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Original Contribution

Life-Course Socioeconomic Position and Type 2 Diabetes Mellitus

The Framingham Offspring Study

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Evidence is lacking on whether the duration and timing of low socioeconomic position (SEP) across a person's life course may be associated with incidence of type 2 diabetes mellitus (T2D). The authors' objectives were to investigate associations between cumulative SEP and the incidence of T2D in the Framingham Offspring Study ($n = 1{,}893$; 52% women; mean baseline age = 34 years). Pooled logistic regression analyses demonstrated that age-adjusted cumulative SEP was associated with T2D in women (for low vs. high cumulative SEP, odds ratio (OR) = 1.92, 95% confidence interval (CI): 1.08, 3.42). Age-adjusted analyses for young-adulthood SEP (7.85 for $\leq$12 vs. >16 years of education, OR = 2.84, 95% CI: 1.03), active professional life SEP (for laborer vs. professional/executive/supervisory/technical occupations, OR = 2.40, 95% CI: 1.05, 5.47), and social-mobility frameworks (for declining life-course SEP, OR = 2.99, 95% CI: 1.39, 6.44; for stable low vs. stable high life-course SEP, OR = 1.85, 95% CI: 1.02, 3.35) all demonstrated associations between low SEP and T2D incidence in women. No association was observed between childhood SEP and T2D in women for father's education (some high school or less vs. any postsecondary education, OR = 1.26, 95% CI: 0.72, 2.22). In men, there was little evidence of associations between life-course SEP and T2D incidence. These findings suggest that cumulative SEP is inversely associated with incidence of T2D in women, and that this association may be primarily due to the women's educational levels and occupations.

adult; diabetes mellitus; educational status; incidence; occupations; parents; risk factors; socioeconomic factors

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio; SEP, socioeconomic position; T2D, type 2 diabetes mellitus.

In 2007, an estimated 17.9 million Americans had physician-diagnosed diabetes; that number is projected to rise to 48.3 million by 2050 (1–3). Approximately 90%–95% of diabetes cases are type 2 diabetes mellitus (T2D) (4), a disease that disproportionately affects disadvantaged populations (5).

Little is known about how specific socioeconomic trajectories experienced across a person's life course influence T2D incidence. A number of models have been proposed to conceptualize life-course socioeconomic position (SEP). The accumulation-of-risk model represents the summation of SEP effects that interact to increase disease risk across a person's life course (6). In contrast, the critical/sensitive-periods model acknowledges that individuals could have heightened vulnerability to low SEP exposure during specific periods in their life courses, resulting in permanent (critical period) or modifiable (sensitive period) changes in disease risk (6). Finally, the social-mobility model reflects the fact that an individual's SEP is dynamic, and it incorporates the trajectory of socioeconomic mobility across one's lifetime in determining disease risk (6).

With regard to the sensitive-periods SEP model, inverse associations have been found between childhood SEP (measured as parents' educational level or occupation) and

incidence (7, 8) and prevalence (9–11) of T2D. Similarly, the results of prospective (7, 10, 12–15) and cross-sectional (16–20) studies typically have shown inverse associations between adult SEP (measured as educational level, occupation, and income) and T2D. There is some indication that this association may be sex-specific. Women with low SEP in childhood (7–11) and adulthood (7, 10, 13, 15–20) have a consistently increased risk of T2D. However, there have been conflicting results for men. Inverse associations between childhood SEP and T2D were observed in some (8–10) but not all (11) studies. Furthermore, some studies found inverse associations between adult SEP and T2D (14, 20); however, most reported weak or no associations (10, 13, 16–19). With regard to the social-mobility SEP framework, initial studies have found that downward and stable low SEP trajectories from childhood to adulthood were associated with increased T2D risk compared with a stable high SEP trajectory in women (7, 11). Very little is known about the association between cumulative SEP and T2D.

Using a life-course SEP approach allows the examination of both the timing and duration of exposure to socioeconomic environments. We therefore could achieve a better understanding of the mechanisms by which socioeconomic disadvantage across the life course might lead to T2D. This adds to the growing literature that interventions up to young adulthood may be an additional source of effective public health approaches to reducing social disparities in rates of T2D.

The primary objective in the present study was to evaluate the extent to which cumulative life-course SEP is associated with T2D incidence in adulthood and whether this association differs by sex. The secondary objectives were to investigate whether childhood and adulthood are sensitive periods in which low SEP increases T2D risk, as well as to determine the impact of social mobility on T2D incidence.

MATERIALS AND METHODS

Study sample

Data were drawn from the prospective Framingham Offspring Study, which was initiated in 1971 and included over 30 years of follow-up on 5,124 male and female offspring (or spouses of offspring) of participants from the Framingham Heart Study original cohort, which has been described in detail elsewhere (21). Clinical examinations, during which each participant completed standardized questionnaires and a physician-administered medical history and underwent a physical examination, were performed approximately every 4 years. The Framingham Heart Study is annually reviewed by the Boston University Medical Center Institutional Review Board.

There were 4,989 Framingham Offspring Study participants in the National Heart, Lung, and Blood Institute repository data set. We excluded 2,136 participants who did not have a father in the original cohort of the Framingham Heart Study (1,598 participants had no parents in original cohort and 538 participants had a mother but no father in original cohort) in which fathers' educational levels were measured. Of the 2,853 eligible participants, those for whom data on fathers' educational level ($n = 119$), the participant's educational level ($n = 531$), or the participant's occupation ($n = 234$) were excluded from analyses. Reasons for missing data included death between examinations 1 and 2 ($n = 98$), lack of attendance at examinations 2 and 3, during which educational attainment was measured ($n = 299$), lack of attendance at examination 2, during which occupation was measured ($n = 262$), unemployment ($n = 7$), retirement ($n = 2$), and lack of response to the educational level or occupation questions ($n = 97$). To minimize misclassification of educational level, we excluded participants who were <28 years of age when their educational level was recorded ($n = 53$). We assumed then when an individual reached 28 years of age, he or she had either completed his or her education or would be included in the highest educational category as defined in this study. Participants with baseline diabetes ($n = 20$) or missing information on diabetes status at all examinations ($n = 3$) were also excluded. The final sample consisted of 1,893 participants (991 women and 902 men).

Childhood SEP: fathers' educational levels

Fathers' educational levels were measured during the enrollment of the participants' fathers in the original cohort of the Framingham Heart Study (1948–1950; mean age of the fathers = 44 years; range, 28–62 years). This approach provided a direct measure of childhood SEP, which is a more robust measure than the commonly used historical recall measures (22). The fathers' educational levels were grouped into 3 categories: low (some high school or less), medium (high school graduate), and high (any postsecondary education). Secondary analyses were conducted using each participant's father's occupation as a measure of childhood SEP. SEP was categorized into 3 categories: low (laborer), medium (clerical or sales occupations), and high (professional, executive, supervisory, or technical occupations).

Young-adulthood SEP: participants' educational levels

Educational attainment typically starts early in life and is completed by adolescence or young adulthood. Access to and pursuit of higher education are influenced by both parental characteristics and early life exposures and are strong determinants of adult SEP (e.g., occupation and income) (23). Participants' educational levels were measured at examination 2 (1979–1982; mean age = 44 years; range, 21–68 years) and examination 3 (1984–1987; mean age = 48 years, range: 24–72 years). To allow participants to reach their maximal educational attainment, the examination 3 data were prioritized. However, if examination 3 educational level data were missing, examination 2 educational level data were used ($n = 547$, 29% of sample). This likely resulted in minimal misclassification, as education assessed in adulthood remains stable throughout the life course. Educational level-based SEP was grouped into 3 categories based on years of education: low ($\leq$12 years), medium (13–16 years), and high ($\geq$17 years).

Active professional life SEP: participants' occupations

Participants' occupations were assessed at examination 2 (1979–1982) and classified into 4 groups: low (laborer), medium (clerical or sales occupations), or high (professional, executive, supervisory, or technical occupations), or homemaker. The homemaker category was considered separate, as this occupation could be found across all family socioeconomic strata.

Life-course SEP frameworks

To test the accumulation-of-risk model, a cumulative SEP measure was created by summing scores for childhood SEP (fathers' education: low = 0, medium = 1, and high = 2), young-adulthood SEP (participant's education: low = 0, medium = 1, and high = 2), and active professional-life SEP (participant's occupation: low = 0, medium or homemaker = 1, and high = 2). The cumulative SEP score ranged from 0 to 6, with higher scores reflecting increased exposure to high SEP. Cumulative SEP was categorized into low (score = 0–1), medium (score = 2–3), and high (score = 4–6) exposure to high life-course SEP, as in other studies (24, 25). These categories were based on theoretical considerations of how cumulative SEP might represent an accumulation of exposures throughout the life course (6). The homemaker category was combined with the closest other SEP category (clerical/sales occupations) when calculating the effect size of the relation between cumulative SEP and T2D incidence. This enabled us to use a 3-level summary score for each life-course period. Higher educational thresholds were used to classify SEP for a participant's, compared with a father's, educational level to account for secular trends in educational attainment across generations of the Framingham Heart Study.

The sensitive-periods framework calculated the effect of SEP measured during each period in the life course (childhood, young adulthood, and active professional life) individually while simultaneously adjusting for other SEP measures.

The social-mobility framework was tested using life-course SEP trajectories. Each SEP measure was dichotomized as follows: fathers' educational level, low (some high school or less) vs. high (high school graduate or above); participant's educational level, low ($\leq$12 years) vs. high ($>$12 years); and participant's occupation, low (laborer) vs. high (homemaker/clerical/sales/supervisory/technical/professional/executive), as was done in other studies (24, 25). These categorizations were consistent with the theoretical underpinnings of trajectories in life-course epidemiology (6). The analyses used fathers' educational level as a measure of childhood SEP and compared trajectories with both the participant's educational level and occupation (in separate analyses). Four potential SEP trajectories were investigated: stable high SEP (high childhood and high adulthood), declining SEP (high childhood and low adulthood), increasing SEP (low childhood and high adulthood), and stable low SEP (low childhood and low adulthood).

T2D ascertainment

T2D was diagnosed on the basis of the American Diabetes Association criteria (4), which define T2D as having fasting plasma glucose levels $\geq$126 mg/dL (7.0 mmol/L) at any examination. Participants who reported fasting for $<$10 hours or whose fasting information was uncertain were classified as having T2D if they were receiving treatment with either insulin or a hypoglycemic agent; had a nonfasting plasma glucose concentration $\geq$200 mg/dL (11.1 mmol/L); or had a nonfasting plasma glucose concentration $\geq$126 mg/dL (7.0 mmol/L) with a diabetes diagnosis at the subsequent Framingham Offspring Study examination. We expected minimal inclusion of type 1 diabetes cases, as baseline diabetes cases were excluded (mean baseline age = 34.4 years) and no participants were $<$30 years of age at the examination during which diabetes was first diagnosed (mean age = 58 years, with 3 participants $<$40 years of age) and required subsequent continuous insulin therapy (indicative of type 1 diabetes). Plasma glucose was measured with a hexokinase reagent kit (Agent glucose test, Abbott, South Pasadena, California). Assays were run in duplicate, and the intraassay coefficients of variation ranged from 2% to 3%. For sensitivity analyses, a more conservative T2D classification was defined. It required a diagnosis at a minimum of 2 Framingham Offspring Study examinations or at the last examination attended. This allowed the assessment of potential outcome misclassification that might result from only using 1 plasma glucose measurement to diagnose T2D.

Covariates

Updated data on age, body mass index (BMI), cigarette smoking, and alcohol consumption were used and were represented in the analyses by time-dependent covariates for Framingham Offspring examinations 1 (1971–1975) through 7 (1998–2001). Age and BMI (calculated as measured weight in kilograms divided by height in meters squared) were included as continuous variables. Cigarette smoking was self-reported (classified as never, past, or current smoker) and defined as smoking regularly in the year before the examination. Alcohol consumption was self-reported as the average number of alcoholic drinks (e.g., wine, beer, or cocktails) consumed per week (continuous variable). Components of adult height are associated with development of insulin resistance and T2D in adulthood (26–29). Given that adult height is an established marker of early life factors (30, 31) and other aspects of childhood environment (30, 31) that may not be fully encompassed by father's SEP, we adjusted for baseline height in our analyses. Baseline height and BMI were not strongly correlated in our data set (Pearson's $r = 0.19$).

Statistical analyses

Age-adjusted means (continuous measures) and proportions (categorical measures) were calculated for baseline covariates and compared across cumulative SEP categories. Multivariable pooled logistic regression adjusted for time-dependent covariates was used to estimate adjusted odds ratios and 95% confidence intervals. In this approach, we created a record for every 4-year interval between examinations for all participants. The binary dependent variable

Table 1. Age-Adjusted Baseline Characteristics According to Cumulative Socioeconomic Position Score, Framingham Offspring Study, 1971–2003

	Cumulative SEP[a] of Female Participants						Cumulative SEP[a] of Male Participants					
	Low (n = 309)		Medium (n = 397)		High (n = 285)		Low (n = 273)		Medium (n = 272)		High (n = 357)	
	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Age[b], years	38.1	37.1, 39.1	33.1	32.2, 34.0	32.5	31.5, 33.6	36.9	35.9, 38.0	34.3	33.3, 35.4	32.4	31.5, 33.3
Body mass index, kg/m^2	24.2	23.7, 24.7	23.6	23.2, 24.0	23.5	23.0, 24.0	26.8	26.4, 27.2	26.6	26.1, 27.0	26.2	25.8, 26.6
Current smoker[c], %	52.5	46.8, 58.2	41.6	36.8, 46.6	35.5	30.1, 41.3	52.3	46.3, 58.3	47.4	41.5, 53.4	31.7	27.1, 36.8
Alcohol, drinks/week	3.8	3.1, 4.6	4.6	4.0, 5.3	5.7	4.9, 6.4	12.6	11.1, 14.1	9.8	8.3, 11.2	10.1	8.8, 11.4
Height, inches	63.1	62.8, 63.3	63.6	63.4, 63.8	64.5	64.2, 64.8	68.6	68.2, 68.9	69.2	68.9, 69.5	69.6	69.3, 69.9

Abbreviations: CI, confidence interval; SEP, socioeconomic position.
[a] Low SEP indicates a score of 0–1; medium, 2–3; and high, 4–6.
[b] Calculated by using univariate analyses.
[c] Values are expressed as percent prevalence rather than mean.

indicated whether a given subject had developed T2D by the end of the interval. Individuals with T2D diagnosed at a previous examination were not included in the population at risk in subsequent examinations. For examinations with known T2D status, any missing covariate data were replaced with data from the closest previously attended examination (32). For age, 4 years was added for each missing examination. If a participant's T2D status was missing and there was no diagnosis of diabetes at a subsequently attended examination, T2D status was coded as no diabetes and covariate data were replaced as described. Of the 11,718 person-examinations included in the analysis, 389 (3%) included updated data. Observations from all examinations were then pooled and analyzed using the generalized estimating equations approach, implemented in PROC GENMOD in SAS (SAS Institute, Inc., Cary, North Carolina) (33). In generalized estimating equations analyses, we specified a binomial distribution and the logit link function, and accounted for the clustering of outcomes by family by assuming compound symmetry covariance structure of residuals. Pooled logistic regression has been shown to be equivalent to using Cox proportional hazards models (34). All analyses were conducted using SAS, version 9.1.

We used multivariable pooled logistic regression analyses to evaluate the associations between cumulative SEP and T2D incidence. In all multivariable analyses, the associations between SEP and T2D were adjusted for age, and subsequent models were adjusted for BMI, smoking, alcohol consumption, and height. No collinearity was detected among covariates when variance inflation factors were used (data not shown). To determine potential sensitive periods, the association between SEP during each life-course period and T2D risk was tested in separate pooled logistic regression analyses. Inclusion of fathers' educational levels, the participants' educational levels, and the participants' occupations in the same multivariable model resulted in minimal variance inflation, permitting simultaneous adjustment for all 3 SEP measures. Finally, pooled logistic regression analyses were performed to evaluate the association between social mobility and T2D risk. The interaction between cumulative SEP and sex was tested in the sex-pooled sample by using a 2-df likelihood ratio test, comparing the multivariable models with and without interaction terms between categories of SEP and sex. The interaction between cumulative SEP and sex was statistically significant ($P = 0.03$); consequently, sex-specific analyses were performed. Sensitivity analyses were completed using a more stringent T2D definition (defined above).

RESULTS

The analyses included 1,893 participants (991 women and 902 men) from the Framingham Offspring Study. Excluded participants were on average older (37.3 vs. 34.4 years of age, $P < 0.0001$) and more likely to smoke (45.4% vs. 43.2%, $P = 0.02$), but they did not differ with regard to other covariates or diabetes incidence (all P values > 0.05).

Age-adjusted baseline participant characteristics, stratified by cumulative SEP, are presented in Table 1. In women, cumulative SEP was directly associated with increased alcohol consumption and height and inversely associated with BMI and smoking. In men, cumulative SEP was directly associated with height and inversely associated with BMI, smoking, and alcohol consumption.

In total, 217 incident T2D cases were observed (95 women and 122 men). Results of pooled logistic regression analyses suggested that age-adjusted cumulative SEP was associated with an almost 2-fold increase in T2D risk in women (for low vs. high cumulative SEP, age-adjusted odds ratio (OR) = 1.92, 95% confidence interval (CI): 1.08, 3.42) (Table 2). When we adjusted individually for T2D risk factors, we found that BMI resulted in the greatest decrease in T2D risk. Simultaneous adjustment for all covariates further attenuated the odds ratios (OR = 1.56, 95% CI: 0.85, 2.88). In men, a nonmonotone U-shaped curvilinear association between cumulative SEP and T2D risk was suggested. Specifically, compared with men with a high cumulative SEP, men with a medium cumulative SEP had a lower T2D risk. This association remained statistically significant in the fully adjusted model (OR = 0.53, 95% CI: 0.32, 0.90).

To investigate potential periods of sensitivity to low SEP exposure, we performed sex-specific pooled logistic regression analyses of relations between the fathers' educational

Table 2. Odds Ratios for Associations Between Cumulative Socioeconomic Position Score and Incidence of Type 2 Diabetes Mellitus in Pooled Logistic Regression Models, Framingham Offspring Study, 1971–2003

Cumulative SEP Score[a]	No. of Participants	No. of Events	Model Adjustment											
			Age		Age and Body Mass Index		Age and Smoking		Age and Alcohol Consumption		Age and Height		Age and Conventional Risk Factors[b]	
			OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Women														
Low	309	42	1.92	1.08, 3.42	1.57	0.87, 2.83	1.96	1.08, 3.55	1.80	1.02, 3.17	1.94	1.08, 3.50	1.56	0.85, 2.88
Medium	397	37	1.75	0.98, 3.15	1.57	0.86, 2.86	1.77	0.98, 3.19	1.68	0.94, 3.01	1.76	0.97, 3.20	1.56	0.84, 2.88
High	285	16	1.00		1.00		1.00		1.00		1.00		1.00	
Men														
Low	273	46	0.97	0.63, 1.50	0.95	0.61, 1.49	0.87	0.56, 1.36	0.97	0.63, 1.50	0.94	0.60, 1.46	0.87	0.55, 1.37
Medium	272	26	0.60	0.36, 1.00	0.56	0.33, 0.93	0.57	0.34, 0.95	0.60	0.36, 1.00	0.59	0.36, 0.98	0.53	0.32, 0.90
High	357	50	1.00		1.00		1.00		1.00		1.00		1.00	

Abbreviations: CI, confidence interval; OR, odds ratio; SEP, socioeconomic position.

[a] Analyses used a cumulative SEP score that included father's education, participant education, and participant occupation. Scores were calculated for each SEP measure separately and then summed (range, 0–6)—father's education: some high school or less = 0, high school graduate = 1, any postsecondary education = 2; participant's education: ≤12 years = 0, 13–16 years = 1, ≥17 years = 2; participant's occupation: laborer = 0, clerical/sales/homemaker = 1, professional/executive/supervisory/technical = 2. Low SEP indicates a score of 0–1; medium, 2–3; and high, 4–6.

[b] Conventional risk factors include body mass index, smoking, alcohol consumption, and height.

levels and occupations and the participants' educational levels and occupations with T2D incidence (Table 3). In women, age-adjusted models showed strong inverse associations of participant educational level and occupation with T2D risk (for ≤12 years vs. >16 years of education, OR = 2.84, 95% CI: 1.03, 7.85; and for laborer vs. professional/executive/supervisory/technical occupation, OR = 2.40, 95% CI: 1.05, 5.47), whereas there was no effect for fathers' educational and T2D (for some high school or less vs. any postsecondary education, age-adjusted OR = 1.26, 95% CI: 0.72, 2.22). These associations were attenuated after adjusting D risk factors and all SEP measures simultaneously. In men, no associations were observed between SEP measures and T2D.

For the social-mobility framework, women with a declining SEP (OR = 2.99, 95% CI: 1.39, 6.44) and a stable low SEP (OR = 1.85, 95% CI: 1.02, 3.35) demonstrated increased age-adjusted T2D risk compared with women with a stable high SEP (Table 4). After adjustment for all covariates, increased T2D risk remained strong in the declining SEP category (OR = 2.84, 95% CI: 1.29, 6.25) but not in the stable low SEP category. Similar trends, although with generally weaker associations, were observed when participant occupation was used instead of educational level as the adulthood measure of SEP. In men, no associations were observed between social mobility and T2D risk.

Sensitivity analyses in which we used a more conservative measure of T2D incidence (described above) showed generally similar trends, although effect sizes were attenuated (see Web Tables 1–3, available at http://aje.oxfordjournals.org/). Generally similar results were achieved for analyses in which we used fathers' occupation as a measure of childhood SEP instead of fathers' educational level, although effect sizes tended to be somewhat lower (Web Tables 4–6).

DISCUSSION

The present study provides evidence of an inverse association between cumulative SEP and T2D risk in women. Results from sensitive-periods and social-mobility analyses indicated that women who experienced low SEP in young adulthood (i.e., low educational attainment) and active professional life (i.e., low occupation achievement) were at a higher risk of developing T2D than were their higher SEP counterparts, but there was little evidence for an association between low childhood SEP and T2D. Adjustment for T2D risk factors attenuated these associations. Overall, there was no association in men.

Prior literature

Very little is known about associations between cumulative SEP and T2D incidence. We found that higher lifetime exposure to low SEP was related to increased T2D risk in women, which supported the accumulation-of-risk SEP framework. In our sensitive-periods analyses, strong inverse associations were observed between participant education and occupation and T2D risk in women. These findings were consistent with previous prospective studies of SEP and T2D (7, 10, 13, 15). Furthermore, women with decreasing and stable low SEP trajectories from childhood to young adulthood had increased T2D risk compared with women with stable high trajectories, which also supported previous findings (7, 11). Combined, results from the sensitive-periods and social-mobility frameworks suggested that educational level and occupation had the largest impact on T2D incidence in women. Overall, there was little evidence of an association between SEP and T2D incidence in men. Results from previous studies evaluating associations between adult SEP and T2D in men are conflicted; some

Table 3. Odds Ratios for the Association Between Socioeconomic Position and Incidence of Type 2 Diabetes in Pooled Logistic Regression Models, Framingham Offspring Study, 1971–2003

SEP Measure and SEP Level	No. of Participants	No. of Events	Model Adjustment							
			Age		Age and Other SEP Measures[a]		Age and Conventional Risk Factors[b]		Age, Other SEP Measures[a], and Conventional Risk Factors[b]	
			OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Women										
Father's occupation[c]										
Laborer	352	38	1.25	0.80, 1.93	1.16	0.72, 1.86	0.94	0.58, 1.52	0.92	0.56, 1.50
Clerical or sales	96	9	1.28	0.59, 2.77	1.51	0.70, 3.24	1.29	0.56, 2.95	1.47	0.63, 3.44
Professional, executive, supervisory, or technical	384	29	1.00		1.00		1.00		1.00	
Father's educational level										
Some high school or less	507	60	1.26	0.72, 2.22	0.94	0.48, 1.85	1.11	0.61, 2.02	0.90	0.44, 1.82
High school graduate	251	17	1.01	0.48, 2.13	0.93	0.43, 1.98	1.02	0.46, 2.23	0.96	0.43, 2.12
Any postsecondary education	233	18	1.00		1.00		1.00		1.00	
Participant's educational level, years										
≤12	438	56	2.84	1.03, 7.85	2.26	0.69, 7.35	2.49	0.84, 7.36	2.13	0.60, 7.52
13–16	441	35	1.95	0.69, 5.52	1.72	0.57, 5.15	1.97	0.66, 5.87	1.79	0.55, 5.84
>16	112	4	1.00		1.00		1.00		1.00	
Participant's occupation										
Laborer	90	13	2.40	1.05, 5.47	1.72	0.67, 4.41	1.81	0.74, 4.45	1.50	0.56, 4.02
Clerical or sales	293	34	2.18	1.10, 4.31	1.71	0.82, 3.54	2.03	1.00, 4.12	1.71	0.80, 3.62
Homemaker	381	37	1.62	0.82, 3.20	1.28	0.63, 2.62	1.53	0.75, 3.11	1.29	0.61, 2.72
Professional, executive, supervisory, or technical	227	11	1.00		1.00		1.00		1.00	
Men										
Father's occupation[c]										
Laborer	316	43	0.96	0.63, 1.46	0.95	0.62, 1.47	0.84	0.55, 1.29	0.83	0.54, 1.29
Clerical or sales	74	8	0.95	0.47, 1.94	0.99	0.49, 1.99	0.78	0.36, 1.68	0.79	0.37, 1.67
Professional, executive, supervisory, or technical	392	48	1.00		1.00		1.00		1.00	
Father's educational level										
Some high school or less	459	70	1.19	0.70, 2.00	1.16	0.65, 2.07	1.07	0.61, 1.80	1.02	0.55, 1.90
High school graduate	211	26	1.42	0.76, 2.65	1.43	0.75, 2.73	1.40	0.74, 2.67	1.36	0.71, 2.60
Any postsecondary education	232	26	1.00		1.00		1.00		1.00	
Participant's educational level, years										
≤12	316	48	1.03	0.64, 1.67	0.99	0.52, 1.87	0.91	0.56, 1.49	1.05	0.55, 2.00
13–16	368	46	0.95	0.58, 1.54	1.00	0.59, 1.69	0.72	0.43, 1.19	0.82	0.48, 1.41
>16	218	28	1.00		1.00		1.00		1.00	
Participant's occupation[d]										
Laborer	325	50	0.98	0.66, 1.45	0.97	0.60, 1.57	0.86	0.57, 1.30	0.85	0.56, 1.28
Clerical or sales	114	10	0.54	0.27, 1.08	0.54	0.27, 1.09	0.47	0.23, 0.98	0.46	0.22, 0.97
Professional, executive, supervisory, or technical	461	62	1.00		1.00		1.00		1.00	

Abbreviations: CI, confidence interval; OR, odds ratio; SEP, socioeconomic position.

[a] "Other SEP measures" refers to adjustment for measures of SEP other than the exposure of interest. For example, analyses on father's educational level are adjusted for participant educational level and occupation.

[b] Conventional risk factors include body mass index, smoking, alcohol consumption, and height.

[c] The study sample was reduced to 1,614 participants because of missing data on father's occupation (women: $n = 832$, 76 cases of type 2 diabetes mellitus; men: $n = 782$, 99 cases of type 2 diabetes mellitus).

[d] Two men were classified as homemakers and were excluded from participant occupation analyses.

Table 4. Odds Ratios for the Association Between Social Mobility of Socioeconomic Position and Incidence of Type 2 Diabetes Mellitus in Pooled Logistic Regression Models, Framingham Offspring Study, 1971–2003

SEP Level in Childhood/Adulthood[a]	No. of Participants	No. of Events	Model Adjustment			
			Age		Age and Conventional Risk Factors[b]	
			OR	95% CI	OR	95% CI
Women						
Father's educational level/ participant's educational level						
Low/low	307	39	1.85	1.02, 3.35	1.54	0.84, 2.83
High/low	131	17	2.99	1.39, 6.44	2.84	1.29, 6.25
Low/high	200	21	1.82	0.93, 3.53	1.79	0.92, 3.51
High/high	353	18	1.00		1.00	
Father's educational level/ participant's occupation						
Low/low	67	9	1.43	0.66, 3.10	1.07	0.47, 2.46
High/low	23	4	3.11	1.07, 9.09	2.35	0.62, 8.88
Low/high	440	51	1.34	0.85, 2.13	1.20	0.75, 1.91
High/high	461	31	1.00		1.00	
Men						
Father's educational level/ participant's educational level						
Low/low	233	39	1.06	0.67, 1.69	1.03	0.63, 1.69
High/low	83	9	1.02	0.50, 2.08	1.17	0.56, 2.45
Low/high	226	31	0.96	0.58, 1.59	0.87	0.51, 1.47
High/high	360	43	1.00		1.00	
Father's educational level/ participant's occupation						
Low/low	227	41	1.09	0.68, 1.75	0.93	0.57, 1.52
High/low	98	9	0.77	0.36, 1.65	0.59	0.27, 1.31
Low/high	232	29	0.84	0.50, 1.40	0.71	0.42, 1.22
High/high	345	43	1.00		1.00	

Abbreviation: CI, confidence interval; OR, odds ratio; SEP, socioeconomic position.

[a] Measures of SEP were as follows: father's education (low = some high school or less; high = high school graduate or above), participant educational level (low = ≤12 years; high = >12 years), and participant occupation (low = laborer; high = housewife or clerical/sales/professional/executive/supervisory/technical occupations).

[b] Conventional risk factors include body mass index, smoking, alcohol consumption, and height.

showed inverse associations (14, 20), and others showed weak or no associations (10, 13, 16–19).

Results from the Nurses' Health Study (in women, n = 100,330; relative risk = 1.50, 95% CI: 1.32, 1.69 (7)) and the Alameda County Study (n = 5,913; in women, hazard ratio = 1.8, 95% CI: 1.3, 2.6 and in men, hazard ratio = 1.4, 95% CI: 1.0, 2.0 (8)) reported increased T2D risk associated with low versus high childhood SEP in age- and race-adjusted models. The effect sizes in our study showed a similar direction but a nonsignificant association for women (e.g., for fathers' occupation, laborer vs. professional/executive/supervisory/technical, OR = 1.25, 95% CI: 0.80, 1.93).

Potential mechanisms

Childhood SEP is inversely associated with birth weight (35) and smoking (36–38) and (in women) obesity (39) in adulthood. Adult SEP has been shown to be inversely associated with obesity (in women (37, 38, 40)), smoking (41), leisure-time physical activity (42–44), and unhealthy diet (45, 46). Chains of risk are also likely at play, resulting from transgenerational effects, because childhood SEP is predictive of adult SEP (47) and risky health behaviors can be modeled as normative to offspring (48). In our study, adjusting for obesity resulted in the greatest reduction in the association between cumulative SEP and T2D in women. Obesity could be an important mechanism that mediates the sex-specific association between life-course SEP and T2D. Obesity, a significant T2D risk factor (49–51) that is thought to raise risk through increasing insulin resistance (52), is a condition that is also socially patterned (53). Childhood obesity has been shown to predict lower adult SEP in women (54). An important mechanism could be obesity-related discrimination, which limits upward social

mobility, particularly in white women (55). This mechanism might explain some of the sex-specific association between SEP and T2D that was observed in women but not in men. It should be noted that adjusting for mediators on the causal pathway is known to induce bias toward the null (56, 57). Thus, to the extent to which obesity is considered a potential mediator of the impact of low SEP, our results that adjusted for BMI may be overly conservative.

Strengths and limitations

There were several limitations to this study. The study population largely included individuals of European descent (representative of the general population of Framingham, Massachusetts, at the study onset). The generalizability of findings to other races and ethnicities and the populations of other countries, some of which have a high prevalence of T2D, is limited (22). Additionally, the study population represented a highly selected sample of Framingham Offspring Study participants ($n = 1{,}893$ of 5,124). However, the largest exclusion criterion was not having a father in the original cohort of the Framingham Heart Study ($n = 2{,}136$, 66% of excluded participants). This exclusion criterion allowed for a direct and more robust measure of childhood SEP. A limitation of the accumulation-of-risk model, as described in this study, is that it assumes that SEP exposure during each period of the life course has an equal effect on T2D risk. This approach simplifies a complex pathway that links cumulative SEP and T2D, and it alone cannot provide information on the association between SEP and T2D risk during specific periods in the life course. Therefore, to complement this model, we investigated sensitive-periods and social-mobility frameworks to help triangulate the effect of SEP at different stages of the life course and its corresponding risk for development of T2D. Finally, data on family history of diabetes and childhood obesity were not available in the limited access data set for the Framingham Offspring Study.

Strengths of the study include the direct assessment of childhood SEP from participants' fathers. Furthermore, we investigated the association between life-course SEP and T2D in a sample with clinically determined T2D, limiting misclassification from the undiagnosed and self-reported T2D that is commonly used in other studies.

CONCLUSION

In summary, the present study found that cumulative SEP was inversely associated with T2D risk in female participants of the Framingham Offspring Study. The cumulative association between SEP and T2D risk appeared to be driven particularly by the participants' educational levels and occupations. There was little evidence of an association in men.

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