Annals of Internal Medicine REVIEW

Economic Evaluation of Combined Diet and Physical Activity Promotion Programs to Prevent Type 2 Diabetes Among Persons at Increased Risk: A Systematic Review for the Community Preventive Services Task Force

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Background: Diabetes is a highly prevalent and costly disease. Studies indicate that combined diet and physical activity promotion programs can prevent type 2 diabetes among persons at increased risk.

Purpose: To systematically evaluate the evidence on cost, cost-effectiveness, and cost–benefit estimates of diet and physical activity promotion programs.

Data Sources: Cochrane Library, EMBASE, MEDLINE, PsycINFO, Sociological Abstracts, Web of Science, EconLit, and CINAHL through 7 April 2015.

Study Selection: English-language studies from high-income countries that provided data on cost, cost-effectiveness, or cost–benefit ratios of diet and physical activity promotion programs with at least 2 sessions over at least 3 months delivered to persons at increased risk for type 2 diabetes.

Data Extraction: Dual abstraction and assessment of relevant study details.

Data Synthesis: Twenty-eight studies were included. Costs were expressed in 2013 U.S. dollars. The median program cost per participant was $653. Costs were lower for group-based programs (median, $417) and programs implemented in community or primary care settings (median, $424) than for the U.S. DPP (Diabetes Prevention Program) trial and the DPP Outcome Study ($5881). Twenty-two studies assessed the incremental cost-effectiveness ratios (ICERs) of the programs. From a health system perspective, 16 studies reported a median ICER of $13 761 per quality-adjusted life-year (QALY) saved. Group-based programs were more cost-effective (median, $1819 per QALY) than those that used individual sessions (median, $15 846 per QALY). No cost–benefit studies were identified.

Limitation: Information on recruitment costs and cost-effectiveness of translational programs implemented in community and primary care settings was limited.

Conclusion: Diet and physical activity promotion programs to prevent type 2 diabetes are cost-effective among persons at increased risk. Costs are lower when programs are delivered to groups in community or primary care settings.

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Diabetes is a highly prevalent, severe, and costly disease in the United States. Approximately 29 million Americans (9.3% of the U.S. population) had diabetes in 2012, and that number is projected to increase (1, 2). Diabetes is the leading cause of kidney failure, blindness, and amputation, as well as a major cause of heart disease and stroke (2). In the United States in 2012, the total medical cost of diagnosed diabetes was estimated at $176 billion, and the cost of productivity loss due to diabetes was another $69 billion (3).

Type 2 diabetes accounts for 90% to 95% of all cases of diagnosed diabetes. Common risk factors for type 2 diabetes include obesity, family history of diabetes, physical inactivity, hypertension, hypercholesterolemia, and elevated glucose level. In addition, approximately 37% of the U.S. population aged 20 years or older and 51% of those aged 65 years or older had prediabetes in 2012, meaning that they were at increased risk for type 2 diabetes (2). However, only about 10% of at-risk persons knew their risk status (4).

Randomized clinical trials around the world have shown that combined diet and physical activity promotion programs could prevent or delay progression to type 2 diabetes among persons at increased risk (5–8). Studies have also demonstrated the feasibility and effectiveness of such programs when they are implemented in primary care or community settings (9). In 2014, a systematic review done for the Community Preventive Services Task Force found that programs implemented in health care or community settings effectively reduced the risk for diabetes in persons at increased risk; increased the likelihood of reversion to normoglycemia; and reduced weight and other risk factors for cardiovascular disease, such as elevated blood pressure and lipid levels (10).

Given the potentially large population that is eligible for diet and physical activity promotion programs and the resources needed for implementation, information on program cost and cost-effectiveness is critical for policy decisions, such as benefit coverage for payers, as well as planning for program design and implementation. As a companion to the aforementioned effectiveness review, we did this systematic economic review for the Community Preventive Services Task

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Force to estimate the cost associated with diet and physical activity promotion programs and the cost-effectiveness and cost–benefit ratios of these programs.

METHODS

Data Sources and Searches

We searched the Cochrane Library, EMBASE, MEDLINE, PsycINFO, Sociological Abstracts, Web of Science, EconLit, and CINAHL for English-language articles published between January 1985 and 7 April 2015. Details of the search strategy are available on the Guide to Community Preventive Services (Community Guide) Web site (www.thecommunityguide.org) and in **Appendix Table 1** (available at www.annals.org) (11). We also screened reference lists of relevant studies and reviews and considered studies identified by the parallel review of the effectiveness of diet and physical activity promotion programs (10).

Study Selection

We included studies that provided information on program cost; cost–benefit ratio; or incremental cost-effectiveness ratio (ICER), which is measured as dollars per life-year gained (LYG), quality-adjusted life-year (QALY) saved, or disability-adjusted life-year (DALY) averted. Included studies on program cost had to evaluate the actual program implementation cost. Included cost-effectiveness or cost–benefit studies had to meet published criteria for conducting and reporting economic evaluation analysis (12).

We used the same inclusion criteria as the aforementioned effectiveness review for study population, intervention, comparison population, and publication language (10). Criteria included a population at increased risk for type 2 diabetes, based on glycemic measures or risk scores for diabetes, presence of cardiovascular disease, or presence of the metabolic syndrome; intervention with both diet and physical activity components delivered in at least 2 contact sessions over at least 3 months; comparison with a similar population receiving either usual care (standard lifestyle advice) or no intervention for the cost-effectiveness studies; and publication in English. We further restricted our review to studies in high-income countries to provide economic estimates relevant to U.S. settings and populations.

Data Extraction and Quality Assessment

Two authors extracted data from each article according to the Cochrane systematic review protocol (13) and the Community Guide protocol for economic evaluations (14).

Data Synthesis and Analysis

Intervention costs are reported as program costs per participant, including costs to identify eligible participants (through recruitment in the community, referral from providers, or screening and referral in study settings) and to implement the diet and physical activity promotion program (staff time, training materials, and other costs). We also generated program costs per participant per session, calculated by dividing program costs per participant by the total number of core and maintenance sessions delivered. Medians and interquartile intervals (IQIs) of study estimates were reported as summary measures. If there were 4 data points, we report the range; if there were 3 or fewer data points, all are reported.

Subgroup analyses of intervention costs were done to explore potential factors affecting costs. For delivery setting, we grouped each study into those based on the U.S. DPP (Diabetes Prevention Program) study, in which the intervention was delivered in a clinical trial setting following rigorous procedures as described in study protocols (5), and those done in real-world settings, in which diet and physical activity promotion programs were translated to community or primary care settings, with (translational DPP programs) or without (translational non-DPP programs) explicit adaptation of DPP training materials.

For delivery method, we categorized each study into 1 of the following groups: individual-based programs, in which a participant met 1-on-1 with the program provider at each core session; group-based programs, in which the participants met as a group with the program provider at each core session; or mixed programs, in which the core sessions included both individual and group sessions.

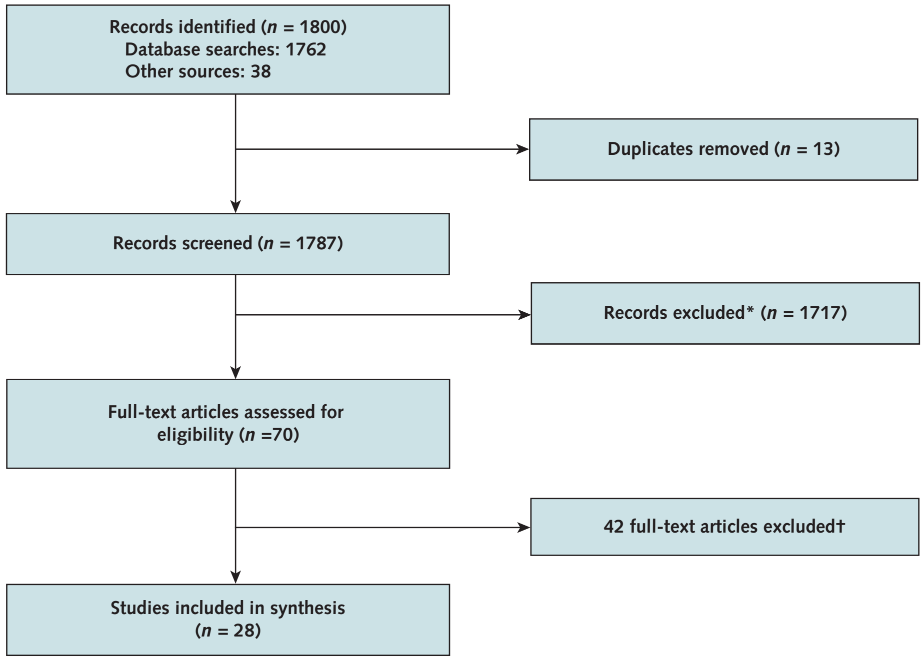
For the type of personnel delivering the program, we grouped each study by whether the program was delivered by health professionals (such as medical staff, physicians, nurses, physiotherapists, case managers, or dietitians), trained laypersons (such as certified diabetes educators, lay health educators, trained community health workers, or trained volunteers with type 2 diabetes), or a mix of health professionals and trained laypersons.

Cost-effectiveness estimates were measured as ICERs, with medians and IQIs provided as summary measures. To improve comparability of ICERs across the studies, we reported them separately by the outcome measures used in different studies: QALYs saved, LYGs, or DALYs averted. For studies found to be cost-saving, we calculated the negative net cost per QALY saved, LYG, or DALY averted whenever possible to calculate the median ICER.

Two economic perspectives were considered: the health system perspective, in which only medical costs and benefits relevant to health systems were considered, and the societal perspective, in which direct nonmedical and indirect costs were also considered. When studies provided sufficient data, we calculated ICERs for perspectives beyond those reported.

As with cost estimates, subgroup analysis of ICERs was done by delivery method. We examined cost-effectiveness estimates by type of analysis: within-trial analysis, in which ICERs were calculated from data on actual costs and benefits; modeling of a trial or extension of trials, in which studies used simulation models to estimate program cost and effectiveness during or beyond the trial period; or modeling of the national

Figure 1. Summary of evidence search and selection.



* Studies had abstracts only, were irrelevant, or did not meet inclusion criteria.
† Did not meet inclusion criteria (for example, included persons with diabetes or had physical activity or diet component but not both). Two studies were conducted in low- or middle-income countries, and 1 did not follow a rigorous cost–benefit analysis.

effect, in which studies estimated ICERs for programs delivered by scaling up programs to the entire country in which the study was conducted.

Because time horizon is important in program planning and budget allocation, we reported ICERs by length of follow-up (short-term [<10 years] or long-term [≥10 years]). In addition, we reported ICERs stratified by country setting (U.S.- or non–U.S.-based) to better inform programs in the United States.

All costs were adjusted to 2013 U.S. dollars by using the Consumer Price Index for medical care services (15) and annual foreign exchange rates from the Federal Reserve Bank for conversion of other currencies (16). If a study did not mention the year used in cost calculations, we assumed costs to be as of 1 year before the study publication year. Interventions were considered cost-effective if the ICER was less than $50 000 per QALY saved, less than $50 000 per LYG (17), or less than the per capita gross domestic product of the relevant country for cost per DALY averted, as recommended by the World Health Organization (18).

Role of the Funding Source

This study was done by employees of the U.S. government as part of their official duties and received no external funding.

Results

After screening, 28 studies met our inclusion criteria and were included in our final review (**Figure 1**) (19–46). Of these, 6 cost-only studies (20–23, 26, 27) and 6 cost-effectiveness studies (19, 24, 25, 28–30) provided information on the actual cost of diet and physical activity promotion programs, and 22 contributed cost-effectiveness estimates of the programs (19, 24, 25, 28–46). Fourteen studies were U.S.-based (19–24, 26, 27, 31, 35–38, 46). No cost–benefit studies were identified.

Intervention Costs

Of the 12 studies that reported the actual costs of implementing the program (20–31), only 4 included costs for identifying persons at increased risk (22, 24, 27, 29). The major cost driver was staff time to deliver the intervention. Most studies provided program cost information embedded in an evaluation of program effectiveness or cost-effectiveness without doing a formal cost analysis (**Appendix Table 2**, available at www.annals.org).

Program costs per participant ranged from $191 to $5881 (median, $653 [IQI, $383 to $1160]). The most expensive program was the 10-year DPP/DPPOS (Diabetes Prevention Program Outcome Study), which cost $5881 per participant (19). The cost from the first 3 years (the trial period for DPP, which was based on individual sessions delivered by health professionals) was $4687; the remaining maintenance and follow-up period, called the DPPOS period, was group-based and accounted for only $1194. The translational programs were less intense than the DPP trial and usually had fewer sessions and shorter duration. Most of them were group-based or had a mixture of group and individual sessions and were delivered by either trained layper-

Table 1. Comparison of Program Costs, by Program Delivery Setting, Method, and Personnel

Group	Studies, *n*	Median Total Cost per Participant (IQI or Range), *2013 U.S. $**	Median Cost per Participant per Session (IQI or Range), *2013 U.S. $**
Setting			
DPP/DPPOS†	1	5881	102
Translational DPP	8	424 (IQI, 340–793)	25 (IQI, 16–48)
Translational non-DPP‡	3	1160 (range, 427–1416)	27 (range, 4–64)
Delivery method§			
Individual-based	2	5881 and 1242	102 and 44
Group-based	8	417 (IQI, 341–600)	17 (IQI, 12–33)
Mixed	3	839, 918, and 1416	8, 20, and 53
Personnel			
Health professionals‖	4	1077 (IQI, 381–1329)	16 (IQI, 7–54)
Trained laypersons	3	191, 357, and 839	16, 17, and 53
Mixed	4	548 (range, 407–918)	31 (IQI, 20–55)

DPP = Diabetes Prevention Program; DPPOS = Diabetes Prevention Program Outcome Study; IQI = interquartile interval.
* Range is provided if there were 4 data points; values from individual studies are provided if there were ≤3 data points.
† Cost per participant was calculated for the DPPOS. Cost per participant per session was calculated for DPP core sessions.
‡ 4 data points; 1 study reported data points from 2 groups.
§ 1 study reported data points from individual- and group-based groups.
‖ Includes only translational studies, not the DPP trial; 5 data points; 1 study reported data points from 2 groups.

sons or a mix of health professionals and trained laypersons (**Appendix Table 2**). They were also less costly than the DPP trial. The median program cost per participant was $424 (IQI, $340 to $793) for the 8 translational DPP programs (20–27) and $1160 (range, $427 to $1416; 4 data points) for the 3 translational non-DPP programs (28–30) (**Table 1**).

The median cost per participant per session was $30. The cost per session of the DPP/DPPOS was $102. The median costs per participant per session for the 8 translational DPP programs and the 3 translational non-DPP programs were $25 (IQI, $16 to $48) and $27 (range, $4 to $64), respectively (**Table 1**).

The median cost per participant was lower in the group-based programs ($417 [IQI, $341 to $600]) (20–25, 28, 29) than in the DPP/DPPOS ($5881) (19) and the translational non-DPP program ($1242) (29) (**Appendix Table 2**), both of which used individual sessions. It was also lower than the median cost of programs with a mix of individual and group sessions (median, $918 [range, $839 to $1416]) (26, 27, 30) (**Table 1**). The median cost per participant for translational programs delivered by trained laypersons (median, $357 [range, $191 to $839]) (21, 22, 26) was lower than for those delivered by health professionals (median, $1077 [IQI, $381 to $1329]; 4 programs; 5 data points) (20, 28–30); however, there was large variation within personnel type, possibly due to a mixture of delivery settings and methods (**Table 1**).

Cost-Effectiveness of the Programs

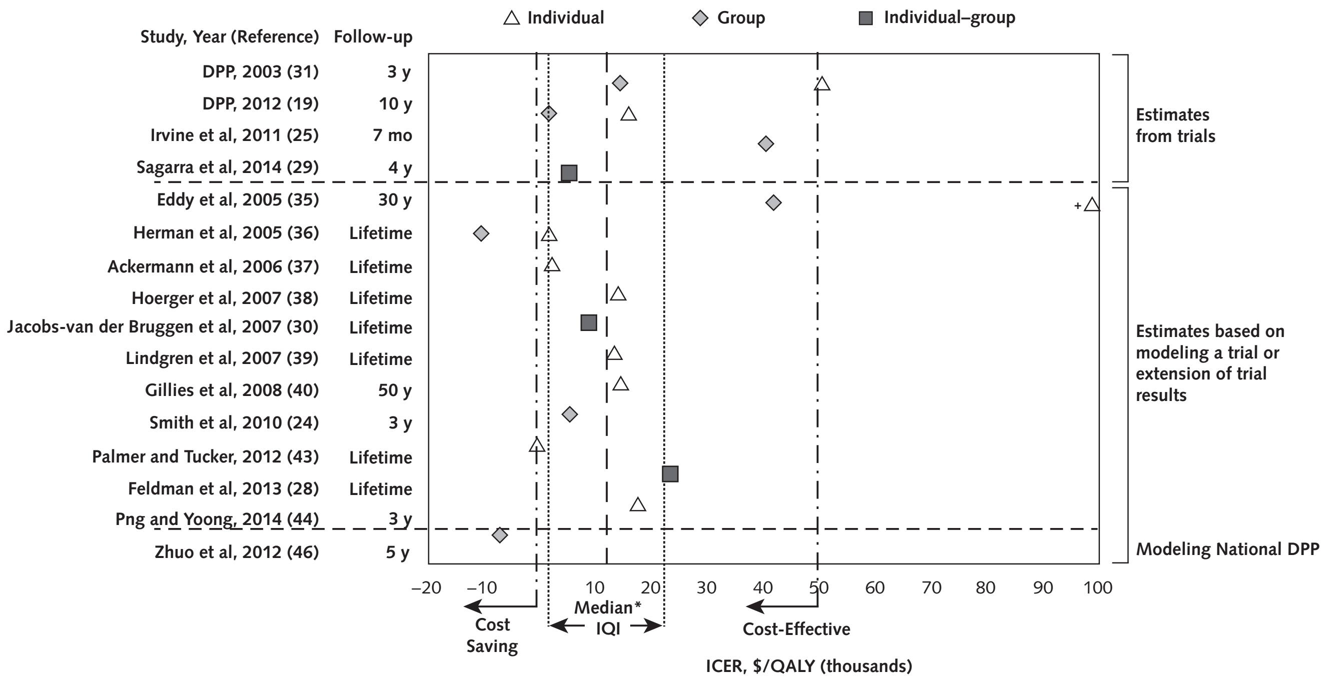
Of 22 studies reporting the cost-effectiveness of the programs, 8 were U.S.-based (19, 24, 31, 35–38, 46). Seventeen studies reported the outcome measure as cost per QALY saved (19, 24, 25, 28–31, 35–40, 42–44, 46), 6 reported cost per LYG (32–34, 39, 40, 43), and 2 reported cost per DALY averted (41, 45). All studies except 1 (42) reported ICERs from a health system perspective. Eight studies (19, 28, 31, 36, 38, 39, 42, 44) reported ICERs from a societal perspective, and 7 (19, 28, 31, 36, 38, 39, 44) reported both health system and societal perspectives. However, only 1 study included all of the costs and benefits from society as a whole (44). Eighteen studies used modeling techniques (24, 28, 30, 32–46), 2 of which modeled the cost-effectiveness of nationwide community-based programs (45, 46). Fourteen studies were based on data from the DPP trial or the Finnish Diabetes Prevention Study, which used individual sessions (19, 31, 33–36, 38–41, 43, 44, 46, 47). Most modeling studies considered the health and cost consequences of the program for at least 10 years (28, 30, 32–43, 45, 46). **Appendix Table 3** (available at www.annals.org) provides estimates of cost-effectiveness or cost–utility ratio from individual studies, which served as the basis for the summary measure of ICERs.

Of the 16 studies that included cost per QALY saved from the health system perspective, all but 1 (35) reported ICERs below the cost-effectiveness threshold of $50 000 per QALY saved (**Figure 2**). Three studies reported cost savings (36, 43, 46). The median ICER from the 16 studies was $13 761 per QALY saved (IQI, $3067 to $21 899).

From the health system perspective, subgroup analyses were done with 5 studies that reported ICERs for both individual- and group-based programs (19, 31, 35, 36, 38). The medians were $15 846 (IQI, $7980 to $72 723) and $1819 (IQI, −$5027 to $16 443) per QALY, respectively. Six studies (24, 25, 28–30, 46) that evaluated the cost-effectiveness of translational programs found a median ICER of $7115 per QALY (IQI, $2252 to $27 582). Two of them were conducted in the United States (24, 46); 1 reported an ICER of $5494 per QALY, and the other reported cost savings.

Studies in the United States reported a median ICER of $9824 per QALY (IQI, $1930 to $41 982; 8 studies), and non-U.S. studies reported a median ICER of $13 860 per QALY (IQI, $6203 to $21 899; 8 studies). By method, the median ICER of the 4 within-trial analy-

Figure 2. Scatter plot of ICERs from 16 cost-effectiveness or cost-utility analyses that reported cost per QALY saved from the health system perspective.



DPP = Diabetes Prevention Program; ICER = incremental cost-effectiveness ratio; IQI = interquartile interval; QALY = quality-adjusted life-year.
* $13 761/QALY (IQI, $3067 to $21 899/QALY).

ses was $28 097 per QALY (range, $5359 to $50 694) (19, 25, 29, 31). Twelve modeling studies reported a median ICER of $13 367 per QALY (IQI, $2303 to $17 614). By time horizon, the median ICERs were $17 614 per QALY (IQI, $5427 to $45 521; 5 studies) for studies that considered the benefits and costs of the program over less than 10 years and $13 367 per QALY (IQI, $1805 to $15 846; 11 studies) for studies that extended 10 years or beyond (**Table 2**).

Two studies conducted in Australia (41, 45) reported cost per DALY averted from the health system perspective and used the Australian 2013 per capita gross domestic product of $67 468 as the cost-effectiveness threshold (48). Both studies found the programs to be cost-effective ($21 195 and $50 707 per DALY).

Six other studies reported ICERs as cost per LYG (32–34, 39, 40, 43); all were below the $50 000 threshold. Two studies showed negative costs per LYG, which indicated cost savings (34, 43). The median ICER was $2684 per LYG (IQI, −$2444 to $17 410).

Discussion

Our review found a median ICER for diet and physical activity promotion programs of $13 761 per QALY saved. The 25th and 75th percentiles of the ICERs from the 16 studies that reported cost per QALY saved from the health system perspective were both under $50 000 per QALY, which is a conventional cost-effectiveness threshold (17). The ICERs of diet and physical activity promotion programs measured by cost per LYG or DALY averted were also all under commonly used cost-effectiveness thresholds (18). Thus, we conclude that diet and physical activity promotion programs are cost-effective and involve an efficient use of health care resources.

Our evidence search identified 4 pertinent systematic or narrative reviews evaluating the evidence on cost-effectiveness of diet and physical activity promotion programs for participants at increased risk for type 2 diabetes (49–52). Results from these reviews also suggested that such programs were either cost-effective or cost-saving, independent of country or delivery setting. Previous reviews did not synthesize evidence on costs of diet and physical activity promotion programs. Our systematic review includes 18 additional studies; supports the overall finding of cost-effectiveness; and provides comparative economic estimates by delivery method, setting, and staffing to inform program planning and implementation.

Given the current evidence base, we cannot definitively conclude that the programs are cost-saving. Only 3 studies that reported cost per QALY saved found the program to be cost-saving (36, 43, 46). For the 2 U.S. studies, 1 (36) reported that the DPP program was cost-saving over a lifetime horizon when delivered in group sessions, and the other (46) reported that a nationwide diabetes prevention program became cost-saving in its 11th year, implying that the programs may not save costs in the short term. However, few health care inter-

Table 2. Comparison of Costs per QALY Saved, by Dimension

Group	Studies, *n*	Median ICER* (IQI or Range), *$/QALY*†
Study perspective‡		
Societal perspective includes only indirect cost		
Health system	2	13 367 and 23 327
Societal	2	6080 and 22 647
Societal perspective includes only direct nonmedical cost		
Health system	4	15 000 (range, 1805 to 50 694)
Societal	4	26 611 (range, 13 574 to 83 310)
Societal perspective includes direct nonmedical and indirect costs		
Health system	1	17 614
Societal	1	37 580
Delivery method‡		
Individual-based	5	15 846 (IQI, 7980 to 72 723)
Group-based	5	1819 (IQI, −5027 to 16 443)
Setting		
United States	8	9824 (IQI, 1930 to 41 982)
Other	8	13 860 (IQI, 6203 to 21 899)
Method		
Within-trial	4	28 097 (range, 5359 to 50 694)
Modeling extension of trials	11	13 367 (IQI, 2303 to 17 614)
Modeling on nationwide, community-based DPP	1	−7069
Time horizon		
Short-term (<10 y)	5	17 614 (IQI, 5427 to 45 521)
Long-term (≥10 y)	11	13 367 (IQI, 1805 to 15 846)

DPP = Diabetes Prevention Program; ICER = incremental cost-effectiveness ratio; IQI = interquartile interval; QALY = quality-adjusted life-year.
* From health system perspective unless otherwise indicated.
† Range is provided if there were 4 data points; values from individual studies are provided if there were ≤3 data points. Costs are in 2013 U.S. dollars.
‡ Data are from the same studies (i.e., the studies reported ICERs from both societal and health system perspectives or from both individual and group delivery methods).

ventions have been found to be cost-saving, and many medical services that are typically covered by insurance have much higher ICERs than the diet and physical activity promotion programs (53). In a 2010 review of the cost-effectiveness of interventions for diabetes prevention and control, the median ICER for lifestyle interventions was at the low end of the spectrum, and the interventions were much more cost-effective than many diabetes treatment interventions, such as intensive glycemic control (49).

Most cost-effectiveness studies in our review were model-based because most trials lasted 3 years or less, but both the health and economic effects of the program were expected to last beyond the trial period. Estimated long-term ICERs of the programs from those modeling studies provided valuable information for decision makers in forecasting the health and economic effects of the program. One common critique of model-based studies is a lack of transparency of the models. To ensure the validity of the estimates, we explicitly abstracted studies in which information on program cost and effectiveness was clearly described in the model. Most studies used either a previously validated model or a model used in previous peer-reviewed publications, and all studies explicitly stated important assumptions used to predict future health and economic outcomes of the program. Model-based ICER estimates varied widely, which could have been due to different model structures and health assumptions, such as the rates of progression of diabetes and its complications beyond the trial period. Despite this variation in the derivation of ICERs with the use of modeling, all but 1 study showed that the ICERs of the programs were far below conventional cost-effectiveness thresholds. The 1 study that reported a much higher ICER used a model with a structure that differed greatly from the other studies and assumed a much slower rate of progression to diabetes in the model (35). However, even for this study, when the intervention was delivered in a group setting, the ICER was below the threshold of $50 000 per QALY.

Our findings have several important implications for programs implemented in the field, such as the National Diabetes Prevention Program, a public–private partnership led by the Centers for Disease Control and Prevention to implement a low-cost intervention adapted from the DPP in communities across the country (54). Group-based programs were less costly and more cost-effective than individual-based programs. In group-based programs, several participants could be counseled in the same session; thus, the cost per participant was lower. Evidence also showed that group-based programs may achieve effectiveness similar to that for individual-based programs (10). To reduce cost and achieve higher cost-effectiveness of diet and physical activity promotion programs, it seems that group-based programs should be used when the programs are implemented in real-world settings.

The cost of these programs may present a barrier to implementation despite the evidence on program cost-effectiveness. The original DPP trial was individual-based and resource-intensive. However, the program cost was much lower when it was implemented in a group format in primary care clinics and communities or translational DPP programs and was lower than or similar to currently reimbursable medical practices. For example, the annual per capita expenditure (in 2012 U.S. dollars) on prescription medications for persons with diabetes was $1423 (3), and Medicare currently pays $25.52 per counseling session for weight-loss programs (55). Further, program scale-up is expected to create economies of scale, further reducing the cost. Programs were found to be more cost-effective in longer-term follow-up studies, given that health benefits often last beyond the program period. In addition, many diabetes-related complications do not appear immediately after a person develops diabetes, which limits the ability of short-term studies to capture the full range of health benefits and medical costs avoided by the intervention.

We identified several limitations of the evidence base that future research should address. First, few studies estimated the cost associated with recruiting and engaging eligible persons to participate in the programs, which may generate additional costs when the programs are scaled up. Second, only 2 studies provided a rigorous cost analysis, and there is a lack of information to better understand the cost of scaling up the programs, such as the cost of programs delivered by trained laypersons (27). Third, only 2 studies evaluated the cost-effectiveness of programs implemented in primary care and community settings in the United States. Fourth, although the societal perspective is often preferred, of the 22 cost-effectiveness studies identified, only 8 reported this perspective and only 1 included all cost and benefit components (12). In addition, 1 study reported an ICER from a health plan (payer) perspective. Fifth, no cost–benefit analyses were identified in the review. Finally, although we attempted to stratify ICERs by program features, these characteristics were so intertwined that formal statistical testing of the effect of a single feature was not feasible.

In summary, the available economic evidence indicates that combined diet and physical activity promotion programs are cost-effective when delivered to persons at increased risk for type 2 diabetes. Evidence further suggests that programs using group sessions delivered by trained diabetes educators or laypersons are an economically efficient approach for communities and health care systems, especially those faced with limited resources and an increasing demand for services.

Health care providers have an essential role in the prevention of type 2 diabetes among patients at increased risk. In most cases, clinicians will be involved in identifying at-risk patients, delivering initial or ongoing behavioral counseling (56), and arranging referrals to available services. Our findings, combined with the findings from the concurrent effectiveness review (10), add to the growing body of evidence that diet and physical activity promotion programs using group sessions delivered by trained personnel are both effective and cost-effective. As national, state, and local efforts to implement evidence-based programs expand, health care providers will have additional, effective intervention options for patients identified as being at increased risk for type 2 diabetes.

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Disclaimer: The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Reproducible Research Statement: *Study protocol, statistical code, and data set:* Available from Dr. Li (e-mail, eok8@cdc.gov).

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Appendix Table 1. Search Strategy: Combined Diet and Physical Activity Promotion Programs Among Persons at Increased Risk–Economic Review*

Number	Searches
Terms defining diabetes	
1	exp diabetes mellitus/
2	diabet$.tw.
3	IDDM.tw.
4	NIDDM.tw.
5	MODY.tw.
6	(late onset adj diabet$).tw.
7	(maturity onset adj diabet$).tw.
8	(juvenil adj diabet$).tw.
9	(syndrome X and diabet$).tw.
10	hyperinsulin$.tw.
11	insulin sensitiv$.tw.
12	insulin$ secret$ dysfunc$.tw.
13	impaired glucose toleran$.tw.
14	exp glucose intolerance/
15	glucose intoleran$.tw.
16	exp insulin resistance/
17	insulin$ resist$.tw.
18	(non insulin$ depend$ or noninsulin$ depend$ or non insulin?depend$ or noninsulin?depend$).tw.
19	(insulin$ depend$ or insulin?depend$).tw.
20	metabolic$ syndrom$.tw.
21	(pluri metabolic$ syndrom$ or plurimetabolic$ syndrom$).tw.
22	((typ$ 1 or typ$ 2) and diabet$).tw.
23	((typ I or typ$ II) and diabet$).tw.
24	or/1-23
25	exp diabetes insipidus/
26	diabet$ insipidus.tw.
27	25 or 26
28	24 not 27
Terms defining cost	
29	exp "costs and cost analysis"/
30	exp health care costs/
31	exp "cost of illness"/
32	*ECONOMICS/
33	or/29-32
Terms defining benefit	
34	benefit.mp.
35	(cost$ or expenditure$).mp.
36	Life years.mp.
37	exp Quality-Adjusted Life Years/
38	Disability adjusted life years.mp.
39	effectiveness.mp.
40	or/34-39
Terms defining both cost and benefit	
41	33 and 40
Additional terms defining cost-effectiveness analysis or cost-benefit analysis	
42	exp COST-BENEFIT ANALYSIS/
43	cost-effectiveness analysis.mp.
44	Cost-utility analysis.mp.
45	Economic evaluation.mp.
46	or/42-45
47	28 and (41 or 46)

Appendix Table 1**–Continued**

Number	Searches
Terms defining lifestyle interventions preventing diabetes	
48	primary prevention/
49	primary prevention.tw.
50	(reduc* adj3 risk).tw.
51	risk reduction behavior/
52	(prevent* adj3 diabet*).tw.
53	health promotion.mp.
54	diabetes mellitus/pc
55	life style/
56	lifestyle*.tw.
57	life style*.tw.
58	prediabet*.mp.
59	weight loss/
60	health education/
61	health educator*.mp.
62	patient education as topic/
63	diet/
64	exp exercise/
65	motor activity/
66	physical activity.tw.
67	walking.mp.
68	or/48-67
69	47 and 68
Defining searching period	
70	limit 69 to yr="1985-Current"
Deduplication of study results	
71	remove duplicates from 70

* Databases that were searched were Cochrane, EMBASE, MEDLINE, PsycINFO, Sociological Abstracts, Web of Science, EconLit, and CINAHL. Searches were done between January 1985 and 7 April 2015. Last run: 7 April 2015.

Appendix Table 2. Summary Evidence Tables of Included Studies Providing Cost of Combined Diet and Physical Activity Promotion Programs to Reduce Type 2 Diabetes Among Persons at Increased Risk

Study, Year (Reference); Location	Population Size, *n*	Population Characteristics	Intervention Setting/ Intervention Format	Duration	Intervention Intensity (Number of Sessions)	Method	Type of Personnel	Cost Valuation for Identifying Clients (Recruitment; Screening)	Cost Valuation for Implementing the Intervention	Total Program Costs per Person	Cost per Person per Session
DPP/DPPOS											
DPP Research Group, 2012 (19); United States	3,243	Participants with IGT and fasting hyperglycemia, aged ≥25 y, BMI ≥24 kg/m^2, 68% women, 45% minority	Clinical trial Intensive lifestyle modification	10 y	Year 1-3: Same as DPP Year 4-10: 4 quarterly group visits, with the option of 2 additional sessions each year	Individual	Health professionals: Case managers Medical staff	–	Staff time: Questionnaire Training materials: Questionnaire Other components: Questionnaire	Year 1: $2,469 Year 2: $1,090 Year 3: $1,127 Year 4: $214 Year 5: $150 Year 6: $134 Year 7: $167 Year 8: $171 Year 9: $157 Year 10: $201 Total: $5,881	$102
Translational DPP											
Kramer et al, 2009 (20); United States	42	Adults with prediabetes and/or metabolic syndrome	Community setting Modified DPP (group lifestyle balance program)	1 y	Core: 12 group sessions Maintenance: 9 group sessions Total: 21 sessions	Group	Health professionals: Trained prevention professionals	–	Staff time: Staff report Training materials: NR Other components: NR	$335	$16
Kramer et al, 2011 (21); United States	81	Adults with prediabetes and/or metabolic syndrome	Community setting Modified DPP (group lifestyle balance program)	1 y	Core: 12 group sessions Maintenance: 9 group sessions Total: 21 sessions	Group	Trained laypeople: Diabetes educators	–	Staff time: NR Training materials: NR Other components: NR	$357	$17
Krukowski et al, 2013 (22); United States	116	Older adults (aged ≥60 y) who were obese (BMI ≥30 kg/m^2) and who had no significant memory problems	12-session translational DPP per reference 20	1 y	Core: 12 weekly group sessions Total: 12 sessions	Group	Trained laypeople: Trained lay health educator	Recruitment:Staff compilation Screening: –	Staff time: Staff compilation Training materials: Staff compilation Other components: Staff compilation	$191	$16
Vadheim et al, 2010 (23); United States	84	Adults at high risk for both diabetes and CVD	Community setting Adapted DPP	10 mo	Core: 16 weekly group sessions Maintenance: 6 monthly group sessions Total: 22 sessions	Group	Mixed health professional and trained laypeople: Diabetes educator, nurse	–	Staff time: NR Training materials: NR Other components: NR	$652	$30
Smith et al, 2010 (24); United States	NR	BMI ≥25 kg/m^2 and metabolic syndrome	2 urban and 2 rural medical practices in Pennsylvania Modified DPP To help patients with metabolic syndrome lose weight and improve at least 1 metabolic syndrome component	3 mo	12 group sessions Total: 12 sessions	Group	Mixed health professional and trained laypeople: Trained health professional and lay health workers	Recruitment:– Screening: NR	Staff time: NR Training materials: NR Other components: NR	$407	$34
Irvine et al, 2011 (25); United Kingdom	3,887	At-risk individuals with diabetes (aged 45-70 y)	Community setting Delivered by Diabetes Prevention Facilitators Promote a 7% weight loss within 6 mo using both diet and exercise	7 mo	Core: 4 group educational sessions in 3 mo Maintenance: 4 monthly group sessions Total: 8 sessions	Group	Mixed health professional and trained laypeople: Diabetes prevention facilitators Physicotherapist Volunteers with diabetes	Recruitment:– Screening: NR	Staff time: Questionnaire Training materials: Questionnaire Other components: Questionnaire	$443	$55
Ockene et al, 2012 (26); United States	312	Participants who were at high risk for type 2 diabetes	Community setting LLDPP between 2004 and 2007 Healthy food choices, walking 4000 steps per day	1 y	3 individual and 13 group sessions Total: 16 sessions	Mixed group and individual	Trained laypeople: Trained community health workers	–	Staff time: NR Training materials: NR Other components: NR	$839	$53

(*Continued on follwing page*)

Appendix Table 2–Continued

Study, Year (Reference); Location	Population Size, *n*	Population Characteristics	Intervention Setting/ Intervention Format	Duration	Intervention Intensity (Number of Sessions)	Method	Type of Personnel	Cost Valuation for Identifying Clients (Recruitment; Screening)	Cost Valuation for Implementing the Intervention	Total Program Costs per Person	Cost per Person per Session
Lawlor et al, 2013 (27); United States	301	Overweight or obese participants (BMI 25-39 kg/m^2) with elevated fasting blood glucose indicating prediabetes	Community setting HELP PD trial A DPP-based lifestyle weight-loss group	2 y	Core: 26 weekly group sessions and 3 individual sessions in 6 mo Maintenance: 18 monthly group sessions Total: 47 sessions	Mixed group and individual	Mixed health professional and trained laypeople: Trained community health workers and dietician	Recruitment: – Screening: NR	Staff time: Questionnaire Training materials: Questionnaire Other components: Questionnaire	Year 1: $613 Year 2: $305 Total: $918	$20
Translational non-DPP											
Feldman et al, 2013 (28); Sweden	142	KMSP in primary care, diagnosed with metabolic syndrome	Primary care Promote healthy lifestyles, in particular changes in dietary and physical activity habits	1 y	Core: 26 group lifestyle counseling and support sessions twice a week for 3 mo Maintenance: 18 biweekly group counseling and support sessions for 9 mo Total: 44 sessions	Group	Health professional: Practice nurses Health coordinator	Recruitment: Program documentation Screening: –	Staff time: Program documentation Training materials: Program documentation Other components: Program documentation	$427	$10
Sagarra et al, 2014 (29); Spain	552	Aged 45-75 y at risk for diabetes with IGT and/or IFG	Primary care setting DE-PLAN project 6-h structured lifestyle intervention (diet and physical activity) similar to Finnish DPS using specific teaching techniques Individual or group format	4.2 y	Year 1: 4 sessions (6 h) Years 2-4: Continuous intervention through telephone calls, text message, letters, and interviews, scheduled for every 6-8 wk	Group or individual (2 groups)	Health professional: Physicians, nurses, and dieticians	Recruitment: Forms Screening: Forms	Staff time: Forms Training materials: Forms Other components: Forms	$1,133 for the whole intensive intervention group $1,077 for the group format $1,242 for the individual format	$4 for the group format* $43 for individual format*
Jacobs-van der Bruggen, 2007 (30); Netherlands	NR	Adults with moderate risks for diabetes, obese adults aged 30-70 y	Community setting Nutrition and exercise for adults with moderate risks for diabetes	3 y	Year 1: 4 individual and 1 group session; 1 individual advice by a researcher; 52 weekly fitness programs Years 2-3: 3 individual and 1 group session; 52 biweekly fitness programs Total: 114 sessions Nutrition: 9 sessions Fitness: 105 sessions	Mixed group and individual	Health professionals: Dietitian, not clear who delivered the fitness program	-	Staff time: Questionnaire Training materials: Questionnaire Other components: Questionnaire	$1,416	Regular session: $64 Fitness: $8

BMI = body mass index; CVD = cardiovascular disease; DE-PLAN = Diabetes in Europe: Prevention Using Lifestyle, Physical Activity, and Nutritional Intervention; DPP = Diabetes Prevention Program; DPPOS = Diabetes Prevention Program Outcome Study; DPS = Diabetes Prevention Study; HELP PD = Healthy Living Partnerships to Prevent Diabetes; IFG = impaired fasting glucose; IGT = impaired glucose tolerance; KMSP = Kalmar Metabolic Syndrome Program; LLDPP = Lawrence Latino Diabetes Prevention Project; NR = not reported.
* Only included cost to deliver lifestyle intervention.

Appendix Table 3. Summary Evidence Tables of Included Studies Providing Cost-Effectiveness of Combined Diet and Physical Activity Promotion Programs to Reduce Type 2 Diabetes Among Persons at Increased Risk

Study, Year (Reference); Country	Population Characteristics	Duration of Intervention/ Follow-up	Cost Data Source	Benefit Data Source	Effectiveness Outcome	Model	QALY/DALY/ LYG	ICER Health System	ICER Society
Within-trial analysis (*n* = 4)									
DPP Research Group, 2003 (31); United States*	IGT	3 y/3 y	Real DPP cost data	Survey, CMS fee schedule	Reduce incidence by 58%	Within trial	0.072 additional QALY	Individual: $50,694/QALY Group: $14,476/QALY	Individual: $83,130/QALY Group: $46,820/QALY
DPP Research Group, 2012 (19); United States*	Participants with IGT and fasting hyperglycemia, ≥25 y, BMI ≥24 kg/m^2, 68% women, 45% minority	10 y/10 y	Real DPP cost data	Survey	DPPOS trial 0.12 additional QALY	Within trial	0.12 additional QALY	Individual: $15,846/QALY Group: $1,819/QALY	Individual: $24,373/QALY Group: $10,351/QALY
Irvine et al, 2011 (25); United Kingdom	At-risk individuals with diabetes (aged 45-70 y)	7 mo/7 mo	Real cost data	Survey, NHS reference cost, drug formulary	0.012 additional QALY	Within trial	0.012 additional QALY	$40,347/QALY	†
Sagarra et al, 2014 (29); Spain	Aged 45-75 y, at risk for diabetes with IGT and/or IFG	4.2 y/4.2 y	Real cost data	Forms	Reduce incidence by 36.5% 0.012 additional QALY	Within trial	0.012 additional QALY	$5,359/QALY	†
Modeling the trial or extension of trials (*n* = 16)									
Segal et al, 1998 (32); Australia	Seriously obese Seriously obese with IGT or NGT	2-3 y/25 y	Based on literature	Survey, insurance scheme	Reducing incidence from 70% to 30%	Markov model	1 additional LYG	$4,561/LYG	†
Caro et al, 2004 (33); Canada	Overweight or obese with IGT	5 y/10 y	Based on Finnish DPS	Literature, fee schedule, formularies	Based on DPP, Finnish DPS At 5th year, incidence −58% At 10th year, incidence −22%	Markov model	0.31 additional LYG	$806/LYG	†
Palmer et al, 2004 (34); Australia, France, Germany, Switzerland, United Kingdom	IGT	3 y/lifetime	DPP apply to fee schedule	Claims	Based on DPP, assuming the effect would not persist beyond the 3rd year	Markov model	0.08 (Australia) 0.07 (France) 0.07 (Germany) 0.06 (Switzerland) 0.16 (United Kingdom)	−$8,176/LYG (Australia) −$11,682/LYG (France) −$15,018/LYG (Germany) −$19,029/LYG (Switzerland) $8,565/LYG (United Kingdom) Mean: −$9,073/LYG	†
Eddy et al, 2005 (35); United States*	IGT	Until diabetes onset/30 y	Year 1 to 3: DPP cost Year 4 and beyond: DPP year 3 cost	Accounting data	Effect of DPP persists as long as receiving the intervention At end of 30 y, incidence −15%	Archimedes Diabetes Model	0.159 additional QALY	Individual: $94,752/QALY Group: $18,409/QALY Individual: $221,549/QALY (HMO perspective) Group: $41,879/QALY (HMO perspective)	-
Herman et al, 2005 (36); United States	IGT	Until diabetes onset/ lifetime	Year 1 to 3: DPP cost Year 4 and beyond: DPP year 3 cost	Claims	The effect of DPP persists as long as receiving the intervention At the end of lifetime, incidence −24%	Markov model	0.57 additional QALY	Individual: $1,805/QALY Group: −$10,450/QALY	Individual: $13,574/QALY
Ackerman et al, 2006 (37); United States	Overweight or obese 50-year-old adults with IGT	Until diabetes onset/ lifetime	Year 1 to 3: DPP cost Year 4 and beyond: DPP year 3 cost	Claims	Based on DPP The DPP effect will continue as long as receiving intervention	Markov model	Age 50 y: 0.59 additional QALY Age 65 y: 0.27 additional QALY	Age 50 y: $2,070/QALY Age 65 y: $2,536/QALY	†
Hoerger et al, 2007 (38); United States*	Aged 45-74 y, overweight and obese (BMI ≥25 kg/m^2) Groups	Until diabetes onset/ lifetime	Year 1 to 3: DPP cost Year 4 and beyond: DPP year 3 cost	Claims	The effect of DPP persists as long as receiving the intervention	Markov model	0.040 additional QALY	Individual: $14,154/QALY Group: $396/QALY	Individual: $28,849/QALY

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Appendix Table 3–Continued

Study, Year (Reference); Country	Population Characteristics	Duration of Intervention/ Follow-up	Cost Data Source	Benefit Data Source	Effectiveness Outcome	Model	QALY/DALY/ LYG	ICER Health System	ICER Society
Jacobs-van der Bruggen et al, 2007 (30); Netherlands	Adults with moderate risks for diabetes, obese adults aged 30-70 y	3 y/lifetime	2 published Dutch trials	Literature	BMI: −0.3 to −1.5 kg/m^2 Physical activity: 50%-75% more from inactive to moderately active, 20% more from moderately to active	Markov model	1.17 additional QALY	$8,735/QALY	†
Lindgren et al, 2007 (39); Sweden	IGT Age 60 y BMI >25 kg/m^2, FPG >6.1	6 y/lifetime	Finnish DPS	Literature	Based on Finnish DPS; no lasting effect if the intervention stops	Markov model	0.2 additional QALY	$14,852/LYG $13,367/QALY	$6,756/LYG $6,080/QALY
Gillies et al, 2008 (40); United Kingdom	NR	Until diabetes onset/50 y	A systematic review of weight loss programs	Literature, such as UKPDS	Hazard ratio, −0.649 from review	Markov model	0.05 additional LYG 0.09 additional QALY	$25,083/LYG $14,352/QALY	†
Bertram et al, 2010 (41); Australia	Age >55 y, or age >45 y plus high BMI, family history of type 2 diabetes mellitus or hypertension; people from "high-risk" groups	Average trial period/ lifetime	A systematic review and meta-analysis of lifestyle interventions	Benefit schedule	Based on meta-analysis Relative risk: 0.49 Assuming 10% decay of effect after the intervention	Microsimulation model	0.05 additional DALY averted	$21,195/DALY	†
Smith et al, 2010 (24); United States	BMI ≥25 kg/m^2 and metabolic syndrome	3 mo/3 y	A community-based DPP in Pennsylvania, United States	Literature (DPP, UKPDS, Framingham Heart Study)	By 1 y, metabolic risk: −16.2% By 3 y, risk: −19%	Markov model	0.01 QALY	$5,494/QALY	†
Neumann et al, 2011 (42); Germany	FINDRISC between 11-20, or FINDRISC ≥21 and without diagnosis of diabetes	5 y/lifetime	SDPP	CODE-2 study calculation of average annual direct health care costs of persons with NGT, IGT, and type 2 diabetes	Based on literature, such as PREDIAS and SDPP in Germany Assuming the effectiveness of the intervention lasts only for 1 y after the intervention (disappears at 7th year)	Markov model	0.02-0.03 QALY depending on sex and age	–	Age 30 y: −$41,772/QALY for men, −$52,136/QALY for women Age 50 y: −$25,079/QALY for men, −$35,217/QALY for women Age 70 y: $39,666/QALY for men, $32,259/QALY for women
Palmer et al, 2012 (43); Australia	NR	10 y/lifetime	DPPOS, using medical benefits schedule in Australia	Survey, unit cost data in Australia	Based on DPPOS trial 0.12 additional QALY	Semi-Markov simulation	0.3 LYG 0.12 QALY	−$234/LYG −$411/QALY	†
Feldman et al, 2013 (28); Sweden	NR	1 y/lifetime	Based on a lifestyle trial in Sweden	Swedish previously published studies	Based on the KMSP in Sweden Assuming effect continued at year 2 then gradually decreased, reaching the level at the start in year 5 and beyond (e.g., −0.4 to −1.1) in BMI in different risk groups +2 to −7 in waist circumference +0.2 to −0.6 in fasting glucose	Markov model	0.05-0.14 additional QALY	$4,104/QALY for men with high risk $23,327/QALY for women with high risk	Cost-saving for men with high risk $22,647/QALY for women with high risk
Png and Yoong, 2014 (44); Singapore	IGT	3 y/3 y	DPP, applying unit cost obtained from the Singapore National University Hospital cost repository Singapore Household Expenditure Survey	Singapore National University Hospital cost repository	Based on 3-y DPP trial, not explicitly reporting the risk reduction	Markov model	0.05 QALY	$17,614/QALY	$37,580/QALY

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Appendix Table 3–Continued

Study, Year (Reference); Country	Population Characteristics	Duration of Intervention/ Follow-up	Cost Data Source	Benefit Data Source	Effectiveness Outcome	Model	QALY/DALY/ LYG	ICER Health System	ICER Society
Modeling nationwide diabetes prevention programs (*n* = 2)									
Colagiuri and Walker, 2008 (45); Australia	Australians aged 45-74 y	10 y/10 y	An unspecified "lifestyle program" at Australia, $500 per person per year	Literature, such as UKPDS	Diabetes incidence in IGT: −60% In IFG: −30%	Markov model	36,009 additional DALY averted in the whole nation	$50,707/DALY	†
Zhuo et al, 2012 (46); United States	18-64 y and 65-84 y U.S. population	Until diabetes onset/25 y	Year 1: Based on YMCA-DPP Year beyond: Based on DPPOS maintenance period	Claims	Year 1: Diabetes incidence: −40% to −50% Year 2: Diabetes incidence: −40% to −50% Year 3 and beyond: −10 to −15%	Markov model	0.04 additional LYG 0.03 additional QALY	16-64 y: −$8,378/QALY 65-84 y: −$5,760/QALY	†

BMI = body mass index; CMS = Centers for Medicare & Medicaid Services; CODE-2 = Cost of Diabetes in Europe–Type 2; DALY = disability-adjusted life-year; DPP = Diabetes Prevention Program; DPPOS = Diabetes Prevention Program Outcome Study; DPS = Diabetes Prevention Study; FINDRISC = Finnish Type 2 Diabetes Risk Score; FPG = fasting plasma glucose; ICER = incremental cost-effectiveness ratio; IFG = impaired fasting glucose; IGT = impaired glucose tolerance; KMSP = Kalmar Metabolic Syndrome Program; LYG = life-year gained; NGT = normal glucose tolerance; NHS = National Health Service; NR = not reported; PREDIAS = Prevention of Diabetes Self-management Program; QALY = quality-adjusted life-year; SDPP = Saxon Diabetes Prevention Programme; UKPDS = United Kingdom Prospective Diabetes Study; YMCA = Young Men's Christian Association.

* Study reported from "societal perspective"; however, it was actually from "health system perspective" because only costs to the health system were included.

† Study did not include or report the cost or cost-effectiveness for the category.