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RESEARCH ARTICLE

Effects of a Digital Diabetes Prevention Program: An RCT

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Introduction: In light of the need to expand the reach and access of clinically proven digital Diabetes Prevention Programs (d-DPPs) and the need for rigorous evidence of effectiveness, the purpose of this study was to determine the effectiveness of a digital Diabetes Prevention Program for improving weight, HbA1c, and cardiovascular risk factors among people with prediabetes compared to enhanced standard care plus waitlist control.

Study Design: This was a single-blind RCT among participants at risk of developing type 2 diabetes and included 12 months of follow-up.

Setting/Participants: A total of 599 volunteer patients with prediabetes were recruited primarily through electronic medical records and primary care practices.

Intervention: Participants were randomized to either a d-DPP (n=299) or a single-session small-group diabetes-prevention education class (n=300) focused on action planning for weight loss. The d-DPPs consisted of 52 weekly sessions, lifestyle coaching, virtual peer support, and behavior tracking tools.

Main Outcome Measures: The primary outcome was a change in HbA1c from baseline to 12 months using intent-to-treat analyses. On the basis of multiple comparisons of endpoints, 95% CIs are presented and 2-sided p<0.025 was required for statistical significance. Secondary outcomes included body weight and cardiovascular disease risk factors.

Results: Among 599 randomized participants (mean age=55.4 years, 61.4% women), 483 (80%) completed the study. The d-DPPs produced significantly greater reductions in HbA1c (0.08%, 95% CI= −0.12, −0.03) and percentage change in body weight (−5.5% vs −2.1%, p<0.001) at 12 months. A greater proportion of the d-DPPs group achieved a clinically significant weight loss ≥5% (43% vs 21%, p<0.001), and more participants shifted from prediabetes to normal HbA1c range (58% vs 48%, p=0.04). Engagement in d-DPPs was significantly related to improved HbA1c and weight loss.

Conclusions: This d-DPPs demonstrated clinical effectiveness and has significant potential for widespread dissemination and impact, particularly considering the growing demand for telemedicine in preventive healthcare services.

Trial Registration: This study is registered at www.clinicaltrials.gov (ClinicalTrials.gov Identifier: NCT03312764).

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INTRODUCTION

In light of the success of the landmark Diabetes Prevention Program (DPP)[1] and subsequent efforts to translate diabetes prevention to community settings, federal policy has supported large-scale DPP dissemination. The Centers for Disease Control and Prevention (CDC) National DPP created public−private partnerships and a system to recognize DPPs in communities across the U.S.[2] In addition, the Centers for Medicare and Medicaid Services established the Medicare Diabetes Prevention Program (MDPP) as a covered benefit.[3] Despite these large-scale investments, evidence suggests that among U.S. adults at high risk for diabetes, only half reported receiving any diabetes risk-reduction advice or referral, and of those receiving advice/referral, only 34% reported participating in a weight loss program, and 40% reported participating in DPP.[4] Thus, the current DPP infrastructure is underutilized, and more methods that increase access and engagement are needed.[4−7]

Numerous studies have tested adaptations that utilize remote technologies to translate the DPP.[8−10] Digital DPPs (d-DPPs) have ranged from teleconferencing, interactive voice recognition, text messaging, mobile applications, web-based systems, wearable and connected devices, and DVDs.[10] Although much heterogeneity exists in terms of technology, sample sizes, and duration of the intervention (e.g., 12 weeks to 2 years), meta-analyses concluded that the average effect of d-DPPs is approximately 4.0% loss of original body weight.[8,10] It has been noted that this literature is plagued by (1) patchwork combinations of remote technologies; (2) a dearth of evidence testing d-DPPs in specific subpopulations, such as older adults; and (3) the inconsistent effects of d-DPPs on HbA1c.[8,9,11−13] The range of HbA1c changes reported in a recent meta-analysis of 15 trials testing technology-mediated diabetes prevention interventions was −0.1% to −0.4%.[8] By contrast, another meta-analysis that included 10 technology-based DPPs found no significant effects on blood glucose control.[12] As such, although the costs of in-person DDPs can be covered within the MDPP, it does not currently allow for digital suppliers owing to a lack of rigorous evidence.

In light of the need to expand the reach and access of clinically proven DPPs, the growing interest in remotely delivered options, and the need for rigorous evidence of effectiveness for policy development, the purpose of the Preventing Diabetes Through Digital Coaching for Translation and Scalability Trial (PREDICTS) was to determine the clinical effectiveness of a scalable, commercially available d-DPP to reduce HbA1c, body weight, and cardiovascular risk factors among people with prediabetes. In addition, because of the importance of MDPP support to widespread dissemination, this study also sought to test this d-DPP in a subgroup of participants aged ≥65 years.

METHODS

This was a single-blind RCT among participants with prediabetes. Trial methods and protocol have been described in detail elsewhere.[14,15] Briefly, participants were identified through electronic health records within the Nebraska Medicine health system, initially contacted by telephone, and screened for a nonfasting HbA1c in the prediabetes range (5.7%−6.4% [39−46 mmol/mol]).[16] Initially, a point of care (POC) HbA1c test (A1CNow+, Professional Multi-test HbA1c system; Polymer Technology System, Inc., Wycombe, United Kingdom) was utilized, but a high proportion of false-positive results (compared with that of a laboratory-derived HbA1c) emerged in the first 6 months of the trial. The protocol was amended following the accrual of 254 participants (42% of the total sample), 116 (46%) of which had an HbA1c test outside the prediabetic range (113 had HbA1c <5.7%; 3 had HbA1c >6.4%).[15] The amendment removed POC screening and determined eligibility with an HbA1c result from a venipuncture blood sample. The sample size was increased from 498 to 599 to ensure a minimum analyzable sample of adults with prediabetes confirmed by laboratory-derived HbA1c. No other changes were made to the protocol.[15] After confirmation of study eligibility and completion of baseline data collection, participants were randomized to either the d-DPP or to an enhanced standard care, small-group education (SGE) class focused on diabetes prevention and action planning for weight loss.[17] Outcome measurements were repeated at 4 and 12 months. The research protocol was approved by the University of Nebraska Medical Center IRB and the Western IRB, and all participants gave written informed consent. The study was registered at www.clinicaltrials.gov (NCT03312764).

Study Sample

Details regarding the recruitment process have been reported previously.[15] Participants were eligible if they were aged ≥19 years (legal adult age in Nebraska), had a BMI ≥25 kg/m^2 (≥22 kg/m^2 if participant self-identified as Asian), and had baseline HbA1c in the prediabetic range (5.7%−6.4% [39−46 mmol/mol]). In addition, participants had to

1. be medically stable (i.e., no uncontrolled hypertension or hyperlipidemia, no current treatment for cancer, no concurrent thyroid or untreated metabolic condition, not a current candidate for bariatric surgery or concurrent antiobesity or antidiabetes therapy);
2. be capable of consent;
3. be willing to be randomized; and
4. have regular access to e-mail and internet.

Individuals were excluded if they (1) were diagnosed with diabetes, congestive heart failure, coronary artery disease, chronic obstructive pulmonary disease, pulmonary hypertension, chronic kidney disease, or dementia; (2) had an unstable cardiac disease or untreated thyroid disease; (3) were taking oral hypoglycemic agents or other medications known to produce weight loss or weight gain; (4) participated in a concurrent weight management program or on a prescribed medical diet; (5) could not engage in physical activity, as determined by the primary care provider; (6) had antiobesity or antidiabetes therapy within the preceding 4 months, had bariatric surgery within the past 3 years, or were planning surgery within the next 12 months; (7) had cancer (other than skin cancer) in the last 5 years; (8) had any mental health condition that would preclude participation; and (9) were currently pregnant or 6 weeks postpartum.

Recruitment aimed to enroll at least 20% of participants aged ≥65 years to allow for age-based subgroup analysis. A multistep population health management process for detection, outreach, and screening was established to enroll study participants.[15] Recruitment took place between December 2017 and April 2019.

Each eligible participant was randomized to d-DPP or SGE using block randomization of variable sizes conducted by trained study staff. Randomization was stratified by age (<65 years/≥65 years) and biological sex, and assignment was made using a web-based randomization system.

The d-DPP (the Omada Health Program) is fully recognized by CDC Diabetes Prevention Recognition Program. The program includes an initial 16-week intensive curriculum focusing on weight loss, followed by a 36-week curriculum focusing on weight maintenance, with a total of 12 months of novel lessons. Using internet-enabled devices (laptop, tablet, or smartphone), participants asynchronously completed the weekly, interactive behavior change curriculum lessons; engaged in private, asynchronous messages with a trained lifestyle health coach; engaged in asynchronous discussions with a virtual peer group (20−30 participants); tracked meals; monitored weight with a wireless scale; and tracked physical activity with connected wearable devices.[14] Participants could use their own wearable device (e.g., Fitbit, Apple Watch) or pedometers were provided on request. Health coaches facilitated group interaction by group discussion boards (approximately 2 group discussion posts per week), contacting participants through secure messaging to provide feedback and advice during key moments (approximately 1−3 direct messages per week), and reinforcing lesson content.

Enhanced standard care was used as a comparison group owing to the lack of consistent availability of diabetes prevention opportunities for patients at Nebraska Medicine. The comparison arm consisted of a 1-time, 2-hour diabetes prevention education class consisting of 12−18 participants, led by a health educator or graduate student with training in nutrition, physical activity, and diabetes prevention strategies. The class included detailed information on current recommendations for physical activity and healthy food choices involving portion size, eating regular meals, and a well-balanced diet based on My Plate recommendations and the development of a personal action plan to prevent diabetes.[14,17,18] The action plan included documenting personally motivating reasons for weight loss to prevent diabetes; physical activity, eating, and weight loss goals; barrier identification and resolution; and developing plans for follow-up with people in the participant's social network. This enhanced care intervention has shown modest and sustained weight loss in similar populations.[17]

Measures

The primary outcome was a change in HbA1c from baseline to 12 months. Secondary outcomes included change in weight, the proportion of participants that lost ≥5% of initial weight, improvement in diabetes risk categories, and changes in blood lipids and blood pressure (BP). All study measures were collected by staff blinded to study group assignment at each assessment point (baseline, 4 months, and 12 months) at the University of Nebraska Medical Center in a 4-week assessment window. Sociodemographic information and health literacy were only collected at baseline. HbA1c was assessed using nonfasting blood samples. Blood was collected by venipuncture and processed by a central diagnostic testing laboratory at the University of Nebraska Medical Center and cardiovascular disease (lipids panels) with the boronate affinity analytical technique. Blood pressure was collected with an automated, calibrated BP monitor with a self-inflating cuff (HEM-757, Omron Healthcare, Inc., Kyoto, Japan). Participants were asked to remain seated for a quiet resting period of 5 minutes before measurements were conducted. Height was measured in stocking feet with a calibrated stadiometer with a fixed vertical backboard and adjustable headboard. Weight was measured with a calibrated medical grade scale in stocking feet, with the participant in the fasting stage.

Weekly engagement in the d-DPP was defined as a week where (1) weight was logged, (2) a lesson was completed, and (3) there was ≥1 coach/group interaction or meal logged. Total weeks of engagement were then summed across the 52-week program. Adverse events (AEs) were documented at 4-month and 12-month visits using a standard interview conducted by blinded study staff. Additional AEs were automatically retrieved from electronic health records or reported to d-DPP health coaches and relayed to study nurse coordinators for documentation and evaluation. The blinded study safety officer adjudicated all AEs.

Statistical Analysis

Power was calculated for an estimated effect size of −0.2% reduction in HbA1c from baseline to 12 months; this assumed a −0.2% reduction in d-DPP and 0.0% reduction in SGE. Using a conservative estimated SD of 0.7[14] and 80% power, the investigators determined that a final analyzable sample of 193 participants per group (386 total) would be needed. Assuming an attrition rate of 20%, the adjusted sample size was set to 241 per group (482 total). As part of the amendment to remove POC eligibility HbA1c testing, the sample size was increased to 599 to ensure a minimum analyzable sample of 386 with confirmed laboratory-derived HbA1c prediabetes.

Demographics and baseline clinical values are summarized by mean (SD) and frequency (%) and assessed for differences using 2 sample *t*-tests for continuous variables and Fisher's exact tests for categorical variables. Between-group differences were evaluated using a repeated measures linear mixed model. Covariates included baseline outcome value, stratification factors sex and age, group, time (4 and 12 months), and group X time interaction. Random effects accounted for repeated time points with an unstructured covariance. Adjusted least-square means (95% CIs) were obtained from the models, and Bonferroni adjustments were utilized for 2 post hoc comparisons between groups at 4 and 12 months, with 2-sided $p<0.025$ deemed statistically significant for each. All primary analyses were conducted as intent to treat.

Differences in the proportion of participants losing ≥5% of baseline weight and movement from prediabetes to normal HbA1c range were assessed using Fisher's exact tests at each time; marginal RRs were calculated with corresponding 95% CIs. To explore results among the Medicare-eligible population, post hoc models were constructed to examine primary outcomes by age categories. To examine the relationships between engagement and outcomes for the d-DPP group, Pearson correlations were calculated to assess the relationship between total weeks of engagement with HbA1c and weight. AEs were summarized by counts and the number of participants affected by group and assessed for differences using Fisher's exact tests.

Sensitivity analyses were performed to verify that results were robust to covariance structure, outcome measured as change from baseline versus raw values, those with laboratory assessments done within the protocol window, those A1c eligible at baseline, and differences in pre and postamendment populations. Restricted maximum likelihood estimation was used to incorporate missing data under a missing at random assumption, and all participants with ≥1 follow-up assessment were included in the analysis; however, missing data sensitivity analyses were performed by a data augmentation algorithm combined with Markov chain Monte Carlo with 100 imputations (Appendix Table 1, available online). Characteristic differences between subjects attending all visits and those missing ≥1 visit are detailed in Appendix Table 2 (available online). All analyses were conducted with R, version 3.6.1, and RStudio, version 1.1.456.

RESULTS

On average, participants were aged 55.4 (SD=12.7) years and weighed 102.9 (SD=21.0) kg at baseline. Average baseline HbA1c was 5.8% (SD=0.3%) or 39.3 mmol/mol (SD=3.3 mmol/mol); 56% had elevated triglycerides (>150 mg/dL), and 36% had high total cholesterol (>200 mg/dL). The study sample was 61% female and 91% White. Participants were less likely to be from racial and ethnic minority groups (10%) than the electronic health record–eligible patients (15%) or the broader metropolitan region (25%) and generally had higher levels of educational attainment and higher incomes. Descriptively, the demographic characteristics of the study sample were representative of the patient population, although not representative of the region (i.e., 12% and 15% of Omaha residents are Latinx or Black).[15]

Baseline characteristics were balanced between groups (Table 1). Figure 1 displays the CONSORT diagram. Retention at 12 months was >80%. The original screening protocol resulted in enrolling 113 participants (19% of the total sample) who had normal HbA1c (<5.7%) and 3 participants (0.5% of the total sample) with HbA1c in the diabetic range (>6.4%) confirmed using a laboratory-analyzed blood draw. In addition, there were differences between those enrolled before and after the change in screening protocol, including weight, sex, HbA1c, and BP (Appendix Table 3, available online).

At 12 months, the d-DPP participants reduced HbA1c by an average of −0.23% (95% CI= −0.26, −0.20) compared with −0.16% (95% CI= −0.19, −0.12) for SGE ($p=0.001$) (Figure 2A and Table 2). The between-group difference in change in HbA1c was −0.08 (95% CI= −0.12, −0.04). This equates to −2.52 mmol/mol (95% CI= −2.89, −2.16) for the d-DPP compared with −1.70 mmol/mol (95% CI= −2.07, −1.33) for SGE. The d-DPP participants lost an average of −5.49% of initial body weight (95% CI= −6.20, −4.78) compared with −2.09% (95% CI= −2.82, −1.37) for SGE ($p<0.001$) (Figure 2B and Table 2). The between-group difference in change in percentage weight loss was −3.40% (95% CI= −4.36, −2.43). A greater proportion of the d-DPP group achieved *clinically significant weight loss*, defined as ≥5% weight loss (RR=1.61, 95% CI=1.36, 1.91, $p<0.001$). More participants in the d-DPP group shifted from the HbA1c prediabetes range to normal range at 12 months (RR=1.22, 95% CI=1.01, 1.46, $p=0.04$) (Figure 2C and D).

Changes in cardiovascular risk factors are displayed in Table 2. Cholesterol/high-density lipoprotein cholesterol (HDL) ratio was significantly lower at 12 months for d-DPP with an average reduction of −0.41 (95% CI= −0.50, −0.33) than for SGE at −0.24 (95% CI= −0.32, −0.15, $p=0.002$). HDL was higher at 12 months for d-DPP at +2.24 mg/dL (95% CI=1.41, 3.07) vs +0.37 mg/dL (95% CI= −0.46, 1.21) for SGE ($p=0.001$). No other cardiovascular disease risk factors demonstrated significant change by condition at 12 months.

The median weeks of active engagement for the d-DPP were 17 weeks (IQR=9–35); 54% of d-DPP participants had ≥17 weeks of active engagement. Higher engagement was correlated with greater weight loss ($r=-0.47$, $p<0.001$) and reduction in HbA1c ($r=-0.20$, $p=0.002$) at 12 months.

Participants aged ≥65 years in the d-DPP saw significantly greater HbA1c reduction of −0.25% (95% CI= −0.29, −0.20) than −0.11% (95% CI= −0.16, −0.06) in the SGE group or of −2.69 mmol/mol (95% CI= −3.21, −2.16) in the d-DPP group than −1.23 mmol/mol (95% CI= −1.77, −0.70) in the SGE

Table 1. Baseline Characteristics Across Groups

Variables	Total sample (N=599)	d-DPP (*n*=299)	SGE (*n*=300)
Age (years), mean (SD)	55.4 (12.7)	55.3 (12.9)	55.6 (12.6)
Senior (aged ≥65 years), *n* (%)	157 (26.2)	80 (26.8)	77 (25.7)
Weight (kg), mean (SD)	102.9 (21.0)	101.8 (19.0)	103.9 (22.8)
BMI (kg/m^2), mean (SD)	36.0 (6.4)	35.8 (6.1)	36.1 (6.6)
HbA1c, %, mean (SD)	5.8 (0.3)	5.8 (0.3)	5.8 (0.2)
HbA1c, mmol/mol, mean (SD)	39.3 (3.3)	40.1 (3.0)	40.1 (3.2)
HbA1c, *n* (%)			
<5.7% (<39 mmol/mol)	113 (18.9)	57 (19.1)	56 (18.7)
5.7%–6.4% (39–46 mmol/mol)	483 (80.6)	240 (80.3)	243 (81.0)
>6.4% (>46 mmol/mol)	3 (0.5)	2 (0.7)	1 (0.3)
Sex, *n* (%)			
Male	231 (38.6)	115 (38.5)	116 (38.7)
Female	368 (61.4)	184 (61.5)	184 (61.3)
Race (could select >1), *n* (%)			
White	542 (90.5)	273 (91.3)	269 (89.7)
African American	39 (6.5)	16 (5.4)	23 (7.7)
Hispanic	19 (3.2)	7 (2.4)	12 (4.0)
Asian	6 (1.0)	4 (1.3)	2 (0.7)
Other	10 (1.7)	4 (1.3)	6 (2.0)
Education level, *n* (%)			
Some high school	3 (0.5)	0 (0.0)	3 (1.0)
High school graduate	76 (12.7)	37 (12.4)	39 (13.0)
Some college, vocational, technical	184 (30.8)	98 (32.9)	86 (28.8)
College graduate	185 (31.0)	97 (32.6)	88 (29.4)
Postgraduate	149 (25.0)	66 (22.1)	83 (27.8)
Income, *n* (%)			
<$35,000	96 (16.4)	48 (16.4)	48 (16.3)
$35,000–$49,999	69 (11.8)	38 (13.0)	31 (10.5)
$50,000–$74,999	122 (20.8)	61 (20.9)	61 (20.7)
$75,000–$99,999	92 (15.7)	46 (15.8)	46 (15.6)
≥$100,000	208 (35.4)	99 (33.9)	109 (36.9)
Systolic BP (mmHg), mean (SD)	128.6 (15.1)	128.6 (16.0)	128.6 (14.1)
Diastolic BP (mmHg), mean (SD)	79.5 (10.7)	79.8 (11.1)	79.1 (10.2)
Cholesterol (mg/dL), mean (SD)	189.0 (36.7)	187.9 (36.2)	190.2 (37.3)
LDL (mg/dL), mean (SD)	102.8 (32.1)	102.8 (31.6)	102.9 (32.7)
HDL (mg/dL), mean (SD)	49.2 (12.5)	48.5 (11.4)	50.0 (13.5)
Triglycerides (mg/dL), mean (SD)	195.7 (115.9)	190.9 (104.0)	200.5 (126.6)

BP, blood pressure; d-DPP, digital Diabetes Prevention Program; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SGE, small group education.

group (p<0.001) (Appendix Table 4, available online). Older participants lost −5.83% of initial body weight (95% CI= −6.86, −4.80), significantly more than the −2.07% (95% CI= −3.12, =1.01) in the SGE arm (p<0.001).

During the trial, 149 AEs were reported; 24 were classified as serious AEs (SAEs). Most SAEs were musculoskeletal (19%) and surgical (35%), and 1 was for low BP secondary to weight loss. A total of 13 SAEs were deemed unrelated to the study, 6 SAEs were determined to be possibly related to the study, and 5 had insufficient information to make a determination. The 6 possibly related AEs were equally balanced between groups, and there was also no difference in the number of events with unknown classification, with 3 in d-DPP and 2 in SGE (Appendix Table 5, available online).

DISCUSSION

This study tested the clinical effectiveness of a d-DPP ready for rapid and widespread dissemination. After

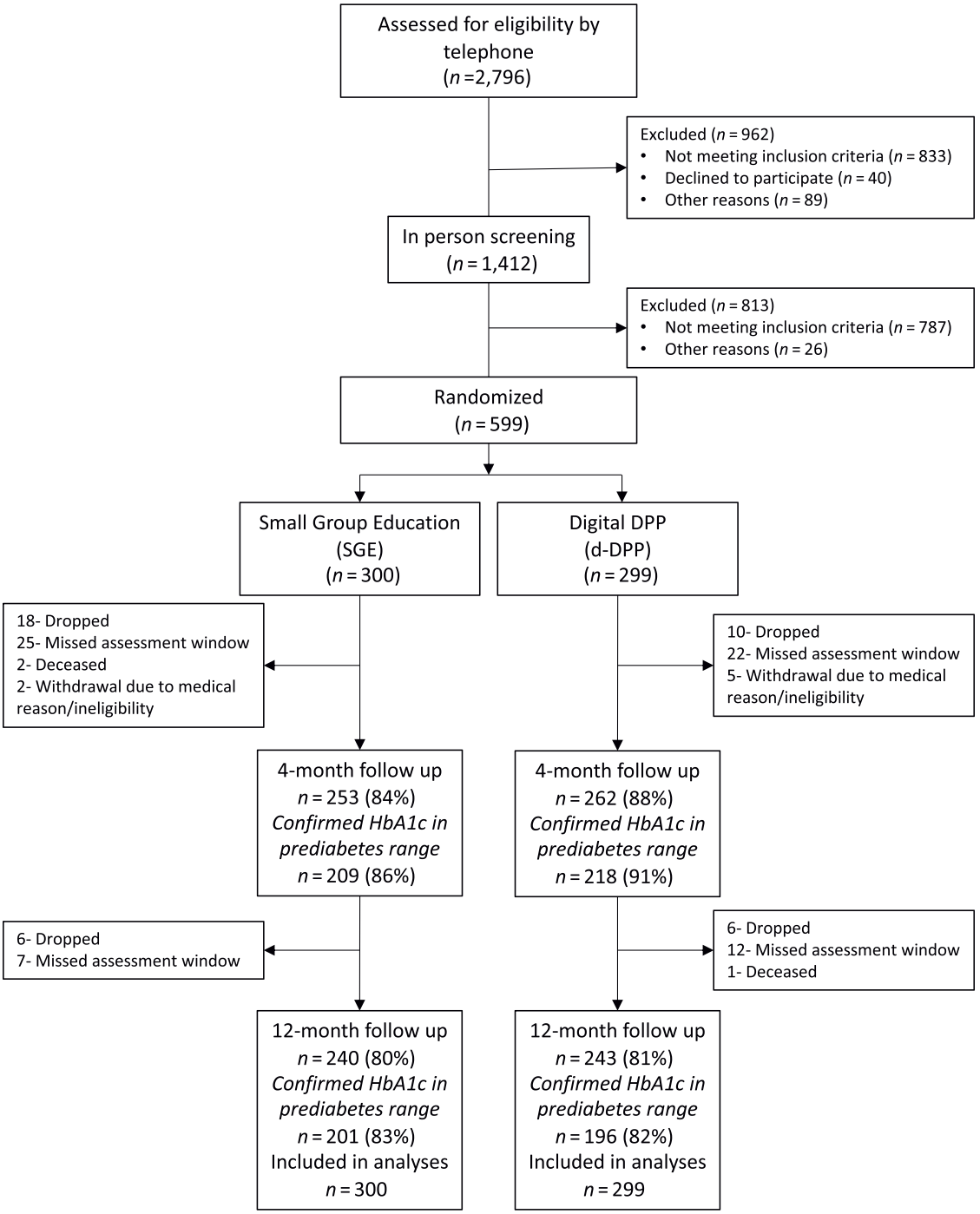

Figure 1. CONSORT diagram describing the study design and participant flow through the trial.

1 year, the d-DPP resulted in significantly greater reductions in HbA1c (−0.23%, −0.82 mmol/mol), body weight (−5.5%, −5.5 kg), HDL, and total cholesterol/HDL ratio than SGE. The d-DPP participants were 61% more likely than SGE participants to lose clinically meaningful body weight (≥5%) at 12 months. These results illustrate that the d-DPP produced a significant and clinically beneficial reduction in the risk factors for type 2 diabetes and are robust with respect to missing data sensitivity analyses.

This findings compare favorably with past research. Meta-analyses of both in-person and technology-based DPPs reported a mean effect on weight loss of about 4%[9,10,19]; the National DPP database shows an

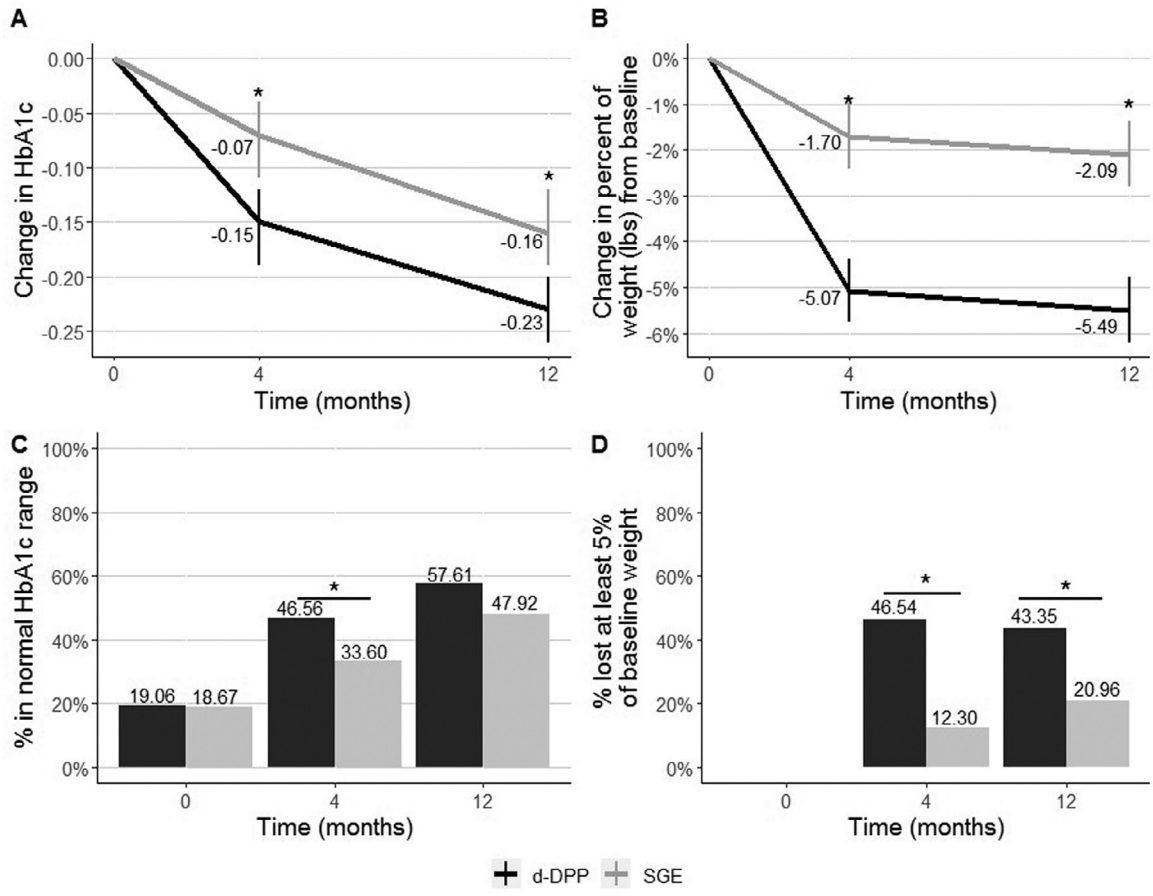

Figure 2. Changes in study outcomes and categories by randomization group and time.
Note: Figure 2A shows the estimated model mean HbA1c (%) change from baseline with 95% CIs by randomization group and time. Figure 2B shows the estimated model mean percent weight change from baseline with 95% CIs by randomization group and time. Model adjusted for baseline weight, randomization group, repeated measurements by time (4 and 12 months), interaction of group by time, and baseline stratification factors of age (≥65 years) and sex. Figure 2C shows the proportion of participants who had HbA1c levels in the normal range (<5.7%) over time. Figure 2D shows the proportion of participants that lost at least 5% of their baseline weight over time. *Asterisk* indicates $p<0.025$ for statistical significance between groups at each time point (Bonferroni correction). Model adjusted for baseline HbA1c value, randomization group, repeated measurements by time (4 and 12 months), interaction of group by time, and baseline stratification factors of age (≥65 years) and sex.
d-DPP, digital Diabetes Prevention Program; SGE, small group education.

average of 4.2% weight loss.[20] Other studies testing d-DPPs have reported reductions of HbA1c ranging from −0.1%[21] to −0.4%.[8,9,11,22] Data from the National DPP database also show an average engagement in 14 sessions across in-person programs, compared with 17 in this study.[20] However, it should be noted that the National DPP defines *engagement* as sessions attended, whereas this study defined *engagement* as a week where weight was recorded, a lesson was completed, and there was ≥1 coach/group interaction or meal logged. To the authors' knowledge, PREDICTS is the largest RCT to show significant reductions in HbA1c, body weight, and cardiovascular risk factors from a d-DPP and to show substantive engagement.

Limitations

The findings of this study must be interpreted in the context of several limitations. One limitation of the study is that although the comparison group received more care than what is typical for patients with prediabetes, it was not a direct comparison with an in-person DPP. However, the purpose of this study was not to show superiority to or equivalence with in-person approaches to diabetes prevention. Rather, the purpose was to show effectiveness relative to care one would typically receive in the community. Moreover, the relative utility of comparative effectiveness among DPPs is debatable; both in-person and digital formats are acceptable by national standards, and people should be given choice for the modality that best fits their needs.

Table 2. Estimated Mean Changes in HbA1C, Percentage Change in Body Weight, and Cardiovascular Risk Factors

Outcomes and time	d-DPP (*n*=299), mean (95% CI)	SGE (*n*=300), mean (95% CI)	Difference between groups, mean (95% CI)	*p*-Value[a]
HbA1c—change from baseline (%)				
4-month change	−0.15 (−0.19, −0.12)	−0.07 (−0.11, −0.04)	−0.08 (−0.12, −0.04)	**<0.001**
12-month change	−0.23 (−0.26, −0.20)	−0.16 (−0.19, −0.12)	−0.08 (−0.12, −0.03)	**0.001**
HbA1c—change from baseline (mmol/mol)				
4-month change	−1.68 (−2.03, 1.32)	−0.81 (−1.18, −0.45)	−0.86 (−1.35, −0.38)	**<0.001**
12-month change	−2.52 (−2.89, −2.16)	−1.70 (−2.07, −1.33)	−0.82 (−1.32, −0.32)	**0.001**
Body weight— change from baseline (%)				
4-month change	−5.07 (−5.76, −4.38)	−1.70 (−2.41, −0.99)	−3.37 (−4.31, −2.43)	**<0.001**
12-month change	−5.49 (−6.20, −4.78)	−2.09 (−2.82, −1.37)	−3.40 (−4.36, −2.43)	**<0.001**
Body weight—change from baseline (kg)				
4-month change	−5.14 (−5.89, −4.39)	−1.71 (−2.48, −0.94)	−3.43 (−4.45, −2.41)	**<0.001**
12-month change	−5.52 (−6.30, −4.75)	−2.18 (−2.97, −1.39)	−3.34 (−4.39, −2.29)	**<0.001**
Cholesterol (mg/dL)				
4-month change	−9.89 (−12.84, −6.95)	−8.21 (−11.22, −5.19)	−1.69 (−5.69, 2.31)	0.41
12-month change	−10.53 (−13.56, −7.49)	−10.00 (−13.07, −6.93)	−0.53 (−4.65, 3.59)	0.80
Cholesterol/HDL ratio				
4-month change	−0.25 (−0.33, −0.17)	−0.13 (−0.21, −0.05)	−0.12 (−0.22, −0.01)	0.04
12-month change	−0.41 (−0.49, −0.33)	−0.24 (−0.32, −0.15)	−0.18 (−0.29, −0.07)	**0.002**
HDL (mg/dL)				
4-month change	0.10 (−0.91, 0.80)	−0.49 (−1.31, 0.34)	0.59 (−0.51, 1.68)	0.29
12-month change	2.24 (1.41, 3.07)	0.37 (−0.46, 1.21)	1.86 (0.74, 2.99)	**0.001**
LDL (mg/dL)				
4-month change	−1.86 (−4.60, 0.88)	−3.89 (−6.74, −1.04)	2.03 (−1.73, 5.79)	0.29
12-month change	−6.88 (−9.70, −4.06)	−4.97 (−7.86, −2.09)	−1.90 (−5.76, 1.95)	0.33
Triglycerides (mg/dL)				
4-month change	−40.51 (−50.67, −30.35)	−23.96 (−34.35, −13.56)	−16.55 (−30.38, −2.73)	**0.02**
12-month change	−35.04 (−45.52, −24.57)	−30.20 (−40.80, −19.61)	−4.84 (−19.07, 9.40)	0.51
Systolic BP (mmHg)				
4-month change	−2.01(−3.66, −0.35)	0.25 (−1.46, 1.95)	−2.25 (−4.53, 0.03)	0.05
12-month change	0.15 (−1.58, 1.88)	−0.92 (−2.66, 0.82)	1.07 (−1.29, 3.43)	0.38
Diastolic BP (mmHg)				
4-month change	−1.43 (−2.62, −0.23)	−0.47 (−1.72, 0.77)	−0.96 (−2.62, 0.70)	0.26
12-month change	−3.71 (−4.97, −2.45)	−3.96 (−5.23, −2.69)	0.25 (−1.47, 1.97)	0.78

Note: Boldface indicates statistical significance ($p<0.025$).
All models adjusted for respective baseline value, randomization group, repeated measurements by time (4 and 12 months), interaction of group by time, and baseline stratification factors of age (≥65 years) and sex.
BP, blood pressure; d-DPP, digital Diabetes Prevention Program; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SGE, small group education.
[a]Bonferroni correction.

Although the comparison group involved far less intensive contact than the d-DPP, the SGE participants experienced small improvements in body weight and HbA1c (85% attended the in-person class; 13% received materials by mail). It is plausible that awareness of pre-diabetes status and participation in a clinical trial resulted in increased attention to nutrition, physical activity, and weight control in SGE participants. It could also be that as a pragmatic study of the SGE intervention without intensive follow-up found,[17] some people may not need intensive intervention to achieve a significant change in weight and HbA1c status. The small improvements in the SGE also speak to the need for RCTs of d-DPP to determine the true magnitude of the impact of the interventions and potentially examine studies that align participant characteristics with the interventions

that most efficiently support weight loss and reductions in HbA1c.

The shift from POC prediabetes screening that resulted in enrollment of 116 participants in the normal range to screening using laboratory testing was a limitation of this study. However, study outcomes were robust in both intention-to-treat (full sample of 599) and per-protocol analyses of laboratory-confirmed prediabetes only (n=483) (Appendix Tables 6–9, available online, and Appendix Figure 1, available online). Another limitation is that although the sample was representative of the local hospital system patient population, it was predominately White and relatively highly educated. Similarly, participants were required to have internet access to be enrolled in the study. Thus, generalization to more diverse populations is limited. However, a clinical trial ran concurrently to PREDICTS and tested the same d-DPP among a low-income, bilingual, ethnically diverse sample and documented significant engagement and improvements in body weight.[23] Furthermore, recent data[24] suggest that 93% of all Americans use the internet and that there is little variation across racial/ethnic groups. Of those aged 50–64 years, 96% report using the internet, and 79% have home broadband access.[24] Although there are certainly socioeconomically disadvantaged individuals that would require assistance to participate in this d-DPP, this study provides much-needed evidence to support reimbursement policies to provide such assistance. Finally, cardiovascular disease risk was not an eligibility requirement. As such, the sample was close to the normal range at baseline; the floor effect may explain less opportunity for movement across the cardiovascular disease outcomes.

Future research is needed to further understand the potential of this d-DPP for implementation and scalability. Additional research is needed that includes larger, more diverse samples, such as marginalized and underserved individuals, as well as diverse geographic locations, levels of urbanization, and types of healthcare systems. Similarly, additional research is needed that further examines the factors that impact health system adoption, implementation, and maintenance of this approach. Because this study included only 12 months of follow-up, further research is needed to determine the long-term effects of this approach on diabetes incidence. In addition, a cost-effectiveness analysis of this d-DPP is needed to fully understand the implications of this approach for reimbursement policies.

CONCLUSIONS

The coronavirus disease 2019 (COVID-19) pandemic in 2020 brought an unprecedented surge in telehealth.[25] People with cardiometabolic risk factors are also at greater risk for COVID-19 complications and are therefore a key population for virtual healthcare delivery to maintain social distancing and reduce community exposure to potential virus transmission. In-person MDPP providers were given guidance by CDC and Centers for Medicare and Medicaid Services to mitigate service disruptions by supplementing with virtual or digital offerings.[26] The MDPP also temporarily relaxed regulations to allow current suppliers to deliver virtual sessions, even though fully virtual providers who are arguably more experienced in remote delivery are still not eligible to be suppliers.[27] These results show that virtual DPP providers can produce clinical benefit at par with in-person delivery and that the magnitude of benefit is larger among Medicare-eligible adults. These results coupled with the capacity for scale and sustainability highlight the great potential for virtual d-DPP.

The d-DPP (and SGE) was offered to study participants at no cost; this mirrors the current approach of offering the program as a covered healthcare benefit as recommended by the Institute for Clinical and Economic Review.[28] Most in-person DPPs are offered at no cost to the participant, with program fees charged to the healthcare payer.[29] Health economic analyses show that in-person DPPs are at least cost neutral[30] and cost saving,[31] which strongly supports payer's return on investment in this preventive service. With the MDPP payment model insufficiently covering the cost of in-person services[32] and the current supply of in-person MDPP providers insufficient to meet the need,[31] leveraging technology and opening access to digital DPPs may solve the demand for suppliers while offering older adults a more accessible format.

Because telehealth is proving to be an acceptable, sustainable mechanism for delivery of many preventive healthcare services, the positive results of this trial should reassure policymakers that digital DPP is a reliable and valid mechanism to produce diabetes prevention benefits. It has never been more important to deliver preventive services at scale than now when in-person access and reach are limited, and resources are constrained.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2021.10.023.

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