EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

Socioeconomic Disparities in Weight and Behavioral Outcomes Among American Indian and Alaska Native Participants of a Translational Lifestyle Intervention Project

Diabetes Care 2015;38:2090–2099 | DOI: 10.2337/dc15-0394

*Luohua Jiang,[1] Haixiao Huang,[2] Ann Johnson,[2] Edward J. Dill,[3] Janette Beals,[2] Spero M. Manson,[2] Yvette Roubideaux,[4] and the Special Diabetes Program for Indians Diabetes Prevention Demonstration Project**

OBJECTIVE

To investigate possible socioeconomic disparities in weight and behavioral outcomes among American Indian and Alaska Native (AI/AN) participants in a translational diabetes prevention project.

RESEARCH DESIGN AND METHODS

We analyzed data from the Special Diabetes Program for Indians Diabetes Prevention (SDPI-DP) Program, an evidence-based lifestyle intervention to prevent diabetes in 36 AI/AN grantee sites. A total of 2,553 participants started the 16-session Lifestyle Balance Curriculum between 1 January 2006 and 31 July 2008. Linear mixed models were used to evaluate the relationships of participant and staff socioeconomic characteristics with weight and behavioral outcomes at the end of the curriculum.

RESULTS

A strong, graded association existed between lower household income and less BMI reduction, which remained significant after adjusting for other socioeconomic characteristics. Compared with others, participants with annual income <$15,000 also had less improvement in physical activity and unhealthy food consumption in bivariate models, but the relationships were only marginally significant in multivariate regressions. Furthermore, grantee sites with fewer professionally prepared staff were less successful at improving participant BMI and healthy food consumption than the other sites. The strong association between income and BMI reduction was reduced by 20–30% in the models with changes in diet variables but was unrelated to changes in physical activity.

CONCLUSIONS

Significant socioeconomic disparities exist in weight outcomes of lifestyle intervention at both participant and site staff levels. Helping low-income participants choose more affordable healthy foods and increasing the proportion of professionally trained staff might be practical ways to maximize the effectiveness of lifestyle interventions implemented in "real-world" settings.

[1]Department of Epidemiology, School of Medicine, University of California, Irvine, Irvine, CA
[2]Centers for American Indian and Alaska Native Health, Colorado School of Public Health, University of Colorado Anschutz Medical Campus, Aurora, CO
[3]Department of Psychology, University of Colorado Denver, Denver, CO
[4]Office of the Director, Indian Health Service, Rockville, MD

Corresponding author: Luohua Jiang, lhjiang@uci.edu.

Received 23 February 2015 and accepted 11 June 2015.

**The grant programs participating in the Special Diabetes Program for Indians Diabetes Prevention Program can be found in the APPENDIX.*

Research over the past few decades has convincingly revealed that lifestyle interventions consisting of exercise and diet behavioral modifications are efficacious in preventing or delaying the onset of type 2 diabetes for those at risk (1–4). To stem the global epidemic of type 2 diabetes, the critical next step is to translate interventions developed in rigorously controlled clinical trials into everyday settings. A number of diabetes prevention initiatives have attempted to implement lifestyle interventions in various "real-world" settings, yielding heterogeneous effectiveness (5). The factors that may be associated with such variation, however, have remained largely underexplored.

The Diabetes Prevention Program (DPP) demonstrated that weight loss was the dominant factor in reducing diabetes risk among the participants in its intensive lifestyle intervention arm (6). Previous analyses of DPP data and other large-scale weight loss programs have consistently found weight loss was greater among older participants and those with better intervention adherence (7–9). A number of psychological and behavioral predictors of weight loss also have been identified (10–12). Yet, only a few publications compared the amount of weight loss among participants with different socioeconomic status (SES); most did not find significant socioeconomic disparities in weight outcomes (8,13,14).

It is well known that diabetes is highly prevalent in many minority populations (15), who often are impoverished. Behavior change interventions frequently are less effective in the real world of these populations, in part due to significant socioeconomic barriers (16). American Indian and Alaska Natives (AI/ANs), the racial/ethnic group with the highest poverty rate in the U.S. (17), clearly face such challenges. In order to reduce the unequal burden of diabetes borne by AI/ANs, it is important to understand the relationship between SES and intervention effectiveness among socioeconomically disadvantaged populations. Furthermore, in addition to individual-level SES, our previous study has noted the association of program staff education with the success of behavioral intervention, as measured by participant retention (18). Therefore, to fully understand potential SES disparities in the effectiveness of lifestyle intervention, it is also critical to investigate the variability in intervention outcomes by staff level SES.

The Special Diabetes Program for Indians Diabetes Prevention (SDPI-DP) demonstration project (19) implemented the DPP lifestyle intervention among $>$2,500 AI/AN participants and collected data that provide a unique opportunity for us to investigate the impact of SES at both individual and site staff levels on weight and related behavioral outcomes across 36 geographically and tribally diverse AI/AN grantee sites. We hypothesized that participants with lower SES would have more challenges in meeting the intervention goals due to limited resources and therefore would lose less weight and benefit less from the intervention. Moreover, we hypothesized that the grantee sites with fewer professionally educated staff members would have less success than other sites in reducing their participants' weight and changing their exercise and diet behaviors.

RESEARCH DESIGN AND METHODS

SDPI-DP

The SDPI-DP Program is a congressionally mandated demonstration project designed to reduce diabetes incidence among AI/ANs with prediabetes through the local translation of the DPP lifestyle intervention. The details of this project are described elsewhere (19). In brief, 36 health care programs serving 80 tribes in 18 states and 11 Indian Health Service (IHS) administrative areas participated in the SDPI-DP. The participating programs implemented the 16-session Lifestyle Balance Curriculum adopted from the DPP (20) and evaluated longitudinally the effectiveness of the prevention activities. After a baseline assessment, participants attended the lifestyle curriculum consisting of diet, exercise, and behavior modification sessions to help each reach and maintain a goal of 7% weight loss. The curriculum was generally provided in group settings (8–12 participants per group) within 16–24 weeks after baseline and typically taught by the program dietitian and/or health educator.

The SDPI-DP protocol was approved by the institutional review board of the University of Colorado Denver and the IHS institutional review board. When required, grantees obtained approval from other entities charged with overseeing research in their programs (e.g., tribal review boards). All participants provided written informed consent and Health Insurance Portability and Accountability Act authorization.

Participants

Participants were recruited locally by each grant program. Eligibility criteria were AI/AN status (based on their eligibility to receive IHS services), being at least 18 years of age, and having either impaired fasting glucose (a fasting blood glucose level of 100–125 mg/dL) and/or impaired glucose tolerance (an oral glucose tolerance test result of 140–199 mg/dL 2 h after a 75-g oral glucose load). Four exclusion criteria included the following: *1*) a previous diagnosis of diabetes; *2*) pregnancy; 3) end-stage renal disease on dialysis; and *4*) active alcohol or substance abuse, current diagnosis of cancer, or any other condition that could affect participation based on provider judgment. Enrollment began in January 2006 and is ongoing. By 31 July 2008, 4,044 participants were identified as being eligible for SDPI-DP. Among them, 2,553 (63.1%) participants started intervention and were included in the analysis of the current study.

Measures

At baseline, within a month of completing the last lifestyle class (usually 4–6 months after baseline, hereafter called the postcurriculum assessment), and annually after baseline, participants underwent a comprehensive clinical assessment to evaluate diabetes risk and incidence. At the same time, each participant completed a questionnaire encompassing sociodemographics, health-related behaviors, and a range of psychosocial factors. The current study includes the following measures.

Outcome Measures

BMI. BMI was calculated using each participant's weight and height (shoeless, in light clothing), assessed by program staff at each assessment.

Physical Activity. The Rapid Assessment of Physical Activity (RAPA) (21) is a nine-item instrument with response options of "yes" or "no" to questions covering a range of weekly physical activity levels from "sedentary" to "regular active" as well as strength training and flexibility. Among the first seven items, the question indicating the highest activity level was used to categorize the participants into one of five levels of physical activity: 1 = sedentary, 2 = underactive, 3 = regular underactive (light activities), 4 = regular underactive, and 5 = regular active.

Diet. Diet information was acquired using a set of culturally adapted questions for self-reported frequency of eating a variety of foods (22). The healthy diet score (α = 0.70) was constructed by averaging the frequency of consuming six kinds of relatively healthy foods (e.g., whole grain bread, fruit, and vegetables), with responses for each question ranging from 1 (less than once a month) to 6 (more than once a day). Similarly, the unhealthy diet score (α = 0.74) was the mean of 12 questions about relatively unhealthy foods (e.g., bacon or sausage, regular soft drinks/soda, and fast food).

To minimize the concern of multiple comparisons, we identified BMI reduction at the postcurriculum assessment (4–6 months after baseline) as the primary outcome of this study. Changes in physical activity and diet were treated as secondary outcome measures.

Participant Demographic and Socioeconomic Characteristics

At baseline, participants answered questions related to their age and sex as well as socioeconomic characteristics, including educational attainment, employment status, marital status, and annual household income.

Staff Demographic and Socioeconomic Characteristics

Sociodemographic characteristics of staff members at each grantee site were obtained from a provider annual questionnaire (PAQ) completed by grantee staff members. In this study, we examined the relationship of weight and behavioral outcomes with percent of female staff ($\leq$70 vs. $>$ 70%), average age of staff members ($<$40 vs. $\geq$40 years), and percent of staff members who completed graduate or professional school ($<$50 vs. $\geq$50%). No information was collected with respect to staff household income or marital status. Thus, staff education level was the only indicator for the SES of site staff members in this study. The PAQs were completed by site staff at three time points: December 2006, 2007, and 2008. In the current study, we used the averages of those three time points for each measurement collected from PAQs as the sociodemographic indicators of each site's staff members.

Statistical Analysis

Means and SDs of the baseline values as well as changes from baseline to postcurriculum assessment were reported for each of the outcome measures. Simple linear regressions (i.e., regression models with only one independent variable in each model) were used to test if the differences in baseline levels or changes of the outcome variables were statistically significant among different sociodemographic subgroups.

Linear mixed models (i.e., multilevel models) were used to estimate the differential intervention effects on BMI reduction and behavioral changes among different subgroups after adjusting for other sociodemographic characteristics. In the linear mixed models, random intercepts at both participant and site level were included to model the correlation between repeated measures from the same participant and the heterogeneity at grantee site level; meanwhile, baseline SES, time (an indicator variable with 1 representing the postcurriculum assessment), and the interaction between baseline status and time were included as fixed effects. The parameter estimates and *P* values of the interaction terms indicate whether the changes from baseline are significantly different by the participant baseline status. After adjusting for age and sex, participant education, employment, marital status, and annual household income were entered into the model gradually. Education and marital status were then removed from the multivariate model due to their insignificant relationships with the outcome variables ($P > 0.2$). Staff education level was added to the multilevel models afterward. Finally, the potential mediational role of changes in physical activity and diet for BMI reduction was assessed by adding changes in those variables to the final regression model of BMI, one at a time and then all three at once.

Missing data in weight and behavioral outcome measures were not imputed. Instead, they were addressed by linear mixed models, which are maximum likelihood–based models that use all available data in model estimation and provide unbiased estimates of the intervention effects under the assumption of missing at random. The socioeconomic variables had various rates of missing data ranging from 12 to 25%. To avoid potential bias caused by excluding incomplete cases (subjects with missing data on any of the independent variables will be excluded from linear mixed model estimation) and to maximize the power of the analysis, a multiple imputation method was used to impute missing baseline socioeconomic data before the final multivariate regression models were fit. The multiple imputations were performed using IVEware developed by the University of Michigan Survey Methodology Program (23). Twenty imputed datasets were generated this way, and the final linear mixed models were fit in each of the 20 datasets. The results were then combined using the SAS MIANALYZE procedure to obtain the proper estimate for the standard error of each parameter of interest.

A series of sensitivity analyses were performed to assess the impact of missing data on the analysis results. First, we repeated the analyses with complete cases only (i.e., excluding the participants with missing data on any of the socioeconomic variables) and found the results were only slightly different from the results based on multiple-imputed data. Further, the conclusions based on the two sets of results were essentially the same. Next, we calculated change scores for each of the weight and behavioral outcomes and used multiple linear regressions to assess the association between SES and changes in outcome variables. We then explored the relationship between percent weight loss and socioeconomic characteristics. Again, the results were only slightly different from what is presented here, implying the potential robustness of our results. Finally, we replaced the original household income variable by an adjusted household income variable, which was defined as three (the median number of people lived in the same household in SDPI-DP) times the ratio of total household income and number of people in the household. The results of this sensitivity analysis were also very similar to the main analysis with all the conclusions remaining the same.

RESULTS

Baseline BMI and behavioral measures by participant and staff sociodemographic characteristics are displayed in Table 1. About a quarter of SDPI-DP participants (25.5%) were males. The male participants had higher levels of physical activity and consumed more unhealthy foods at baseline. Younger, less educated, and never married participants had higher BMI and ate healthy foods less often and unhealthy foods more often than their counterparts. Retired participants had lower BMI, higher healthy diet scores, and lower unhealthy diet scores than the others. Baseline BMI did not differ significantly by annual household income level. However, participants with lower household income consumed healthy foods less often and unhealthy foods more often than those with greater income. Turning to staff characteristics, participants from grantee sites with fewer female, older, and more professionally prepared staff reported higher baseline BMI.

Table 2 presents improvements in weight and behavioral outcomes at the postcurriculum assessment (4–6 months after baseline) by participant and staff characteristics. Among the 1,883 participants who had weight measured at both baseline and postcurriculum, the average weight loss was 3.8%. Male participants lost significantly more weight than female participants (4.4 vs. 3.7%, P = 0.003). Older, retired, and married participants had significantly more weight loss than their counterparts. Conversely, those with lower baseline household income made less improvement in body weight. Female participants increased more in aerobic physical activity than the males (0.62 vs. 0.43, P = 0.006). Those with an education level less than high school and baseline annual household income <$15,000 improved less than the other participants in physical activity. With respect to diet behaviors, the participants with $15,000 to <$30,000 household income and from sites with fewer professionally trained staff members improved less than others in their consumption of healthy foods. Older, retired, separated/divorced/widowed participants, as well as those with low household income (<$15,000) or recruited by sites with older and more educated staff, experienced less reduction in their unhealthy food consumption.

In multilevel regression models of weight and behavioral outcomes with sex and age only (model 1), female participants exhibited significantly less reduction in BMI, but greater improvement in physical activity (Table 3). Older participants lowered their BMI more than their younger counterparts, but had less reduction in unhealthy diet. After introducing employment status into the model (model 2), age was only marginally associated with BMI reduction (β = −0.07, P = 0.07). Further, the relationship of age with unhealthy diet was attenuated. Adding baseline annual household income to the regression models (model 3) further reduced the association between age and BMI. Model 3 also illustrates that BMI reduction was significantly smaller among those with lower household income after controlling for age, sex, and employment status. Specifically, the amount of BMI reduction 4–6 months after baseline among the participants with income <$15,000 was 0.49 kg/m^2 less than in those with a $50,000 or higher annual household income (P = 0.0006). The participants with income <$15,000 also made marginally less improvement in physical activity (β = −0.15, P = 0.10) and unhealthy diet (β = 0.10, P = 0.08). In the final multilevel regression models (model 4), the associations between participant characteristics and outcome measures were similar to those observed in model 3. Additionally, participants from sites with fewer staff members completing graduate or professional education experienced significantly smaller BMI reduction (β = 0.24, P = 0.002) and marginally less increase in healthy diet scores (β = −0.07, P = 0.06).

Table 4 reveals the potential mediational role of changes in physical activity and diet for the socioeconomic disparities in the effectiveness of lifestyle intervention presented in Table 3. In model 5, we reran model 4 from Table 3 using data from participants without missing data on any of the behavioral change scores. Despite different sample sizes (2,553 for model 4 vs. 1,555 for model 5), the parameter estimates were very similar. In addition, Table 4 shows that the associations of BMI reduction with participant sex, age, and staff education did not change substantially after adding behavioral changes into the model. However, the strong association between baseline income and BMI reduction at the postcurriculum assessment (4–6 months after baseline) was reduced by 20–30% in the models with changes in diet variables (models 7–9). Conversely, adding changes in physical activity did not modify the relationship between income and BMI (model 6).

CONCLUSIONS

A socioeconomic gradient in type 2 diabetes prevalence among developed countries has been extensively documented (24–29). To reduce the dramatic diabetes disparities borne by socioeconomically disadvantaged populations, prevention strategies that can be implemented effectively among those populations are urgently needed. Although lifestyle intervention has proven to be highly efficacious in preventing diabetes in multiple clinical trials, this study suggests its effectiveness may not be optimal for participants of low SES. Consistent with our hypotheses, we found that SDPI-DP participants with lower SES, especially those reporting lower annual household income, had significantly less weight loss, less improvement in physical activity, and less reduction in unhealthy food consumption than those with higher incomes. These results resonate with our previous findings of low retention rates among SDPI-DP participants with low household income (30), highlighting the important role of income for an individual's success when participating in a lifestyle intervention.

Previous data analyses of the DPP and other weight loss programs have shown that sex, age, race, baseline body weight, as well as a number of psychological and behavioral factors were significantly associated with weight loss in lifestyle intervention programs (7–10). Yet, to the best of our knowledge, the current study is the first to report socioeconomic disparities in the effectiveness of such interventions. The DPP study also investigated the relationship between income and achieving weight loss goals but found no significant association after adjusting for age (13). The DPP had fewer participants with low income than SDPI-DP and did not separate participants with <$15,000, the group that achieved the least weight loss among SDPI-DP participants. This may partially explain the different findings of the two studies. Or it could reflect differences between rigorously controlled randomized clinical trials and translational projects implemented in "real-world" settings.

The Finnish national diabetes prevention program, a translational initiative that uses lifestyle intervention to prevent diabetes in a primary health care setting of Finland, reported similar lifestyle intervention effects in all socioeconomic groups (14). However, education and occupation were used as factors representing socioeconomic position in that study. Consistent with a previous study reporting socioeconomic inequalities in diabetes prevalence (24), we found income, rather than education or employment

Table 1—Baseline BMI and behavioral measures by participant and staff demographic and socioeconomic characteristics

		BMI (n = 2,553)		RAPA (n = 2,240)		Healthy diet (n = 2,357)		Unhealthy diet (n = 2,355)	
	n (%)	Mean (SD)	P^a	Mean (SD)	P^a	Mean (SD)	P^a	Mean (SD)	P^a
Total	2,553 (100.0)	35.82 (7.34)		3.75 (1.08)		3.39 (0.82)		2.87 (0.72)	
Participant characteristics									
Sex									
Female	1,901 (74.5)	35.97 (7.37)	0.08	3.62 (1.08)	**<0.0001**	3.41 (0.81)	0.22	2.82 (0.69)	**<0.0001**
Male (ref)	652 (25.5)	35.39 (7.24)		4.11 (1.01)		3.36 (0.83)		3.05 (0.76)	
Age			**<0.0001**[b]		**0.03**[b]		**0.0001**[b]		**<0.0001**[b]
18 to <40 years	731 (28.6)	37.84 (7.57)	**<0.0001**	3.66 (1.14)	**0.01**	3.32 (0.83)	**<0.0001**	3.07 (0.69)	**<0.0001**
40 to <50 years	774 (30.3)	36.44 (7.59)	**<0.0001**	3.73 (1.06)	0.13	3.37 (0.80)	**0.0007**	2.92 (0.70)	**<0.0001**
50 to <60 years	645 (25.3)	34.33 (6.64)	**0.03**	3.80 (1.04)	0.63	3.41 (0.82)	**0.01**	2.80 (0.71)	**<0.0001**
≥60 years (ref)	403 (15.8)	33.34 (6.21)		3.84 (1.07)		3.55 (0.80)		2.54 (0.68)	
Education status			**0.004**[b]		**<0.0001**[b]		**<0.0001**[b]		**0.03**[b]
<High school graduate	318 (14.1)	36.68 (8.17)	**0.006**	4.03 (1.07)	**0.0001**	3.32 (0.87)	**<0.0001**	2.93 (0.75)	**0.006**
High school graduate	477 (21.1)	36.61 (7.71)	**0.004**	3.74 (1.10)	0.80	3.34 (0.81)	**<0.0001**	2.89 (0.71)	**0.03**
Some college	1,024 (45.4)	35.61 (6.95)	0.32	3.69 (1.09)	0.58	3.36 (0.83)	**<0.0001**	2.88 (0.71)	**0.02**
≥College graduate (ref)	438 (19.4)	35.20 (7.14)		3.72 (1.03)		3.56 (0.75)		2.79 (0.69)	
Employment status			**<0.0001**[b]		**0.03**[b]		**<0.0001**[b]		**<0.0001**[b]
Retired	168 (7.5)	32.59 (6.12)	**<0.0001**	3.92 (1.09)	**0.02**	3.68 (0.83)	**<0.0001**	2.41 (0.65)	**<0.0001**
Unemployed/student	416 (18.5)	36.91 (8.23)	**0.02**	3.80 (1.09)	0.17	3.42 (0.81)	0.08	2.93 (0.77)	0.56
Employed (ref)	1,665 (74.0)	35.95 (7.12)		3.71 (1.08)		3.34 (0.81)		2.91 (0.69)	
Marital status			**<0.0001**[b]		0.50[b]		0.07[b]		**<0.0001**[b]
Separated/divorced/widowed	510 (25.2)	34.65 (6.69)	**0.005**	3.76 (1.12)	0.53	3.38 (0.80)	0.34	2.77 (0.74)	**0.006**
Never married	323 (16.0)	38.29 (9.04)	**<0.0001**	3.72 (1.11)	0.26	3.30 (0.87)	**0.02**	3.06 (0.78)	**<0.0001**
Married/live together (ref)	1,189 (58.8)	35.76 (7.20)		3.80 (1.05)		3.42 (0.80)		2.87 (0.69)	
Annual household income			0.33[b]		**0.0006**[b]		**<0.0001**[b]		**0.002**[b]
<$15,000	371 (19.4)	36.11 (8.26)	0.28	3.91 (1.06)	**0.006**	3.36 (0.89)	**0.001**	2.96 (0.83)	**0.001**
$15,000 to <$30,000	411 (21.5)	36.44 (7.58)	0.07	3.80 (1.09)	0.21	3.36 (0.82)	**0.0008**	2.95 (0.70)	**0.002**
$30,000 to <$50,000	569 (29.8)	36.02 (6.90)	0.31	3.62 (1.10)	0.18	3.31 (0.84)	**<0.0001**	2.87 (0.68)	0.11
≥$50,000 (ref)	558 (29.2)	35.57 (7.06)		3.71 (1.05)		3.53 (0.70)		2.80 (0.67)	
Staff characteristics									
Proportion of female staff									
≤70%	562 (23.4)	36.44 (7.62)	**0.01**	3.72 (1.08)	0.30	3.48 (0.82)	**0.03**	2.80 (0.71)	**0.01**
>70% (ref)	1,839 (76.6)	35.55 (7.28)		3.77 (1.08)		3.40 (0.82)		2.89 (0.72)	
Average age of staff members									
<40 years	835 (34.8)	35.20 (7.24)	**0.007**	3.78 (1.09)	0.49	3.44 (0.83)	0.34	2.92 (0.75)	**0.01**
≥40 years (ref)	1,566 (65.2)	36.05 (7.42)		3.75 (1.07)		3.41 (0.81)		2.84 (0.70)	
Proportion of staff with graduate or professional degree									
<50%	1,257 (52.4)	35.36 (7.27)	**0.006**	3.73 (1.08)	0.21	3.38 (0.85)	**0.05**	2.89 (0.74)	0.15
≥50% (ref)	1,144 (47.6)	36.19 (7.45)		3.79 (1.08)		3.45 (0.78)		2.85 (0.70)	

ref, reference group. Boldface data indicate $P \leq 0.05$. [a]Two-sided P value for each dummy variable from univariate regression analysis unless otherwise noted. [b]P value of χ^2 test for cross tabulation.

Table 2—Improvements in weight, BMI, and behavioral outcomes at postcurriculum assessment by participant and staff demographic and socioeconomic characteristics (among completers of postcurriculum assessments only)

		Change in outcome variables (postcurriculum − baseline)									
		% Weight change (*n* = 1,883)		BMI (*n* = 1,883)		RAPA (*n* = 1,595)		Healthy diet (*n* = 1,604)		Unhealthy diet (*n* = 1,606)	
	n (%)	Mean (SD)	*P*[a]	Mean (SD)	*P*[a]	Mean (SD)	*P*[a]	Mean (SD)	*P*[a]	Mean (SD)	*P*[a]
Total	1,883 (100.0)	−3.8 (0.04)		−1.39 (1.71)		0.57 (1.15)		0.35 (0.73)		−0.50 (0.65)	
Baseline participant characteristics											
Sex											
Female	1,414 (75.1)	−3.7 (0.04)	**0.003**	−1.31 (1.66)	**0.001**	0.62 (1.17)	**0.006**	0.35 (0.72)	0.92	−0.50 (0.65)	0.69
Male (ref)	469 (24.9)	−4.4 (0.05)		−1.61 (1.85)		0.43 (1.09)		0.35 (0.74)		−0.52 (0.65)	
Age			**<0.0001**[b]		**0.02**[b]		0.55[b]		0.34[b]		0.12[b]
18 to <40 years	491 (26.1)	−3.4 (0.04)	**<0.0001**	−1.27 (1.78)	**0.002**	0.58 (1.21)	0.45	0.32 (0.74)	0.85	−0.57 (0.72)	**0.03**
40 to <50 years	576 (30.6)	−3.6 (0.05)	**<0.0001**	−1.35 (1.83)	**0.01**	0.52 (1.13)	0.15	0.39 (0.74)	0.14	−0.49 (0.62)	0.51
50 to <60 years	497 (26.4)	−4.0 (0.05)	**0.01**	−1.37 (1.63)	**0.03**	0.57 (1.12)	0.37	0.37 (0.72)	0.29	−0.50 (0.64)	0.41
≥60 years (ref)	319 (16.9)	−4.8 (0.04)		−1.65 (1.48)		0.65 (1.16)		0.31 (0.68)		−0.45 (0.59)	
Education status			**0.05**[b]		0.06[b]		0.16[b]		0.75[b]		0.57[b]
<High school graduate	215 (12.5)	−4.3 (0.05)	0.59	−1.53 (1.76)	0.72	0.39 (1.20)	**0.05**	0.35 (0.82)	0.47	−0.44 (0.70)	0.25
High school graduate	359 (20.9)	−4.1 (0.05)	0.89	−1.46 (1.81)	0.91	0.59 (1.19)	0.97	0.34 (0.75)	0.33	−0.52 (0.64)	0.78
Some college	786 (45.7)	−3.5 (0.04)	0.06	−1.27 (1.62)	**0.05**	0.60 (1.18)	0.94	0.35 (0.71)	0.34	−0.50 (0.64)	0.90
≥College graduate (ref)	359 (20.9)	−4.1 (0.04)		−1.48 (1.62)		0.59 (1.03)		0.40 (0.65)		−0.50 (0.61)	
Employment status			**0.0001**[b]		**0.01**[b]		0.77[b]		0.29[b]		0.06[b]
Retired	143 (8.4)	−5.4 (0.04)	**<0.0001**	−1.80 (1.38)	**0.003**	0.65 (1.16)	0.50	0.31 (0.60)	0.36	−0.37 (0.60)	**0.02**
Unemployed/student	276 (16.1)	−3.7 (0.05)	0.93	−1.33 (1.87)	0.80	0.56 (1.26)	0.87	0.31 (0.84)	0.17	−0.49 (0.74)	0.52
Employed (ref)	1,290 (75.5)	−3.8 (0.04)		−1.36 (1.67)		0.57 (1.13)		0.38 (0.71)		−0.52 (0.63)	
Marital status			**0.0004**[b]		**0.01**[b]		0.66[b]		0.44[b]		**0.01**[b]
Separated/divorced/widowed	384 (24.9)	−3.6 (0.04)	**0.02**	−1.27 (1.55)	**0.03**	0.57 (1.23)	0.82	0.35 (0.74)	0.99	−0.42 (0.70)	**0.003**
Never married	232 (15.0)	−3.0 (0.05)	**0.0002**	−1.19 (1.81)	**0.02**	0.48 (1.15)	0.43	0.28 (0.79)	0.22	−0.52 (0.72)	0.61
Married/live together (ref)	926 (60.1)	−4.2 (0.04)		−1.49 (1.71)		0.55 (1.10)		0.35 (0.69)		−0.55 (0.61)	
Annual household income			**0.009**[b]		**0.003**[b]		0.07[b]		0.08[b]		0.20[b]
<$15,000	254 (17.3)	−3.1 (0.05)	**0.001**	−1.09 (1.79)	**0.0003**	0.41 (1.22)	**0.05**	0.36 (0.82)	0.37	−0.43 (0.80)	**0.03**
$15,000 to <$30,000	313 (21.3)	−3.6 (0.04)	**0.05**	−1.30 (1.62)	**0.03**	0.57 (1.09)	0.72	0.27 (0.72)	**0.01**	−0.51 (0.63)	0.44
$30,000 to <$50,000	452 (30.7)	−3.7 (0.04)	0.07	−1.33 (1.55)	**0.03**	0.67 (1.20)	0.42	0.40 (0.71)	0.77	−0.50 (0.62)	0.33
≥$50,000 (ref)	453 (30.8)	−4.3 (0.05)		−1.57 (1.80)		0.60 (1.14)		0.41 (0.68)		−0.55 (0.60)	
Staff characteristics											
Proportion of female staff											
≤70%	431(24.3)	−3.9 (0.05)	0.75	−1.43 (1.69)	0.66	0.62 (1.14)	0.39	0.38 (0.66)	0.36	−0.49 (0.65)	0.55
>70% (ref)	1,342 (75.7)	−3.9 (0.05)		−1.39 (1.74)		0.56 (1.16)		0.34 (0.75)		−0.51 (0.66)	
Average age of staff members											
<40 years	562 (31.7)	−4.1 (0.05)	0.23	−1.44 (1.72)	0.57	0.61 (1.13)	0.51	0.37 (0.74)	0.42	−0.56 (0.65)	**0.05**
≥40 years (ref)	1,211 (68.3)	−3.8 (0.05)		−1.39 (1.73)		0.56 (1.16)		0.34 (0.73)		−0.48 (0.65)	
Proportion of staff with graduate or professional degree											
<50%	946 (53.4)	−3.5 (0.04)	**0.0002**	−1.27 (1.62)	**0.0004**	0.60 (1.12)	0.40	0.31 (0.75)	**0.02**	−0.54 (0.66)	**0.03**
≥50% (ref)	827 (46.6)	−4.3 (0.05)		−1.56 (1.83)		0.55 (1.19)		0.40 (0.70)		−0.46 (0.65)	

ref, reference group. Boldface data indicate $P \leq 0.05$. [a]Two-sided *P* value for each dummy variable from univariate regression analysis unless otherwise noted. [b]*P* value of χ^2 test for cross tabulation.

Table 3—Multilevel regression models of BMI and behavioral outcomes[a]

	Change in outcome variables (postcurriculum – baseline)			
	BMI (n = 2,553)[b]	RAPA (n = 2,240)[b]	Healthy diet (n = 2,357)[b]	Unhealthy diet (n = 2,355)[b]
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Model 1: sex and age only				
Female*time	0.29 (0.11, 0.46)**	0.20 (0.08, 0.32)**	−0.00 (−0.08, 0.08)	0.03 (−0.04, 0.10)
Age (10-year increment)*time	−0.09 (−0.15, −0.02)**	−0.00 (−0.05, 0.04)	0.00 (−0.03, 0.03)	0.04 (0.01, 0.06)**
Model 2: model 1 + employment status				
Female*time	0.27 (0.09, 0.45)**	0.21 (0.08, 0.33)**	0.00 (−0.08, 0.08)	0.03 (−0.04, 0.10)
Age (10-year increment)*time	−0.07 (−0.14, 0.01)	−0.01 (−0.06, 0.04)	0.01 (−0.02, 0.04)	0.03 (−0.00, 0.06)*
Employment status (ref: employed)				
Retired*time	−0.23 (−0.55, 0.10)**	−0.02 (−0.25, 0.22)	−0.11 (−0.26, 0.04)	0.10 (−0.03, 0.23)
Unemployed/student*time	0.01 (−0.21, 0.23)	−0.03 (−0.18, 0.11)	−0.08 (−0.18, 0.02)	−0.00 (−0.09, 0.08)
Model 3: model 2 + annual household income				
Female*time	0.26 (0.08, 0.44)**	0.21 (0.09, 0.34)***	0.00 (−0.08, 0.08)	0.03 (−0.04, 0.10)
Age (10-year increment)*time	−0.06 (−0.13, 0.01)	−0.01 (−0.06, 0.04)	0.01 (−0.02, 0.04)	0.03 (0.00, 0.06)*
Employment status (ref: employed)				
Retired*time	−0.31 (−0.64, 0.02)	0.01 (−0.22, 0.25)	−0.09 (−0.24, 0.06)	0.08 (−0.05, 0.22)
Unemployed/student*time	−0.14 (−0.39, 0.10)	0.03 (−0.13, 0.19)	−0.06 (−0.17, 0.04)	−0.03 (−0.13, 0.06)
Annual household income (ref: ≥$50,000)				
<$15,000*time	0.49 (0.21, 0.77)***	−0.15 (−0.34, 0.03)	−0.05 (−0.16, 0.07)	0.10 (−0.01, 0.20)
$15,000 to <$30,000*time	0.25 (0.03, 0.48)*	−0.02 (−0.19, 0.14)	−0.07 (−0.18, 0.04)	0.05 (−0.04, 0.14)
$30,000 to <$50,000*time	0.21 (0.00, 0.42)*	0.04 (−0.11, 0.19)	−0.00 (−0.10, 0.09)	0.03 (−0.05, 0.12)
Model 4: model 3 + proportion of staff completing graduate or professional school				
Participant characteristics				
Female*time	0.26 (0.08, 0.44)**	0.21 (0.09, 0.34)***	0.00 (−0.08, 0.08)	0.03 (−0.04, 0.10)
Age (10-year increment)*time	−0.05 (−0.12, 0.02)	−0.01 (−0.06, 0.04)	0.01 (−0.03, 0.04)	0.03 (−0.00, 0.06)
Employment status (ref: employed)				
Retired*time	−0.29 (−0.62, 0.04)	0.02 (−0.22, 0.25)	−0.09 (−0.25, 0.06)	0.08 (−0.05, 0.21)
Unemployed/student*time	−0.13 (−0.38, 0.11)	0.03 (−0.13, 0.19)	−0.06 (−0.17, 0.04)	−0.03 (−0.13, 0.06)
Annual household income (ref: ≥$50,000)				
< $15,000*time	0.50 (0.22, 0.77)***	−0.15 (−0.34, 0.04)	−0.05 (−0.17, 0.07)	0.09 (−0.01, 0.20)
$15,000 to <$30,000*time	0.26 (0.04, 0.49)*	−0.02 (−0.19, 0.14)	−0.07 (−0.18, 0.03)	0.05 (−0.05, 0.14)
$30,000 to <$50,000*time	0.21 (0.01, 0.42)*	0.04 (−0.11, 0.19)	−0.00 (−0.10, 0.09)	0.03 (−0.06, 0.12)
Site characteristics				
Proportion of staff with graduate or professional degree <50%*time	0.24 (0.09, 0.39)**	0.04 (−0.07, 0.15)	−0.07 (−0.13, 0.00)	−0.02 (−0.08, 0.04)

ref, reference group. [a]Linear mixed models based on all available data with imputed baseline socioeconomic data as independent variables. [b]Sample sizes vary because some participants had missing data in the behavioral outcome measures at both time points. *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

status, was the factor that remained significantly or marginally correlated with weight and behavioral outcomes in the final models. Given household income is a direct measure of economic resources for an individual, our findings confirm the important role that economic resources play in shaping a person's healthy behaviors as well as making changes in those behaviors.

Our mediational analysis suggests that difficulty in making dietary changes might partially explain the suboptimal weight loss achieved by the participants with low household income, while changes in physical activity did not affect that association. This corroborates the importance of economic resources in achieving the goals of this kind of intervention, whereas more physical activity may not cost the participants a lot, replacing unhealthy foods with healthy choices usually requires adequate income. Recent studies investigating the association between food prices and health outcomes reported that higher prices of healthy foods were associated with various adverse health outcomes (31–33). Furthermore, the association between food insecurity and diet-related chronic diseases among low-income adults has been consistently reported (34,35). In low-income communities, unhealthy foods such as processed foods are usually inexpensive and highly accessible, whereas healthy choices such as fruits and vegetables are often more expensive and less available. As a result, food-insecure adults consumed diets of poorer quality than their food-secure counterparts. These findings along with ours imply the affordability and availability of healthy foods could be a necessary condition for effective diabetes prevention.

In addition to the association between participant SES and the effectiveness of lifestyle intervention, we also found that the grantee sites with fewer professionally prepared staff members were less successful at improving participant BMI and diet. In a previous report (30), we found grantee sites with older staff were more successful in participant retention. Turning to weight loss and related behavioral changes, however, the education level of staff members seems to be more important. These findings indicate both participant and staff socioeconomic characteristics were related to the magnitude of intervention benefits. In particular, recruiting staff with advanced

Table 4—Multilevel regression models of BMI controlling for changes in diet and physical activity[a]

	Model 5 (n = 1,555)[b]	Model 6 (n = 1,555)[b]	Model 7 (n = 1,555)[b]	Model 8 (n = 1,555)[b]	Model 9 (n = 1,555)[b]
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Participant characteristics					
Female*time	0.24 (0.05, 0.43)**	0.20 (0.01, 0.39)*	0.28 (0.09, 0.47)**	0.36 (0.17, 0.54)***	0.28 (0.09, 0.47)**
Age (10-year increment)*time	−0.06 (−0.14, 0.02)	−0.06 (−0.13, 0.02)	−0.04 (−0.12, 0.03)	−0.03 (−0.10, 0.05)	−0.03 (−0.10, 0.05)
Employment status (ref: employed)					
Retired*time	−0.41 (−0.77, −0.06)*	−0.31 (−0.66, 0.03)	−0.41 (−0.76, −0.06)*	−0.34 (−0.69, 0.01)	−0.36 (−0.70, −0.02)*
Unemployed/student*time	−0.09 (−0.35, 0.18)	−0.10 (−0.36, 0.15)	−0.11 (−0.37, 0.14)	−0.06 (−0.31, 0.19)	−0.05 (−0.30, 0.20)
Annual household income (ref: ≥$50,000)					
<$15,000*time	0.52 (0.22, 0.82)***	0.55 (0.25, 0.84)***	0.41 (0.11, 0.71)**	0.33 (0.04, 0.61)*	0.36 (0.07, 0.66)*
$15,000 to <$30,000*time	0.27 (0.02, 0.51)*	0.28 (0.05, 0.52)*	0.19 (−0.06, 0.43)	0.16 (−0.07, 0.40)	0.15 (−0.09, 0.38)
$30,000 to <$50,000*time	0.22 (−0.00, 0.44)*	0.23 (0.01, 0.45)*	0.19 (−0.04, 0.41)	0.18 (−0.04, 0.39)	0.15 (−0.07, 0.36)
Baseline RAPA*time		−0.28 (−0.39, −0.17)***			−0.22 (−0.33, −0.11)***
Change in RAPA*time		−0.42 (−0.52, −0.32)***			−0.29 (−0.39, −0.19)***
Baseline healthy diet*time			−0.15 (−0.27, −0.04)**		−0.12 (−0.23, −0.00)*
Change in healthy diet*time			−0.45 (−0.58, −0.33)***		−0.40 (−0.53, −0.28)***
Baseline unhealthy diet*time				0.42 (0.28, 0.56)***	0.35 (0.21, 0.49)***
Change in unhealthy diet*time				0.80 (0.65, 0.94)***	0.72 (0.57, 0.86)***
Site characteristics					
Proportion of staff completing graduate/professional school <50%*time	0.25 (0.08, 0.42)**	0.26 (0.10, 0.42)**	0.22 (0.06, 0.38)**	0.27 (0.11, 0.43)**	0.24 (0.08, 0.40)**

ref, reference group. [a]Linear mixed models based on paired data with imputed baseline socioeconomic variables and nonimputed changes in behaviors as independent variables. [b]Because 998 participants had missing data on at least one of behavioral change, the sample sizes of models in Table 4 are smaller than those of models in Table 3. *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

professional training could be crucial to maximize the effectiveness of lifestyle interventions. On the other hand, the proportion of professionally trained staff might be an indicator for site-level SES and/or the remoteness of the site, because the sites with lower overall SES might be less likely to attract or maintain staff with professional degrees. Future studies investigating the relationship between neighborhood characteristics, staff SES, and lifestyle intervention effectiveness are warranted to understand the underlying mechanism for the observed association between staff education and weight loss.

The findings of the current study need to be interpreted in light of several limitations. First, the SDPI-DP participants were all AI/ANs, which may limit the generalizability of our findings to other populations. However, the large sample of lifestyle intervention participants from diverse AI/AN communities, especially of low income, indicates good generalizability among AI/ANs and makes a unique contribution to the literature. Second, although we collected data describing participant and staff SES, we did not have data representing neighborhood socioeconomic characteristics. Previous research suggests that both individual and neighborhood characteristics are related to the risk of type 2 diabetes (26,36). It will be illuminating to investigate the relationship between neighborhood characteristics and lifestyle interventions beyond the effects of individual- and staff-level factors in the future. Third, both physical activity and diet measures were self-reported, which are subject to recall bias and measurement error. However, the strong correlations of improvements in physical activity and diet measures with BMI reduction suggest the potential validity of these reports. Finally, without a control group, the relationships between SES and changes in intervention outcomes presented here could be confounded by baseline values of the outcome measures. Yet the fact that baseline BMI did not significantly differ across annual household income levels reduces the concern of this potential confounding effect.

In summary, this study demonstrated that the SDPI-DP lifestyle intervention was successful at making substantial improvements in weight and behavioral outcomes among all SES groups of SDPI-DP participants. Yet, significant socioeconomic disparities exist in those outcomes at both the participant and site staff levels. These findings are alarming because they suggest that populations with lower SES, already burdened with higher diabetes prevalence, may benefit less from a proven diabetes prevention strategy. Therefore, simply translating the DPP lifestyle intervention across the general population without proper attention to such socioeconomic differences may not fully reduce the diabetes disparities that plague underserved populations as we had hoped. Helping low-income participants find ways to choose more affordable and available healthy foods, such as beans and legumes, could be a practical way to maximize the effectiveness of lifestyle interventions implemented in "real-world" settings, especially among socioeconomically disadvantaged populations. Meanwhile, improving professional training of staff members who implement the intervention might offer another possibility to increase the intervention effectiveness of some implementation sites.

Acknowledgments. The authors would like to express their gratitude to the IHS as well as tribal and urban Indian health programs and participants involved in the SDPI-DP Program.

Funding. Funding for the SDPI-DP project was provided by the IHS (HHSI242200400049C to S.M.M.). Manuscript preparation was supported in part by the American Diabetes Association (#7-12-CT-36 to L.J.) and the National Institute of Diabetes and Digestive and Kidney Diseases (1P30DK092923 to S.M.M.).

Duality of Interest. No potential conflicts of interest relevant to this article were reported.

Author Contributions. L.J. designed the study, researched the data, contributed to the discussion, and wrote, reviewed, and edited the manuscript. H.H. researched the data, performed data analysis, and reviewed and edited the manuscript. A.J. and E.J.D. contributed to the discussion and reviewed and edited the manuscript. J.B. participated in the design of the SDPI-DP project, contributed to the discussion, and reviewed and edited the manuscript. S.M.M. and Y.R. conceptualized and designed the SDPI-DP project, contributed to the discussion, and reviewed and edited the manuscript. L.J. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Appendix

The grant programs participating in the SDPI-DP program are as follows: Confederated Tribes of the Chehalis Reservation, Cherokee Nation, Cheyenne River Sioux Tribe, the Chickasaw Nation, Coeur d'Alene Tribe, Colorado River Indian Tribes, Colville Confederated Tribes, Cow Creek Band of Umpqua Tribe, Fond du Lac Reservation, Gila River Health Care, Haskell Health Center, Ho-Chunk Nation, Indian Health Board of Minneapolis, Urban Native Diabetes Prevention Consortium, Kenaitze Indian Tribe IRA, Lawton IHS Service Unit, Menominee Indian Tribe of Wisconsin, Mississippi Band of Choctaw Indians, Norton Sound Health Corporation, Pine Ridge IHS Service Unit, Pueblo of San Felipe, Quinault Indian Nation, Rapid City IHS Diabetes Program, Red Lake Comprehensive Health Services, Rocky Boy Health Board, Seneca Nation of Indians, Sonoma County Indian Health Project, South East Alaska Regional Health Consortium, Southcentral Foundation, Trenton Indian Service Area, Tuba City Regional Health Care Corporation, United American Indian Involvement, Inc., United Indian Health Services, Inc., Warm Springs Health & Wellness Center, Winnebago Tribe of Nebraska, and Zuni Pueblo.

References

1. Pan XR, Li GW, Hu YH, et al. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. Diabetes Care 1997;20:537–544
2. Tuomilehto J, Lindström J, Eriksson JG, et al.; Finnish Diabetes Prevention Study Group. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. N Engl J Med 2001;344:1343–1350
3. Knowler WC, Barrett-Connor E, Fowler SE, et al.; Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002;346:393–403
4. Norris SL, Zhang X, Avenell A, et al. Long-term effectiveness of weight-loss interventions in adults with pre-diabetes: a review. Am J Prev Med 2005;28:126–139
5. Dunkley AJ, Bodicoat DH, Greaves CJ, et al. Diabetes prevention in the real world: effectiveness of pragmatic lifestyle interventions for the prevention of type 2 diabetes and of the impact of adherence to guideline recommendations: a systematic review and meta-analysis. Diabetes Care 2014;37:922–933
6. Hamman RF, Wing RR, Edelstein SL, et al. Effect of weight loss with lifestyle intervention on risk of diabetes. Diabetes Care 2006;29:2102–2107
7. West DS, Elaine Prewitt T, Bursac Z, Felix HC. Weight loss of black, white, and Hispanic men and women in the Diabetes Prevention Program. Obesity (Silver Spring) 2008;16:1413–1420
8. Wadden TA, West DS, Neiberg RH, et al.; Look AHEAD Research Group. One-year weight losses in the Look AHEAD study: factors associated with success. Obesity (Silver Spring) 2009;17:713–722
9. Svetkey LP, Clark JM, Funk K, et al. Greater weight loss with increasing age in the weight loss maintenance trial. Obesity (Silver Spring) 2014;22:39–44
10. Delahanty LM, Peyrot M, Shrader PJ, Williamson DA, Meigs JB, Nathan DM; DPP Research Group. Pretreatment, psychological, and

behavioral predictors of weight outcomes among lifestyle intervention participants in the Diabetes Prevention Program (DPP). Diabetes Care 2013;36:34–40
11. Tsai AG, Fabricatore AN, Wadden TA, et al. Readiness redefined: a behavioral task during screening predicted 1-year weight loss in the Look AHEAD study. Obesity (Silver Spring) 2014;22:1016–1023
12. Dill EJ, Manson SM, Jiang L, et al. Psychosocial predictors of weight loss among American Indian and Alaska Native participants in a diabetes prevention translational project [article online], 2015. J Diabetes Res. Available from http://www.hindawi.com/journals/jdr/aa/324168/abs/. Accessed 28 May 2015
13. Wing RR, Hamman RF, Bray GA, et al.; Diabetes Prevention Program Research Group. Achieving weight and activity goals among Diabetes Prevention Program lifestyle participants. Obes Res 2004;12:1426–1434
14. Rautio N, Jokelainen J, Oksa H, et al. Socioeconomic position and effectiveness of lifestyle intervention in prevention of type 2 diabetes: one-year follow-up of the FIN-D2D project. Scand J Public Health 2011;39:561–570
15. Centers for Disease Control and Prevention. *National Diabetes Statistics Report, 2014*. Available from http://www.cdc.gov/diabetes/pubs/statsreport14.htm. Accessed 12 October 2014
16. Stuart-Shor EM, Berra KA, Kamau MW, Kumanyika SK. Behavioral strategies for cardiovascular risk reduction in diverse and underserved racial/ethnic groups. Circulation 2012;125:171–184
17. Macartney S, Bishaw A, Fontenot K. Poverty rates for selected detailed race and Hispanic groups by state and place: 2007-2011 [Internet], 2013. Available from https://www.census.gov/prod/2013pubs/acsbr11-17.pdf. Accessed 12 October 2014
18. Manson SM, Jiang L, Zhang L, Beals J, Acton KJ, Roubideaux Y; SDPI Healthy Heart Demonstration Project. Special Diabetes Program for Indians: retention in cardiovascular risk reduction. Gerontologist 2011;51(Suppl. 1):S21–S32
19. Jiang L, Manson SM, Beals J, et al.; Special Diabetes Program for Indians Diabetes Prevention Demonstration Project. Translating the Diabetes Prevention Program into American Indian and Alaska Native communities: results from the Special Diabetes Program for Indians Diabetes Prevention demonstration project. Diabetes Care 2013;36:2027–2034
20. Diabetes Prevention Program (DPP) Research Group. The Diabetes Prevention Program (DPP): description of lifestyle intervention. Diabetes Care 2002;25:2165–2171
21. Topolski TD, LoGerfo J, Patrick DL, Williams B, Walwick J, Patrick MB. The Rapid Assessment of Physical Activity (RAPA) among older adults. Prev Chronic Dis 2006;3:A118
22. Teufel-Shone NI, Jiang L, Beals J, et al. Demographic characteristics and food choices of participants in the Special Diabetes Program for American Indians Diabetes Prevention Demonstration Project. Ethn Health 2015;20:327–340
23. Raghunathan TE, Solenberger PW, Hoewyk JV. IVEware: Imputation and Variance Estimation Software [Internet]. Available from http://www.isr.umich.edu/src/smp/ive/. Accessed 17 February 2012
24. Robbins JM, Vaccarino V, Zhang H, Kasl SV. Socioeconomic status and type 2 diabetes in African American and non-Hispanic white women and men: evidence from the Third National Health and Nutrition Examination Survey. Am J Public Health 2001;91:76–83
25. Signorello LB, Schlundt DG, Cohen SS, et al. Comparing diabetes prevalence between African Americans and whites of similar socioeconomic status. Am J Public Health 2007;97:2260–2267
26. Krishnan S, Cozier YC, Rosenberg L, Palmer JR. Socioeconomic status and incidence of type 2 diabetes: results from the Black Women's Health Study. Am J Epidemiol 2010;171:564–570
27. Lidfeldt J, Li TY, Hu FB, Manson JE, Kawachi I. A prospective study of childhood and adult socioeconomic status and incidence of type 2 diabetes in women. Am J Epidemiol 2007;165:882–889
28. Agardh EE, Ahlbom A, Andersson T, et al. Socio-economic position at three points in life in association with type 2 diabetes and impaired glucose tolerance in middle-aged Swedish men and women. Int J Epidemiol 2007;36:84–92
29. Agardh E, Allebeck P, Hallqvist J, Moradi T, Sidorchuk A. Type 2 diabetes incidence and socio-economic position: a systematic review and meta-analysis. Int J Epidemiol 2011;40:804–818
30. Jiang L, Manson SM, Dill EJ, et al.; Special Diabetes Program for Indians Diabetes Prevention Demonstration Project. Participant and site characteristics related to participant retention in a diabetes prevention translational project. Prev Sci 2015;16:41–52
31. Powell LM, Chaloupka FJ. Food prices and obesity: evidence and policy implications for taxes and subsidies. Milbank Q 2009;87:229–257
32. Rahkovsky I, Gregory CA. Food prices and blood cholesterol. Econ Hum Biol 2013;11:95–107
33. Anekwe TD, Rahkovsky I. The association between food prices and the blood glucose level of US adults with type 2 diabetes. Am J Public Health 2014;104:678–685
34. Seligman HK, Laraia BA, Kushel MB. Food insecurity is associated with chronic disease among low-income NHANES participants. J Nutr 2010;140:304–310
35. Larson NI, Story MT. Food insecurity and weight status among U.S. children and families: a review of the literature. Am J Prev Med 2011;40:166–173
36. Auchincloss AH, Diez Roux AV, Mujahid MS, Shen M, Bertoni AG, Carnethon MR. Neighborhood resources for physical activity and healthy foods and incidence of type 2 diabetes mellitus: the Multi-Ethnic Study of Atherosclerosis. Arch Intern Med 2009;169:1698–1704