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RESEARCH ARTICLE

Cost-Effectiveness of a Community-Based Diabetes Prevention Program with Participation Incentives for Medicaid Beneficiaries

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Objective. To examine the cost-effectiveness of a community-based Diabetes Prevention Program (DPP) for Medicaid beneficiaries from the perspective of the health care sector.

Data Sources/Study Setting. A total of 847 Medicaid enrollees at high risk for type 2 diabetes participating in a community-based DPP.

Study Design. Pre- and post clinical outcome and cost data were used as inputs into a validated diabetes simulation model. The model was used to evaluate quality-adjusted life years (QALYs) and health care costs over a 40-year time horizon from the perspective of the health care sector.

Data Collection/Extraction Methods. Clinical outcome and cost data were derived from a study examining the effect of financial incentives on weight loss.

Principal Findings. Study participants lost an average of 4.2 lb ($p < .001$) and increased high-density lipoprotein cholesterol by 1.75 mg/dl ($p = .002$). Intervention costs, which included financial incentives for participation and weight loss, were $915 per participant. The incremental cost-effectiveness ratio was estimated to be $14,011 per QALY but was sensitive to the time horizon studied.

Conclusions. Widespread adoption of community-based DPP has the potential to reduce diabetes and cardiovascular-related morbidity and mortality for low-income persons at high risk for diabetes and may be a cost-effective investment for Medicaid programs.

Key Words. Cost-effectiveness, Medicaid, health care costs

Diabetes is a common and costly chronic disease that disproportionally affects minority and low-income populations. In 2012, the 22.3 million U.S. residents with diabetes incurred an economic burden of $176 billion in excess direct

medical costs and $69 billion in reduced productivity (Dall et al. 2014). Diabetes continues to be a leading cause of heart attack, stroke, heart failure, eye disease, lower-extremity amputations, and renal failure in the United States (Gregg et al. 2014; Desai et al. 2015). Over 90 percent of adults with diabetes have type 2 diabetes, and the age-standardized prevalence of combined diagnosed and undiagnosed diabetes among adults in 2012 was approximately two times higher among blacks (21.8 percent), Asians (20.6 percent), and Hispanics (22.6 percent) compared to non-Hispanic whites (11.3 percent; Menke et al. 2015). Type 2 diabetes prevalence is also higher in those with less than a high school education compared to high school graduates (18.6 vs. 9.7 percent) and in those with incomes in the lowest versus highest income tertile (17.8 vs. 8.0 percent). Fully 38.0 percent of adults in the United States have prediabetes, a metabolic state that increases the risk of developing type 2 diabetes fourfold relative to normoglycemic adults (Gerstein et al. 2007; Menke et al. 2015).

The Diabetes Prevention Program demonstrated that in less than 3 years, an intensive lifestyle intervention or pharmacotherapy with metformin delays or prevents the onset of type 2 diabetes among high-risk adults by 58 and 31 percent, respectively, with persistent reduction in diabetes incidence for 15 years (Knowler et al. 2002; Diabetes Prevention Program Research Group 2012; Diabetes Primary Prevention Research Group 2015). Since then, the Diabetes Prevention Program lifestyle intervention (DPP) has been adapted for delivery in community settings using a lower-cost, group-based lifestyle intervention in which participants have achieved significant reductions in weight, although usually less than those observed in the original DPP (Mudaliar et al. 2016; Alva et al. 2017; Ely et al. 2017). The DPP has been adapted to specific racial and ethnic groups, including African American, Hispanic/Latino, Native Hawaiian and Other Pacific Islander, Arab American, and American Indian and Native Alaskan communities, and implemented in varied settings (Ackermann et al. 2008, 2015; Amundson et al. 2009; Mau et al. 2010; Whittemore 2011; Ali, Echouffo-Tcheugui, and

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Williamson 2012; Ockene et al. 2012; Ackermann 2013; Albright and Gregg 2013; Jiang et al. 2013; O'Brien et al. 2015a, b; Hall et al. 2016; Van Name et al. 2016). Racial and ethnic diversity as measured by the percentage of nonwhite participants was greatest in workplace and church settings, following by community settings (e.g., the YMCA), primary care, and hospital outpatient. Weight loss across settings had the opposite trend, being greatest in hospital-based programs and lowest in workplace and church settings (Whittemore 2011).

The expansion of Medicaid under the 2010 Affordable Care Act (ACA) substantially increased insurance coverage for low-income individuals with diabetes and prediabetes. The ACA emphasized the prevention of chronic disease, laying a foundation for initiatives like the Million Hearts Campaign and the Medicaid Incentives for Prevention of Chronic Diseases (MIPCD) grant program (Koh and Sebelius 2010; Frieden and Berwick 2011). The MIPCD program was designed to examine the effectiveness of various financial and nonfinancial incentives to Medicaid enrollees to promote tobacco cessation, weight management, and prevention or better control of hypertension, lipid disorders, and diabetes (Koh and Sebelius 2010; Hoerger et al. 2015).

As part of the MIPCD program, Minnesota Department of Human Services and Minnesota Department of Health conducted the We Can Prevent Diabetes (WCPD) study to increase delivery of the DPP lifestyle program to Minnesota Medicaid enrollees with prediabetes (Desai et al. 2017a). The WCPD study examined the effects of a DPP intervention that included two reward-based financial incentive designs (one individually earned incentive and another a hybrid of individual- and group-earned incentive) versus the effects of a DPP intervention without financial incentives on weight loss and related metabolic parameters.

This study examines the cost-effectiveness of WCPD from the perspective of the health care sector. The Second Panel on Cost Effectiveness in Health and Medicine has recently recommended that the societal perspective should be used as the reference case for cost-effectiveness analyses (Sanders et al. 2016). However, the societal perspective lacks direct policy implications in our context, whereby administrators of Medicaid programs make decisions regarding allocations of resources based on their impact on the health of their enrollees and health care costs. To our knowledge, this is the first study to examine the cost-effectiveness of implementing a community-based DPP specifically in a low-income population.

METHODS

The results of the WCPD cluster randomized controlled trial showed that participants in all three study arms experienced significant weight loss and improvements in cholesterol, with no significant difference between the study arms in these clinical outcomes. Because the WCPD study found no effect on mean weight loss using financial incentives, we pooled participants into a single study cohort and use pre- and postvalues for weight and cholesterol as inputs into a long-term simulation model of diabetes outcomes and costs (Desai et al. 2017b). Intervention costs were derived from the WCPD and were estimated from the perspective of the health care sector. We employ multiple sensitivity analysis to examine the cost-effectiveness of WCPD under alternative scenarios including an attenuated clinical effect and different time horizons. These methods are described in more detail below.

Minnesota Medicaid Diabetes Prevention Program: We Can Prevent Diabetes

The WPCD was a pragmatic three-arm cluster randomized controlled trial (cRCT) designed to test whether financial incentives lead to increased participation in the DPP and greater weight loss. Study participants were adult Minnesota residents enrolled in Medical Assistance or MinnesotaCare, Minnesota's subsidized programs for low-income individuals (collectively referred to as Medicaid) with prediabetes or a history of gestational diabetes. Participants were recruited from 13 primary care clinic systems (21 participating clinics) serving patients in the Minneapolis-St. Paul metropolitan area. All participants received the group-delivered DPP free of charge, with each group consisting of 8–15 participants. The DPP is based on the Centers for Disease Control and Prevention's National Diabetes Prevention Program standardized DPP curriculum. The DPP Core program included 16 weekly 1-hour sessions aimed at reducing dietary fat intake, increasing physical activity, problem-solving, weight loss, and other topics. The DPP Maintenance program consists of an additional eight monthly 1-hour "booster" sessions, each tailored to a DPP groups' self-identified needs for weight loss maintenance. The DPP was delivered by formally trained and certified DPP Master Trainers as part of the national YMCA Y-DPP program. In the last 18 months, clinic staff and community health workers formally trained by certified DPP Master Trainers also delivered the DPP to participants (Desai et al. 2017a).

The WCPD included an arm that earned financial incentives based on participants' individual achievement of study goals (IND), an arm that earned financial incentives based on achieving individual as well as group-based study goals (GRP), and an attention control which received the DPP but did not receive financial incentives for weight loss. In addition to attending the DPP free of charge, participants in all three WCPD study arms received study materials, transportation, child care, 3-month access to the YMCA or other community facilities, a $25 initial DPP attendance incentive, and a $25 reimbursement for a clinic follow-up visit.

Individual and group participants received a financial incentive each time they attended a class session. IND participants received additional goal-based incentives for attending 75 percent of Core sessions; 75 percent of Post-Core sessions; achieving 5, 7, and 10 percent weight loss during the Core period; and 5, 7, or 10 percent weight loss by the end of the Post-Core sessions. GRP participants received group goal-based incentives if the entire DPP group achieved 75 percent Core session attendance, 75 percent of Post-Core session attendance, 7 percent or 10 percent weight loss from baseline during the Core, and 7 percent or 10 percent weight loss from baseline at the end of the Post-Core period. In addition, GRP participants received individual goal-based incentives for achieving 5 percent weight loss during the Core period and during the Post-Core period. A potential maximum of $520 in incentives could be earned by each participant in the IND or GRP arms. These monetary incentives were delivered on a reloadable debit card issued to all participants.

Patient Cohort

The cRCT clinical data were used to assign demographics and risk factors at baseline. The patient cohort included 847 Medicaid beneficiaries who were randomized to either the IND (309), GRP (259), or AC (279) study arms, as well as an additional 307 individuals who initially agreed to participate in the study but did not attend their first class, and were therefore not assigned to a study arm. This unassigned group is employed as a reference group from which to calculate incremental health care costs as described below.

Clinical Effectiveness of WCPD

The clinical effectiveness of WCPD was determined using data from the cRCT. Participants in the WCPD trials attended on average 12 of 24 DPP

sessions. Using linear mixed models with random effects and a repeated time measurement, WCPD participants lost an average of 4.2 lb (SE = 0.17; $p < .001$) over a median of 17 weeks. High-density lipoprotein cholesterol (HDL) also increased by 1.75 mg/dl (SE = 0.55; $p = .002$). There were no statistically or clinically significant differences in other clinical risk factors, including glycosylated hemoglobin, blood pressure, or low-density lipoprotein cholesterol. There were also no statistically or clinically significant differences in clinical risk factors between the incentive arms. As a result, we conducted the base case analyses with the three arms combined and improvements in weight and HDL observed in WCPD against a counterfactual of no improvement in weight or HDL.

Intervention Costs

Intervention costs were derived from the cRCT and were estimated from the perspective of the health care sector. Intervention costs include the YMCA program coaching costs, clinic costs, financial incentive costs, and the incremental health care costs associated with the intervention. These costs were calculated as long-term average costs of implementation and exclude research and development costs. As the financial incentives were not found to be successful in improving clinical outcomes, we conducted a sensitivity analysis excluding financial incentives (described below).

YMCA program costs include staffing costs for the lifestyle coaches and other costs for delivering the WCPD curriculum. Clinic costs include costs of program materials, including measuring cups, exercise band, home scales, and paper and other materials used to produce the DPP curriculum and educational materials. Clinic costs also include resources and services to support participation such as transportation and childcare. Financial incentive costs include participation and goal-based incentive provided to program participants. YMCA, clinic, and financial incentive costs were derived from invoices to the WCPD program.

Baseline and incremental health care costs were estimated using Medicaid claims data. Medicaid beneficiaries who were not assigned to a study arm were used as a reference group in order to calculate incremental health care costs associated with WCPD participation. Costs for professional, outpatient, and pharmacy services were estimated using the amounts paid by Medicaid for these services. Costs for WCPD participants were estimated at the individual level for the year prior and the year post their first WCPD session. Costs for the 307 individuals who enrolled in the study but who dropped out before

knowing the results of their randomization were similarly calculated for the year prior and the year post their scheduled WCPD session. These analyses were limited to individuals who were enrolled in Medicaid, without dual coverage under Medicare, for one full year prior and one full year post their first WCPD session.

Incremental costs were estimated a generalized linear model assuming a gamma distribution and a log link function. This specification was chosen based on standard tests for assessing the appropriateness of using alternative health care cost distributions. The model adjusted for age, gender, and baseline weight, and included indicators for WCPD participation, time (baseline or postintervention), and a time by WCPD participation interaction term. A standardized difference-in-difference estimate was calculated among all study participants as they were alternatively assigned to the WCPD participant and nonparticipant groups in the pre- and postperiods. Standard errors were estimated using the nonparametric bootstrap, and significance values were computed using the percentile method (Efron 1993).

Long-Term Cost-Effectiveness Analysis

We estimated cost-effectiveness of WCPD using a simulation model designed to evaluate the long-term health outcomes and costs associated with interventions among patients with newly diagnosed type 2 diabetes (Clarke et al. 2004). The United Kingdom Prospective Diabetes Study Outcomes Model (UKPDS-OM, version 2.0) employs an integrated system of parametric equations to estimate the absolute risk of the first occurrence of each of seven diabetes-related complications (fatal or nonfatal myocardial infarction, other ischemic heart disease, stroke, heart failure, amputation, renal failure, and eye disease) and death based on patient characteristics (e.g., age and gender) and time-varying risk factors (HbA1c, systolic BP, HDL, LDL, weight, and smoking status). Data from the UKPDS were used to develop the predictive equations for diabetes-related complications and mortality and to assign utilities conditional on disease state. Individuals from the cRCT were entered into the UKPDS-OM model, and the changes in clinical outcomes and costs that were observed in the cRCT were used to evaluate changes in life expectancy, quality-adjusted life years (QALYs), and future costs related to the WCPD intervention. Incremental cost-effectiveness ratios (ICERs) are reported as the incremental change in cost associated with the intervention arm divided by the incremental change in QALYs.

Costs of Diabetes Complications

Costs of diabetes-related complications were estimated using Symmetry Episode Treatment Group (ETG) software applied to the cost accounting system of a large Mid-Western health plan. ETG is an illness classification methodology that organizes medical and pharmaceutical claims into meaningful episodes of care. The ETG software was used to calculate estimated annual costs for diabetes-related complications based on data derived from adults with diabetes. Adults were identified as having diabetes if they received one or more inpatient or two or more outpatient diagnoses of diabetes within 1 year using International Classification of Diseases Version 9 (ICD9) diagnoses codes 250-250.99. Diabetes-related complications included myocardial infarction, other ischemic heart disease, heart failure, stroke amputation, blindness, and renal failure. Annual cost in absence of complications was estimated using Medicaid claims data described above.

Base Case and Sensitivity Analyses

The cost-effectiveness analysis assumed the perspective of the health care sector, a 40-year time horizon, and a 3 percent discount rate for both QALYs and costs. This analysis used as inputs the effect on weight and HDL that was observed in the cRCT, intervention costs estimated from the cRCT, and costs for diabetes-related complications estimated from health plan data. The base case assumed that the intervention effect would persist over time. An alternative scenario assumed that the clinical effects persisted at 50 percent of observed values.

The Diabetes Prevention Program Outcomes Study (DPPOS) revealed that participants in the intensive lifestyle intervention arm partially regained weight during a 10-year follow-up period (Diabetes Prevention Program Research et al. 2009). Thus, we have included a sensitivity analysis in which WCPD participants regain 50 percent of their weight over a 5-year period. In this analysis, the 4.2 lb weight loss declines to 2.1 lb over a 5-year period. We have also included a sensitivity analysis assuming a larger weight loss: 9.5 lb, which was demonstrated in an evaluation of a YMCA-based DPP for Medicare beneficiaries (Alva et al. 2017). Additional sensitivity analyses were performed to investigate influence of time horizon and intervention costs.

A probabilistic sensitivity analysis was used to estimate second-order uncertainty. The UKPSD Outcomes Model provides a full set of equation parameters that were derived from bootstrap samples of the original UKPDS

trial population. We created 1,000 bootstrapped estimates drawing from the available set of model parameters. We used these estimates to calculate estimates of incremental costs and effects, which we plotted in a cost-effectiveness plane.

RESULTS

The patient cohort sample characteristics are shown in Table 1. Among patients assigned to a study arm, the mean age was 48.3 years (SD = 11.9), 71 percent were female, and 83 percent were non-white. The mean weight at baseline was 220.7 lb (SD = 56.0). Mean baseline A1c was 5.9 percent; systolic blood pressure was 126.4 mm Hg, LDL was 116.6 mg/dl, and HDL was 49.3 mg/dl. The unassigned comparison group was on average younger (46.5 years, $p = .023$) and had lower baseline weight (209.7 lb, $p = .004$) and systolic blood pressure (123.0 mm Hg, $p = .007$).

Table 1: Patient Cohort Characteristics

	Assigned to a Study Arm (N = 847)		*Unassigned Comparison Group (N = 307)*		
	Mean	*SD*	*Mean*	*SD*	*p-value*
Age	48.3	11.9	46.5	13.0	.023
Female (%)	71		72		.792
Race/ethnicity (%)					
Black or African American	64		58		.000
Non-Latino white	17		13		
American Indian or Alaskan Native	10		12		
Asian	4		8		
Hispanic or Latino	4		8		
Unknown	1		1		
Height/weight					
Height (inches)	64.9	5.2	64.3	4.7	.189
Weight (pounds)	220.7	56.0	209.7	57.5	.004
Clinical indicators					
A1c	5.9	.2	5.9	.3	
Systolic BP	126.4	17.2	123.0	18.6	.007
LDL	116.6	34.6	112.3	34.6	.159
HDL	49.3	16.4	50.1	15.9	.570
Past smoker (%)	14		12		.803
Current smoker (%)	32		33		

Intervention costs are shown in Table 2. YMCA program coaching costs were estimated to be $429 per person. Clinic program materials costs were estimated to be $105, and clinic costs for participation support were $211 per person. Incentives costs were $148 per person across the three groups. Incentive costs in the AC arm only—without individual or group-based performance incentives—were $34 per person. The estimate of incremental health care costs was small and statistically insignificant: $22 (SE = $535). There were similarly no significant differences between participants and nonparticipants in professional, outpatient, inpatient, or pharmacy costs (data not shown). Total intervention costs are estimated to be $915 per participant and occur in the first year of the simulation. Costs of diabetes-related complications are shown in Table 3. Costs were greater for fatal than for nonfatal events, and event costs were greater than state costs (i.e., ongoing costs).

Table 4 shows the results of the cost-effectiveness analysis. Assuming a sustained weight loss of 4.2 lb and an improvement in HDL by 1.75 mg/dl, life expectancy increases by .030 years and quality-adjusted life expectancy increases by .028 QALYs across the entire intervention cohort. The projected improvements in quality of life associated with WCPD were the result of lower cumulative probabilities of ischemic heart disease (20.5 vs. 21.1 percent without WCPD), heart failure (16.4 vs. 17.1 percent), and cardiovascular-related mortality (31.5 vs. 31.9 percent) over the 40-year period. Treatment costs increase by $398 over the 40-year follow-up period and the ICER is $14,011 per QALY. Assuming that only 50 percent of the observed clinical improvement related to WCPD is sustained, life expectancy increases by .009 years, quality-adjusted life expectance increases by .008 QALYs, treatment costs increase by $762, and the ICER is $91,830 per QALY.

Incremental cost-effectiveness ratios are somewhat less favorable under the assumption that 50 percent of the weight loss among WCPD participants

Table 2: Intervention Costs

	Year 1	*Years 2+*
WCPD program costs	$429	$0
Clinic program materials costs	$105	$0
Clinic participation support costs	$211	$0
Incentive costs, mean (SD)	$148 ($123)	$0
Incremental health care costs, mean (SE)	$22 ($535)	$0
Total	$915	$0

Note: Costs are in 2015 dollars.

Table 3: Costs of Complications Used as Inputs to the UKPDS Outcomes Model

	*Fatal**	*Nonfatal, Initial**	*Nonfatal, State*[†]
Ischemic heart disease	13,542	27,084	8,857
Myocardial infarction	43,469	40,380	11,334
Heart failure	33,490	19,019	13,049
Stroke	17,309	12,294	4,477
Amputation	68,616	52,751	13,463
Blindness		4,775	2,484
Renal failure	98,575	98,575	98,575
Annual costs without complications			1,649

Note: Costs are annual amounts in 2015 dollars.
*Costs in year of event.
[†]Costs per subsequent year.

is regained over a 5-year period. The ICER is $24,247 when the initial weight loss is 4.2 lb and $166,772 when the initial weight loss is 2.1 lb, corresponding to a 50 percent improvement in clinical outcomes. Conversely, ICERs are more favorable when the weight loss is greater. The ICER is $3,849 when the initial weight loss is 9.5 lb and $22,409 for a 50 percent improvement in clinical outcomes.

The cost-effectiveness of the WCPD program is sensitive to changes in the time horizon. Under a 20-year time horizon, the ICER is $60,831 when the clinical effects persist over time and $312,063 for a 50 percent improvement in clinical outcomes. Under a 10-year time horizon, the ICER is $302,667 when the clinical effects persist over time and $2,568,914 for a 50 percent improvement in clinical outcomes.

We also considered alternative assumptions regarding treatment costs. Under a low-cost scenario, we include only $34 of incentive costs, which is the mean in the active control arm. In this scenario, treatment costs were $801. Under a high-cost scenario, we assumed that incremental health costs would persist over time and treatment costs were $992.

Under a low-cost treatment scenario, the ICER was $9,998 when the clinical effects persist over time and $78,096 for a 50 percent improvement in clinical outcomes. Under the high-cost treatment scenario, the ICER was $16,722 when the clinical effects persist over time and $101,107 for a 50 percent improvement in clinical outcomes.

Figure 1 presents results from our analysis of second-order uncertainty. As all estimated incremental effects are positive, only one quadrant is

Table 4: Cost-Effectiveness of We Can Prevent Diabetes (WCPD) Diabetes Prevention Program (DPP)

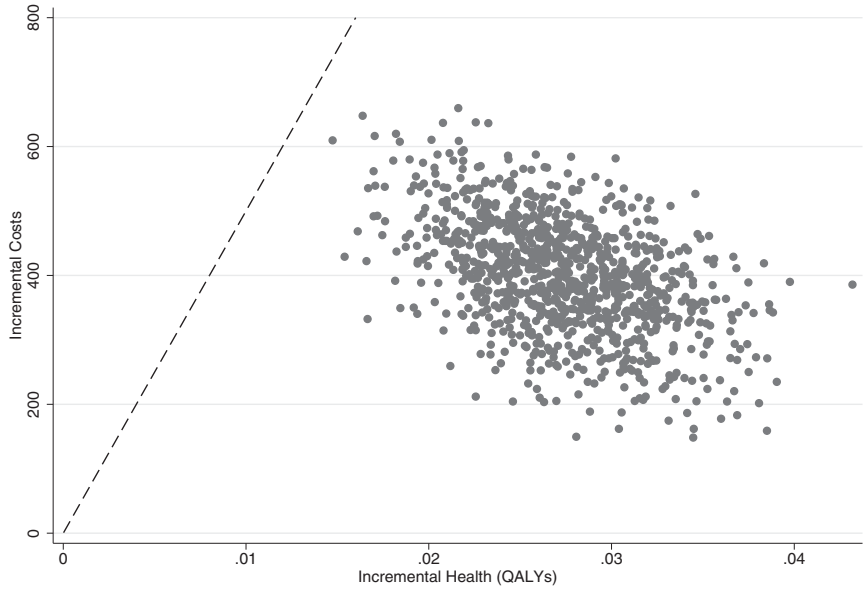
	Life Expectancy	*Quality-Adjusted Life Years (QALYs)*	*Total Cost*	*Incremental Cost-Effectiveness Ratio (ICER)*
Base case: Intervention effects persist over a time horizon of 40 years				
Usual care	17.67	14.09	$58,318	
WCPD	17.70	14.12	$58,716	$14,011
WCPD 50%	17.68	14.10	$58,080	$91,830
Sensitivity analyses				
Weight is partially regained over a 5-year period as observed in the DPPOS				
Usual care	17.67	14.09	58,318	
WCPD	17.69	14.11	57,892	$24,247
WCPD 50%	17.68	14.10	58,211	$166,772
Increased weight loss (9.5 lb) as observed in a community-based DPP for Medicare				
Usual care	17.68	14.10	58,252	
WCPD	17.73	14.15	57,523	$3,849
WCPD 50%	17.70	14.12	57,888	$22,409
Time horizon of 20 years				
Usual care	13.49	10.79	$39,537	
WCPD	13.50	10.80	$40,110	$60,831
WCPD 50%	13.49	10.79	$40,374	$312,063
Time horizon of 10 years				
Usual care	8.23	6.61	$20,291	
WCPD	8.23	6.61	$21,079	$302,667
WCPD 50%	8.23	6.61	$21,156	$2,568,914
Low treatment costs				
Usual care	17.67	14.09	$58,318	
WCPD	17.70	14.12	$58,602	$9,998
WCPD 50%	17.68	14.10	$58,996	$78,096
High treatment costs				
Usual care	17.67	14.09	$58,318	
WCPD	17.70	14.12	$58,736	$16,772
WCPD 50%	17.68	14.10	$59,157	$101,107

presented. The angled line indicates the $50,000 per QALY ICER threshold. The median incremental cost is $401 with an interquartile range of $344 to $459. The median incremental effect is .027 QALY with an interquartile range of .024 to .031 QALY.

DISCUSSION

By 2034, the number of U.S. residents with diagnosed or undiagnosed diabetes is projected to increase to 44.1 million, with $336 billion in annual

Figure 1: Cost-Effectiveness Plane



Notes: The plotted values show estimates of incremental costs and effects created from 1,000 bootstrapped estimates drawing from the available set of model parameters. The dashed line indicates the $50,000 per QALY ICER threshold.

diabetes-related medical spending (Huang et al. 2009) (i.e., direct costs). The burden of this ongoing epidemic will continue to fall disproportionately on lower income persons who are served by Medicaid. Therefore, it is a high priority to identify and implement cost-effective strategies to delay or prevent onset of diabetes. Community-based DPP programs have the potential to reduce the incidence of diabetes and cardiovascular-related complications for millions of persons who are at high risk of progressing to diabetes at relatively low cost. The WCPD DPP intervention used in this study cost $915 compared to $1,866 for the original DPP (both estimates converted to 2015 dollars using the consumer price index) (Eddy, Schlessinger, and Kahn 2005).

The WCPD was cost-effective by commonly accepted standards, both in the base case and in an alternative analysis assuming that only 50 percent of the weight loss persisted after 5 years. The WCPD remained cost-effective in sensitivity analyses that considered alternative assumptions regarding the intervention's effects and costs. However, the cost-effectiveness of WCPD was sensitive

to alternate assumptions regarding the time horizon for the analysis and might not be considered cost-effective under time horizons of 10 years or less.

To our knowledge, this is the first study to demonstrate the cost-effectiveness of implementing a community-based DPP specifically in a low-income population, a population where we might not expect participants to be as successful given many other competing priorities, limited access to health eating and physical activity environments, limited budget to purchase healthy foods or gym memberships, and lack of time to participate in intensive, long-term lifestyle change programs. This is also the first study to examine the cost-effectiveness of implementing the DPP using direct financial incentives. Although a previous study has examined a DPP implementation in a low-income population, this study did not include a cost-effectiveness analysis (Ackermann et al. 2015). Thus, this is first study to demonstrate that implementing the DPP with low-income participants remains cost-effective even with the addition of incentives. This has important policy implications as CMS is in the midst of a DPP Medicaid reimbursement demonstration project (National Association of Chronic Disease Directors 2017).

Our findings are similar to other DPP cost-effectiveness analyses. Studies based on the original DPP and subsequent long-term follow-up with the DPP Outcomes Study (DPPOS) found mean ICERs for a health system ranging from cost-saving to $20,000 per QALY depending the time horizon (Herman et al. 2005, 2013; Ackermann et al. 2006; Hoerger et al. 2007; Diabetes Prevention Program Research Group 2012; Zhuo et al. 2012). Pragmatically delivered community-based DPP programs like the WCPD study were also found to be cost-effective and even cost-saving from the societal perspective (Smith et al. 2010; Feldman, Hellstrom, and Johansson 2013).

This cost-effectiveness analysis has several limitations. Clinical outcomes were measured pre and post, without a randomized control group; the base case assumed that the intervention effects would persist over time, and we assumed that ongoing education and support would not be necessary to maintain the intervention effect. However, our sensitivity analyses showed that the intervention remained cost-effective when improvements in weight and HDL were assumed to be 50 percent of the observed effects. We employed a simulation model (UKPDS-OM, version 2.0) that was not specifically designed to predict outcomes in prediabetes populations. In particular, the original UKPDS included recently diagnosed adults with type 2 diabetes, while patients in the WCPD study were at high risk for developing diabetes. However, in contrast to other leading risk models such as the American College of Cardiology (ACC)/American Heart Association model or the

Framingham Risk Score, UKPDS-OM incorporates weight and glucose levels as clinical risk factors and allows for a greater age range of patients by including those age 18–39 (Fox et al. 2007; Goff et al. 2014). Our analysis considers the effect of changes in clinical risk factors on diabetes-related macrovascular and microvascular complications and comorbidities. It does not consider changes in outcomes or costs related to the incidence of type 2 diabetes independent of these complications. However, most medical costs incurred by patients with type 2 diabetes are related to complications and comorbidities (Li et al. 2013).

The perspective for this cost-effectiveness analysis was the health care sector, and cost and benefits were limited to health services covered by the program. Thus, the analysis does not consider patients' time costs of participation or any benefits from mitigation of the productivity loss that had been shown to be associated with the development of diabetes. The analysis is also limited to acute care services. Thus, the model results may be conservative in not considering potential increases in long-term care that might result from more severe morbidity from diabetes-related complications.

Despite some limitations, the data suggest that under certain analytic assumptions, providing the DPP free to Medicaid beneficiaries with prediabetes, along with support for participation including transportation and childcare, may meet current thresholds for cost-effective investment over the long term. While disenrollment in Medicaid might mitigate the financial benefit to Medicaid, it is likely that the clinical benefit would carry over to those who subsequently insure participants.

These findings are particularly timely given the large and growing diabetes inequities in the United States. Diabetes prevalence is two times higher among low-income, less educated, and non-white individuals (Menke et al. 2015). Low uptake and low effectiveness of the DPP among Medicaid beneficiaries may further exacerbate diabetes disparities (Ely et al. 2017; Ritchie, Kaufmann, and Sauder 2017). Medicaid beneficiaries in our study on average attended 12 of 24 DPP sessions. Among 14,757 DPP participants, each additional DPP session attended resulted in an additional 0.3 percent weight loss (Ely et al. 2017). This suggests that inexpensive strategies to more effectively sustain Medicaid beneficiaries' attendance and clinical outcomes may improve the cost-effectiveness of community-based DPP. Although the transactional incentives we evaluated had little impact on study outcomes, it is possible that other financial incentive designs merit evaluation of their potential to increase attendance, weight loss, and physical activity (Volpp et al. 2008; Kullgren et al. 2013; Haff et al. 2015; Patel et al. 2016).

Finally, additional research is needed to determine the durability of the health benefit in community-based DPP, to identify characteristics of subgroups of the overall target population who were most likely to benefit from the intervention, to ascertain whether subsequent reinforcement or booster programs may be beneficial from a clinical and cost perspective, and to explore the joint impact and cost-effectiveness of adding metformin treatment to the community-based DPP lifestyle intervention (Diabetes Prevention Program Research Group 2012).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the supporting information tab for this article:

Appendix SA1: Author Matrix.