Cost-Effective Intervention for the Prediabetic Population

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Abstract

Background: Progression from prediabetes to type 2 diabetes can be prevented or slowed with cost-effective lifestyle interventions targeting weight loss through improved diet and increased physical activity. This study provides estimates of the potential long term economic implications to society and federal budget implications if implemented on a national scale in the U.S.

Methods and Findings: Using an epidemiologically-based microsimulation model, we analyzed the potential health and economic implications if a national lifestyle intervention patterned after the National Diabetes Prevention Program were implemented among the estimated 37.9 million overweight or obese adults age 40 to 70 whose prediabetes is either already diagnosed or whose diabetes might be detected under the recent national screening recommendations. Cumulative over ten years, the average medical savings ranged from $10,970 for adults ages 40-49 at time of intervention, to $15,250 for adults ages 65-70 at time of intervention. Cumulative over 20 years, population medical savings were highest ($21,840) for the age 40-49 population and lowest ($8,030) for the age 65-70 population reflecting that lifestyle intervention increases longevity which in turn increases lifetime medical expenditures. If one quarter of these 37.9 million adults (9.5 million) completed the intervention, then cumulative over 10 years there could be $121 billion lower medical expenditures, $219 billion higher economic output, 2.5 million fewer cases of diabetes, and 800,000 fewer deaths. Over 20 years societal economic benefits continue to grow, though Medicare and Social Security expenditures for the additional 1.5 million people alive offset almost all the cumulative Medicare savings and additional federal tax revenues.

Conclusions: A large-scale program to provide access to lifestyle intervention to millions of adults with prediabetes could be highly cost effective. The health and economic rewards to society extend beyond the 10-year window used for calculating federal budget implications.

1. Introduction

Approximately 86 million U.S. adults in 2012 had prediabetes, where blood sugar (glucose) levels are elevated but below the threshold for type 2 diabetes (Centers for Disease Control and Prevention (CDC), 2014b). An estimated 89% of these adults are unaware they have prediabetes, and absent intervention 15 to 30% could develop type 2 diabetes within five years (Centers for Disease Control and Prevention (CDC), 2014b; YanFeng Li, Geiss Linda S, Burrows Nilka R, Rolka Deborah B, & Albright Ann, 2013). Whereas prediabetes is associated with $510 higher average annual medical costs (in 2012) compared to similar adults without prediabetes, the additional medical costs associated with diagnosed diabetes averages $10,970 annually (Centers for Disease Control and Prevention (CDC), 2014a; American Diabetes Association, 2013). These numbers illustrate the economic consequences of progression from prediabetes to diabetes independent of the individual and societal toll burden of diabetes in terms of reduced quality of life and higher mortality.

The Diabetes Prevention Program (DPP) and follow-up Outcomes Study (DPPOS) found that intensive lifestyle intervention can slow progression to type 2 diabetes (Knowler et al., 2002; Knowler et al., 2009; Diabetes Prevention Program Research Group, 2015). In this clinical trial, the lifestyle intervention group received counseling to make lifestyle modifications—including improved nutrition, healthy eating behaviors, and increased physical activity. Diabetes onset among the intervention group, compared to the control group, was 58% lower after 3 years (Knowler et al., 2002), 34% lower after 10 years (Knowler et al., 2009), and 27% lower after 15 years (Diabetes Prevention Program Research Group, 2015). The Community Preventive Services Task Force endorsed diabetes prevention programs modeled on the DPP as effective and cost effective (Community Preventive Services Task Force, 2015). The U.S. Preventive Services Task Force (USPSTF) recently issued recommendations that could help identify individuals with prediabetes, and also has held out the DPP as an effective model for reducing cardiovascular disease and type 2 diabetes (Community Preventive Services Task Force, 2015; Siu, 2015; LeFevre, 2014). Although these two USPSTF recommendations could result in broad insurance coverage for lifestyle intervention, the economic consequences of widespread implementation of DPP-type interventions are not well known.

Previous work by the authors suggests that achieving DPPOS results has positive societal economic implications of $17,800 to $26,800 per participant cumulative over 10 years, including $6,300 to $11,200 in reduced medical expenditures (Dall et al., 2015). The ranges reflect that medical savings and other economic benefits such as higher labor force participation rates vary by age group. Little work has been published on the return on investment of lifestyle intervention, though one recent analysis of a digital behavioral counseling service modeled after DPP estimated break-even within three years and net savings of $1,512 per participant within 5 years and $7,918 within 10 years (Su, hen, Iacobucci, Dall, & Perreault, 2016).

Widespread implementation of USPSTF diabetes screening recommendations and subsequent identification of millions of adults with prediabetes would require a large-scale program to provide access to lifestyle intervention to millions of Americans to prevent and/or slow progression to type 2 diabetes. This study addresses two questions:

(1) What might a large-scale program look like?

(2) What are the clinical and economic implications from both a societal and federal budgetary perspective? The study used budget windows of 10 years (currently used for federal budget scoring) and 20 years (to determine whether a 10-year window understates the benefits of interventions targeted at preventing and/or managing chronic disease).

2. Methods

The microsimulation model uses a Markov approach where each person's characteristics and risk factors at the beginning of each year determine the probability of changes in health outcomes during the year. The annual cycle repeated for 20 years unless mortality occurred sooner.

We first describe the proposed intervention and the target population. Then, we describe the epidemiologically-based simulation model used to examine the potential clinical and economic benefits of this intervention.

2.1. Nationwide Implementation of The National Diabetes Program to Reduce Progression from Prediabetes to Type 2 Diabetes

The building blocks of a national intervention are comprehensive screening for prediabetes, identification of effective and cost-effective interventions, and capacity-building to make interventions available to millions of Americans.

- **Screening –** Detection is the first critical step to directing patients to lifestyle intervention, but only 8.1 million of the estimated 86 million (89%) adults in 2012 with prediabetes were unaware of their condition (YanFeng Li et al., 2013). Our analysis of the 2012 National Health and Nutrition Examination Survey (NHANES) data suggests among adults that met either the new USPSTF diabetes screening criteria or the Centers for Medicare and Medicaid Services (CMS) screening criteria (for Medicare beneficiaries), there were 58.5 million adults with previously undetected prediabetes of whom 47.5 million were overweight or obese. An additional 6.6 million overweight or obese adults had diagnosed prediabetes. However, we limited our modeling to the 37.9 million adults between age 40 and 70 in line with USPSTF diabetes screening recommendations (Siu, 2015). The USPSTF recommends screening for abnormal blood glucose as part of cardiovascular risk assessment in adults aged 40 to 70 years who are overweight or obese and says that clinicians should offer or refer patients with abnormal glucose to intensive behavioral counseling interventions to promote a healthful diet and physical activity. (B recommendation) Furthermore, the USPSTF says that clinicians should consider screening at a younger age or with a lower body mass index in persons with a family history of diabetes, a history of gestational diabetes or polycystic ovarian syndrome, or members of certain racial and ethnic groups (that is, African Americans, American Indians or Alaskan Natives, Asian Americans, Hispanics or Latinos, or Native Hawaiians or Pacific Islanders) (Siu et al, 2015) Medicare screening criteria are: (a) obese; or (b) have hypertension, or hypercholesterolemia, or known elevated blood glucose levels; or (c) family history of diabetes or history of gestational diabetes. For the population age 65 to 70 we applied the CMS screening criteria, and for the population age 40 to 64 we applied the USPSTF screening criteria.

- **Effective intervention -** We modeled the implications of achieving DPP/DPPOS results among the 37.9 million adults described above. Interventions modeled after DPP focus on lifestyle changes, improving diet and exercise, aimed at reducing body weight and improving blood glucose, blood pressure, and cholesterol levels. DPPOS-reported weight loss varied by age group, but on average participants lost over 6kg the first year (about 7.2%) then gradually regained weight and stabilized at 2kg below their starting weight from years 5 through 10 (Knowler et al., 2009). We converted weight changes to change in body mass index (BMI) for modeling. Efforts have been made to design affordable and cost-effective community-based programs based on the DPP intervention model (Lawlor et al., 2013; Su et al., 2016). For modeling, we used $177 per participant as the cost of screening and prediabetes diagnosis, and $724 in the first year and $206 in the second year for lifestyle intervention costs. These estimates are based in part on the Healthy Living Partnerships to Prevent Diabetes (HELP PD) trial, which adapted the DPP approach to community-based settings and calculated $7.65 per screening test (in 2015 dollars) (Lawlor et al., 2013). In July 2016, CMS stated in its CY 2017 Medicare Physician Fee Schedule (MPFS) proposed rule that diabetes prevention programs be reimbursed at a maximum rate of $450 per program participant in the first year and $180 in the second year. (CMS, 2016) These rates are consistent with recommendations made by the CMS Office of the Actuary in certifying the Medicare Diabetes Prevention Program based on an analysis of data collected as part of a three-year Center for Medicare and Medicaid Innovation (CMMI) grant awarded to the YMCA of the USA to recruit and enroll adults aged 65 and older in community based diabetes prevention programs. (CMS Office of the Actuary, 2016). These rates are significantly lower than those used in the HLPD PD trial and in our analysis. Centers for Medicare and Medicaid Services. CY 2017 Medicare Physician Fee Schedule Proposed Rule. July 2016. Centers for Medicare and Medicaid Services Office of the Actuary. Certification of Medicare Diabetes Prevention Program. March 14, 2016.Our analysis of 2012 NHANES data suggests that approximately 2.5 people would be screened to detect each new case of prediabetes under the new USPSTF guidelines. The modeled cost for follow-up diagnosis

($158) reflects national average estimates for primary care physician preventive office visits and lab costs, so the modeled cost for screening and diagnosis is $177 per person identified with prediabetes. HELP PD reported monthly cost (2015 dollars) of about $103 during the intensive phase (months 1-6) and $17 during the maintenance phase (months 7-24)—suggesting approximately $724 in the first year and $206 in the second year. Other DPP-type interventions have reported both lower and higher costs. Modeled treatment costs do not include time, travel, or other costs to the patient associated with program participation.

2.2. The Simulation Tool and Modeling Assumptions

The epidemiologically-based microsimulation model used to examine the clinical and economic implications of lifestyle intervention has been described elsewhere, including detailed technical appendices (Dall et al., 2015; Su et al., 2015; Semilla, Chen, & Dall, 15 A.D.; Su et al., 2016). These prior publications document the data sources, assumptions, and model validation efforts. We provide a brief overview of the model here.

2.2.1. Population Modeled

The population modeled is the 37.9 million overweight or obese adults age 40 to 70 with prediabetes. We used the 2012 NHANES to estimate the size of the national population who would be candidates for intervention, but combined the 2007-2012 files to increase sample size for creating the analytic file. Using the NHANES sample weights to determine probability of selection, among the overweight and obese sample with prediabetes we drew a random sample (with replacement) of 100,000 observations for each age group (40-49, 50-59, 60-64, and 65-70).

2.2.2. Scenarios Modeled

For each person we simulated annual outcomes over the subsequent 20 years under two scenarios:

(1) Simulated natural history of disease—following trends in clinical outcomes (body weight, blood pressure, cholesterol levels, and A1c level) and disease onset observed among the U.S. adult population. (2) Achieving average, annual weight change over ten years reported by DPPOS participants and simulated after ten years based on natural history of disease (Knowler et al., 2009). We converted weight changes to change in body mass index (BMI) for modeling. Differences in population outcomes between the two scenarios provides estimates of intervention effect on health status, medical expenditures and other economic outcomes, mortality, and quality of life. The scenarios were modeled separately by age group (40-49, 50-59, 60-64, and 65-70) and then scaled to national totals based on the estimated size of the prediabetic population in each age group.

2.2.3. Health Transition States and Probabilities

Equations predicting annual change in disease states came from published clinical and observational studies as described in detail elsewhere (Dall et al., 2015; Su et al., 2015). Annual change in body weight absent intervention reflects the average difference in BMI between subsequent ages in a cross-sectional analysis of 2007-2012 NHANES data, with the relationship between age and BMI calculated separately by sex and body weight category (BMI<25, 25≤ BMI<30, BMI≥30). Annual change in systolic and diastolic blood pressure, total cholesterol and high density lipoprotein cholesterol was linked to age, sex, and change in BMI using parameters from the published literature (Neter, Stam, Kok, Grobbee, & Geleijnse, 2003; Heianza et al., 2012; Dall et al., 2015). Annual change in A1c was linked to age, BMI change, and total cholesterol (Dall et al., 2015). Equations to predict incidence of atrial fibrillation, left ventricular hypertrophy, ischemic heart disease, myocardial infarction, congestive heart failure, stroke, chronic kidney disease, renal failure, and peripheral vascular disease, amputation and retinopathy came from the United Kingdom Prospective Diabetes Study Outcomes Model, the Framingham Heart Study, and other sources (Clarke et al., 2004; Hippisley-Cox & Coupland, 2010; Wilson et al., 2008; U.S.Department of Health and Human Services, 2009).
Annual mortality probability associated with individual disease states and all-cause mortality came from published equations (Clarke et al., 2004; Centers

for Disease Control and Prevention, 2013). Quality of life reductions associated with disease states were based on published findings for a nationally representative sample of U.S. adults (Zhang et al., 2012; Sullivan, Lawrence, & Ghushchyan, 2005).

2.2.4. Medical Expenditures and Economic Outcomes

Annual medical expenditures were estimated using a generalized linear model with gamma distribution and log link, analyzing data from the 2009-2013 files (n~170,000) of the Medical Expenditure Panel Survey (MEPS) (Dall et al., 2015). Explanatory variables were age, sex, race, insurance status, overweight, obese, presence of modeled diseases, and interaction terms for diabetes and modeled diseases. Costs associated with end of life were based on published estimates (Riley & Lubitz, 2010). Estimated Medicare expenditures reflect that beneficiaries pay out of pocket for approximately 23% of services (Boards of Trustees of the Federal Hospital Insurance and Federal Supplementary Medical Insurance Trust Funds, 2012).
The association between disease presence and economic outcomes is based on regression analysis with MEPS data (Dall et al., 2015). The same explanatory variables described above were used, with employed status (n~25,000) and receipt of Supplemental Security Income for disability (n~26,000) both estimated by logistic regression and annual missed work days (n~19,000) for employed adults analyzed using negative binomial regression. Ordinary least squares regression with MEPS data (n~166,000) modeled household income. Probability of employment and household income was simulated through age 70. To calculate federal receipts from income taxes we used a 10% rate, which reflects the national median effective tax rate for income and Social Security taxes. Our simulation suggests DPP participation is associated with increased life expectancy, which in turn can increase government expenditures for Social Security. We assume that each additional year of life after age 65 is associated with $13,200 in additional Social Security costs, which reflects average expenditures per beneficiary and that 90% of adults age 65 and older receive Social Security benefits.
All monetary estimates are in 2015 dollars and reported as present values using a 3% discount rate. Costs associated with the value of participant time and incidental costs (e.g., travel) to participate in lifestyle intervention were not included.

3. Results

Of the estimated 37.9 million candidates for lifestyle intervention, the average age was 54.5 years with average BMI of 32.4 and average A1c of 5.9 (Table 1). The population consisted of 14.7 million people ages 50-59, 12.1 million ages 40-49, 6.0 million ages 60-64 and 5.1 million ages 65-
70. The youngest group modeled (age 40-49) had the highest long-term economic impact from intervention of the age categories analyzed (Tables 2 and 3). Reduced onset of diabetes and the other diseases modeled reduces projected cumulative, average medical expenditures by $10,970 per participant (11.2%) over 10 years and $21,840 (17.5%) over 20 years. The cumulative net economic benefits from intervention (including non-medical economic benefits), rises from $33,740 per participant over 10 years to $87,840 over 20 years. Higher levels of tax payments and lower Medicare costs combine to improve the federal budget outlook averaging $7,320 per participant over 20 years following intervention. Average life expectancy for this cohort rises by 0.3 years through year 10 and 1.2 years through year 20.

Table 1. Prediabetic Starting Population Characteristics

	Overweight or Obese				
	Age 40-49	**Age 50-59**	**Age 60-64**	**Age 65-70**	**Total Age 40-70**
Averages					
Age	44.9	54.9	61.9	67.4	54.5
Hemoglobin A1c	5.89	5.90	5.90	5.92	5.90
Body mass index	33.4	32.2	31.5	31.7	32.4
Systolic blood pressure	123.3	128.2	129.1	130.6	127.1
Diastolic blood pressure	76.4	75.9	73.0	69.9	74.8
Total cholesterol	207.5	211.6	205.9	200.9	207.9
HDL-cholesterol	46.5	49.0	51.1	51.9	48.9
Percentages					
Male	55.2	54.7	44.4	47.4	52.2
Insured	73.2	83.2	82.5	96.2	81.6
Current smoker	30.8	20.5	20.7	13.5	22.9
Hypercholesterolemia [a]	43.1	61.5	64.0	70.1	57.2
Hypertension [a] (controlled or uncontrolled)	43.1	53.1	66.9	68.6	54.2
Ischemic heart disease	5.8	6.4	9.6	13.2	7.6
PDM Population (millions) [b]	**12.1**	**14.7**	**6.0**	**5.1**	**37.9**
Diagnosed PDM	1.2	2.0	1.0	0.8	5.0
Undiagnosed PDM, meets USPSTF screening criteria	10.9	12.7	5.0	4.3	32.9

Notes: Estimates are based on analysis of the combined 2007-2012 National Health and Nutrition Examination Survey files using sample weights.

[a] Hypercholesterolemia status was determined for the starting population by either a survey response indicating that the person had previously been told by a health professional that he/she had high blood cholesterol level, or if total cholesterol exceeded 240 mg/dL. Hypertension status was determined by survey response indicating previously having been told by a health professional that he/she had high blood pressure, or self-report of taking medications for high blood pressure, or if systolic blood pressure exceeded 139 or diastolic blood pressure exceeded 89.

[b] Population estimated reflect the adult population with diagnosed prediabetes or undiagnosed prediabetes who meet the 2015 USPSTF screening criteria for prediabetes/diabetes, or the CMS screening criteria for Medicare beneficiaries. Numbers might not sum to totals because of rounding. The population over age 70 was not modeled due to small sample size and lack of data on the value of lifestyle intervention for this population.

Table 2. Clinical and Gross Economic Impact of Lifestyle Intervention per Participant Age 40-49

	5 years	10 years	15 years	20 years
Clinical and Quality of Life Impact				
Disease onset/adverse event probability				
Diabetes	-18%	-29%	-22%	-17%
Ischemic heart disease	0%	-1%	-2%	-2%
Congestive heart failure	-2%	-5%	-8%	-10%
Stroke	-1%	-3%	-4%	-5%
Heart attack	-1%	-2%	-3%	-4%
Renal failure	0%	-1%	-1%	0%
Amputation	0%	0%	0%	-1%
Diabetic retinopathy	0%	-1%	-1%	-1%
Mortality probability	-1%	-4%	-9%	-12%
Years of life	0.0	0.1	0.5	1.0
Quality-adjusted life years	0.1	0.3	0.7	1.2
Economic Impact				
Medical expenditures	$(3,520)	$(10,970)	$(18,170)	$(21,840)
% Savings	7.4%	11.3%	16.2%	17.5%
Medicare expenditures	$(10)	$(50)	$(200)	$(740)
Non-medical economic impact	$7,390	$23,870	$45,470	$67,100
Household income	$7,390	$23,440	$46,640	$68,970
Years of employment	0.07	0.30	0.69	1.08
Absenteeism avoided (days)	0	2.7	8.0	13.8
Productivity from absenteeism avoided	$0	$430	$(1,170)	$(1,870)
Total economic impact	$10,910	$34,840	$63,640	$88,940
Screening and treatment costs	$1,100	$1,100	$1,100	$1,100
Screening and diagnosis	$180	$180	$180	$180
Lifestyle intervention	$920	$920	$920	$920
Net economic impact	$9,810	$33,740	$62,540	$87,840
Federal Impact	$750	$2,440	$4,960	$6,580
Federal revenues	$740	$2,350	$4,670	$6,910
Social Security and disability receipts (+) and payments (-)	$10	$100	$300	$(320)
Net government impact (Medicare, federal revenues, Social Security)	$760	$2,490	$5,160	$7,320

Notes: Simulated outcomes for the overweight or obese prediabetic U.S. adult population age 40 to 70 at time of intervention under the scenario of achieving average weight loss reported by the Diabetes Prevention Program and Outcomes Study versus the absence of intervention. Medical expenditure numbers in parentheses represent savings. Non-medical economic numbers in parentheses represent decreases. Federal transfer payments in parentheses represent outflow of federal dollars. Estimates use 3% discount rate.

Intervention costs exclude engagement costs associated with participant time or transportation. Medical savings reflect reduced onset and severity of diseases modeled.

Table 3. Average Cumulative Impact of Lifestyle Intervention per Participant

	Age 40-49	Age 50-59	Age 60-64	Age 65-70	Age 40-70
Cumulative Over 10 Years					
Diabetes onset probability	-29%	-26%	-25%	-22%	-26%
Mortality probability	-4%	-8%	-13%	-14%	-8%
Quality adjusted life years	0.3	0.4	0.6	0.6	0.5
Economic impact					
Medical expenditures	($10,970)	($12,920)	($13,810)	($15,250)	($12,750)
% Savings	16%	16%	14%	13%	15%
Medicare expenditures	($50)	($1,620)	($7,630)	($10,750)	($3,290)
Non-medical impact	$23,870	$30,910	$18,900	$3,640	$23,110
Gross economic impact	$34,840	$43,830	$32,710	$18,890	$35,860
Screening and treatment costs	$1,100	$1,100	$1,100	$1,090	$1,100
Net economic impact	$33,740	$42,730	$31,610	$17,800	$34,760
Net federal benefits [a]	$2,490	$4,570	$8,780	$9,940	$5,290
Cumulative Over 15 Years					
Diabetes onset	-22%	-19%	-18%	-15%	-19%
Mortality probability	-9%	-15%	-20%	-18%	-14%
Quality-adjusted life years	0.7	1.0	1.3	1.3	1.0
Economic impact					
Medical expenditures	($18,170)	($18,340)	($16,810)	($14,550)	($17,540)
% Savings	17%	15%	12%	10%	15%
Medicare expenditures	$(200)	$(4,030)	$(9,760)	$(10,250)	$(4,540)
Non-medical impact	$45,470	$46,850	$18,650	$3,660	$36,180
Gross economic impact	$63,640	$65,190	$35,460	$18,210	$53,720
Screening and treatment costs	$1,100	$1,100	$1,100	$1,090	$1,100
Net economic impact	$62,540	$64,090	$34,360	$17,120	$52,620
Net federal benefits [a]	$5,160	$6,770	$6,450	$4,130	$5,850
Cumulative Over 20 Years					
Diabetes onset probability	-17%	-14%	-12%	-11%	-14%
Mortality probability	-12%	-18%	-20%	-12%	-16%
Quality-adjusted life years	1.2	1.7	2.1	1.8	1.6
Economic impact					
Medical expenditures	($21,840)	($17,670)	($11,760)	($8,030)	($16,780)
% Savings	17%	15%	12%	9%	14%
Medicare expenditures	$(740)	$(3,350)	$(5,670)	$(5,240)	$(3,130)
Non-medical impact	$67,100	$50,090	$18,650	$3,660	$44,350
Gross economic impact	$88,940	$67,760	$30,410	$11,690	$61,130
Screening and treatment costs	$1,100	$1,100	$1,100	$1,090	$1,100
Net economic impact	$87,840	$66,660	$29,310	$10,600	$60,030
Net federal benefits [a]	$7,320	$560	($5,720)	($8,680)	$490

Notes: Simulated outcomes for the overweight or obese prediabetic U.S. adult population age 40 to 70 at time of intervention under the scenario of achieving average weight loss reported by the Diabetes Prevention Program and Outcomes Study versus the absence of intervention. Estimates use 3% discount rate. [a] Consists of Medicare, tax receipts, and Social Security and disability payments. Intervention costs exclude engagement costs associated with participant time or transportation. Medical savings reflect reduced onset and severity of diseases modeled.

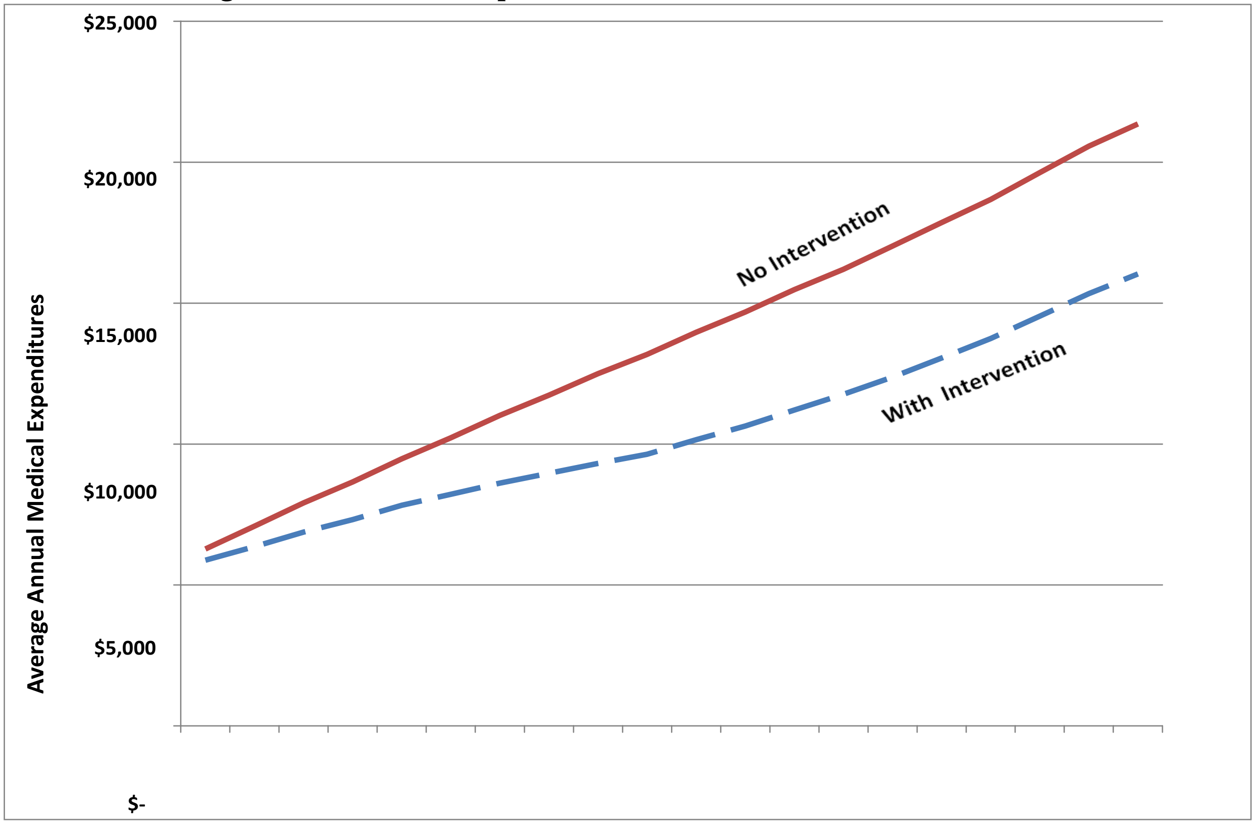
Among the overall population age 40-70, lifestyle intervention is projected to reduce diabetes onset by 26% through year 10, by 19% through year 15, and by 14% through year 20—reflecting that intervention sometimes only delays disease onset (Table 3). This simulated reduced risk of diabetes onset is more conservative than reported outcomes from the DPP trials—which reports 34% reduced risk after 10 years and 27% reduced risk after 15 years (Knowler et al., 2009; Diabetes Prevention Program Research Group, 2015).

Estimated benefits from intervention differ by age group (Table 3). Cumulative 10-year medical savings per participant is highest for the age 65-70 population ($15,250, or 13% savings).

Across 20 years, average cumulative net economic impact ranges from $87,840 (age 40-49) to $10,600 (age 65-70). Over 20 years, societal medical savings associated with the population age 65+ at time of intervention declines—reflecting that increased longevity raises lifetime cohort medical costs even though intervention lowers average annual costs per participant still living.

The average annual medical savings from lifestyle interventions grow over time among the population living (Figure 1). Using undiscounted medical costs, intervention is associated with $400 (6% savings) lower medical costs the year following intervention, $3,540 (27% savings) lower medical costs in the tenth year following intervention, and $5,320 (25% savings) lower costs in the twentieth year following intervention.

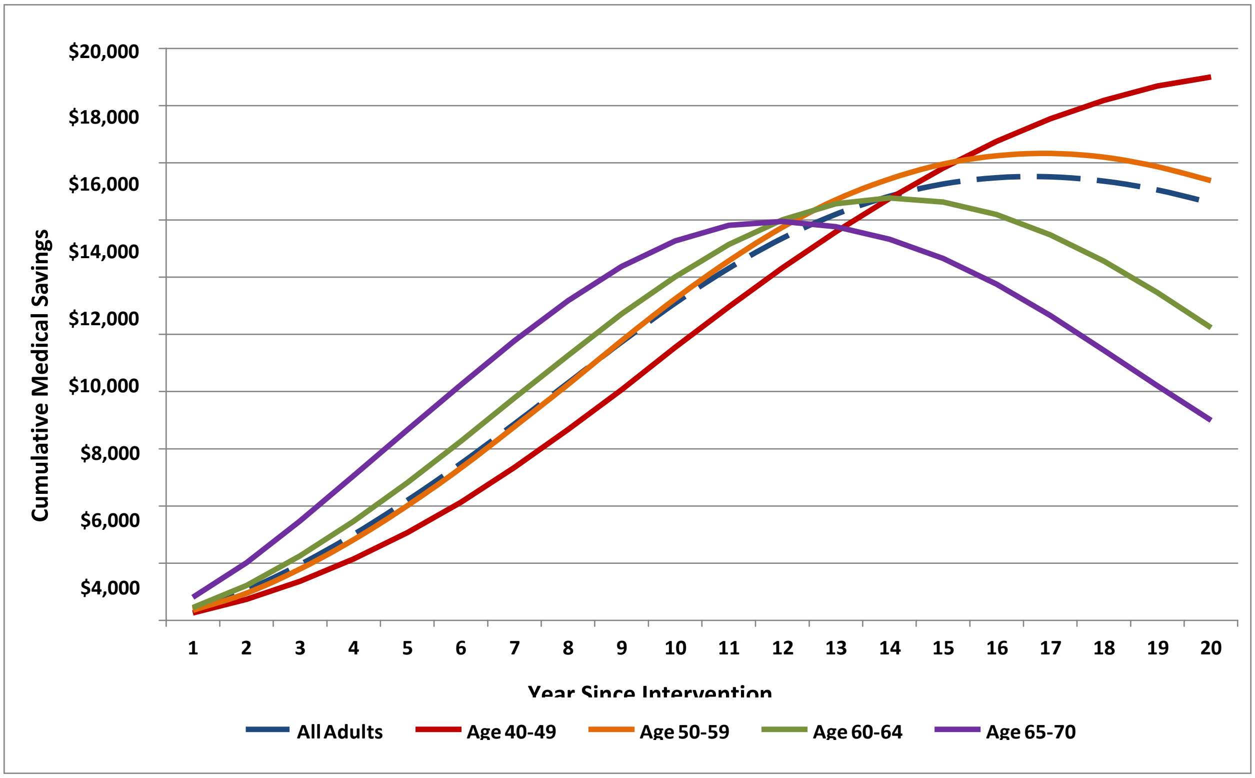
Figure 1. Simulated Average Annual Medical Expenditures



Notes: Simulated average annual medical costs (undiscounted) among the overweight or obese U.S. adult population age 40 to 70 with prediabetes at time of intervention, under the scenario of achieving average weight loss reported by the Diabetes Prevention Program and Outcomes Study versus the absence of intervention.

On a cumulative basis for the entire adult cohort participating in the intervention, and using a 3% discount rate, population average medical savings rise each year peaking at year 17 ($15,510) before starting to decline (Figure 2). This peak is reached in year 12 for the population age 65-70 at time of intervention, and reached in year 20 (last year simulated) for the population age 40-49 at time of intervention. This trend of rising and peaking cumulative medical benefits reflects (a) the benefits of intervention per person continues to rise over time, and (b) because more people are still alive (and incurring medical costs) under the intervention scenario then the population- level savings start to diminish over time. Looking only at medical savings, these findings suggest that a time horizon of 10 years for evaluating programs around diabetes prevention will under state the value of intervention, while a time horizon of 20 years might be appropriate for younger populations but might understate the value of intervention among older populations.

Figure 2. Cohort Average Cumulative Medical Savings per Participant



Notes: Simulated average annual medical costs (undiscounted) among the overweight or obese U.S. adult population age 40 to 70 with prediabetes at time of intervention, under the scenario of achieving average weight loss reported by the Diabetes Prevention Program and Outcomes Study versus the absence of intervention.

3.1. National Implementation

Not all of the 37.9 million candidates for lifestyle intervention would choose to participate in such a program. A recent Gallup poll reports 90% of Americans 20+ pounds overweight want to lose weight, but only 48% indicated they were “seriously trying to lose weight” (Norman J, 2015). The percentage seriously trying to lose weight declines to 24% for adults 1-19 pounds overweight. Table 4 summarizes the national societal and federal budget implications if 25% of the 37.9 million candidates (9.5 million) participated—with the impact doubled if participation reached 50%. Cumulative over 10 years:

- Net societal economic benefits could reach $329 billion; including: $121 billion in reduced medical expenditures ($31 billion in reduced Medicare expenditures), $219 billion in non-medical benefits from higher employment and productivity, and $10 billion in additional screening, diagnosis and treatment costs.
- There could be 2.5 million fewer diabetes cases in the tenth year.
- An additional 800,000 people could be alive in the tenth year, with cumulative 4.3 million quality-adjusted life years gained.

The estimated net federal impact could be $50 billion in net benefits from a combination of reduced Medicare expenditures and higher tax revenues, offset by higher social security costs from increased longevity.

Table 4. National Total Potential Impact of Lifestyle Intervention with 25% Participation

	Age 40-49	Age 50-59	Age 60-64	Age 65-70	Age 40-70
Population (millions)	3.0	3.7	1.5	1.3	9.5
Cumulative Over 10 Years					
Diabetes onset (millions)	(0.9)	(1.0)	(0.4)	(0.3)	(2.5)
Mortality (millions)	(0.1)	(0.3)	(0.2)	(0.2)	(0.8)
Quality-adjusted life years (millions)	1.0	1.6	0.9	0.8	4.3
Economic impact (billions)					
Medical expenditures	$(33)	$(48)	$(21)	$(19)	$(121)
% Savings	16%	16%	14%	13%	15%
Medicare expenditures	$(0)	$(6)	$(11)	$(14)	$(31)
Non-medical impact	$72	$114	$28	$5	$219
Gross economic impact	$106	$161	$49	$24	$340
Screening and treatment costs	$3	$4	$2	$1	$10
Net economic impact	$102	$157	$47	$23	$329
Net federal benefits (billions) [a]	$8	$17	$13	$13	$50
Societal economic return on investment	32:1	40:1	30:1	17:1	33:1
Federal government cost per QALY [b]	NA	NA	NA	NA	NA
Cumulative Over 15 Years					
Diabetes onset (millions)	(0.7)	(0.7)	(0.3)	(0.2)	(1.8)
Mortality (millions)	(0.3)	(0.6)	(0.3)	(0.2)	(1.4)
Quality adjusted life years (millions)	2.1	3.7	2.0	1.6	9.4
Economic impact (billions)					
Medical expenditures	$(55)	$(68)	$(25)	$(18)	$(166)
% Savings	17%	15%	12%	10%	15%
Medicare expenditures	$(1)	$(15)	$(15)	$(13)	$(43)
Non-medical impact	$138	$173	$28	$5	$343
Gross economic impact	$193	$240	$53	$23	$509
Screening and treatment costs	$3	$4	$2	$1	$10
Net economic impact	$189	$236	$51	$22	$498
Net federal benefits (billions) [a]	$16	$25	$10	$5	$55
Societal economic return on investment	58:1	59:1	32:1	17:1	49:1
Federal government cost per QALY [b]	NA	NA	NA	NA	NA
Cumulative Over 20 Years					
Diabetes onset (millions)	(0.5)	(0.5)	(0.2)	(0.1)	(1.3)
Mortality (millions)	(0.4)	(0.7)	(0.3)	(0.2)	(1.5)
Quality adjusted life years (millions)	3.6	6.2	3.1	2.3	15.2
Economic impact (billions)					
Medical expenditures	$(66)	$(65)	$(18)	$(10)	$(159)
% Savings	17%	15%	12%	9%	14%
Medicare expenditures	$(2)	$(12)	$(8)	$(7)	$(30)
Non-medical impact	$203	$184	$28	$5	$420

Gross economic impact	$269	$250	$45	$15	$579
Screening and treatment costs	$3	$4	$2	$1	$10
Net economic impact	$266	$246	$44	$13	$569
Net federal benefits (billions) [a]	$22	$2	$(9)	$(11)	$5
Societal economic return on investment	81:1	62:1	28:1	11:1	56:1
Federal government cost per QALY [b]	NA	NA	$2,770	$5,300	NA

Notes: Simulated outcomes for the overweight or obese prediabetic U.S. adult population age 40 to 70 at time of intervention under the scenario of achieving average weight loss reported by the Diabetes Prevention Program and Outcomes Study versus the absence of intervention. National estimates reflect the potential benefits and costs if 25% of candidates participated in a lifestyle intervention.
QALY=quality adjusted life year. Estimates use 3% discount rate. [a] Consists of simulated Medicare, tax receipts, and Social Security and disability payments. [b] Estimates assume federal payment for screening, diagnosis, and intervention costs for the population age 65 and older. Intervention costs
exclude engagement costs associated with participant time or transportation. The population over age 70 was not modeled due to small sample size and lack of data on the value of lifestyle intervention for this population.

Cumulative over 20 years, projected total medical savings reach $159 billion—including $30 billion in Medicare savings. Medicare savings over 20 years is nearly identical to savings over 10 years because even though intervention reduced average costs per patient the intervention increased life expectancy (with 1.5 million more people alive at year 20 and 15.2 million quality-adjusted life years gained). The projected net societal economic impact is $569 billion in benefits, but the federal budget impact largely disappears ($5 billion in net benefits) reflecting higher Social Security expenditures.

The societal benefit-to-cost ratio through 10 years ranges from 17:1 for the age 65-70 population to 40:1 for adults age 50 to 59. On average, each $1 for screening, diagnosis, and lifestyle intervention returns $33 in societal economic benefits. Across 20 years, this ratio peaks at 81:1 for adults age 20-44.

3.2. Sensitivity Analysis

This study modeled the weight loss (and partial weight regain) reported by the DPPOS. One concern is that translational programs sometimes achieve lower average weight loss, so our estimates might overstate potential benefits. Reported average weight loss from DPP was 7.2% in the first year. Although the study results are not linear with respect to the amount of weight loss, each 1 percentage point change in weight loss is approximately equal to a 14% change in study outcomes. Thus, achieving average weight loss of 6.2% or 5.2% would, respectively, result in economic benefits approximately 14% or 28% lower than estimated based on our simulation of DPP results. Additional sensitivity analyses are reported elsewhere (Dall et al., 2015; Su et al., 2015), but other key parameters that affect simulation results are annual change in A1c levels (which affects onset of diabetes and some sequelae of diabetes) and the chosen discount rate. Our simulated changes in annual A1c levels might be conservative—as we simulate lower onset rates of diabetes relative to DPP-reported rates for both the intervention and control groups. A higher discount rate reduces estimated savings (e.g., 20-year cumulative medical savings are 17% lower when using a 6% discount rate and 21% higher when using a 0% discount rate relative to using a 3% discount rate). A higher discount rate, though, tends to have a larger adverse effect on estimated economic benefits of intervention among younger adults relative to the effect on older adults. This reflects, in part, that the medical benefits of lifestyle intervention among a younger population grow more slowly over time and a younger population has greater life expectance relative to the older populations modeled.

4. Discussion

We described a possible broad-based intervention and quantified the anticipated health improvement and economic implications if implemented among a general population whose prediabetes might be detected under USPSTF and CMS screening recommendations. We looked at the economic impact from both societal and federal budgetary perspectives using both the 10- year window currently used by the Congressional Budget Office for scoring federal legislation and a 20-year window that illustrates the potential long-term impact of interventions. Key findings include:

1. Screening and lifestyle treatment for prediabetes is highly cost effective from a societal perspective. The USPSTF diabetes screening recommendation highlights that widespread coverage of screening for prediabetes is a critical first step toward making progress in slowing the progress to type 2 diabetes. Relative to the costs of caring for patients with diabetes, screening and intervention costs are minimal.

2. Because of the long natural progression of diabetes, intervention is often better understood when examined beyond ten years. The intervention modeled provides federal budget benefits within a 10- and 15-year timeframe, with continued benefits over 20 years for younger populations. For older populations, the longer time horizon reveals deterioration in the federal budget outlook due to increased longevity and associated higher costs for Social Security and Medicare.

3. Intervention among the pre-Medicare (age 60-64) population can reduce future Medicare expenditures by approximately $7,630 per participant over 10 years and $9,760 over 15 years. This benefit far exceeds the estimated cost for screening, diagnosis and intervention. Cumulative over 10 years, the estimated average reduction in Medicare costs from the intervention is $10,750 for Medicare participants age 65-70.

National implementation of lifestyle intervention modeled on the DPP and offered in the community is likely to build on the National Diabetes Prevention Program overseen by CDC, now that the CMS Office of the Actuary has certified this program as eligible for nationwide expansion and the US Secretary of Health and Human Services has indicated Medicare would begin offering the program as a benefit beginning in January 2018. (CMS, 2016) Additionally, because of a provision of the Affordable Care Act that requires health plans to cover preventive services that have received an “A” or “B” recommendation from the US Preventive Services Task Force, health plans will be required to cover both screening and participation in prevention programs beginning in January 2018. The 37.9 million adults modeled by this study are based on the population in 2012, as identified using NHANES data, and include 21.7 million commercially insured plus a portion of the 7 million uninsured in 2012 who likely would gain coverage under the Affordable Care Act. Hence, active employer participation in financing the interventions for employees and their families would reduce the necessary cost of a federal effort to lower financial barriers to the interventions. Additionally, Congress could decide to make lifestyle interventions a required benefit in both Medicare and Medicaid, further reducing barriers to enrollment. The population constructed using NHANES data suggests approximately 4.9 million Medicaid and 5.1 million Medicare beneficiaries with prediabetes in 2012 would be candidates for intervention (increasing to 13 million Medicare beneficiaries if all age groups were represented rather than the age 70 cutoff used in our analysis).

4.1. Simulation Model Strengths and Limitations

Detailed documentation of the microsimulation model used and its strengths and limitations is published elsewhere (Dall et al., 2015; Su et al., 2015). Simulation allows for a better understanding of the pathways by which improvements in body weight and glycemic levels can prevent or delay disease onset and severity. Simulation allows for comparisons across different populations, time horizons, and from societal and federal budget perspectives.

Model limitations include the following:

(1) Multiple data sources (longitudinal and cross-sectional) from different time periods and populations were used to inform key parameters and predictive equations. For modeling weight change as a person ages (which is a key component of the model), validation activities suggested similar results to those reported by Sheehan et al. based on a 20-year follow-up of a nationally representative sample of 5,117 adults in the National Health Examination Follow-up Study (Sheehan, DuBrava, DeChello, & Fang, 2003).

(2) Some predictive equations are based on analysis of the general adult population when published predictive equations for a population with prediabetes are unavailable. It is unclear what impact this has on the simulation results, though the predictive equations capture differences in biometrics between the population with prediabetes and the general adult population.

(3) Some older data sources were used, and standards of care such as statin use have evolved over time. The analytic file used to create the population for simulation is based on a representative sample of adults in the 2007-2012 NHANES, so the biometrics (e.g., cholesterol levels) of the simulated population are reflective of this time period. Model calibration and validation activities included simulating national population outcomes and comparing simulated results to published statistics—e.g., reflecting onset of cardiovascular disease and other outcomes modeled.

(4) Limiting the simulation to the age 40 to 70 likely understates the national estimate of overweight or obese population who are candidates for program participation. Among the population older than age 70, the length of remaining life expectancy limits the usefulness of simulating results past 10 years. In addition, it is unclear how well the prediction equations in the simulation can model health events for the oldest populations because such populations are generally not well represented in the data sources used for modeling (whether clinical trials or national data sources such as NHANES or MEPS which are representative samples of the non-institutionalized population).

4.2. Conclusion

Millions of Americans are at risk of developing type 2 diabetes. Public and private efforts have developed effective, community-based or online interventions that can reverse or slow the progression from prediabetes to diabetes. The new USPSTF recommendations for diabetes screening and lifestyle intervention are important steps in tackling the costly burden of diabetes, but a concerted effort is needed to take proven interventions to scale so millions of people can benefit from them. In assessing the federal budgetary consequences of such an initiative, Congress should look beyond ten years because the benefits continue for decades. If even a quarter of the targeted prediabetic population completed the intervention, the net societal economic benefit over 20 years would be $569 billion.

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References

1. American Diabetes Association (2013). Economic costs of diabetes in the U.S. in 2012. *Diabetes care*. 36(4):1033-1046. http://care.diabetesjournals.org/content/early/2013/03/05/dc12- 2625.full.pdf+html

2. Boards of Trustees of the Federal Hospital Insurance and Federal Supplementary Medical Insurance Trust Funds (2012). 2012 Annual Report of the Boards of Trustees of the Federal Hospital Insurance and Federal Supplementary Medical Insurance Trust Funds. https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/ReportsTrustFunds/downloads/tr2012.pdf

3. Centers for Disease Control and Prevention (CDC) (2014a). National Diabetes Statistics Report, 2014. Centers for Disease Control and Prevention. http://www.cdc.gov/diabetes/pubs/statsreport14/national-diabetes-report-web.pdf

4. Centers for Disease Control and Prevention (CDC) (2014b). Prediabetes. Centers for Disease Control and Prevention. http://www.cdc.gov/diabetes/consumer/prediabetes.htm

5. Centers for Disease Control and Prevention, N. C. H. S. (2013). Underlying Cause of Death 1999-2010 on CDC WONDER Online Database, released 2012. Centers for Disease Control and Prevention, National Center for Health Statistics [Electronic version]. Clarke, P. M., Gray, A. M., Briggs, A., Farmer, A. J., Fenn, P., Stevens, R. J. et al. (2004). A model to estimate the lifetime health outcomes of patients with type 2 diabetes: the United Kingdom Prospective Diabetes Study (UKPDS) Outcomes Model (UKPDS no. 68). *Diabetologia, 47*, 1747-1759.

6. Community Preventive Services Task Force (6-10-2015). Diabetes Prevention and Control: Combined Diet and Physical Activity Promotion Programs to Prevent Type 2 Diabetes Among People at Increased Risk. http://www.thecommunityguide.org/diabetes/combineddietandpa.html. http://www.thecommunityguide.org/diabetes/combineddietandpa.html

7. Dall, T. M., Storm, M. V., Semilla, A. P., Wintfeld, N., O'Grady, M., & Venkat Narayan, K. M. (2015). Value of Lifestyle Intervention to Prevent Diabetes and Sequelae. *American journal of preventive medicine, 48*, 271-280.

8. Diabetes Prevention Program Research Group (2015). Long-term effects of lifestyle intervention or metformin on diabetes development and microvascular complications over 15- year follow-up: the Diabetes Prevention Program Outcomes Study. *Lancet Diabetes Endocrinol., 3,* 866-875.

9. Heianza, Y., Arase, Y., Fujihara, K., Hsieh, S. D., Saito, K., Tsuji, H. et al. (2012). Longitudinal Trajectories of HbA1c and Fasting Plasma Glucose Levels During the Development of Type 2 Diabetes The Toranomon Hospital Health Management Center Study 7 (TOPICS 7). *Diabetes care, 35,* 1050-1052.

10. Hippisley-Cox, J. & Coupland, C. (2010). Predicting the risk of Chronic Kidney Disease in Men and Women in England and Wales: prospective derivation and external validation of the QKidney-Scores. *BMC family practice, 11,* 49. Knowler, W. C., Barrett-Connor, E.,

Fowler, S. E., Hamman, R. F., Lachin, J. M., Walker, E. A. et al. (2002). Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N.Engl.J Med, 346*, 393-403.

11. Knowler, W. C., Fowler, S. E., Hamman, R. F., Christophi, C. A., Hoffman, H. J., Brenneman, A. T. et al. (2009). 10-year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. *Lancet, 374,* 1677-1686.

12. Lawlor, M. S., Blackwell, C. S., Isom, S. P., Katula, J. A., Vitolins, M. Z., Morgan, T. M. et al. (2013). Cost of a group translation of the Diabetes Prevention Program: Healthy Living Partnerships to Prevent Diabetes. *Am.J Prev.Med, 44,* S381-S389.

13. LeFevre, M. L. (2014). Behavioral counseling to promote a healthful diet and physical activity for cardiovascular disease prevention in adults with cardiovascular risk factors: U.S. preventive services task force recommendation statement. *Ann.Intern Med, 161*, 587-593.

14. Neter, J. E., Stam, B. E., Kok, F. J., Grobbee, D. E., & Geleijnse, J. M. (2003). Influence of weight reduction on blood pressure a meta-analysis of randomized controlled trials.
15. *Hypertension, 42,* 878-884.

16. Norman J (2015). Half of Overweight in U.S. Not Seriously Trying to Lose Weight. http://www.gallup.com/poll/187580/half-overweight-not-seriously-trying-lose-weight.aspx. Riley, G. F. & Lubitz, J. D. (2010). Long-term trends in Medicare payments in the last year of life. *Health Serv.Res., 45,* 565-576.

17. Semilla, A. P., Chen, F., & Dall, T. M. (15 A.D.). Reductions in Mortality Among Medicare Beneficiaries Following the Implementation of Medicare Part D. *American Journal of Managed Care, 21,* S165-S172.

18. Sheehan, T. J., DuBrava, S., DeChello, L. M., & Fang, Z. (2003). Rates of weight change for black and white Americans over a twenty year period. *Int.J Obes.Relat Metab Disord., 27,* 498-504. Siu, A. L. (2015). Screening for Abnormal Blood Glucose and Type 2 Diabetes Mellitus:

19. U.S. Preventive Services Task Force Recommendation Statement. *Ann.Intern.Med., 163,* 861- 868. Su, W., Chen, F., Iacobucci, W., Dall, T. M., & Perreault, L. (2016). Return on Investment for Digital Behavioral Counseling in Patients with Prediabetes and Cardiovascular Disease. *Prev.Chronic.Dis.* 13; 150357. http://www.cdc.gov/pcd/issues/2016/15_0357.htm

20. Su, W., Huang, J., Chen, F., Iacobucci, W., Mocarski, M., Dall, T. M. et al. (2015). Modeling the clinical and economic implications of obesity using microsimulation. *J.Med.Econ.*, 1-12. http://informahealthcare.com/doi/abs/10.3111/13696998.2015.1058805

21. Sullivan, P. W., Lawrence, W. F., & Ghushchyan, V. (2005). A national catalog of preference-based scores for chronic conditions in the United States. *Medical care, 43*, 736-749.

22. U.S.Department of Health and Human Services, P. H. S. N. I. o. H. (4-13-2009). The Framingham Study: An Epidemiological Intervention of Cardiovascular Diseases: Section 34: Some Risk Factors Related to the Annual Incidence of Cardiovascular Disease and

Death Using Pooled Repeated Biennial Measurements: Framingham Heart Study, 30 Year Followup. Wilson, P. W., Bozeman, S. R., Burton, T. M., Hoaglin, D. C., Ben-Joseph, R., & Pashos, C. L. (2008). Prediction of first events of coronary heart disease and stroke with consideration of adiposity. *Circulation*, *118*, 124-130.

23. Yan Feng Li, Geiss Linda S, Burrows Nilka R, Rolka Deborah B, & Albright Ann (2013). Awareness of Prediabetes--United States, 2005-2010. *Morbidity and Mortality Weekly Report, 62,* 209-212.

24. Zhang, P., Brown, M. B., Bilik, D., Ackermann, R. T., Li, R., & Herman, W. H. (2012). Health Utility Scores for People With Type 2 Diabetes in US Managed Care Health Plans Results from Translating Research Into Action for Diabetes (TRIAD). *Diabetes care*, *35*, 2250- 2256.

