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Cost effectiveness and return on investment of a scalable community weight loss intervention

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ABSTRACT

This study assessed the lifetime health and economic consequences of an efficacious scalable community weight loss program for overweight and obese adults. We applied a state-transition Markov model to project lifetime economic outcome (US dollar) and the degree of disease averted as a result of a weight loss intervention, compared with no intervention, from a payer perspective. Effect sizes of the intervention on weight loss, by sex, race and ethnicity, and body mass index (BMI) of participants, were derived from a 12-month community program. Relative risk of diseases across BMI levels and other parameters were informed by the literature. A return on investment (ROI) analysis was conducted to present the overall cost-benefit of the program. Simulation results showed that among 33,656 participants and at a cost of $2.88 million, the program was predicted to avert (with a corresponding estimated medical costs saved of) 78 cases of coronary heart disease ($28 million), 9 cases of strokes ($971,832), 92 cases of type 2 diabetes ($24 million), 1 case of colorectal cancer ($357,022), and 3 cases of breast cancer ($483,259) over the participant lifetime. The estimated medical costs saved per participant was $1403 ($1077 of African American men and $1532 of Hispanic men), and the ROI was $16.7 ($12.8 for African American men and $18.3 for Hispanic men) for every $1 invested. We concluded that a scalable efficacious community weight loss program provides a cost-effective approach with significant ROI, which will assist informed decisions for future adoption and dissemination.

1. Introduction

Excess body weight is linked to a series of negative health conditions, such as coronary heart disease (CHD) (Romero-Corral et al., 2006), stroke, type 2 diabetes (T2D), and obesity-related cancers (Calle and Kaaks, 2004; Bianchini et al., 2002). It was projected that, with rising obesity, an additional 6–8.5 million cases of diabetes, and 5.7–7.3 million cases of heart disease and stroke will occur in the next two decades for USA and UK combined (Wang et al., 2011). In light of the social, clinical, and economic burden of obesity, it is imperative to develop effective and affordable interventions that facilitate clinically significant weight loss for those overweight and obese individuals, especially in communities that suffer from a high prevalence of obesity yet lack resources for obesity prevention and control.

Lifestyle interventions, that typically include self-regulatory strategies such as goal setting, self-monitoring and feedback, promote healthy eating and increased physical activity for weight loss and can reduce the risk for T2D or heart diseases (Hamman et al., 2006; Look AHEAD Research Group, 2010; Mokdad et al., 2003). It was estimated that for every kilogram of weight loss, there was a 16% reduction in risk for T2D for overweight or obese individuals (Hamman et al., 2006); with every unit reduction in Body Mass Index (BMI), the risk of CHD decreased by 16% and 14% for obese men and women, respectively (Anderson and Konz, 2001). To achieve these health outcomes, 5% weight loss is considered clinically meaningful and is commonly used as a criteria of success for weight loss interventions (Williamson et al., 2015; Wing et al., 2011). Several lifestyle interventions have demonstrated the effectiveness of losing at least 5% initial body weight for program participants (Franz et al., 2007; The Diabetes Prevention Program Research Group, 2002). However, lifestyle interventions can be costly to implement and difficult to scale, thus, an increasing number of economic evaluations (Saha et al., 2010; Ali et al., 2012; Schwander

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et al., 2016; The Diabetes Prevention Program Research Group, 2012; Roux et al., 2008; Eddy et al., 2005) have been conducted to assess the cost-effectiveness of weight loss programs.

A within-trial cost-effectiveness analysis for a 10-year T2D prevention program showed that lifestyle interventions on weight loss through diet and physical activity was cost-effective, with an incremental cost-effectiveness ratio of $12,878 per quality-adjusted life year compared to placebo (The Diabetes Prevention Program Research Group, 2012). Moreover, several studies have demonstrated the cost-effectiveness of lifestyle interventions for individuals at risk of developing T2D within experimental studies (Herman et al., 2005; Palmer et al., 2004; Jacobs-van der Bruggen et al., 2009). However, there is limited availability of information on the long-term cost-benefit of community weight loss programs that attempt to take lifestyle interventions to scale outside of an experimental study. Decision analytic models have been used to assess the long-term effect of interventions on health or economic outcomes, which otherwise would be costly or unfeasible if assessed in experimental trials that provide short-term clinical effectiveness. The purpose of this investigation was to assess the long-term health and economic benefits for a scalable, 12-month community weight loss program when delivered to the general public.

2. Methods

2.1. Community weight loss program

Weigh and Win (WAW), implemented in Denver, Colorado by IncentaHEALTH LLC, is a 12-month, community-based weight loss program whose goal is to provide a scalable, accessible, and evidence-based intervention. Over four years, 33,656 persons who were at least 18 years old and with BMI ≥ 25 enrolled in the program and 40% of them lost weight based on the intention-to-treat analysis. Nineteen percent of those who lost weight had lost 5% of their initial body weight (Estabrooks et al., 2017). African American participants were more likely to achieve 5% weight loss (25%) compared to non-Hispanic White participants (19%) and Hispanic participants (20%). Further details about the intervention have been published elsewhere (Estabrooks et al., 2017). We used the de-identified, aggregated WAW data to derive the intervention effect sizes.

2.2. Study design

We developed a state-transition Markov model (Sonnenberg and Beck, 1993) to estimate lifetime costs of participants, and to identify the number of diseases averted as a result of a community weight loss program compared with no intervention from a payer perspective. We accounted for the formal healthcare care costs paid by payers. We chose this decision-analytic model because 1) clinical situations or events can be expressed in terms of health states that individuals can be in, and how they move between each state, and how likely the move may occur (Siebert et al., 2012); and 2) it provides a relatively transparent analysis and accessibility when compared with other models, such as discrete-event simulation models (Standfield et al., 2014). We conducted a counterfactual analysis to determine what would have happened to the same simulated person if he/she had not participated in the weight loss program, and we then compared expected health and economic outcomes between the simulated participant and his or her counterfactual participation-free version. The performance of the program projected by this model was further examined using the Return on Investment (ROI) metric. All analyses were conducted between 2016 and 2017.

2.3. Model structure

Based on the literature, we hypothesized that greater health benefits would accrue over the lifetime for participants who lost at least 5% of initial body weight compared to those who failed to do so (Douketis et al., 2005; Jensen et al., 2014; Mudaliar et al., 2016). By using the state-transition Markov model, we assumed that a participant is always in one of a finite number of discrete health states (Markov states) (Sonnenberg and Beck, 1993). Accordingly, the model was designed to simulate the progression of a hypothetical closed cohort (men started at age 53 years and women at age 54 years, respectively, which were the average ages for WAW participants by sex) in terms of the reduced risk of developing a specific disease as members lost weight and proliferated corresponding health outcomes. The corresponding costs of individuals were saved in each Markov state in the model as the cohort progressed. Moreover, we assumed that the simulation cohort begins with no history of the five diseases (CHD, stroke, T2D, and colorectal and breast cancers) as evidence shows a strong association between weight loss and the reduction of risk in each of the five diseases considered (Calle and Kaaks, 2004; Hamman et al., 2006; Anderson and Konz, 2001; Roux et al., 2008; Lavie et al., 2009). As the simulation progressed, a proportion of the cohort may maintain their current health status, or progress into one of the five diseases or they might die, depending on age, sex, BMI, and the impact of weight loss.

The impact of weight loss was categorized in three Markov states: lost ≥ 5% weight, lost < 5% weight, and did not lose weight. Because stroke events can be major or minor, after a first stroke, we defined related long-term complications by two Markov states: post-major and post-minor stroke, (Pignone et al., 2007; Greving et al., 2008) and no future stroke event would occur. The other 4 diseases were reflected as one post-event Markov state. For persons projected to progress into one of the 5 disease states, possible outcomes modelled were either continuation of the disease (post-event), or death resulting from it. Movement between each Markov state, such as from baseline weight to loss of ≥ 5% weight; from no disease history to development of a disease; or from any of the disease states to death, were measured by transition probabilities and assumed independent of the preceding states (the feature of Markov model). The model cohort was stratified by sex, race, ethnicity, and BMI reflecting the demographic characteristics of WAW participants. Fig. 1 presents the schematic model flow, using the illustration of 12 Markov states. The time horizon of the simulation was lifetime (47 cycles for men and 46 cycles for women) with a one-year cycle (though participants can continue beyond one year in the intervention program) because most of the data used for cost estimates were reported in an annual basis.

2.4. Data sources

Table 1 summarizes parameter estimates and 95% confidence intervals if available. Otherwise, we used 50% higher or lower than mean value as the upper and lower range of parameter estimates (Briggs et al., 2012)

2.5. Effect of WAW program

The 12-month intervention affected two groups. The first group included the proportion of participants who had, relative to their baseline body weight, either lost ≥ 5% of their initial body weight or lost < 5% weight (at any time point of the intervention), or did not lose weight (by the end of the program). The second group included the proportion of participants in the groups of lost ≥ 5% weight, lost < 5% weight, and did not lose weight that maintained their current weight loss level, lost more weight, or regained weight after the program. These were calculated as the level of weight change between initial weigh-in and most recent weigh-in (enrollment duration) among those who had lost ≥ or < 5% weight at any time point of the intervention (the average duration of enrollment was 1.7 years). Both effects were stratified by sex, race and ethnicity, and BMI category. For example, for those who had achieved at least 5% weight loss, the proportions of this group that either maintained ≥ 5% weight loss, regressed to < 5% weight loss, or regained to baseline weight or more were used as

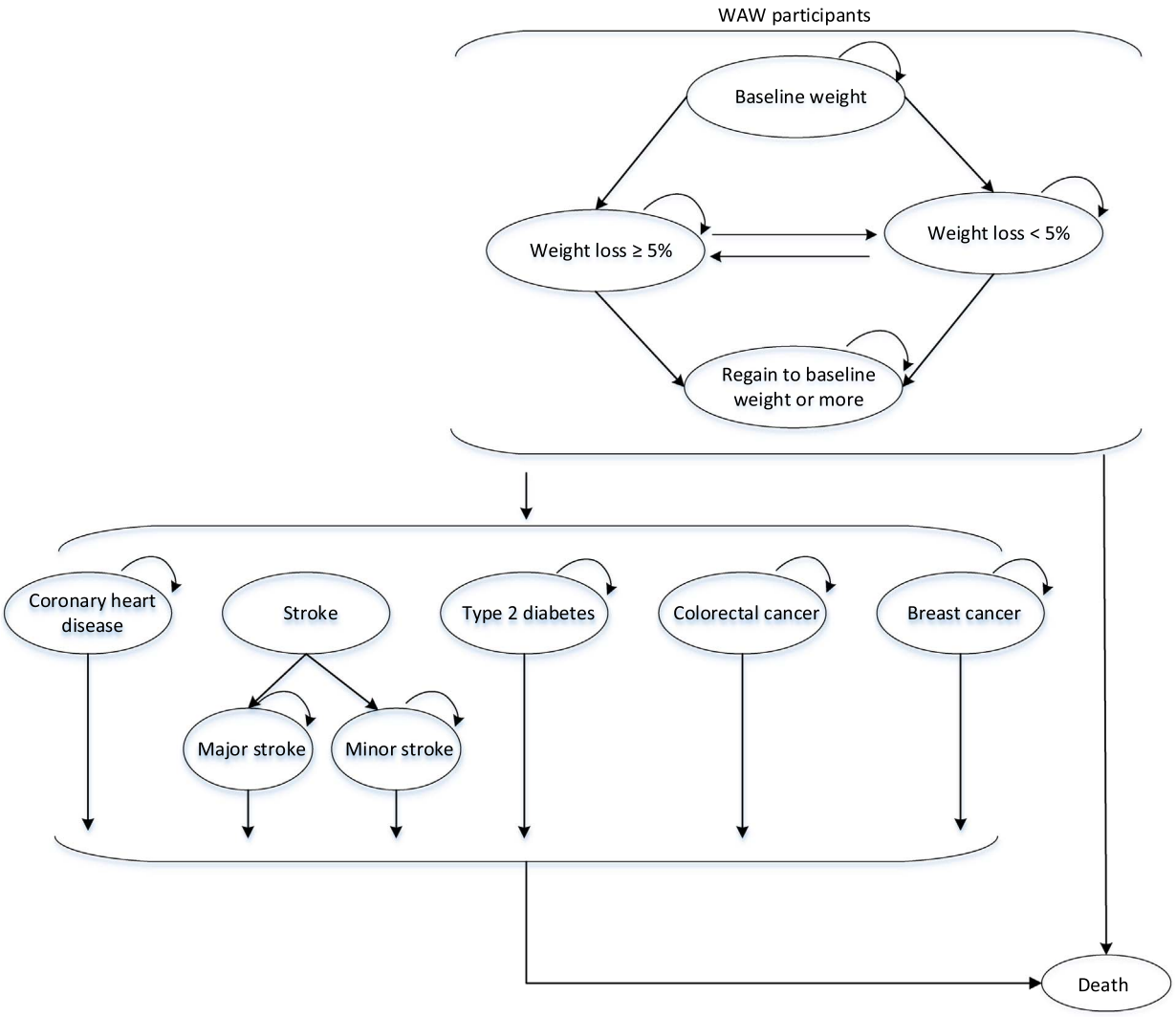

Fig. 1. Schematic overview of the decision-analytic model.
Illustration of the 12-state Markov process represented as a state-transition diagram. In this process, circles represent possible health states, and arrows represent allowed transitions among these discrete health states. In each cycle of the Markov model, transition probabilities denote the likelihood with which people within a particular health state will stay in that state (represented by the tight curvilinear arrows to and from a single circle); transition to a new health state; or die. Death is an absorbing state from which no future transitions are possible. WAW, weight and win community weight loss program.

transition probabilities between the Markov states representing the maintenance of weight loss in the simulation model (see Fig. 1 & Table 1). For those who did not lose weight at the end of the program or regained to baseline weight or more, we assumed they would maintain their weight throughout the simulation period.

Based on the participants who reached different degrees of weight loss, we converted the 5% weight loss into point reduction of BMI, which translated into altered disease incidence with its association with per-unit BMI reduction, for each subgroup. Specifically, the point reduction of BMI for participants losing ≥ 5% weight was estimated by multiplying 0.05 (the lower bound of the effect) with average baseline BMI for the overweight (mean BMI = 27.6) and obese (mean BMI = 36.9) participants, which resulted in 1.38 and 1.85 point reduction of BMI, respectively. Next, we derived a 0.218 point reduction of risk for developing CHD among overweight male participants by multiplying 1.38 with 0.158 (CHD risk reduction for per-unit BMI reduction among overweight men). For participants who lost < 5% weight, we assumed the effect size on the point reduction of BMI was 0.5 times the effect size for those who had lost ≥ 5% weight (0.025 equals to the average of the effect sizes for those who had lost < 5% weight [range, 1%–4%]), and varied this multiplier (range, 0.25–0.75) in the sensitivity analysis. For those who did not lose weight or who regained to baseline weight or more, we assumed no effect on risk reduction for disease (i.e., similar to the general population with similar demographic characteristics and BMI). To prevent overestimating the program effect, we assumed that the result of weight loss had no impact on disease-specific mortality.

2.6. Disease incidence

The estimated probability of developing a disease for overweight or obese participants was calculated using general age and sex-specific disease incidence as derived from published literature (stroke) (Rothwell et al., 2005) or population-based databases (T2D, (Centers for Disease Control and Prevention, 2017) and colorectal and breast cancers (National Cancer Institute, 2016)), and combined with relative risk (relative to normal weight), also derived from published literature (Moghaddam et al., 2007; Munsell et al., 2014; Wilson et al., 2002), for an age, sex, and BMI-specific disease risk. For CHD risk, we adopted the declining exponential approximation of life expectancy method (Beck et al., 1982) to derive an annual risk from the 10-year risk (Wilson et al., 1998) by age for men and women respectively and applied them

Table 1
Source of parameter input values and distributions.

Parameter	Mean (range)		Distribution		
	Men	Women	Men	Women	Source
Proportion of WAW participants who had ≥ 5% weight loss by sex, race/ethnicity, and BMI category[a]					(Estabrooks et al., 2017), authors
Overweight	15% (5% [Black], 6% [Hispanic])	17% (13% [Black], 16% [White])			
Obese	20% (16% [Hispanic], 20% [Others[b]])	20% (13% [Black], 19% [Hispanic])			
Proportion of WAW participants who had lost < 5% weight by sex, race/ethnicity, and BMI category[a]					(Estabrooks et al., 2017), authors
Overweight	21% (18% [Black], 22% [White])	21% (20% [Hispanic], 24% [Others[b]])			
Obese	20% (19% [Black], 21% [White])	21% (20% [Hispanic], 23% [White])			
Annual transition probability[a]					(Estabrooks et al., 2017), authors
Overweight					
Weight loss ≥ 5% to weight loss ≥ 5%	0.794	0.784			
Weight loss ≥ 5% to weight loss < 5%	0.155	0.154			
Weight loss ≥ 5% to baseline weight or more	0.051	0.062			
Weight loss < 5% to weight loss ≥ 5%	0.002	0.002			
Weight loss < 5% to weight loss < 5%	0.258	0.276			
Weight loss < 5% to baseline weight or more	0.731	0.722			
Obese					
Weight loss ≥ 5% to weight loss ≥ 5%	0.795	0.802			
Weight loss ≥ 5% to weight loss < 5%	0.142	0.131			
Weight loss ≥ 5% to baseline weight or more	0.063	0.067			
Weight loss < 5% to weight loss ≥ 5%	0.003	0.005			
Weight loss < 5% to weight loss < 5%	0.266	0.277			
Weight loss < 5% to baseline weight or more	0.731	0.718			
Disease incidence % point reduction per unit BMI reduction[c]					
Coronary heart disease	0.158 (0.079–0.237)	0.143 (0.072–0.215)	Beta(12.98, 69.17)	Beta(13.38, 80.18)	Anderson and Konz, 2001
Stroke	0.04 (0.02–0.07)		Beta(15.32, 367.68)		Lavie et al., 2009; Kurth et al., 2002
Type 2 diabetes (per kilogram)	0.16 (0.08–0.24)		Beta(12.63, 66.32)		Hamman et al., 2006
Colorectal cancer[d]	0.048 (0.012–0.080)	0.008 (0.002–0.044)	Beta(7.54, 149.58)	Beta(0.517, 64.07)	Moghaddam et al., 2007
Breast cancer[d]		0.016 (0.012–0.038)		Beta(5.125, 315.18)	Munsell et al., 2014
All-cause mortality by age and sex					Centers for Disease Control and Prevention, 2011
Disease-specific incidence by age and sex (except for stroke (Rothwell et al., 2005))					Wilson et al., 1998; Centers for Disease Control and Prevention, 2017; National Cancer Institute, 2016
Disease-specific mortality by age and sex (except for CHD (Cooper et al., 2000))					National Cancer Institute, 2016; Centers for Disease Control and Prevention, 2011; Centers for Disease Control and Prevention, 2015
Relative risk of disease by BMI category, relative to normal weight					Wilson et al., 2002
Coronary heart disease					Wilson et al., 2002
Overweight	1.43 (1.19–1.73)	1.22 (0.99–1.52)	LN(0.3716, 0.0955)	LN(0.1989, 0.1094)	
Obese	1.58 (1.24–2.03)	1.54 (1.19–1.98)	LN(0.4574, 0.1257)	LN(0.4318, 0.1299)	
Stroke					Wilson et al., 2002
Overweight	1.28 (0.86–1.91)	1.10 (0.77–1.56)	LN(0.2469, 0.2036)	LN(0.0953, 0.1801)	

(*continued on next page*)

Table 1 (*continued*)

Parameter	Mean (range)		Distribution		
	Men	Women	Men	Women	Source
Obese	1.61 (0.98–2.67)	1.02 (0.65–1.59)	LN(0.4762, 0.2557)	LN(0.0198, 0.2282)	
Type 2 diabetes					Wilson et al., 2002
Overweight	1.27 (0.97–1.67)	0.91 (0.72–1.15)	LN(0.2390, 0.1386)	LN(−0.0943, 0.1195)	
Obese	1.85 (1.31–2.61)	1.36 (1.03–1.78)	LN(0.6152, 0.1758)	LN(0.3075, 0.1396)	
Colorectal cancer					Moghaddam et al., 2007
Overweight	1.16 (1.07–1.27)	1.03 (0.96–1.10)	LN(0.1484, 0.0437)	LN(0.0296, 0.0347)	
Obese	1.40 (1.33–1.47)	1.07 (0.97–1.18)	LN(0.3365, 0.0255)	LN(0.0677, 0.0500)	
Breast cancer					Munsell et al., 2014
Overweight		1.10 (1.06–1.13)		LN(0.0953, 0.0163)	
Obese		1.18 (1.12–1.25)		LN(0.1655, 0.0280)	
Annual formal costs					
Weight loss intervention	84 (42–126)		Gamma(16, 0.19)		(Estabrooks et al., 2017), authors
Coronary heart disease	13912 (6956–20868)	16102 (8051–24153)	Gamma(15.37, 0.001)	Gamma(15.36, 9.54)	Roux et al., 2008
Major stroke					Greving et al., 2008; Michaud et al., 2015; Buskens et al., 2004
During the first year	33275 (16638–49913)		Gamma(15.36, 4.62)		
During the subsequent year	19430 (9715–29145)		Gamma(15.36, 7.91)		
Minor stroke					Pignone et al., 2007; Michaud et al., 2015; Russell et al., 1998
During the first year	5835 (2917–8752)		Gamma(15.36, 0.003)		
During the subsequent year	998 (500–1498)		Gamma(16.59, 0.017)		
Type 2 diabetes	11464 (5732–17196)	14041 (7021–21062)	Gamma(15.37, 0.0013)	Gamma(15.37, 0.001)	Roux et al., 2008
Colorectal cancer	19708 (9854–29562)	21383 (10692–32075)	Gamma(15.37, 7.80)	Gamma(15.37, 7.19)	Roux et al., 2008
Breast cancer	14169 (7085–21254)		Gamma(15.36, 0.001)		Roux et al., 2008
Death	2482 (1241–3723)		Gamma(15.37, 0.006)		Michaud et al., 2015
Discount rate (for both costs and health utility)	3% (1%–5%)				Sanders et al., 2016

Abbreviation. CHD, coronary heart disease; WAW, weight and win community weight loss program; BMI, body mass index.

[a] Parameter estimates were based on the intention-to-treat analysis. We assumed a fixed (time-invariant) transition probability.

[b] Others included Asian, Native American, and unknown.

[c] Data was not available for stroke and type 2 diabetes, stratified by sex.

[d] Estimated from linear interpolation.

as constant annual probabilities for each subgroup.

2.7. Mortality

We obtained age and sex-specific all-cause mortality from the life table (Centers for Disease Control and Prevention, 2011). Age-, sex-, and disease-specific mortality for stroke and T2D, and mortality for colorectal and breast cancers were derived from the population-based database (National Cancer Institute, 2016; Centers for Disease Control and Prevention, 2014). Mortality based on CHD was obtained from the published literature (Cooper et al., 2000). For all-cause mortality in the years following any of the 5 disease incidence, we assumed mortality rates to be twice that of the general population.

2.8. Cost

We used the number of intent-to-treat participants (n = 33,656) and total intervention costs of $2,822,698 (including the maintenance and oversight of technical system support of $1,124,803, kiosk leasing of $349,500, participant-related prizes and activities unrelated to weight loss of $248,151, program implementation personnel of $383,119, marketing personnel and activity costs were $344,054, and weight loss incentives of $300,000, and internet and short message service use of $36,759) (Estabrooks et al., 2017) to derive the one-time intervention cost per participant of $84 ($148 for per-protocol participants of 19,029). We obtained the associated medical costs of CHD, T2D, and colorectal and breast cancers from a published simulation model (Roux et al., 2008), which used a longitudinal medical claims database to derive these estimates. For the costs of stroke, we used other published sources (Greving et al., 2008; Michaud et al., 2015; Buskens et al., 2004). All costs were adjusted for inflation to 2016 US dollars using the Consumer Price Index and future accrued costs were converted to net present value using a 3% discount rate (Sanders et al., 2016).

2.9. Estimating the benefits

We calculated the difference of projected lifetime costs per person between the WAW program and no interventions. The difference was further divided by the intervention costs per participant to derive a ROI. ROI values > 1 indicate that WAW produced savings that exceeded the cost of the program. The number of cases of disease predicted to be averted and corresponding medical savings were estimated as well as the total savings generated from participating in the WAW program (the product of the average savings per participant and the number of intent-to-treat participants).

2.10. Sensitivity analysis

We conducted threshold analysis to determine the threshold of the program cost where ROI would become negative which signals failure of the program investment. Moreover, to determine the robustness of the simulation results, we conducted probabilistic sensitivity analysis (PSA) to evaluate uncertainty pertaining to parameter values by randomly and simultaneously drawing values of all input parameters from their assumed distributions as described in Table 1. PSA was conducted with 10,000 iterations.

All analyses were performed in TreeAge (version TreeAge Pro 2015, TreeAge Software, INC, Williamstown, Mass).

3. Results

Table 2 shows the results of reach by the WAW program and estimated medical savings, by sex and race and ethnicity. The overall medical costs saved over the lifetime span due to the WAW program was $1403 per person. With exception of African American participants, men accrued greater medical savings than women. In general, non-Hispanic Whites generated greater saving per person, than Hispanics and African Americans, although WAW showed greater effectiveness for African American participants.

Table 2
Effect on reach and projected medical cost saved due to the WAW program compared to no intervention, by sex race, and ethnicity.

Subgroups	Reach (percentage)[a]	Projected medical costs saved per person	ROI[c]	Program cost threshold per person[d]
Overall	0.4	$1403	16.7	$1487
Non-Hispanic White		$1420	16.9	$1504
Women	0.22	$1397	16.7	$1481
Men	0.06	$1506	18.0	$1590
African American		$1243	14.8	$1327
Women	0.02	$1287	15.3	$1371
Men	0.004	$1077	12.8	$1161
Hispanic		$1365	16.3	$1449
Women	0.07	$1321	15.7	$1405
Men	0.02	$1532	18.3	$1616
Others[b]		$1556	18.6	$1640
Women	0.008	$1463	17.4	$1547
Men	0.007	$1904	22.7	$1988

Abbreviation: WAW, weight and win community weight loss program; ROI, return on investment.
[a] WAW participants consisted of 0.4% of the local population. Reach was calculated as the proportion of the subgroup of participants in the local population.
[b] Others included Asian, Native American, and unknown.
[c] ROI by race, ethnicity, and sex groups was calculated by using projected medical costs saved per person multiplying the number of participants in the subgroup and dividing by the proportion of total program costs distributed to that subgroup.
[d] The threshold of the program cost was where ROI would become negative with greater costs.

3.1. Simulated disease events averted

Over the lifespan of 33,656 enrolled participants, the weight loss program was predicted to avert (and correspondingly costs saved) 78 cases of CHD ($28 million), 9 cases of strokes ($971,832), 92 cases of T2D ($24 million), 1 case of colorectal cancer ($357,022) and 3 cases of breast cancer ($483,259) (Table 3, including 10-year time span results).

3.2. Overall benefits and the program cost threshold

The program thus generated a total savings of $47.3 million, and the estimated ROI is $16.7 (ranged from $12.8 for African American men to $18.3 for Hispanic men; Table 2) over the lifetime course of participants for every $1 investment to the WAW program. Although the individual projected lifetime cost savings were small ($1403), the projected cost savings extrapolated to the population level (the WAW

Table 3
Projected number of cases averted (with corresponding medical costs saved) due to the WAW program when comparing participants to simulated non-participants over a lifetime span and a 10-year time horizon.

	Lifetime[a]		10-year	
Averted events	N	Medical costs	N	Medical costs
Coronary heart disease	78	$27,515,648	138	$14,409,480
Stroke	9	$971,832	3	$229,870
Type 2 diabetes	92	$23,755,907	131	$11,703,537
Colorectal cancer	1	$357,022	0	0
Breast cancer	3	$483,259	0	0

Abbreviation: WAW, weight and win community weight loss program.
[a] 47 cycles for men and 46 cycles for women.

program implementation community, population size = 5,012,333), are quite high, approximating 1 billion dollars of savings (range: 0.9–1.1 billion) using an estimated obesity prevalence of 14.4% (standard error, 0.87), in Colorado, based on data from the 2001 Behavioral Risk Factor Surveillance System (Mokdad et al., 2003).

We identified the threshold of program costs that produce a negative ROI of $1487. That is, when the one-time WAW program cost becomes greater than $1487 per participant, the program should no longer be favored over no intervention. The threshold varied from $1504 ($1481 for women and $1590 for men) for non-Hispanic whites to $1327 ($1371 for women and $1161 for men) for African Americans (Table 2).

3.3. Sensitivity analysis

Results of the PSA indicated that the mean total medical costs saved due to the WAW programs was $1400 (standard deviation = $450) and they were $700 and $2428 at the 2.5th and 97.5th percentiles, respectively. The corresponding ROI estimates were $18.7, $8.2, and $28.4.

4. Discussion

Our results show that the WAW program can be effective and cost-saving over long-term. We found that one new T2D case was prevented for every 364 participants, which is similar to what Jacobs-van der Bruggen et al. (2007) have reported previously in a community intervention to facilitate weight loss. Given that our results reflect great long-term ROI from a payer perspective, we did not conduct additional analysis based on societal perspective, as the benefit from weight loss should out-pace short-term costs incurred by participants over time.

Studies show that intervention cost greatly affects cost-effectiveness results (Saha et al., 2010; Roux et al., 2008; Eddy et al., 2005), yet our simulation demonstrated that cost-effectiveness of WAW was robust in that actual cost per participant would have to increase from $84 to over $1487 per person before the program would no longer be considered cost-effective. These findings were comparable with those of Roux et al. (2008), who found that interventions based upon physical activity to promote weight loss were cost-effective when annual intervention costs ranged from $1230 to $5308 (in 2003 US dollar) per person, depending on the intensity of the program. With significant results of long-term ROI, our evaluation of WAW suggests scaling such a program could overset initial cost challenges often related to the intervention's economic sustainability (Ali et al., 2012).

Although our results demonstrate the feasibility and scalability of a low-cost, easy-to-implement, community weight loss program, we also found that about half of the people who enrolled in WAW never returned for a second weigh-in. This is an important finding in that it corresponds with attrition rates in clinical weight loss interventions, such as the Move! Program in the Veterans Affairs Healthcare system (Chan and Raffa, 2017). The cost of high attrition, however, appears to be much lower in a scalable intervention such as WAW due to low resource use (for example, no in-person staff time per participant initiating enrollment). Our findings also point to robust cost-effectiveness across participants from different racial and ethnic groups. This suggests that a fruitful area of future research will be to determine intervention strategies that can close the attrition gap from enrollment to more sustained participation, and to suggest potential differences in strategies when considering interventions that vary in scalability.

There have been a number of calls for financially feasible interventions that generalize to typical community contexts (Levy et al., 2007; Neve et al., 2010; Hersey et al., 2012). Our study showcases the long-term health and economic benefits of a low-cost community weight loss program, which has not been adequately assessed so far. However, studies using a modelling approach like the one used here should be carefully interpreted for translation and application in public health decision making (Roux et al., 2008). Indeed, we join others in calling for increased funding and focus on translational research that focuses on external validity and scalability to speed the translation of effective weight-loss interventions into broad community practice (Hardy et al., 2015).

Our study has several limitations. Although we incorporated race and ethnic components into the simulation model, we were restricted by the absence of available data on disease burdens specific to race and ethnicity and corresponding medical costs. It was thus not feasible to extend the model to assess long-term health and economic consequences of interventions in sub-populations by race and ethnic groups. This lack is certainly of concern, given that ethnic minorities are disproportionately affected by obesity and T2D (Clarke et al., 2009) and that WAW data showed greater effectiveness among African American participants (Estabrooks et al., 2017). However, the long-term benefits for WAW participants should be greater given the present study using average risk of diseases and corresponding medical costs for the model population as a whole (lower bound analysis).

Due to the data availability, we were unable to account for other important social determinants of health, such as socioeconomic status (SES). As a partial remedy, our stratification of the cohort by race and ethnicity might have captured some differences in SES given the association between race/ethnicity and SES. In line with data availability, we recognize the issue of heterogeneity imposed by combing several data sources (e.g. population-based data, systematic review, or clinical trials) in the simulation models. However, the advantage should outweigh the potential negative effect because the application of the decision analytic modelling approach allows us to project the long-term outcomes (synthesized evidence) beyond a trial's duration, and provides a more detailed estimate of health and economic consequences at a population level, which extends results from regression-based studies.

We only considered five potential disease outcomes in our simulation model, which is less inclusive than those considered in other cost-effectiveness models (Roux et al., 2008; Jacobs-van der Bruggen et al., 2009; Jacobs-van der Bruggen et al., 2007). This may have resulted in an underestimation of the potential benefits relevant to other diseases related to obesity, but nevertheless, the effect should be minimal given that it is not always possible to isolate overlapping effects from other diseases when conducting cost of illness studies. Decision analytic model guidelines emphasize that models should be kept as simple as possible, providing they capture all essential aspects of disease processes to inform decision making (Saha et al., 2010; Weinstein et al., 2003; Sculpher et al., 2000)

We acknowledge the assumption that our simulated cohort started in the health state of no history of five diseases considered in the model may be inconsistent with the reality that overweight or obese individuals have a higher risk of developing a disease than their counterparts. However, this issue may be minimal in the study because 1) we used the aggregated age- and sex-specific disease incidence rates, which include individuals with different levels of BMI and comorbidities; 2) BMI was linked to the diseases considered in the model through relative risks (relative to normal weight) on disease incidence.

We derived the probability of overall risk reduction of a disease due to 5% weight loss as a function of the mean BMI reduction of overweight or obese participants in the WAW program, which may overestimate the impact of weight loss on disease risk reduction due to availability of data. However, by accounting for wide ranges of disease risk and BMI reduction, as demonstrated in our sensitivity analyses, this issue should be alleviated. Finally, our approach implicitly assumed that the impact of the WAW program on weight loss may last for a year (as risk of disease was estimated), and thus, conversely, our results may be inflated, given that previous studies revealed that although health promotion programs can be effective in producing weight loss, weight loss often plateaus after 6 months, and weight regain begins after 12 months (Franz et al., 2007). However, due to the average 1.7-year weight loss duration (Estabrooks et al., 2017) in the WAW program, the

above concern is somewhat attenuated.

5. Conclusion

This study provides an economic case for a scalable community weight loss program. The study results can be used to inform decisions about future adoption and dissemination of such programs.

Conflict of interest statement

Todd McGuire is employed by, holds the patent to, and is a part owner of IncentaHEALTH LLC. All other authors declare that they have no conflict of interest.

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