. Specific search terms are available from the corresponding author as Appendix 1: Systematic Review Search Strategy and Terms.

Eligibility Criteria

Studies that met the following criteria were included: (1) published from December 2018 through 2021; (2) primary data collected in the US; (3) included key health disparity populations; (4) fit our definition of mobile technology; (5) addressed the adult population; (6) focused on the self-management of BP, nutritional behavior, and/or physical activity; and (7) manuscript was available in the English language. The study team decided preemptively to focus on synthesizing published data from the last 3 years due to rapid changes in technology and the recent increase in mHealth interventions designing to address health disparities. Studies based solely on medical adherence or that relied on a single intervention (ie, texting), were excluded. In addition, studies that focused on a single subpopulation (eg, postpartum mothers, HIV patients) were excluded to increase generalizability of the findings.

Selection of Studies and Extraction

Study selection consisted of the following stages: (1) title and abstract screening, (2) full-length review, (3) data extraction, and (4) analysis. Duplicate studies were removed and those that remained were uploaded and assessed through Covidence, a reference manager software program. Each title and abstract were screened by a reviewer. Two independent reviewers performed the full-length review. If there were disagreements, a third reviewer made the determination. One reviewer performed the extraction and another checked for consistency. Discrepancies in extractions were addressed using a third independent reviewer. Reviewers utilized a standardized extraction form that asked for key outcome(s), focus population, aim, study design, length of intervention, data collection start/end dates, technology used, inclusion criteria, sample size, mean age, sex, breakdown of health disparity population(s), and outcomes for each of the domains (baseline and follow-up). Most study outcomes were reported through mean difference significance. Data were reported as provided and based on the key outcome(s) being addressed.

Results

Search Results

The literature search retrieved 467 studies, 14 of which were duplicates. During the title and abstract screening, 330 were declared irrelevant. The remaining 123 studies proceeded to full-text review; 110 of these were excluded. Main reasons for exclusion included (1) study sample did not represent the general population (n=35), (2) study did not focus on at least 1 key outcome (n=17), and (3) participants were not adults (n=17). Only 13 studies were selected from the following categories for extraction: (1) BP only,[10] (2) BP and nutritional behavior,[11] (3) nutritional behavior only,[12–14] (4) nutritional behavior and physical activity,[15–17] (5) BP and physical activity,[18] (6) physical activity only,[19–21] and (7) all 3 key outcomes.[22] Figure 1 provides the study selection flow diagram.

Summary of Study Characteristics

Study characteristics are summarized in Table 1. Participants were recruited from around the US; studies included 5 in California,[12,16–19] 2 in North Carolina,[13,22] 1 in Maryland,[14] and 5 from various other states.[15] Most were randomized controlled trials (n=8), whereas others were cohort (n=2), single-arm pretest-posttest (n=1), pilot (n=1), and qualitative (n=1) study designs. Intervention durations varied; 8 studies lasted between 3 and 6 months, but others ranged from 56 days to 2 years. The mean age of participants in the studies ranged from 39 to 62 years old. Study sample sizes ranged from 8 to 533 baseline participants. A total of 3 studies included 100% female participants, while 6 additional studies included 70-99% female participants in their study samples. Most studies included 90% or more participants who identified as a US racial/ethnic minority (n=10), and 6 of these 10 studies were solely focused on these populations.

Summary of mHealth Interventions

Eleven studies utilized mobile applications as their intervention; almost all combined this method with another technology (eg, accelerometer/pedometer, social media, smartwatches) (n=10). One study used mobile applications as the sole mHealth intervention. Messaging/email (n=7), social media (n=3), and phone calls (n=2) were among the interventions that were used less often, but they were always used in combination with another mHealth intervention. Smartwatches were often used as

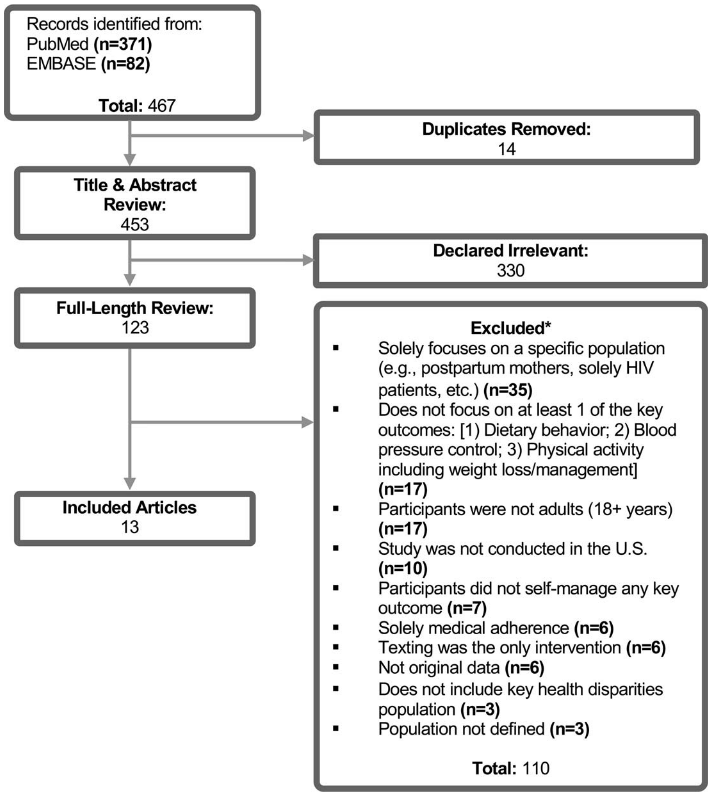

Figure 1. Summary of literature search and article review process.

***Third independent reviewer determined disagreements; only the primary reason for exclusion is counted**

accelerometers/pedometers that were able to sync health data with an application for easier tracking (n=3). Four studies had in-person elements. Eight studies directly assessed feasibility, and 1 efficacy. Tables 2a, 2b, and 2c provide summaries of the interventions paired with the technologies used in the interventions.

Smartphone Applications

Of the smartphone applications used in the studies, 8 were commercially available and 2 were developed by the research teams. However, the app created by the Neffa-Creech et al[12] group has been certified by various national obesity prevention or reduction agencies. Commercially available applications included MyFitnessPal,[13,17] FitBit[15,22] (using its smartwatch/accelerometer), Weight Watchers,[16] Hypertension Personal Control Program (HPCP)[18] (coaching), OMCRON (tracking),[18] VeggieBook,[12] Nutritionix,[11] and the Striiv Band[21] (using its pedometer). Most of the scores obtained from the apps were self-reported, except those that synced with certain step-counting tools (eg, smartwatches, accelerometers) or other similar measures. Eight applications were easily accessible for a range of smartphones, but some applications were only available on Android[10] or iOS[18] platforms.

Key Outcome Features

BP Control. A pilot (nonrandomized) study by Fukuoka et al[22] addressing BP control produced significant BP and hip and waist circumference reductions using various technologies, including a mobile app to track food/drink consumption and weigh-ins. Persell et al[18] found no significant BP reductions between participants who used either a coaching or tracking app. Similarly, Steinberg et al,[11] whose study consisted of an app and text message vs app-only intervention, found no significant between-group differences in BP reduction. In the study by Vu et al,[10] participants believed tracking their health scores helped them achieve their goals, as well as increased their comfort in using health apps.

Physical Activity. To track physical activity, studies either asked participants to self-report, synced a step-counting mHealth intervention, or used the smartphone itself. Physical activity promotion modules in the study by Joseph et al[20] delivered contents on a weekly basis until month 4, then every 2 weeks until the culmination of the intervention. The results yielded a significant increase in physical activity (20-50 min/wk), self-regulation ($r=0.397$; $P=.01$), and behavioral capability ($r=0.440$; $P=.004$). In the same study,[21] multimedia modules were accompanied by discussion boards to help participants engage and reflect on various topics. Participants also received notifications when others made a post. The discussion board included a general and meet-up forum, which provided participants the opportunity to engage in topics other than the weekly module. However, there were no significant changes in familial ($r=0.103$; $P=.55$) or friend ($r=0.083$; $P=.62$) support.

Collins et al[21] found that there were significant within-group differences for quality of life and aerobic and strength training exercises, but no between-group differences for interventions whose groups both used a pedometer and its app to track steps (intervention group integrated additional mHealth). Nevertheless, the pedometer was rated as highly motivating by all participants. The study by Bender et al[15] had 2 phases, the first providing the intervention group the Fit&Trim program,

Table 1. Study characteristics

First author (year), location[a]	Study design, duration	Sample size (N=baseline → evaluation); age, y; and sex	US racial/ethnic minority, %[b]	Key outcomes: Blood pressure	Key outcomes: Dietary behavior	Key outcomes: Physical activity
King[19] (2020), Santa Clara and San Mateo Counties, CA	Cohort, 12 mo	Sample size: N=245 → 231 Mean age: 62.3 (SD=8.4) Female sex: 78.80%	H: 98.4 A: 1.2			x
Vu[10] (2017), Atlanta, GA	Cohort, 56 days	Sample size: N=33 → 9 Mean age: 53.8 (SD=11.5) Female sex: 75.76%	AA: 93.9	x		
Neffa-Creech[12] (2020), Los Angeles County, CA	Qualitative, 10 wk	Sample size: N=8 → 8 Age range: 30-49[c] Female sex: 100%	H: 100		x	
Bender[15] (2018), San Francisco and San Mateo Counties, CA	RCT, 3 mo	Sample size: N=67 → 61 Mean age: 41.7 (SD=12.0) Female sex: 52.20%	A: 100		x	x
Persell[18] (2020), Chicago, Illinois	RTC, 6 mo	Sample size: N=333 → 297 Mean age: 58.9 (SD=12.8) Female sex: 61.30%	AA: 34.7 H: 7.7 A: 4.4	x		x
Patel[13] (2019), central NC	RTC, 6 mo	Sample size: N=100 → 76 Mean age: 42.7 (SD=11.7) Female sex: 84.00%	AA: 22 H: 3		x	
Thomas[16] (2020), Providence, RI	RTC, 6 mo	Sample size: N=146 → 89 Mean age: 58.3 (SD=10.3) Female sex: 78.10%	AA: 2.1 H: 1.4 A: 0.7		x	x
Rosas[17] (2020), San Francisco, CA	RTC, 24 mo	Sample size: N=191 → 190 Mean age: 50.2 (SD=12.2) Female sex: 61.80%	H: 100		x	x
Fukuoka[22] (2018), San Francisco, CA	Pilot, 8 wk	Sample size: N=54 → 52 Mean age: 45.30 (SD=10.75) Female sex: 68.50%	H: 100	x	x	x
Steinberg[11] (2020), Raleigh, Durham, and Chapel Hill, NC	RTC, 3 mo	Sample size: N=59 → 43 Mean age: 49.9 (SD=11.9) Female sex: 100%	AA: 17 H: 6	x	x	
Joseph[20] (2021), AZ	Single-arm pretest-posttest, 4 mo	Sample size: N=20 → 16 Mean age: 56.2 (SD=4.3) Female sex: 100%	AA: 100			x
Collins[21] (2019), Wichita, KS	RTC, 3 mo	Sample size: N=69 → 67 Mean age: 58.7 (SD=6.82) Female sex: 85.5%	H: 100			x
Trude[14] (2018), Baltimore, MD	RTC, 6-8 mo	Sample size: N=533 → 373 Mean age: 39.31 (SD=9.31) Female sex: 90.89%	AA: 96.60		x	

A, Asian; AA, African American; H, Hispanic; RCT, randomized controlled trial

[a] Location format varies; reported as provided

[b] Values may not add up to 100% due to reporting of other races

[c] No mean age was provided

Table 2a. Summary of key outcomes/risk and type of technology for blood pressure (BP) control

First author (year)	Technology: Mobile app	Accelerometer/ pedometer	Social media	Phone calls	Messaging/ email	Smart-watch	Website	Bluetooth (enabled) BP monitor	Scale	In-person counseling	Intervention	Principal findings
Vu[10] (2017)	x				x						Research team developed an app used to track BP, blood glucose, and total cholesterol. Questionnaires assessed frequency of app use and change in perception.	• On average, participants had 3.98 weekly interactions with the app. Of these, 78.9% were to log BP, 20.2% blood glucose, and 1.01% total cholesterol. • Increase in comfort using (84.8% to 100%) and regularly using a health app (9% to 88.9%). • Significant increase in participants believing the app helped them achieve their goals (P=.0006).
Persell[18] (2020)	x							x			IG and CG were provided with a Bluetooth BP monitor to promote management of HPCP score and hypertension-related behaviors. However, the IG received a coaching (HPCP) and the CG a tracking (OMCRON) app.	• Not significant between-group difference in systolic (P=.16) and diastolic (P=.61) BP. • Significant difference in mean for self-confidence when managing BP score between IG and CG (P<.001) • No significant difference in self-reported minutes per week of exercise.
Fukuoka[22] (2018)	x		x	x	x	x				x	Daily use of Fitbit (smartwatch, accelerometer) and its app (logged food/drink/calories and twice-weekly weigh-in), weekly social media group interaction (Facebook), and two 1-h (approximately) in-person counseling sessions. At 3-wk follow-up and 8-wk final visit, BMI, hip and waist circumference, and BP were measured.	• Significant systolic (P<.0005) and diastolic (*p* <.001) BP reductions. • Significant hip and waist circumference reductions (P<.0005). • Significant loss of 3.3 (SD±3.4) % body weight (P<.0005), averaging a reduction of 2.4 kg (5.3 lb) (P<.0005). • Significant associated change in percent body weight with diet tracking (P=.01) and change in IPAQ score (P=.03).
Steinberg[11] (2020)	x				x						IG: Nutritionix (app) + DASH adherence tailored feedback text messages (wk 1-2: daily, wk 3+: weekly). CG: use of Nutritionix app.	• No significant between-group differences of systolic (P=.23) and diastolic (P=.07) BP reductions. • Both groups improved DASH scores (*P*<.001). However, no between-group differences on any nutritional component within the DASH diet. • No significant difference in app usage between groups (P=.54) • IG had a steeper reduction of tracking over time (about 1 d/mo faster) than the control group (P<.001).

BMI, body mass index; CG, control group; DASH, Dietary Approaches to Stop Hypertension; HPCP, Hypertension Personal Control Program; IG, intervention group; IPAQ, International Physical Activity Questionnaire

Table 2b. Summary of key outcomes/risk and type of technology for dietary behavior

First author (year)	Technology: Mobile app	Accelerometer/ pedometer	Social media	Phone calls	Messaging/ email	Smartwatch	Website/ computer	Scale	In-person component	Intervention	Principal findings
Neffa-Creech[12] (2020)	x									In-person 30-min interviews with mothers who frequently used VeggieBook, an app that provided healthy culturally relevant recipes and tips, to understand the behaviors and motivations of positive food changes.	• Three main themes emerged: mothers invited (1) and involved (2) their children to use the app while cooking with them, and mothers were open to trying new recipes (3).
Bender[15] (2018)	x		x			x			x	**Phase 1** (1-3 mo)—IG: Fit&Trim intervention, which consisted of educational materials, using a Fitbit Zip (accelerometer) with its mobile app (diet and exercise tracker), and social media group (Facebook). WG: received Fitbit. **Phase 2** (3-6 mo)—IG: 3-month maintenance period (in-person weigh-ins, 5 in-person coaching sessions, and independent tracking). WG: began Fit&Trim intervention.	• 90% of participants completed the intervention (feasibility). • By study completion, both groups achieved 5% body weight reduction (IG=5.2%; WG=5.8%). • In phase 1, 36% of IG and 6% of WG participants achieved 5% body weight loss. • In phase 2, 47% of WG and 18% of IG participants achieved 5% body weight loss.
Patel[13] (2019)	x							x		Participants used MyFitnessPal (app/website) and were randomized into either (1) both weight and diet tracking, with weekly lessons, action plans, and feedback (simultaneous); (2) weight tracking through week 4, then added diet, with the same behavioral components (Sequential); or (3) app only (self-guided).	• Significant weight reduction for all arms. However, no between-group difference for losing 3% or 5% of body weight for any arm. • Days per week diet was tracked was 1.9 (IQR, 0.3-5.5) for sequential, 5.3 (IQR, 1.8-6.7) for simultaneous, and 2.9 (IQR, 1.2-5.2) for the app-only arm (not asked to track). No significant difference between arms. • Days per week weight was tracked was 4.8 (IQR, 1.9-6.3) in sequential and 5.1 (IQR, 1.8-6.3) in simultaneous. No significant difference between arms.
Thomas[16] (2020)	x						x			IG: Weight Watchers + computer-based virtual reality program. Participants observed and guided the main character throughout the day (home, work, gym, and friend's gathering). CG: Weight Watchers online platform.	• Significant weight loss at 3 and 6 mo for both groups ($P<.001$ for both). • No significant between-groups difference at 3 mo ($P>.085$), but significant at 6 mo. IG (4.7 ± 1.1 kg) lost almost as much as CG (2.6 ± 1.1 kg). • No between-groups difference on number of participants losing 5% of their body weight at 3 or 6 mo (all $P>.210$).

Table 2b. Continued

First author (year)	Technology								In-person component	Intervention	Principal findings
	Mobile app	Accelerometer/ pedometer	Social media	Phone calls	Messaging/ email	Smartwatch	Website/ computer	Scale			
Rosas[17] (2020)	x	x			x				x	IG: Vida Sana intervention, which entailed a family-based orientation, 22 group sessions, use of activity tracker and its application, and MyFitnessPal (app/ website) to assess diet. CG: usual care (provided by primary care clinicians).	• Significant weight loss (5% body weight reduction) after 12 mo (P=.005) but not 2 years between arms (P=.93). • IG participants were significantly more likely to achieve 5% weight reduction. • No significant change in waist circumference, exercise, energy expenditure, and health-related problems/quality of life. • Attendance to sessions positively correlated with weight loss at 12 mo (P=.002).
Fukuoka[22] (2018)	x		x	x	x	x		x	x	Daily use of Fitbit (smartwatch, accelerometer) and its app (logged food/drink/calories and twice-weekly weigh-in), weekly social media group interaction (Facebook), and two 1-h (approximately) in-person counseling sessions. At 3-wk follow-up and 8-wk final visit, BMI, hip and waist circumference, and BP were measured.	• Significant loss of 3.3% (SD=3.4%) body weight (P<.0005), averaging a reduction of 2.4 kg (5.3 lb) (P<.0005). • Significant hip and waist circumference reductions (P<.0005). • Significant associated change in percent body weight with Diet tracking (p=.01) and change in IPAQ score (P=.03). • Significant systolic (P<.0005) and diastolic (P<.001) BP reductions.
Steinberg[11] (2020)	x				x					IG: Nutritionix (app) + DASH adherence tailored feedback text messages (week 1-2: daily, week 3+: weekly). CG: use of Nutritionix app.	• Both groups improved DASH scores (P<.001). However, no between-group differences on any nutritional component within the DASH diet. • No significant difference in app usage between groups (P=.54) • IG had a steeper reduction of tracking over time (about 1 d/mo faster) than the control group (P<.001). • No significant between-group differences of systolic (P=.23) and diastolic (P=.07) BP reductions.

Table 2b. Continued

First author (year)	Technology								In-person component	Intervention	Principal findings
	Mobile app	Accelerometer/ pedometer	Social media	Phone calls	Messaging/ email	Smartwatch	Website/ computer	Scale			
Trude[14] (2018)			x		x				x	Assess the impact of a childhood obesity intervention on their caregivers. Adults were directly targeted on social media (Facebook, Instagram) and received goal-setting text messages (3 times/wk).	• No significant change in caregiver food acquisition, home food preparation, and fruit/vegetable daily consumption. • Association between increase in daily food consumption by 0.24 servings for each point increase in exposure to the childhood obesity intervention (0.24±0.11; 95% CI, 0.04-0.47). • Social media exposure tripled daily fruit intake (3.16±0.92; 95% CI, 1.33-4.99) and (unexpectedly) unhealthy food acquisition (0.47±0.23; 95% CI, 0.02-0.93).

BMI, body mass index; BP, blood pressure; CG, control group; DASH, Dietary Approaches to Stop Hypertension; IG, intervention group; IQR, interquartile range; WG, wait-list control group

which used various mHealth and educational materials. The wait-list group solely received an accelerometer (Fitbit). In phase 2, the intervention group began a maintenance period while the wait-list group started the Fit&Trim intervention. Even though both groups achieved 5% weight reduction, 47% of the wait-list group vs 36% of the intervention group achieved this goal once starting the Fit&Trim program. Participants in the study by Persell et al[18] were provided with a BP monitor and assigned to either a coaching or tracking mobile application. This study yielded no significant change in weekly exercise. In the study by Rosas et al,[17] even though they found significant between-group 5% body weight reductions at 12 months, there was no significant difference at 24 months.

Nutritional Acquisition. Applications helping manage nutritional acquisition featured the following: vegetable and fresh produce–based recipes with pictures, culturally relevant recipes, healthy food tips on various topics (eg, grocery shopping), and the ability to view a list of vegetables to then access specific recipes. Steinberg et al[11] found that using a tracking app and Dietary Approaches to Stop Hypertension (DASH) diet adherence text messages did not help increase diet adherence compared with the app-only group.

Patel et al[13] randomized participants into a simultaneous weight + diet tracking or sequential weight then adding diet tracking intervention. They also provided action plans, which consisted of self-evaluating current behaviors and beliefs, to determine how to overcome foreseeable barriers. However, there were no significant between-group differences in weight reduction and tracking either diet or weight. Neffa-Creech et al[12] interviewed participants who consistently used a culturally tailored recipe app, VeggieBook. They found that those who frequently utilized the software were open to

Table 2c. Summary of key outcomes/risk and type of technology for physical activity

First author (year)	Technology									In-person component	Intervention	Principal findings
	Mobile app	Accelerometer/ pedometer	Social media	Phone calls	Messaging/ email	Smart-watch	Website	Bluetooth (enabled) BP monitor	Scale			
King[19] (2020)		x					x			x	Group 1: participants had a virtual advisor at their convenience, which was an animated and interactive computer-based character. Group 2: participants had a human advisor. They were community residents (30+ years or older) who were physically active providing advising. Both (IG and CG): received 28 (10-15 min) advising sessions throughout 12 mo.	• Increased steps for both the virtual advisor (539.8/d [IQR, −327 to 1600]) and human advisor (304.2/d [IQR, −987 to 1245]) groups. • The average total walking was 158.6 min/wk for the virtual advisor and 134.8 min/wk for the human advisor. • On average, group 1 consumed 3.2 h with the virtual advisor and group 2 spent 6.9 h with the human advisor.
Bender[15] (2018)	x		x			x				x	Phase 1 (1-3 mo)—IG: Fit&Trim intervention, which consisted of educational materials, using a Fitbit Zip (accelerometer), mobile app (diet and exercise tracker), and social media group (Facebook). WG: received Fitbit. Phase 2 (3-6 mo)—IG: 3-month maintenance period (in-person weigh-ins, 5 in-person coaching sessions, and independent tracking). WG: began Fit&Trim intervention.	• By study completion, both groups achieved 5% body weight reduction (IG=5.2%; WG=5.8%). • In phase 1, 36% of IG and 6% of WG participants achieved 5% body weight loss. • In phase 2, 47% of WG and 18% of IG participants achieved 5% body weight loss. • 90% of participants completed the intervention (feasibility).
Persell[18] (2020)	x							x			IG and CG were provided with a Bluetooth BP monitor to promote management of HPCP score and hypertension-related behaviors. However, the IG received a coaching (HPCP) and the CG a tracking app (OMCRON).	• No significant difference in self-reported minutes per week of exercise. • Not significant between-group difference in systolic (P=.16) and diastolic (P=.61) BP. • Significant difference in mean for self-confidence when managing BP score between IG and CG (P<.001).
Thomas[16] (2020)	x						x				IG: Weight Watchers + computer-based virtual reality program. Participants observed and guided the main character throughout the day (home, work, gym, and friend's gathering). CG: Weight Watchers online platform.	• Significant weight loss at 3 and 6 mo for both groups (P<.001). • No significant between-group difference in weight reductions at 3 mo (P>.085), but significant at 6 mo. IG (4.7±1.1 kg) lost almost as much as CG (2.6±1.1 kg). • No between-group difference on number of participants losing 5% of their body weight at 3 or 6 mo (P>.210).

Table 2c. Continued

First author (year)	Technology: Mobile app	Accelerometer/ pedometer	Social media	Phone calls	Messaging/ email	Smart-watch	Website	Bluetooth (enabled) BP monitor	Scale	In-person component	Intervention	Principal findings
Rosas[17] (2020)	x	x			x					x	IG: Vida Sana intervention, which entailed a family-based orientation, 22 group sessions, use of activity tracker and its application, and MyFitnessPal (app/website) to assess diet. CG: usual care (provided by primary care clinicians).	• Significant weight loss (5% body weight reduction) after 12 mo (P=.005) but not 2 years between arms (P=.93). • IG participants were significantly more likely to achieve 5% weight reduction. • No significant change in waist circumference, exercise, energy expenditure, and health-related problems/quality of life. • Attendance to sessions positively correlated with weight loss at 12 mo (P=.002).
Fukuoka[22] (2018)	x		x	x	x	x				x	Daily use of Fitbit (smartwatch, accelerometer) and its app (logged food/drink/calories and twice-weekly weigh-in), weekly social media group interaction (Facebook), and two 1-h (approximately) in-person counseling sessions. At 3-wk follow-up and 8-wk final visit, BMI, hip and waist circumference, and BP were measured.	• Significant hip and waist circumference reductions (P<.0005). • Significant loss of 3.3% (SD=3.4%) body weight (P<.0005), averaging a reduction of 2.4 kg (5.3 lb) (P<.0005). • Significant associated change in percent body weight with diet tracking (P=.01) and change in IPAQ score (P=.03). • Significant systolic (P<.0005) and diastolic (P<.001) BP reductions.
Joseph[20] (2021)	x	x			x						Assessed the feasibility of a research team developed app (Smart Walk) and text message combination to increase physical activity. The app was culturally tailored, and participants answered a preintervention and postintervention survey.	• Significant increase in physical activity, from 20 min/wk at baseline to 50 min/wk at 4 mo (r=0.503; P<.001) • Significant increase in self-regulation (r=0.397; P=.01) and behavioral capability (r=0.440; P=.004) • Significant decrease in self-efficacy (r=−0.364; P=.02). • No significant changes for outcome expectations (r=−.029; P=.87), familial social support (r=0.103; P=.55), and social support from friends (r=0.083; P=.62).

Table 2c. Continued

First author (year)	Technology: Mobile app	Accelerometer/ pedometer	Social media	Phone calls	Messaging/ email	Smart-watch	Website	Bluetooth (enabled) BP monitor	Scale	In-person component	Intervention	Principal findings
Collins[21] (2019)	x	x		x	x						IG: handout on the benefits of PA, text messaging 5 days per week (based on scripted counseling approach), and a biweekly 20-min motivational phone call per month, later moving to a phone call every 4 wk for 2 mo. CG: handout on the benefits of PA. Both: used the Striiv Band app to monitor pedometer.	• Significant within-group difference for aerobic (P<.0001) and strength training (P<.0001) exercise behaviors. However, there were no significant between-group differences. • Significant within-group differences in quality of life (physical functioning, bodily pain, general health, vitality, social functioning, emotional role, and mental health) (P<.031) but no between-group differences.

BMI, body mass index; BP, blood pressure; CG, control group; IG, intervention group; IQR, interquartile range; PA, physical activity

trying new recipes and frequently had their children get involved in food preparation.

Application Features

Application features included logbooks for various measures, notifications/reminders, information on health-related topics, adequate literacy level, language availability, tailored features, goal setting, personal profile pages, home page with central access, and ability to provide feedback. Applications tracked BP, total cholesterol, blood glucose, diet, physical activity, weight, medication adherence, sleep, and stress management. Studies provided health-related information by linking to outside sources, gathering specific information, or developing multimedia modules (eg, pictures, video).

Adjustable Features. Some studies tailored their applications based on the participant's input.[10,18] For example, Vu et al[10] developed an app to help participants understand their health scores by using a slider with the following colors: green, yellow, and red. This sliding scale was personalized based on a questionnaire earlier in the study (eg, different scale for participants who did or did not have hypertension). Persell et al[18] encouraged participants to retake their BP if an outlier value was recorded, and if the value was persistent, then to contact their medical provider. This personalized coaching was based on algorithms. Other coaching features were understanding barriers to adherence and tips on how to progress/achieve goals. For example, it was shown that visually impaired individuals may benefit from dual-tone features (eg, icons) and adequate space distribution.[10]

Cultural & Other Types of Tailoring. Culturally or locally tailored features included a focus group with input from community members or other key group(s) to design the application,[15,17,20] integrating health workers familiar with the beliefs and culture of the target population,[15] providing information on free local health screenings,[10] personalized feedback or reminders,[11,13,17,18,20,22] including discussion board forums,[20] multimedia modules narrated by a community spokesperson,[20] inspirational quotes,[20] reviewing of and integration of literature on target population,[20] and implementing individual semistructured interviews postintervention. The personal profile pages in the study by Joseph et al,[20] which produced significant increase in physical activity (20-50 min/wk), were inspired from various social media platforms (eg, Facebook), which allowed them to share select information (eg, age, neighborhood, brief biography). The same study[20] aimed to structure their application to emulate the social and behavioral elements of its target community. For example, they tailored the application to provide population-specific statistics while integrating pictures of diverse members of the African American community modeling the activity being discussed.

Other mHealth

Two of the studies featured virtual advisor (VA)[19] or virtual reality (VR)[16] interventions. The study by Thomas et al[16] had significant weight loss at the midpoint and end point of the intervention. However, no significant between-group differences existed between utilizing an app + computer-based VR program vs app-only. The VR experience followed Alex, a middle-aged white woman, throughout her day. The participant would be able to see role-modeled behavior and then be able to guide the character through the different scenes (home, work, gym, and gathering).

King et al[19] showed an increase in steps for a VA vs human advisor (HM) intervention, with the VA averaging more walking time. Contrastingly, the HM amounted to more counseling time. The VA was a character named Carmen whom the participants could interact with at their convenience by touching simple speech boxes. The VA (539.8/d [interquartile range (IQR), −327 to 1600]) had a greater increase in steps walked compared with the HA (304.2/d [IQR, −987 to 1245]. These results may be promising, but there was no report of any significant between-group differences of the means. Although the overall rating for support was higher in the HA group, findings suggest that the VA achieved the same outcomes as the HA intervention, but with less advisor time.

Discussion

Mobile health technologies present a feasible approach to reduce BP, improve nutrition, and increase physical activity among diverse US populations. This review found that of the 13 studies, most had significant cardiometabolic disease risk factor reduction or were associated with improved chronic disease self-management. Mobile applications were the most-used technology; features that were common included notifications, the ability to track various health outcomes, provided health information, goal-setting capabilities, and tailored features. Studies that selected commercially available applications seem to have done so purposefully. Although limited funding led a study[10] to produce an Android-only application, this approach assisted the research team in being able to quickly refine the software and see immediate improvements. Vu et al[10] suggested that sending reminders through the application may be more beneficial than utilizing another messaging system (ie, email). This may be particularly relevant for populations that may not have or do not frequently engage with another platform. In addition, Neffa-Creech et al[12] suggested that receiving actions plans, feedback, and skill training materials via email did not produce differences from those that received an app-only intervention.

Applications that were thoroughly tailored to the target populations have shown significant results. We speculate that participant and community-specific feedback may be a valuable tool to increase retention and efficacy. However, as seen in the study by Steinberg et al,[11] any feedback is not necessarily better than no feedback. They utilized an automated algorithm to provide feedback, which primarily consisted of the participant's name, their DASH diet adherence score from the day before, and its breakdown. They reported no significant between-group differences for a diet tracking app + DASH messages vs app-only interventions.

This systematic review has several strengths. First, this review offers a robust assessment of the application, feasibility, and efficacy of mHealth interventions in targeting cardiometabolic disparities. Ten studies had a 90% or more ethnic/racial minority sample, with 6 of these solely targeting one of these populations. This allowed for the assessment of studies that reflect the populations most affected by CVD. Most of the studies clearly stated their objectives, inclusion and exclusion criteria, and results; highlighted their respective limitations; and clarified potential sources of bias. Included studies were published within the last 3 years, which allows for a better understanding of current interventions and market applications. Finally, this was a carefully designed literature search that went in accordance with the PRISMA guidelines.[9] We do not comment on any of the interventions, but understanding this literature sets the ground to expand interventions shown to produce positive health outcomes.

Our work is not without limitations. First, meta-analysis of findings could not be completed due to studies often having different measures for their findings and drastically varying sample sizes of participants. Second, we did not gather sufficient data to draw conclusions for any specific health disparity population. Because 9 studies had samples that were at least 70% female, findings may not be generalizable to the male population. Similarly, results may not translate well across health disparity populations, US locations (5 studies were based in California), or smartphone software users. Due to small sample size and/or lack of control group, some studies found it difficult to interpret findings in other measures. Feasibility was assessed, primarily, through study completion, feedback, and participation. For example, Persell et al[18] were not able to detect systolic BP differences smaller than 5 mm Hg. The same study, which assessed an intervention consisting of a coaching vs tracking app with a BP monitor, reported that their machine learning software performed better with more users contributing data. In the Joseph et al[20] study, there was minimal usage of the discussion board feature. It is unknown whether other studies that had similar features had alike interactions. Ultimately, inconsistencies in how studies addressed feasibility and outcomes makes it difficult to draw specific and targeted conclusions regarding impacts on health overall.

Another main limitation seen in the studies stemmed from the short intervention lengths. Only 1 study[17] of the 13 was longer than 1 year, with most of them lasting 3-6 months (n=8). As evidenced in the study by Rosas et al,[17] long-term changes may not be sustainable after the 2-year mark. Other elements that may have influenced findings were due to most measures being self-reported and based on participant recall. Finally, Fukuoka et al,[22] in a study with a 100% Hispanic sample, found significant reduction of BP, hip and waist circumference, and body weight. However, they were able to identify that the sample was relatively acculturated. Incorporating acculturation scales may be a valuable instrument to help understand which interventions may be most helpful for certain populations.

Conclusions

Findings from our review show that mHealth may help reduce BP, improve nutritional acquisition, and increase physical activity in health disparity populations. The main limitations in our analysis of studies include small sample sizes, short intervention duration, and difficulty standardizing results between studies. Almost all interventions (n=11) utilized mobile applications, most integrating other mHealth and some in-person components. Most of the studies either assessed feasibility in these communities from the start or had to switch to examining feasibility from an initial examination of efficacy. Studies that specifically tailored their interventions to target communities seemed to have the most consistent and significant results. Further research is needed to fully understand the effects of mHealth on reducing CVD disparities in US populations experiencing health disparities.

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Conflict of Interest

No conflicts of interest reported by authors.

Author Contributions

Research concept and design: Cora-Cruz, Martin-Hammond, Purnell; Acquisition of data: Cora-Cruz, Wilson, Vargas, Thompson, Enenmoh, Goffe; Data analysis and interpretation: Cora-Cruz, Wilson, Vargas, Thompson, Enenmoh, Goffe, Martin-Hammond, Purnell; Administrative: Cora-Cruz, Wilson, Vargas, Thompson, Enenmoh, Goffe, Purnell; Manuscript draft: Cora-Cruz, Wilson, Vargas, Thompson, Enenmoh, Goffe, Purnell; Supervision: Purnell, Martin-Hammond.

References

1. Heron M. Deaths: leading causes for 2019. *Natl Vital Stat Rep*. 2021;70(9):1-114. July 2021. Last accessed June 21, 2022, from https://pubmed.ncbi.nlm.nih.gov/34520342/
2. Virani SS, Alonso A, Aparicio HJ, et al. Heart disease and stroke statistics—2021 update: a report from the American Heart Association. *Circulation*. 2021;143(8):e254-e743. https://doi.org/10.1161/CIR.0000000000000950
3. Chareonrungrueangchai K, Wongkawinwoot K, Anothaisintawee T, Reutrakul S. Dietary factors and risks of cardiovascular diseases: an umbrella review. *Nutrients*. 2020;12(4):1088. https://doi.org/10.3390/nu12041088
4. Fiuza-Luces C, Santos-Lozano A, Joyner M, et al. Exercise benefits in cardiovascular disease: beyond attenuation of traditional risk factors. *Nat Rev Cardiol*. 2018;15(12):731-743. https://doi.org/10.1038/s41569-018-0065-1
5. Virani SS, Alonso A, Benjamin EJ, et al. Heart disease and stroke statistics—2020 update: a report from the American Heart Association. *Circulation*. 2020;141(9):e139-e596. https://doi.org/10.1161/CIR.0000000000000757
6. Mazimba S, Peterson PN. *JAHA* spotlight on racial and ethnic disparities in cardiovascular disease. *J Am Heart Assoc*. 2021;10(17):e023650. https://doi.org/10.1161/JAHA.121.023650
7. Muncan B. Cardiovascular disease in racial/ethnic minority populations: illness burden and overview of community-based interventions. *Public Health Rev*. 2018;39:32. https://doi.org/10.1186/s40985-018-0109-4
8. Agnihothri S, Cui L, Delasay M, Rajan B. The value of mHealth for managing chronic conditions. *Health Care Manag Sci*. 2020;23(2):185-202. https://doi.org/10.1007/s10729-018-9458-2
9. Page MJ, Moher D, Bossuyt PM, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ*. 2021;372: n160. https://doi.org/10.1136/bmj.n160
10. Vu M, Nguyen V, Vishwanath S, Wolfe C, Patel S. Know your numbers: creation and implementation of a novel community health mobile application (app) by student pharmacists. *J Am Pharm Assoc (2003)*. 2018;58(2):191-198.e2. https://doi.org/10.1016/j.japh.2017.11.003
11. Steinberg DM, Kay MC, Svetkey LP, et al. Feasibility of a digital health intervention to improve diet quality among women with high blood pressure: randomized controlled feasibility trial. *JMIR Mhealth Uhealth*. 2020;8(12):e17536. https://doi.org/10.2196/17536
12. Neffa-Creech D, Clarke P, Evans SH, Glovinsky J. "Food is something everyone should

participate in": a positive deviance approach to understanding the use of a food and nutrition app in low-income, Latino homes. *SAGE Open Med*. 2020;8:2050312120934842. https://doi.org/10.1177/2050312120934842
13. Patel ML, Hopkins CM, Brooks TL, Bennett GG. Comparing self-monitoring strategies for weight loss in a smartphone app: randomized controlled trial. *JMIR Mhealth Uhealth*. 2019; 7(2):e12209. https://doi.org/10.2196/12209
14. Trude AC, Surkan PJ, Anderson Steeves E, Pollack Porter K, Gittelsohn J. The impact of a multilevel childhood obesity prevention intervention on healthful food acquisition, preparation, and fruit and vegetable consumption on African-American adult caregivers. *Public Health Nutr*. 2019;22(7):1300-1315. https://doi.org/10.1017/S1368980018003038
15. Bender MS, Cooper BA, Flowers E, Ma R, Arai S. Filipinos Fit and Trim—a feasible and efficacious DPP-based intervention trial. *Contemp Clin Trials Commun*. 2018;12:76-84. https://doi.org/10.1016/j.conctc.2018.09.004
16. Thomas JG, Goldstein CM, Bond DS, Hadley W, Tuerk PW. Web-based virtual reality to enhance behavioural skills training and weight loss in a commercial online weight management programme: the Experience Success randomized trial. *Obes Sci Pract*. 2020;6(6):587-595. https://doi.org/10.1002/osp4.451
17. Rosas LG, Lv N, Xiao L, et al. Effect of a culturally adapted behavioral intervention for Latino adults on weight loss over 2 years: a randomized clinical trial. *JAMA Netw Open*. 2020;3(12): e2027744. https://doi.org/10.1001/jamanetworkopen.2020.27744
18. Persell SD, Peprah YA, Lipiszko D, et al. Effect of home blood pressure monitoring via a smartphone hypertension coaching application or tracking application on adults with uncontrolled hypertension: a randomized clinical trial. *JAMA Netw Open*. 2020;3(3):e200255. https://doi.org/10.1001/jamanetworkopen.2020.0255
19. King AC, Campero MI, Sheats JL, et al. Effects of counseling by peer human advisors vs computers to increase walking in underserved populations: the COMPASS randomized clinical trial. *JAMA Intern Med*. 2020;180(11):1481-1490. https://doi.org/10.1001/jamainternmed.2020.4143
20. Joseph RP, Ainsworth BE, Hollingshead K, Todd M, Keller C. Results of a culturally tailored smartphone-delivered physical activity intervention among midlife African American women: feasibility trial. *JMIR Mhealth Uhealth*. 2021; 9(4):e27383. https://doi.org/10.2196/27383
21. Collins TC, Lu L, Valverde MG, Silva MX, Parra-Medina D. Efficacy of a multi-component intervention to promote physical activity among Latino adults: a randomized controlled trial. *Prev Med Rep*. 2019;16:100965. https://doi.org/10.1016/j.pmedr.2019.100965
22. Fukuoka Y, Vittinghoff E, Hooper J. A weight loss intervention using a commercial mobile application in Latino Americans—Adelgaza trial. *Transl Behav Med*. 2018;8(5):714-723. https://doi.org/10.1093/tbm/ibx039