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## Uptake, retention, and outcomes of the National Diabetes Prevention Program by enrollee characteristics and program type

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### Abstract

**Aims:** To describe National Diabetes Prevention Program (NDPP) uptake, retention, and outcomes by enrollee characteristics and program type.

**Methods:** We studied 776 adult University of Michigan employees, dependents, and retirees with prediabetes and overweight or obesity who enrolled in one of four CDC-recognized NDPPs at no out-of-pocket cost. Programs included 1) an in-person classroom-based program led by certified diabetes educators in an endocrinology outpatient clinic; 2) an in-person classroom-based program led by trained peer instructors in community settings; 3) an in-person fitness-focused program led by trained lifestyle coaches; and 4) an online digital program led by personal health coaches with virtual group meetings. Data from the insurer and surveys were analyzed.

**Results:** Older individuals with hypertension and cardiovascular disease were more likely to enroll in classroom-based programs. Program time, location, and perceived focus on diet or physical activity influenced program selection. Retention, weight loss, and physical activity were greater among enrollees in in-person classroom-based programs. Changes in blood pressure, lipid

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#### Author Contributions

W.H.H. researched the data, wrote the manuscript, and reviewed and edited the manuscript. K.L.J. and C.V. contributed to the discussion and reviewed and edited the manuscript. L.N.M. researched the data, performed statistical analyses, assisted in writing the manuscript, contributed to the discussion, and reviewed and edited the manuscript. W.H.H is the guarantor of this work and as such, had full access to all of the data in the study and takes responsibility for the integrity of the data and accuracy of the data analysis.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Duality of Interest

No potential conflicts of interest were reported.

#### Prior Presentation

None

levels, self-rated health, and health-related quality-of-life did not differ by program, nor did Type 2 diabetes mellitus incidence.

**Conclusions:** Individuals with prediabetes who enrolled in a NDPP achieved health benefits regardless of the type of program they chose.

### Keywords

Prospective observational study; Prediabetes; Type 2 diabetes mellitus; Prevention

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## 1. Introduction

In 2002, the Diabetes Prevention Program clinical trial demonstrated that an intensive behavioral lifestyle intervention that employed a low-fat, calorie-restricted diet and moderate physical activity reduced the incidence of Type 2 diabetes mellitus by 58% over 2.8 years in adults  $\geq 25$  years of age with BMI  $\geq 24$  kg/m<sup>2</sup>, elevated fasting glucose, and impaired glucose tolerance [1]. Based upon these findings, the Centers for Disease Control and Prevention (CDC) launched the National Diabetes Prevention Program (NDPP) to provide high-quality lifestyle change programs to people with prediabetes to reduce their risk of Type 2 diabetes mellitus and improve their overall health [2]. Between 2012 and 2020, over 2,000 CDC-recognized programs enrolled over 450,000 adults with prediabetes in the 1-year NDPP [3]. Between 2012 and 2016, 36% of enrollees achieved 5% weight loss and 42% reported at least 150 min of physical activity per week [4].

CDC-recognized lifestyle change programs differ in their format (in-person vs. online), leaders (medical personnel vs. trained peer leaders), and locations (hospital vs. community-settings). To date, CDC has not systematically described the characteristics of individuals with prediabetes who elected to participate in the various types of programs, assessed NDPP retention by program type, or reported outcomes according to participant-level characteristics and the types of programs in which the participants enrolled.

The purpose of this study was to describe and compare the baseline characteristics of individuals with prediabetes who enrolled in one of four different CDC-recognized NDPPs with distinct formats, leaders, and locations and to describe and compare program retention and 1- and 2-year outcomes according to the type of NDPP selected. The results are important to understand participant preferences, retention, and outcomes to better connect participants to programs and optimize their outcomes.

## 2. Subjects, materials and methods

### 2.1. Study setting

The University of Michigan is a large, public, research university in Ann Arbor, Michigan, with satellite campuses in Flint and Dearborn, Michigan. Beginning in 2015, the university offered the NDPP at no out-of-pocket cost to university employees, dependents, and retirees  $\geq 18$  years of age who had prediabetes and overweight or obesity and who were enrolled in the university's self-funded health insurance program. The university selected four programs fully-recognized by CDC to provide the NDPP: 1) a health system-based program which

provided in-person classes led by certified diabetes educators in an endocrinology outpatient clinic in Ann Arbor (health system); 2) a community-based program offered by a not-for-profit voluntary health organization which provided in-person classes led by trained peer instructors in community settings across southeastern Michigan (including Dearborn and Flint) (community); 3) a program offered by a not-for-profit charitable organization which provided in-person classes led by trained lifestyle coaches in a fitness facility in Ann Arbor (fitness-focused); and 4) an online digital program which provided flexibly-timed online classes and virtual group meetings led by personal health coaches (online). In some settings, the community-based program offered access to wellness centers. The fitness-focused program offered enrollees family memberships to the facility which included free fitness classes and free childcare. The online program provided wearable activity trackers and digital scales.

## 2.2. Study population

We identified 64,131 university employees, dependents, and retirees 18 years of age without evidence of Type 1 or Type 2 diabetes mellitus and identified 8,131 of them (12.7%) as having prediabetes and overweight or obesity based on health plan records [5]. Prediabetes was defined by either a health plan claims diagnosis of prediabetes or a hemoglobin A1c (HbA1c) level of 5.7 to 6.4% (39 to 46 mmol/mol). Overweight or obesity were defined by BMI  $\geq 25.0$  kg/m<sup>2</sup> ( $\geq 23.0$  kg/m<sup>2</sup> for Asians). Individuals were excluded if they had histories of Type 1 or Type 2 diabetes mellitus. Individuals with prediabetes were identified and encouraged to enroll in a NDPP as previously described [5,6]. This study focused on the 776 people with prediabetes and overweight or obesity who enrolled in a NDPP between August 2015 and July 2019 and attended at least one session.

## 2.3. Data collection

We used data from the health plan, including data collected from NDPP providers, and data from surveys of enrollees to describe the characteristics of adults with prediabetes who enrolled in a NDPP [5,6]. Demographic (age, sex, race, and zip code) and clinical variables (body mass index (BMI), blood pressure, lipids, HbA1c, and medical history) were obtained from the health plan. Baseline values were defined as the last values recorded before the date of enrollment in a NDPP. One-year and 2-year follow-up values of clinical variables were defined as the last reported values in the time interval between the date of NDPP enrollment plus 365 days and between the date of enrollment plus 366 to 730 days, respectively. We defined incident Type 2 diabetes mellitus on the basis of HbA1c and self-report. The 1-year incidence of Type 2 diabetes mellitus based on HbA1c was calculated as the number of enrollees with HbA1c values  $\geq 6.5\%$  (48 mmol/mol) measured during year 1 divided by the number of enrollees who had at least one HbA1c value measured during year 1 multiplied by 100. The 2-year incidence of Type 2 diabetes mellitus was calculated as the number of enrollees with HbA1c values  $\geq 6.5\%$  (48 mmol/mol) during year 1 or year 2 divided by the number of enrollees who had at least one HbA1c value measured during year 1 or 2 multiplied by 100.

We classified residential address zip codes as being within or outside the city of Ann Arbor and merged zip codes with data from the U.S. Census Bureau and the National

Neighborhood Data Archive (NaNDA) to describe neighborhood indicators of median household income, percent unemployment, percent of families receiving Supplemental Nutrition Assistance Program (SNAP) benefits, and to describe neighborhood access to public transportation, internet, and social services [7–10]. NaNDA is available through the U-M Institute for Social Research Survey Research Center at [nanda.isr.umich.edu](http://nanda.isr.umich.edu).

Information provided by the NDPPs to the health plan was used to calculate the percentages of enrollees who completed specific numbers of sessions, the mean number of sessions attended, weights, percent weight loss, and physical activity minutes. Three of the four programs assessed reported weight as measured with a calibrated scale at the in-person visit and reported by the enrollee at each session and physical activity minutes by self-report. The online program used digital scales that directly uploaded the weight each week. The online program used wearable fitness trackers to measure physical activity and estimated that 250 steps were equivalent to one minute of vigorous physical activity.

We also surveyed NDPP enrollees at baseline, 1 year, and 2 years [6,11]. We mailed surveys to all 776 enrollees and received 532 completed surveys (69% crude response rate). When we excluded those who had died, opted out of the research, or could not be contacted because of incorrect addresses, the adjusted response rate was 74%. As previously reported, there were only minor differences between survey respondents and non-respondents at baseline [6]. The surveys assessed clinical and social variables, reasons for choosing specific NDPP programs, and self-reported progression to Type 2 diabetes mellitus at 1 and 2 years follow-up [6]. Progression to Type 2 diabetes mellitus was ascertained with the survey question “Have you been diagnosed with diabetes?”. Clinical variables included self-rated health, EQ-5D-5L-derived health utility scores, and the EQ-5D visual analog scale [12]. Social variables included full or part-time employment and affiliation with the university as an employee, retiree, or dependent. Reasons for choosing a specific program included convenience (class time and location), groups of people attending the program (family, coworkers, or friends), and perceived focus of the program on diet or physical activity.

#### 2.4. Data analysis

We compared the baseline characteristics of adults with prediabetes and overweight or obesity who enrolled in each of the four NDPPs using t-tests for continuous variables and chi-square tests for categorical variables. Changes in risk factors (BMI, blood pressure, lipids, and HbA1c) were calculated by subtracting baseline values provided by the health plan from 1-year and 2-year values. Changes in weight were calculated by subtracting the first values recorded by the NDPP program from the last values recorded at or before the 6-month and 1-year timepoints. Weekly minutes of physical activity was assessed as the mean of up to the last three non-missing non-zero values of self-reported or fitness tracker assessed minutes of physical activity at 6 month and 12 month visits. The percent of people with at least 150 min of physical activity per week at six and twelve months was calculated as the proportion with mean minutes of physical activity  $\geq 150$  per week.

We assessed program retention among enrollees as the percentage of enrollees who attended the program at a given week divided by the number of enrollees who attended during the first week of the program multiplied by 100. A participant was considered to be retained

through a given week if he or she attended a session that week or during a subsequent week [3]. We also assessed the number of core sessions and maintenance sessions attended. Core sessions were defined as any sessions numbered 1 through 16 that were attended during the first 168 days after enrollment. Using this variable, we calculated the mean and median number of core sessions attended and the number and percent of enrollees who attended at least 75% (12 of 16) of the core sessions. Maintenance sessions, offered at least monthly, were defined as any sessions numbered 17+ that were attended between 112 days and 425 days of enrollment. Using this variable, we calculated the mean and median number of maintenance sessions attended and the number and percent of enrollees who attended at least 75% (6 of 8) of the maintenance sessions. Since the online virtual sessions were “unlocked” weekly and could be accessed at any time after they were unlocked, we calculated attendance of maintenance sessions as completing at least one session numbered 17+ in each 28-day period between 112 days and 425 days.

All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

## 2.5. Human subjects approval

The study was reviewed and approved by the University of Michigan Institutional Review Board for Human Research (HUM#00108065) and was granted a waiver of documented informed consent. Study participants were mailed informed consent documents with the surveys and the return of a completed survey was considered to indicate consent.

## 3. Results

There were 776 individuals with prediabetes and overweight or obesity who enrolled in the NDPP (Table 1). NDPP enrollees were  $53 \pm 10$  years of age (mean  $\pm$  SD); 72% were women, and 82% were white. Most (86%) had made at least one primary care provider visit in the past year and 70% had visited a specialist. Mean BMI was  $34.1 \pm 7.0$  kg/m<sup>2</sup>. Blood pressure and lipids were generally well-controlled. Mean HbA1c was  $5.9 \pm 0.3\%$  ( $41 \pm 0$  mmol/mol). Medical claims diagnoses for overweight/obesity, hypertension, and dyslipidemia were common. More than one-third of participants (36%) were receiving antihypertensive medications and approximately one-quarter (24%) were receiving lipid lowering medications. Only 2% of participants had health plan claims diagnoses for smoking and 8% had claims diagnoses for cardiovascular disease.

Of the 776 NDPP enrollees, 277 (36%) enrolled in the health system program, 45 (6%) in the community program, 206 (27%) in fitness-focused program, and 248 (32%) in the online program (Table 1). In general, enrollees in the in-person classroom-based health system and community programs were older than enrollees in the fitness-focused and online programs (Table 1). There were no differences in the sex or race distributions of enrollees in the individual programs although men tended to be more likely to enroll in the fitness-focused and online programs and whites tended to be more likely to enroll in the classroom-based health system and community programs. Mean BMI levels did not differ by program. Systolic blood pressure was lowest in fitness-focused enrollees. This may in part reflect the younger ages of those enrollees. Diastolic blood pressure, lipid, and HbA1c levels did not differ across programs. Enrollees in the classroom-based health system and

community programs were more likely to have made at least one primary care provider visit in the past year and to have claims diagnoses for hypertension and cardiovascular disease, perhaps related to their older ages. Individuals who lived in Ann Arbor were more likely to enroll in the health system and fitness-focused programs which were offered in Ann Arbor. Enrollees in the community program were more likely to live in neighborhoods with lower median neighborhood incomes, higher percentage unemployment, and higher percentage of individuals receiving federal Supplemental Assistance Program (SNAP) benefits. Those who enrolled in the community program were also the least likely to live in households with internet subscriptions and computing devices. Individuals who enrolled in the fitness-focused program were the most likely to have available public transit and social services, perhaps related to the fact that those enrollees were more likely to live in the city of Ann Arbor which provides many social services.

We used surveys to further assess the characteristics of enrollees and their program preferences (Table 1). Eighty-seven percent of NDPP enrollees were university employees; only 13% were dependents or retirees. University of Michigan employment status was not associated with program selection. Enrollees were significantly more likely to choose the health system and community programs based on “convenient location” and the online program based on “convenient time”. Enrollees were most likely to choose the fitness-focused program because of “people attending” and its perceived “focus on activity” and the health system program because of its perceived “focus on diet”. Program enrollees did not differ by self-reported health or by health-related quality-of-life as assessed by the EQ-5D-5L and its visual analog scale (Table 1).

In general, attendance during the core phase of the NDPP was good: 73% of enrollees attending at least 75% of core sessions in the first 6 months (Table 2). Attendance for the core sessions was greatest for the health system program (81% attending 75% of core sessions) followed by the community program (78%) and the online program (77%). Attendance of the core sessions was lowest for the fitness-focused program (58%). Forty-seven percent of enrollees attended at least 75% of maintenance sessions in the last 8 months. Attendance of at least 75% of maintenance sessions was greatest for the community program (69%), intermediate for the fitness-focused (48%) and health system program (46%) and lowest for the online program (43%). This might be due in part to differences in the way attendance was calculated for the online program. Overall, the median numbers of core and maintenance sessions attended were 14 and 5, respectively. The median number of core sessions attended was greatest for the online enrollees (16), followed by the community (15), health system (14), and fitness-focused programs (13). Attendance of maintenance sessions was greatest for community program enrollees (7), followed by health system (5) and fitness-focused (5), and online program enrollees (4).

As previously described, overall retention was good among NDPP enrollees (median number of sessions attended 18, median retention 38 weeks) with 77% retained through 18 weeks and 40% retained through 44 weeks [11]. Fig. 1 shows enrollee retention by program and week. Retention in the community program at 44 weeks was better, but not significantly better, than the health system program (OR 1.61 (95% CI 0.95, 2.74)). Retention in the fitness-focused program was somewhat worse (OR 0.79 (95% CI 0.62, 1.01)) and retention

in the online program was significantly worse than in the health system program (OR 0.61 (95% CI 0.49, 0.77)). When we considered the in-person classroom-based health system and community programs together and compared retention in them to retention in the fitness-focused and online programs, retention was significantly worse for the fitness-focused (OR 0.75 (95% CI 0.59, 0.95) and online programs (OR 0.58 (95% CI 0.47, 0.72)).

Table 3 shows changes in body weight and physical activity at 6 months and 12 months by program. Average percent weight loss at 6 months was  $4.1\% \pm 4.6\%$  and at 12 months was  $4.8\% \pm 5.5\%$ . Thirty-seven percent of enrollees achieved 5% weight loss at 6 months and 44% achieved the CDC goal of 5% weight loss at 12 months. Nine percent of enrollees achieved 10% weight loss at 6 months and 15% achieved 10% weight loss at 12 months. Fifty-six percent reported 150 min of physical activity per week at 6 months and 63% at 12 months.

In general, percent weight loss at 12 months was greatest in community program enrollees ( $7.9\% \pm 6.6\%$ ), intermediate in health system program enrollees ( $5.0\% \pm 5.4\%$ ), and least in the online ( $4.3\% \pm 5.4\%$ ), and fitness-focused program enrollees ( $4.3\% \pm 5.0\%$ ). Percent weight loss was greater for men than women ( $5.9\%$  vs  $4.4\%$  at 12 months respectively,  $p = 0.0060$ ) and men were more likely to achieve 5% and 10% weight loss at 12 months (50% of men and 41% of women achieved 5% weight loss at 12 months,  $p = 0.0442$ , and 23% of men and 12% of women achieved 10% weight loss at 12 months,  $p = 0.0022$ ). The percentage of enrollees who reported 150 min of physical activity per week at 12 months was greater for enrollees in the in-person community (73%), fitness-focused (70%), and health system (64%) programs, and least for enrollees in the online program (47%). Men were more likely than women to report 150 min of physical activity at 6 months but there was no difference at 12 months (at 6 months 67% of men and 52% of women reported achieving the physical activity goal,  $p = 0.0008$ , and at 12 months 59% of men and 65% of women reported achieving the physical activity goal,  $p = 0.3773$ ).

Table 3 summarizes the 1- and 2-year changes in risk factors and outcomes for NDPP enrollees overall and stratified by NDPP provider. Overall, there was a decrease in BMI of  $1.2 \pm 2.4 \text{ kg/m}^2$  at 1 year. The reduction in BMI was greatest among participants in the community program ( $-2.3 \pm 2.1 \text{ kg/m}^2$ ) followed by the health system program ( $-1.3 \pm 2.4 \text{ kg/m}^2$ ), the online program ( $-1.0 \pm 2.6 \text{ kg/m}^2$ ), and the fitness-focused program ( $-0.9 \pm 2.2 \text{ kg/m}^2$ ). There were also improvements in systolic and diastolic blood pressure, lipid profiles, and HbA1c. The improvements in these risk factors did not differ among the enrollees in the four programs. The reduction in BMI persisted at 2 years ( $-0.6 \pm 2.7 \text{ kg/m}^2$ ) and remained significantly greater in those who had enrolled in the community, health system, and online programs compared to the fitness-focused program. Improvements in diastolic blood pressure, total cholesterol, HDL cholesterol, triglycerides, and LDL cholesterol persisted with no differences among enrollees in the different programs. At 1 year and 2 years, 8% and 11% of participants reported being diagnosed with Type 2 diabetes mellitus. Incident Type 2 diabetes mellitus tended to be less frequently reported among community program enrollees at 1 year and 2 years but the differences among enrollees in the different programs were not statistically significant.

There were only slight changes in health-related quality-of-life overall. Most participants had no change in self-rated health at 1 year or 2 years. EQ-5D-5L scores were unchanged although nearly half of participants (45% at 1 year and 46% at 2 years) indicated at least a 3-point increase in their health-related quality-of-life as assessed by the EQ-5D visual analog scale. There were no differences in the change in health-related quality-of-life as assessed by the EQ-5D visual analog scale among enrollees in the different programs.

#### 4. Discussion

We observed clearcut differences in the characteristics of enrollees who participated in the four NDPP programs offered by their employer at no out-of-pocket cost. Enrollees in the in-person classroom-based health system and community programs were older than enrollees in the fitness-focused and online programs. Enrollees in the community and health system programs were also more likely to have received medical care in the past year as evidenced by at least one visit to a primary care provider, claims diagnoses for hypertension and cardiovascular disease, and treatment for hypertension. The latter findings may in part reflect their older ages. Enrollees in the health system and community programs were more likely to report choosing these programs based on their convenient locations. Those who enrolled in the community program were least likely to live in households with internet subscriptions and computing devices. Enrollees in the online program were more likely to report choosing it because of its flexible time. Enrollees were most likely to choose the fitness-focused program because of other people attending the program and its perceived focus on physical activity. Individuals who lived in Ann Arbor were more likely to enroll in the fitness-focused and health system programs which were offered only in Ann Arbor. Enrollees who chose the health system, community, fitness-focused, and online programs did not differ by self-reported health or health-related quality-of-life.

Retention also varied by program (Fig. 1). Despite having the greatest attrition before week 16, the community program had the highest retention at week 44. The health system and fitness-focused programs had slightly greater late attrition than the community program. The difference in longer-term retention between the community program and the health system and fitness-focused programs must be interpreted with caution because of the small number of enrollees in the community program. The online program had substantial attrition between weeks 16 and 20 but thereafter, had better retention. Some of the difference in retention between the in-person programs and the online program may be related to differences in how retention was assessed. Other studies have, however, suggested that retention is lower, and outcomes are worse among enrollees in programs that do not provide in-person contact [13,14].

The CDC reported that between 2012 and 2016, 36% of NDPP enrollees nationwide achieved the weight loss goal of  $\geq 5\%$  at 1 year and 42% met the physical activity goal of 150 min per week [4]. In our study, 44% of enrollees achieved the 5% weight loss goal and 63% reported achieving the physical activity goal. Weight loss and physical activity at 1 year differed across the programs. The percentage of NDPP enrollees achieving  $\geq 5\%$  weight loss at 1 year was 71% for community program enrollees, 45% for health system enrollees, 40% for online enrollees, and 38% for fitness-focused enrollees. In contrast, 73%



of the community, 70% of the fitness-focused, 64% of the health system, and 47% of online program enrollees achieved the physical activity goal.

Older age has previously been associated with greater NDPP retention [3] and greater retention has been associated with greater weight loss [4]. This may explain the greater weight loss among community program and to a lesser extent health system program enrollees. Although prior studies have reported greater weight loss among NDPP enrollees who were white than among participants who were Hispanic or Asian, we did not observe differences in percent weight loss by race [4]. Men were more likely than women to achieve both the weight loss and physical activity goals. These differences in outcomes by sex have been described for the NDPP [4]. The fact that men were more likely to select the fitness-focused program and the fact that enrollees perceived that the program had a greater focus on physical activity may also explain the higher percentage of fitness-focused program enrollees who achieved the physical activity goal. The lower percentage of online program enrollees achieving the physical activity goal may be related to differences in how physical activity was assessed. However, lower self-reported physical activity for the online program enrollees may also be related to the higher attrition as attrition has been associated with less self-reported physical activity [4].

A recent *meta*-analysis of 63 studies that tested lifestyle modification strategies for Type 2 diabetes mellitus prevention examined weight loss outcomes according to the intervention strategy, provider type, and delivery setting of the programs. Programs were classified as including group education from healthcare professionals in clinical settings, group education from community members in community settings, and education/counseling delivered remotely using technology. The weight loss observed in group education programs in clinical settings led by healthcare professionals was 1.1 kg (95% CI -2.3, 0.1 kg). Weight loss in group education programs in community settings led by community members was -2.1 kg (95% CI -3.1, -1.0 kg). Education/counseling using remote technology was associated with a 0.1 kg weight loss (95% CI -2.8, 2.5 kg). Only the programs that employed group interventions in community settings led by community members achieved significant weight loss [15].

In our study, enrollees in the community program conducted by peer instructors in community settings had the best outcomes. This suggests that trained non-medical personnel are effective intervention delivery agents potentially achieving similar or even better weight loss outcomes. Interestingly, we found that participants in the community program likely had lower socioeconomic position than enrollees in other NDPPs based on geocoding data. Both Cannon et al. [3] and Galaviz [15] reported that racial minority groups and those with lower socioeconomic position had lower NDPP retention and less favorable outcomes. In contrast, a survey of NDPP lifestyle coaches reported that lower-income groups were more likely to report having motivation and family support as facilitators to NDPP participation and adherence compared to higher-income groups [16,17]. Despite historically lower participation and poorer outcomes among minority populations, it is possible that community program enrollees were more motivated and able to achieve greater weight loss. They may have also benefited from the fact that programs were offered in their communities and led by trained peer instructors.

Despite differences in the likelihood that enrollees in the four NDPPs achieved the CDC weight loss and physical activity goals, we saw improvements in blood pressure, lipid, and HbA1c levels across programs and did not observe differences among programs at 1 year or 2 years. Few previous studies have reported HbA1c outcomes among NDPP participants, and those that did, did not demonstrate significant improvements in HbA1c [15]. We also found no differences in self-rated health across programs at 1 and 2 years but found that almost one-half of enrollees indicated at least a 3-point increase in the EQ-5D visual analog scale for health-related quality-of-life at 1 year and 2 years. Previous research suggests that a 3-point change is clinically significant [18].

In this study, we also found that despite differences in the achievement of weight loss and physical activity goals by enrollees across the four programs, the incidence of Type 2 diabetes mellitus did not differ by NDPP program at 1 or 2 years. Type 2 diabetes mellitus incidence was 8% at 1 year and 11% at 2 years, without significant differences among the programs. Previously, we demonstrated that after adjusting for age group, sex, and race, NDPP enrollees with prediabetes reduced their incidence of Type 2 diabetes mellitus by 40% at 1 year and 20% at 2 years compared to non-enrollees based on HbA1c criteria, and by 57% at 1 year and 46% at 2 years based on self-report [11].

Our study has limitations. First, program uptake was low. Although our total study population was smaller than previous studies of the NDPP [4], retention was good and we were able to describe differences in outcomes by program type. Second, there was heterogeneity in the assessment of retention and physical activity. Fortunately, the CDC has established standard procedures for program evaluation as a condition for accreditation as NDPP program providers that accommodate various methods of physical activity assessment [19]. Third, although enrollees were free to choose the NDPP in which they enrolled, relatively few enrolled in the community program. This may have resulted in both limited power to detect associations and spurious chance associations. Finally, the generalizability of our results may be limited as this study was performed with a single employer group with limited diversity.

In summary, our results suggest that enrollees in in-person programs are more likely to achieve the CDC weight loss and physical activity goals than enrollees in the online program. We also confirmed that weight loss outcomes are noninferior or even better in group interventions led by trained community members in community settings. Finally, we found that when provided a choice of NDPPs in which to enroll, individuals with prediabetes and overweight or obesity can achieve overall Type 2 diabetes mellitus prevention regardless of the program type or delivery method of the NDPP in which they enroll. The challenge remains to increase the diagnosis of and awareness of prediabetes at a population level and to increase program enrollment.

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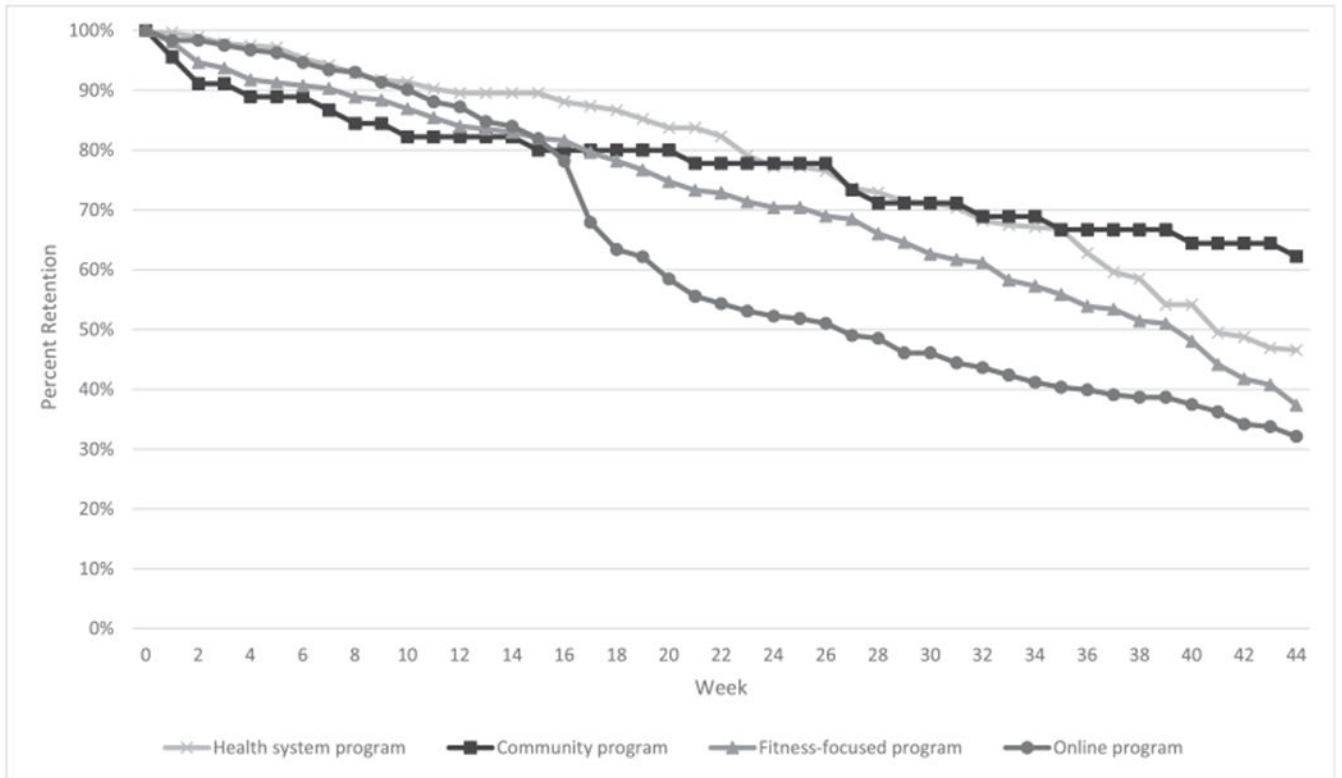
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**Fig. 1.** Enrollee retention by NDPP program and week. NDPP: National Diabetes Prevention Program.

Table 1

Baseline characteristics of NDPP enrollees with prediabetes and overweight or obesity, stratified by CDC-recognized NDPP provider.

	Enrolled in NDPP	Health system program	Community program	Fitness-focused program	Online program	p-value
N (%)	776	277 (36%)	45 (6%)	206 (27%)	248 (32%)	–
Age (years)	53 ± 10	55 ± 9	57 ± 8	51 ± 11	51 ± 11	<0.0001
Sex						0.1545
Women	557 (72%)	212 (77%)	33 (73%)	142 (69%)	170 (69%)	
Men	219 (28%)	65 (23%)	12 (27%)	64 (31%)	78 (31%)	
Race						0.3975
Asian	54 (8%)	24 (10%)	1 (3%)	11 (6%)	18 (9%)	
Black	49 (8%)	13 (5%)	3 (8%)	18 (10%)	15 (7%)	
White	538 (82%)	200 (83%)	34 (89%)	140 (81%)	164 (81%)	
Other	12 (2%)	3 (1%)	0 (0%)	3 (2%)	6 (3%)	
At least 1 PCP visit in past year	663 (86%)	249 (90%)	43 (98%)	171 (84%)	200 (82%)	0.0041
At least 1 specialist visit in past year	539 (70%)	206 (74%)	33 (75%)	144 (71%)	156 (64%)	0.0516
Body Mass Index (kg/m <sup>2</sup> )	34.1 ± 7.0	33.8 ± 6.3	33.6 ± 7.5	34.3 ± 7.1	34.3 ± 7.5	0.7589
Blood pressure (mmHg)						
Systolic	126 ± 15	128 ± 15	128 ± 17	123 ± 14	126 ± 14	0.0154
Diastolic	74 ± 10	74 ± 10	73 ± 10	74 ± 9	75 ± 10	0.5546
Lipids (mg/dl)						
Total cholesterol	196 ± 39	199 ± 37	185 ± 35	195 ± 40	196 ± 40	0.1772
HDL-cholesterol	53 ± 14	54 ± 14	53 ± 14	50 ± 12	53 ± 15	0.0697
Triglycerides	147 ± 96	152 ± 102	134 ± 80	143 ± 77	147 ± 105	0.6762
LDL-cholesterol	113 ± 32	114 ± 31	105 ± 26	115 ± 34	111 ± 32	0.2709
HbA1c (%)	5.9 ± 0.3 (41 ± 0 mmol/mol)	5.9 ± 0.3 (41 ± 0 mmol/mol)	5.8 ± 0.3 (40 ± 0 mmol/mol)	5.8 ± 0.4 (40 ± 0 mmol/mol)	5.9 ± 0.3 (41 ± 0 mmol/mol)	0.1701
Health plan claims diagnoses of ...						
Overweight/obesity	355 (46%)	126 (45%)	17 (38%)	102 (50%)	110 (44%)	0.4697
Hypertension	285 (37%)	119 (43%)	20 (44%)	60 (29%)	86 (35%)	0.0100
Any antihypertensive medication	283 (36%)	113 (40%)	22 (49%)	60 (29%)	88 (35%)	0.0175
Dyslipidemia	282 (36%)	113 (41%)	16 (36%)	62 (30%)	91 (37%)	0.1180

	Enrolled in NDPP	Health system program	Community program	Fitness-focused program	Online program	p-value
Any lipid lowering medication	188 (24%)	77 (28%)	12 (27%)	39 (19%)	60 (24%)	0.1566
Smoking	17 (2%)	6 (2%)	1 (2%)	2 (1%)	8 (3%)	0.4451
Cardiovascular disease	61 (8%)	29 (10%)	6 (13%)	13 (6%)	13 (5%)	0.0577
Reside within city of Ann Arbor	272 (35%)	94 (34%)	9 (20%)	114 (55%)	55 (22%)	<0.0001
Neighborhood indicators <sup>a</sup>						
Median income (\$)	71,287	71,784	65,204	71,546	71,603	0.1601
Percent unemployment	34.4 ± 4.6	34.6 ± 4.6	35.1 ± 4.9	33.4 ± 4.1	34.7 ± 4.7	0.0089
Percent receiving SNAP benefits	8.2 ± 6.0	7.7 ± 4.8	11.4 ± 10.1	7.7 ± 5.1	8.6 ± 6.7	0.0006
Transit stops per square mile	4.6 ± 9.0	3.9 ± 8.3	3.5 ± 8.6	6.7 ± 9.2	3.8 ± 9.4	0.0015
Childcare services in zip code area	24.0 ± 14.8	22.7 ± 13.6	21.0 ± 14.2	30.4 ± 15.2	20.5 ± 14.5	<0.0001
Child/youth services in zip code area	1.3 ± 1.7	1.2 ± 1.7	1.0 ± 1.5	1.9 ± 1.9	1.1 ± 1.6	<0.0001
Elderly/disable services in zip code area	3.9 ± 2.6	3.7 ± 2.5	4.1 ± 3.0	4.5 ± 2.5	3.6 ± 2.6	0.0009
Percent of households with internet subscription	89 ± 0.1	89 ± 0.1	86 ± 0.1	90 ± 0.0	88 ± 0.1	0.0002
Percent of households with any computing device with internet	88 ± 0.1	89 ± 0.1	85 ± 0.1	89 ± 0.0	87 ± 0.1	<0.0001
N (%) with baseline survey data	532	201 (38%)	37 (7%)	130 (24%)	164 (31%)	–
Employed by UM	334 (87%)	140 (88%)	19 (86%)	72 (85%)	103 (87%)	0.9361
Reasons for choosing program						
Convenient time	400 (77%)	155 (79%)	28 (78%)	75 (58%)	142 (89%)	<0.0001
Convenient location	398 (76%)	167 (85%)	32 (89%)	88 (68%)	111 (69%)	0.0002
People attending	44 (8%)	15 (8%)	3 (8%)	18 (14%)	8 (5%)	0.0524
Perceived focus on diet	238 (46%)	107 (54%)	16 (44%)	47 (36%)	68 (43%)	0.0115
Perceived focus on physical activity	235 (45%)	81 (41%)	11 (31%)	86 (67%)	57 (36%)	<0.0001
Self-rated health						
Excellent/Very good	260 (49%)	93 (47%)	23 (62%)	60 (47%)	84 (51%)	0.2949
Good/Fair/Poor	270 (51%)	107 (54%)	14 (38%)	69 (53%)	80 (49%)	
EQ-5D-5L health utility score	0.86 ± 0.14	0.87 ± 0.13	0.89 ± 0.13	0.87 ± 0.13	0.85 ± 0.17	0.3708
EQ-5D visual analog scale score	76 ± 14	75 ± 14	76 ± 16	76 ± 14	77 ± 14	0.7496

NDPP: National Diabetes Prevention Program, HbA1c: Hemoglobin A1c, HDL: High-density lipoprotein cholesterol, LDL: Low-density lipoprotein cholesterol, PCP: Primary Care Provider, SNAP: Supplemental Nutrition Assistance Program.

Data are expressed as N (%) or mean ± standard deviation. P-values indicate significance between NDPP program types.

Neighborhood indicators determined by merging residential zip codes with data reported from U.S. Census Bureau and the National Neighborhood Data Archive.

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**Table 2**

Participation in NDPP stratified by provider.

	Enrolled in NDPP	Health system program	Community program	Fitness-focused program	Online program	p-value
N (%)	776	277 (36%)	45 (6%)	206 (27%)	248 (32%)	–
Core sessions (sessions 1–16)						
Mean number of core sessions attended	13 ± 4	13 ± 3	13 ± 4	12 ± 4	14 ± 4	<0.0001
Median number of core sessions attended	14 (11–16)	14 (12–15)	15 (13–16)	13 (9–15)	16 (13–16)	–
Attended 75% of core sessions in first 6 months	570 (73%)	225 (81%)	35 (78%)	119 (58%)	191 (77%)	<0.0001
Maintenance sessions (sessions 17 +)						
Mean number of maintenance sessions attended	5 ± 3	5 ± 2	7 ± 2	5 ± 2	4 ± 3	<0.0001
Median number of maintenance sessions attended	5 (3–8)	5 (3–7)	7 (5–9)	5 (3–7)	4 (1–8)	–
Attended 75% of maintenance sessions in last 8 months	277 (47%)	102 (46%)	24 (69%)	78 (48%)	73 (43%)	0.0515

NDPP: National Diabetes Prevention Program.

Data are expressed as N (%), mean ± standard deviation, or median (interquartile range). P-values indicate significance between NDPP program types.

**Table 3**  
Six-, 12-month, and 2-year changes in risk factors and outcomes for NDPP enrollees overall and stratified by provider.

	Enrolled in NDPP	Health system program	Community program	Fitness-focused program	Online program	p-value
N (%)	776	277 (36%)	45 (6%)	206 (27%)	248 (32%)	-
<b>6-months</b>						
Weight						
N	774	277	45	206	246	-
Weight (lbs)	-8.6 ± 10.4	-9.2 ± 9.6	-13.0 ± 11.3	-7.5 ± 10.3	-8.0 ± 10.9	0.0063
Percent weight loss	4.1 ± 4.6	4.5 ± 4.3	6.4 ± 5.2	3.4 ± 4.5	3.8 ± 4.9	0.0004
5% weight loss	37%	40%	58%	34%	33%	0.0098
10% weight loss	9%	10%	16%	6%	9%	0.1496
Physical activity						
N	662	270	42	169	181	-
Physical activity change (minutes)	13 ± 119	11 ± 123	33 ± 81	29 ± 115	-5 ± 122	0.0348
150 min/week physical activity	56%	69%	67%	60%	32%	<0.0001
<b>12-months</b>						
Weight						
N	514	213	35	142	124	-
Weight change (lbs)	-10.1 ± 12.1	-10.3 ± 12.3	-16.1 ± 14.0	-9.5 ± 11.3	-8.6 ± 11.7	0.0126
Percent weight loss	4.8 ± 5.5	5.0 ± 5.4	7.9 ± 6.6	4.3 ± 5.0	4.3 ± 5.4	0.0030
5% weight loss	44%	45%	71%	38%	40%	0.0038
10% weight loss	15%	15%	29%	11%	17%	0.0589
Physical activity						
N	329	190	30	59	50	-
Physical activity change (minutes)	24 ± 168	8 ± 147	98 ± 193	78 ± 209	-24 ± 146	0.0004
150 min/week physical activity	63%	64%	73%	70%	47%	0.0407
Body Mass Index						
N	653	243	38	170	202	-
Change in BMI (kg/m <sup>2</sup> )	-1.2 ± 2.4	-1.3 ± 2.4	-2.3 ± 2.1	-0.9 ± 2.2	-1.0 ± 2.6	0.0104
Blood pressure (mmHg)						
N	641	240	35	169	197	-

	Enrolled in NDPP	Health system program	Community program	Fitness-focused program	Online program	p-value
Change in systolic	-2 ± 15	-4 ± 16	-1 ± 18	0 ± 14	-3 ± 15	0.1191
Change in diastolic	-1 ± 15	-2 ± 11	0 ± 10	-1 ± 11	-1 ± 11	0.5641
Lipids (mg/dl)						
N	240	108	16	49	67	-
Change in total cholesterol	-6 ± 32	-7 ± 34	6 ± 20	-4 ± 30	-8 ± 32	0.4469
N	238	107	16	48	67	-
Change in HDL-cholesterol	1 ± 8	0 ± 8	1 ± 7	1 ± 9	2 ± 7	0.4706
N	234	106	16	47	65	-
Change in triglycerides	-27 ± 103	-39 ± 113	-3 ± 37	-9 ± 81	-25 ± 111	0.2993
N	352	135	26	83	108	-
Change in LDL-cholesterol	-4 ± 25	-3 ± 28	-1 ± 20	-5 ± 22	-6 ± 24	0.6464
HbA1c						
N	475	197	26	118	134	-
Change in HbA1c (%)	-0.1 ± 0.4 (0 ± 0 mmol/mol)	-0.1 ± 0.3 (0 ± 0 mmol/mol)	-0.1 ± 0.3 (0 ± 0 mmol/mol)	-0.1 ± 0.4 (0 ± 0 mmol/mol)	-0.1 ± 0.4 (0 ± 0 mmol/mol)	0.7143
Incidence of diabetes						
N	546	222	35	140	149	-
Incidence of diabetes by HbA1c	43 (8%)	19 (9%)	1 (3%)	12 (9%)	11 (7%)	0.6820
N	439	171	31	105	132	-
Incidence of diabetes by self-report	14 (3%)	6 (4%)	1 (3%)	2 (2%)	5 (4%)	0.8564
<b>Two-years</b>						
Body Mass Index						
N	600	216	38	165	181	0.0019
Change in BMI (kg/m <sup>2</sup> )	-0.6 ± 2.7	-0.8 ± 2.9	-1.7 ± 3.1	0.0 ± 2.3	-0.6 ± 2.6	
Blood pressure (mmHg)						
N	597	220	36	164	177	0.0970
Change in systolic	0 ± 16	-1 ± 17	-1 ± 20	2 ± 14	-2 ± 15	
Change in diastolic	-1 ± 11	-2 ± 11	-1 ± 9	0 ± 11	-2 ± 11	0.3010
Lipids (mg/dl)						
N	160	64	9	39	48	0.4261
Change in total cholesterol	-2 ± 31	-5 ± 33	6 ± 11	-5 ± 33	3 ± 30	
N	161	64	9	39	49	

	Enrolled in NDPP	Health system program	Community program	Fitness-focused program	Online program	p-value
Change in HDL-cholesterol	1 ± 7	0 ± 8	3 ± 6	2 ± 8	2 ± 6	0.3158
N	234	106	16	47	65	
Change in triglycerides	-27 ± 103	-39 ± 113	-3 ± 37	-10 ± 81	-25 ± 111	0.2993
N	341	126	24	88	103	
Change in LDL-cholesterol	-4 ± 28	-5 ± 31	-8 ± 16	-6 ± 25	-1 ± 27	0.5197
HbA1c						
N	414	163	21	104	126	
Change in HbA1c (%)	0.0 ± 0.5 (0 ± 0 mmol/mol)	0.0 ± 0.6 (0 ± 0 mmol/mol)	0.1 ± 0.5 (0 ± 0 mmol/mol)	0.0 ± 0.5 (0 ± 0 mmol/mol)	-0.1 ± 0.3 (0 ± 0 mmol/mol)	0.2654
Incidence of diabetes						
N	653	251	39	169	194	
Incidence of diabetes by HbA1c	73 (11%)	32 (13%)	3 (8%)	18 (11%)	20 (10%)	0.7301
N	402	151	30	98	123	
Incidence of diabetes by self-report	25 (6%)	12 (8%)	1 (3%)	5 (5%)	7 (6%)	0.6892

BMI: Body Mass Index, NDPP: National Diabetes Prevention Program, HbA1c: Hemoglobin A1c, HDL: High-density lipoprotein cholesterol, LDL: Low-density lipoprotein cholesterol, PCP: Primary Care Provider.

Data are expressed as N (%) or mean ± standard deviation. P-values indicate significance between those who enrolled in NDPP program types.