Sustained Low Income, Income Changes, and Risk of All-Cause Mortality in Individuals With Type 2 Diabetes: A Nationwide Population-Based Cohort Study

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OBJECTIVE

There is limited evidence on the association of sustained low-income status, income changes, and all-cause mortality risk in individuals with type 2 diabetes (T2D).

RESEARCH DESIGN AND METHODS

Using the Korean Health Insurance Service database, we studied 1,923,854 adults with T2D (aged ≥30 years) without cardiovascular disease and cancer, who were enrolled from 2009 through 2012 and followed to the end of 2020 (median 10.8 years of follow-up). We defined income levels based on the amount of health insurance premiums and categorized them into quartiles, the first being the low-income group, and assessed the income status annually in the preceding 5 years. Cox proportional hazards models were used to quantify the association of low-income status and income changes with mortality, with adjustment for sociodemographic factors, comorbidities, and diabetes duration and treatment.

RESULTS

Participants who consecutively had low income showed a higher risk of mortality (hazard ratio [HR] 1.19; 95% CI 1.16–1.22), compared with those who had never been in the low-income group. This association was much stronger for consecutive recipients of Medical Aid, reflecting very-low-income status (HR 2.26; 95% CI 2.16–2.36), compared with those who had never been Medical Aid beneficiaries. Sustained low- and very-low-income status was associated with increased risk of mortality, specifically for younger adults (aged <40 years) and males. Those who experienced declines in income between the first (preceding 5 years) and the last (baseline) time points had an increased risk of mortality, regardless of baseline income status.

CONCLUSIONS

Among Korean adults with T2D, sustained low-income status and declines in income were associated with increased risk of mortality.

Type 2 diabetes (T2D) has been on the rise over the past decades, and the total number of people with diabetes is predicted to rise to 700 million by 2045 globally (1).

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One of the many recognized factors to significantly affect risk of T2D is socioeconomic status (SES), particularly income (2,3). Moreover, results of previous studies have suggested that low SES may contribute to a poor prognosis of T2D, which in turn could lead to an increased risk of mortality (4,5). Low-income status may be related to high levels of psychological stress, harmful behavioral effects, and poor access to healthy diets and medical care (6–8). Those with T2D may have poor compliance with medical treatment due to income insecurity, which heightens risk of diabetes complications, leading to increased risk of mortality (9).

In prior studies investigators have observed the positive association between low-income status and mortality among people with T2D. However, in all previous studies one measure of income was used, at baseline (10–16). Such a single measure may be inaccurate and would not reflect fluctuation of income over time (10). Serial measures over years can be used to overcome this limitation. Observing changes in income allows us to look at individuals' income dynamics throughout their lifetime. Specifically, we may explain how income dynamics affect risk of mortality by focusing on declines and rises in income. Thus, the information on the pattern and change of income over time is expected to provide better insight into the relationship between income and health outcomes (17).

To address these gaps in knowledge, we used serial measures of income over years to investigate the association of sustained low-income and income change with risk of mortality. In South Korea, there are two systems for universal health insurance coverage, the National Health Insurance System (NHIS) and the Medical Aid system. The NHIS provides insurance for medical payment to the majority of the Korean population. In this program, income is a key factor in determining health insurance premiums (18). With use of the information on health insurance premiums, income status over time can be identified. The Medical Aid system provides medical services such as examinations and treatment mainly for those with very-low-income status, accounting for 3% of Korea's total population (19). This means that individuals who have consistently received the Medical Aid benefits may have also been in continuous poverty, which ultimately may affect health. We aimed to investigate the association of multiple low-income exposures and change of income status with risk of mortality among adults with T2D, using the data from the Korean NHIS database.

RESEARCH DESIGN AND METHODS

Source of Data

The data examined in this study were from the NHIS claims database. The NHIS, a single insurer managed by the government, is a required policy that secures a health insurance program for ~97% of the Korean population. The system provided an eligible database including information on health examinations (questionnaires on lifestyle and general health examinations), medical treatment (identified according to the medical expense covered by the health care providers), medical care institution (no. of physicians, equipment, location, and type of institution), and registration of death. This study was approved by the institutional review board of Soongsil University (IRB no. SSU-202003-HR-201-01) and complies with the ethics guidelines of the World Medical Association Declaration of Helsinki.

Study Population

Initially, we included adults with T2D aged ≥30 years who had undergone health screening examinations between 2009 and 2012 (index years) (*n* = 2,699,316). Presence of T2D was defined according to ICD-10 codes E11–E14 (20,21), claims for at least one prescription history of oral antidiabetes medication or insulin, or fasting glucose level ≥126 mg/dL. We did not include individuals with type 1 diabetes codes (E10). Then, those who had missing information for income (*n* = 138,601) were excluded along with those who had previous history of cancer (*n* = 304,504) or myocardial infarction or stroke (*n* = 279,326), as having those conditions may be a confounder that would affect both declines in income and early death. We further excluded those who have at least one missing covariates (*n* = 52,640). Finally, we had a total of 1,923,854 subjects in the analysis (Supplementary Fig. 1).

Definitions and Measurements

In South Korea, monthly household income determines health insurance premiums. According to the amount of monthly health insurance premiums paid by individuals, we divided the income status into 4 levels ranging from quarter 1 (lowest) to quarter 4 (highest) in each year. Low-income status was defined as being categorized into the first quartile. "Medical Aid beneficiaries" was interpreted to mean participants who received medical benefits according to the Medical Care Assistance Act. Approximately 3% of the total population with the lowest income level were classified as Medical Aid beneficiaries. Very-low-income status was defined according to participants receiving Medical Aid in each year. If people experience declines in income to the point where they meet the criteria of Medicaid in the previous year, they can receive Medicaid during the following year, whereas Medical Aid beneficiaries experiencing income rise may switch to NHIS if they meet the criteria.

The number of times an individual was categorized for low- or very-low-income status was counted every year for the preceding 5 years until each index year (2009–2012). Then, we used cumulative numbers of having low- or very-low-income status to investigate the association with risk of all-cause mortality. For example, when participants enrolled in 2009 fell into the low-income category once between 2005 and 2009, the score was marked 1. In addition, we evaluated the change of income status using the longest interval of the available income data. For instance, the change of income status was compared between income in 2005 and income in 2009 when study participants were enrolled in 2009.

The primary outcome was all-cause mortality until 31 December 2020. Information on deaths was based on data of the nationwide death certificate from the Korean National Statistical Office.

Information on lifestyle-related factors was obtained with use of questionnaires. Smoking status was classified into three categories: never, former, and current. Alcohol consumption was also categorized into three levels: nondrinking, mild to moderate drinking (<30 g/day), and heavy drinking (≥30 g/day). For physical activity, regular exercise was defined as at least 30 min of moderate physical activity per day for at least 5 days a week or at least 20 min of strenuous physical activity per day at least 3 days a week (22). BMI was calculated as weight in kilograms divided by the square of height in meters. Presence of hypercholesterolemia was defined as having at least one claim per year for prescription of antihyperlipidemic agents under ICD-10 codes E78 or total cholesterol ≥240 mg/dL. Presence of hypertension was defined as having at least one prescription of antihypertensive medications under ICD-10 codes I10–I15 per year or systolic/diastolic blood pressure ≥140/90 mmHg. Chronic kidney disease was defined according to estimated glomerular filtration rate <60 mL/min. Other clinical comorbidities were defined using the ICD-10 codes and the prescription lists in the NHIS database. Newly diagnosed diabetes was defined as no history of claims for ICD-10 code of diabetes (E11–E14) or antidiabetes medication before the index date and fasting plasma glucose (FPG) ≥126 mg/dL at the index date.

Statistical Analysis

Baseline characteristics are presented as means with SDs or numbers and percentages. Characteristics of the participants by cumulative numbers of having low- or very-low-income status were compared with one-way ANOVA for continuous variables and χ^2 test for categorical variables. We calculated mortality rate by dividing the number of deaths by the total number of person-years of follow-up, and mortality rate is presented per 1,000 person-years. Hazard ratios (HRs) and 95% CIs for all-cause mortality were estimated with Cox proportional hazards models. The proportional hazards assumption was evaluated with use of the Schoenfeld residuals test with the logarithm of the cumulative hazards function based on Kaplan-Meier estimates for cumulative numbers of low- or very-low-income status. There was no significant departure from proportionality in hazards over time. To assess the cumulative numbers of having low- and very-low-income status associated with risk of mortality for adults with T2D, *P* for linear trend was applied with linear regression, using the ordinal number assigned to each category of cumulative numbers of having low- and very-low-income status. We adjusted for confounders at baseline using four different models. Model 1 was adjusted for age and sex. Model 2 was adjusted further for smoking status (never, former, or current), alcohol consumption (never, mild to moderate, or heavy), physical activity (regular exercise or not), BMI (continuous), baseline income status, and health insurance type (employee insured, self-employed insured, or Medical Aid). We also adjusted for presence or absence of hypertension, hypercholesterolemia, and chronic kidney disease in model 3, and blood glucose concentrations, duration of diabetes (<5 years, ≥5 years), no. of prescriptions for oral antidiabetes medications per year (<3, ≥3), and history of insulin prescription, to account for comorbidities and diabetes duration and treatment, respectively. The potential effect modification by age, sex, BMI (<25, ≥25 kg/m^2), smoking (current, other), alcohol consumption (heavy drinking, other), hypertension, and hypercholesterolemia was evaluated with stratified analyses and interaction testing with a likelihood ratio test. We conducted a sensitivity analysis where categorized BMI (<18.5 kg/m^2, 18.5 to < 23 kg/m^2, 23 to <25 kg/m^2, 25 to < 30 kg/m^2, and ≥30 kg/m$^{2)}$ was included as a covariate in the statistical models (23).

Statistical analyses were performed with SAS, version 9.4 (SAS Institute, Cary, NC). *P* values provided are two sided, with the level of significance at 0.05.

RESULTS

Baseline characteristics are presented in Table 1, with stratification by cumulative numbers of having low-income status for individuals with T2D. Those who were had low-income status at least once were more likely to be female, nonsmokers, nondrinkers, and either obese (BMI ≥30 kg/m^2) or underweight (BMI <18.5 kg/m^2). They were less likely to be self-employed insured and physically active, and they used more antidiabetes medication (n > 3) and insulin treatment. Among participants who had low-income status at least once, those who had low-income more were more likely to be older, female, Medical Aid beneficiaries, never smokers, and nondrinkers. In addition, those who had low-income status more were more likely to be either obese (BMI ≥30 kg/m^2) or underweight (BMI <18.5 kg/m^2). They were more likely to have hypertension, hypercholesterolemia, chronic kidney disease, antidiabetes medications (n > 3), insulin treatment, and longer diabetes durations (≥5 years). Overall, similar trends were seen in the cumulative numbers of those receiving Medical Aid, reflecting very-low-income status of individuals with T2D (Supplementary Table 1).

Table 2 displays the association of low- and very-low-income status with risk of mortality in adults with T2D. A total of 204,177 deaths occurred during a median of 10.8 years (interquartile range 9.7–11.3) of follow-up. The cumulative numbers of low- and very-low-income status were associated with increased risk of mortality (both *P* for trend <0.0001) after adjustment for age, sex, smoking, drinking, physical activity, baseline income, health insurance type, BMI, hypertension, hypercholesterolemia, chronic kidney disease, plasma glucose concentrations, diabetes durations, use of antidiabetes medications, and insulin treatment. In model 2, the baseline income attenuated the most on the effect estimates. Those who consecutively had low-income status had the highest increased risk of mortality (HR 1.19; 95% CI 1.16–1.22), while this association was stronger for consecutive recipients of Medical Aid for 5 years (HR 2.26; 95% CI 2.16–2.36). In addition, strength of associations was similar across the categories of 1–4 cumulative very-low-income years but increased steeply for 5 cumulative very-low-income years.

Table 3 shows the analyses stratified by potential effect modifiers of the association between cumulative numbers of low-income status and mortality risk. The association between cumulative numbers of having low-income status and mortality substantially differed by age-group and sex. Specifically, there was a higher risk of mortality associated with low-income status for adults aged <40 years (HR 2.13; 95% CI 1.96–2.31) ($P_{\text{interaction}}$ < 0.0001) and males (HR 1.25; 95% CI 1.22–1.28) ($P_{\text{interaction}}$ < 0.0001). Furthermore, the association was stronger for those who smoked, drank heavily, and did not have hypertension (all $P_{\text{interaction}}$ < 0.0001). In Supplementary Table 2, stratified analyses showed similar patterns in the association between cumulative numbers of very-low-income status and risk of mortality. Interestingly, there was much higher risk of mortality associated with very-low-income status for adults aged <40 years (HR 5.30; 95% CI 4.55–6.17) and males (HR 2.49; 95% CI 2.35–2.63) (both $P_{\text{interaction}}$ < 0.0001).

The change of income status between the first time point (preceding 5 years, 2004–2007) and the last time point

Table 1—Characteristics at baseline by cumulative numbers of years of having low-income status among individuals with T2D

Baseline characteristics	Total (1,923,854)	0 (1,201,607)	1 (221,701)	2 (147,386)	3 (110,905)	4 (90,624)	5 (151,631)
	Cumulative numbers of years of having low-income status						
Categorical variables							
Age group, years							
<40	8.1	8.0	10.6	9.9	8.4	7.0	4.1
40–64	67.4	66.4	69.5	69.1	69.4	69.5	67.4
≥65	24.5	25.6	19.9	21.1	22.2	23.5	28.6
Sex							
Male	61.0	64.0	58.6	56.3	55.2	55.2	53.4
Female	39.0	36.0	41.4	43.7	44.8	44.8	46.6
Health insurance type							
Self-employed insured	31.9	34.9	27.4	26.8	25.9	25.1	28.3
Employee insured	67.1	65.1	72.4	72.8	73.1	73.4	61.3
Medical Aid	1.0	0.0	0.2	0.4	0.9	1.5	10.4
Smoking status							
Never	54.0	52.6	54.5	56.0	57.1	56.9	57.8
Former	17.6	19.3	15.8	15.1	14.7	14.6	14.1
Current	28.4	28.1	29.7	28.9	28.3	28.5	28.1
Alcohol consumption, g/day							
None	54.0	52.5	54.3	55.6	56.6	57.4	60.4
Mild to moderate (<30)	34.9	36.0	34.5	33.7	33.1	32.9	30.4
Heavy (≥30)	11.1	11.5	11.1	10.7	10.3	9.8	9.3
Regular exercise, yes*	20.5	21.4	19.0	18.9	18.8	19.3	18.9
BMI, kg/m^2							
<18.5	1.4	1.3	1.5	1.6	1.6	1.7	1.9
18.5 to <23	24.5	23.9	25.1	25.4	26.0	26.0	26.4
23 to <25	24.9	25.3	24.5	24.4	24.2	24.5	24.3
25 to <30	41.5	42.2	40.6	40.5	40.2	39.9	39.5
≥30	7.7	7.4	8.3	8.2	8.0	7.9	7.9
Hypertension, yes	52.5	52.3	51.0	51.4	52.4	53.6	56.8
Hypercholesterolemia, yes	38.2	38.4	37.2	37.5	37.4	37.6	39.5
Chronic kidney disease, yes	9.9	10.1	8.7	8.9	9.1	9.5	11.0
Use of antidiabetes medication (≥3)	13.0	12.9	12.9	12.9	13.3	13.2	14.3
Insulin treatment, yes	6.5	6.4	6.4	6.4	6.5	6.7	7.4
Diabetes durations (≥5 years)	27.0	27.4	25.9	25.9	26.2	26.5	27.6
Newly diagnosed T2D**	49.3	49.0	50.7	50.7	50.0	49.2	46.8
Continuous variables							
Age	55.8 (11.7)	55.9 (11.9)	54.7 (11.7)	55.0 (11.6)	55.5 (11.4)	56.1 (11.1)	57.8 (10.9)
BMI, kg/m^2	25.1 (4.0)	25.1 (3.3)	25.1 (3.5)	25.1 (3.5)	25.0 (3.5)	25.0 (3.5)	25.0 (8.3)
Waist circumference, cm	85.3 (8.9)	85.5 (8.7)	85.0 (8.8)	84.9 (9.2)	84.8 (9.4)	84.9 (9.5)	85.1 (9.1)
Systolic blood pressure, mmHg	129.0 (15.9)	128.9 (15.7)	128.9 (16.0)	129.0 (16.1)	129.1 (16.2)	129.4 (16.4)	129.5 (16.4)
Diastolic blood pressure, mmHg	79.4 (10.3)	79.4 (10.3)	79.4 (10.4)	79.4 (10.4)	79.4 (10.4)	79.5 (10.5)	79.4 (10.5)
Fasting glucose levels, mg/dL	139.3 (48.5)	138.5 (47.0)	141.0 (50.3)	140.5 (50.3)	140.8 (51.3)	140.3 (51.0)	139.6 (51.6)
Fasting cholesterol levels, mg/dL	199.7 (46.3)	199.4 (45.5)	200.5 (47.0)	200.5 (51.8)	200.2 (46.3)	200.3 (45.9)	199.6 (46.2)

Data are presented as percentages for categorical variables and means (SD) for continuous variables. We divided the income status into four levels ranging from quarter 1 (lowest) to quarter 4 (highest) in each year. Low income status was defined as being categorized into the first quartile. *Regular exercise was defined to be at least 30 min of moderate physical activity per day at least 5 days a week or at least 20 min of strenuous physical activity per day at least 3 days a week. **Newly diagnosed T2D was defined as no history of claims for ICD-10 code of diabetes (E11–E14) or antidiabetes medication before index date and FPG ≥126 mg/dL at index date.

(baseline, 2009–2012), and the corresponding risk of all-cause mortality are shown in Table 4. In each income quartile group, participants with a decline in income had a higher risk of mortality, while participants with an income rise had a lower risk of mortality, compared with those who had a persistent income status between 5 years ago and baseline. For example, among those who were initially in the third quartile of income, those who experienced a decline in income to the lowest quartile had increased risk of mortality (HR 1.06; 95% CI 1.03–1.09), while those who experienced an income rise had decreased risk of mortality (HR 0.93; 95% CI 0.91–0.95). These associations were consistent in the other income quartiles. Additionally, a growth in income was associated with decreased risk of mortality, even if there was no substantial increase of income up to the top quartile. For example, those who were initially in the second quartile of income and moved up to the third quartile of income had decreased risk of mortality (HR 0.93; 95% CI 0.91, 0.96). When we included BMI as a categorical variable (<18.5 kg/m^2, 18.5 to <23 kg/m^2, 23 to <25 kg/m^2, 25 to <30 kg/m^2, and ≥30 kg/m^2) in the statistical models, the results did not change materially (Supplementary Table 3).

Table 2—Association of low- and very-low-income status with risk of mortality in adults with T2D

	No. of participants	No. of deaths	Total no. of person-years of follow-up	Mortality rate* (per 1,000 person-years)	Model 1	Model 2	Model 3	Model 4
Cumulative no. of years of having low-income status**								
0	1,201,607	122,224	12,237,681	10.0	1 (Ref.)	1 (Ref.)	1 (Ref.)	1 (Ref.)
1	221,701	21,950	2,241,297	9.8	1.15 (1.14, 1.17)	1.07 (1.06, 1.09)	1.08 (1.06, 1.09)	1.07 (1.05, 1.09)
2	147,386	15,550	1,491,549	10.4	1.20 (1.18, 1.22)	1.11 (1.09, 1.13)	1.11 (1.09, 1.13)	1.11 (1.09, 1.13)
3	110,905	12,329	1,119,158	11.0	1.23 (1.21, 1.25)	1.14 (1.11, 1.16)	1.14 (1.11, 1.16)	1.14 (1.11, 1.16)
4	90,624	10,617	913,301	11.6	1.24 (1.22, 1.27)	1.14 (1.12, 1.17)	1.14 (1.12, 1.17)	1.15 (1.12, 1.17)
5	151,631	21,507	1,496,997	14.4	1.36 (1.34, 1.38)	1.18 (1.16, 1.21)	1.18 (1.15, 1.21)	1.19 (1.16, 1.22)
P for trend					<0.0001	<0.0001	<0.0001	<0.0001
Cumulative no. of years of having very-low-income status (receiving Medical Aid)**								
0	1,880,260	196,406	19,111,259	10.3	1 (Ref.)	1 (Ref.)	1 (Ref.)	1 (Ref.)
1	7,445	1,426	69,969	20.4	1.83 (1.74, 1.93)	1.73 (1.64, 1.82)	1.70 (1.61, 1.79)	1.64 (1.56, 1.73)
2	7,303	1,440	67,359	21.1	1.77 (1.68, 1.86)	1.68 (1.60, 1.77)	1.65 (1.57, 1.74)	1.58 (1.50, 1.66)
3	8,319	1,596	75,681	21.1	1.70 (1.62, 1.78)	1.62 (1.54, 1.70)	1.60 (1.52, 1.68)	1.53 (1.46, 1.61)
4	7,089	1,339	64,210	20.9	1.77 (1.68, 1.87)	1.68 (1.59, 1.77)	1.66 (1.57, 1.75)	1.62 (1.54, 1.71)
5	13,438	1,970	111,504	17.7	2.64 (2.53, 2.76)	2.47 (2.37, 2.59)	2.44 (2.33, 2.55)	2.26 (2.16, 2.36)
P for trend					<0.0001	<0.0001	<0.0001	<0.0001

Data are HR (95% CI) unless otherwise indicated. Model 1: adjustment for age and sex. Model 2: additional adjustment for smoking status (never, former, or current), alcohol consumption (never, mild to moderate, or heavy), physical activity (regular exercise or not), BMI (continuous), and baseline income status and adjustment for health insurance type (employee insured, self-employed insured, or Medical Aid) in relation to cumulative number having low-income status. Model 3: additional adjustment for presence or absence of hypertension, hypercholesterolemia, and chronic kidney disease. Model 4: additional adjustment for plasma glucose concentrations, duration of diabetes (<5 years, ≥5 years), no. of prescriptions for oral antidiabetes medications (<3, ≥3), and insulin prescription history. Ref., reference. *We calculated mortality rate by dividing no. of deaths by total no. of person-years of follow-up. Mortality rate is presented per 1,000 person-years. **No. of times an individual was categorized as having low- or very-low-income status was counted every year for preceding 5 years until each index year (2009–2012).

CONCLUSIONS

This is the first study with investigation of the relationship of sustained low income and income change with risk of all-cause mortality among individuals with T2D. In this nationwide population-based cohort study of >1.9 million participants, sustained low-income status and dropped income were significantly associated with increased risk of all-cause mortality. Specifically, those who consecutively had low income for the past 5 years showed a 19% increase in mortality compared with those who had never been in the low-income group. In addition, compared with those who had never been Medical Aid beneficiaries, those who consecutively received Medical Aid had >2.3-fold risk of mortality. This association was particularly stronger for younger adults (aged <40 years) and males. Moreover, for those who experienced declines in income there was an association with increased risk of mortality, regardless of initial income status.

Multiple studies have included investigated of the association between income and mortality among those with T2D. In a Swedish study of 217,364 people with T2D (aged <70 years), investigators found that the HR in the lowest individual income quintile for all-cause mortality was 1.71 (95% CI 1.60–1.83) compared with the highest quintile (14). Even in Canada, where much of health care is universally funded, income-based inequities in health and access to care still exist (24). It has been reported that compared with older people, generally >65 years of age, who receive pension for assisted financial help for health care, those who are in the younger age-group (aged 30–64 years) in poverty without any pension had a higher risk of mortality (25). In another study of 505,677 Korean people (aged 40–79 years), individuals with both lower household income and diabetes had the highest risk of all-cause mortality (11). Though income was defined differently, the associations between low-income status and increased mortality were consistent. In contrast, in a study of 6,177 U.S. adults with self-reported diagnosed diabetes (aged ≥25 years), investigators used family income-to-poverty ratio (IPR) as a proxy variable of income status (10). In comparisons with the highest level of IPR, there was no significant association with mortality risk in any other levels of IPR. In all of

Table 3—Association between cumulative numbers of years of having low-income status and mortality risk stratified by selected factors

	Cumulative numbers of years of having low-income status						
	0	1	2	3	4	5	*P* for interaction
Age-group, years							
<40	1 (Ref.)	1.35 (1.26, 1.45)	1.51 (1.39, 1.63)	1.56 (1.42, 1.71)	1.64 (1.48, 1.82)	2.13 (1.96, 2.31)	<0.0001
40–64	1 (Ref.)	1.15 (1.12, 1.19)	1.22 (1.18, 1.27)	1.31 (1.26, 1.36)	1.37 (1.31, 1.43)	1.52 (1.47, 1.58)	
≥65	1 (Ref.)	1.04 (1.02, 1.06)	1.07 (1.04, 1.09)	1.09 (1.06, 1.12)	1.09 (1.06, 1.11)	1.10 (1.07, 1.13)	
Sex							
Male	1 (Ref.)	1.11 (1.09, 1.13)	1.16 (1.13, 1.18)	1.19 (1.16, 1.22)	1.19 (1.16, 1.23)	1.25 (1.22, 1.28)	<0.0001
Female	1 (Ref.)	1.00 (0.98, 1.03)	1.02 (0.99, 1.05)	1.04 (1.01, 1.08)	1.06 (1.03, 1.10)	1.10 (1.07, 1.14)	
BMI, kg/m^2							
<25	1 (Ref.)	1.07 (1.05, 1.10)	1.12 (1.09, 1.14)	1.14 (1.12, 1.17)	1.15 (1.11, 1.18)	1.19 (1.16, 1.22)	0.33
≥25	1 (Ref.)	1.06 (1.04, 1.09)	1.08 (1.05, 1.12)	1.13 (1.09, 1.16)	1.15 (1.11, 1.19)	1.20 (1.17, 1.24)	
Current smoking							
No	1 (Ref.)	1.05 (1.03, 1.07)	1.08 (1.05, 1.10)	1.11 (1.08, 1.13)	1.11 (1.08, 1.14)	1.16 (1.13, 1.19)	<0.0001
Yes	1 (Ref.)	1.13 (1.10, 1.16)	1.18 (1.15, 1.22)	1.21 (1.17, 1.25)	1.23 (1.19, 1.28)	1.28 (1.24, 1.32)	
Heavy drinking							
No	1 (Ref.)	1.06 (1.04, 1.08)	1.10 (1.08, 1.12)	1.13 (1.11, 1.16)	1.14 (1.11, 1.17)	1.18 (1.15, 1.21)	<0.0001
Yes	1 (Ref.)	1.15 (1.11, 1.20)	1.17 (1.12, 1.23)	1.16 (1.09, 1.22)	1.21 (1.14, 1.28)	1.29 (1.23, 1.35)	
Hypertension							
No	1 (Ref.)	1.07 (1.05, 1.10)	1.15 (1.11, 1.18)	1.15 (1.11, 1.19)	1.18 (1.13, 1.22)	1.25 (1.21, 1.29)	<0.0001
Yes	1 (Ref.)	1.07 (1.05, 1.09)	1.09 (1.06, 1.11)	1.13 (1.10, 1.16)	1.13 (1.10, 1.16)	1.17 (1.14, 1.20)	
Hypercholesterolemia							
No	1 (Ref.)	1.08 (1.06, 1.10)	1.11 (1.09, 1.14)	1.14 (1.11, 1.17)	1.15 (1.12, 1.19)	1.20 (1.17, 1.23)	0.44
Yes	1 (Ref.)	1.06 (1.03, 1.09)	1.09 (1.06, 1.13)	1.13 (1.09, 1.17)	1.13 (1.09, 1.17)	1.17 (1.14, 1.21)	
Newly diagnosed T2D*							
No	1 (Ref.)	1.07 (1.05, 1.09)	1.11 (1.09, 1.14)	1.14 (1.12, 1.17)	1.16 (1.13, 1.19)	1.18 (1.15, 1.21)	0.32
Yes	1 (Ref.)	1.07 (1.04, 1.09)	1.10 (1.07, 1.13)	1.12 (1.09, 1.16)	1.12 (1.08, 1.16)	1.21 (1.17, 1.24)	

Adjustment for age, sex, smoking status (never, former, or current), alcohol consumption (never, mild to moderate, or heavy), physical activity (regular exercise or not), BMI (continuous), baseline income status, health insurance type (employee insured, self-employed insured, or Medical Aid), presence or absence of hypertension, hypercholesterolemia, chronic kidney disease, plasma glucose concentrations, duration of diabetes (<5 years, ≥5 years), no. of prescriptions for oral antidiabetes medications (<3, ≥3), and insulin prescription history. *Newly diagnosed T2D was defined as no history of claims for ICD-10 code of diabetes (E11–E14) or antidiabetes medication before index date and FPG ≥126 mg/dL at index date.

these studies, income was measured at a single point in time, which is subject to fluctuate over time. To reduce this possibility, in our study we assessed change of income over time.

Interestingly, the association of low- and very-low-income status with increased risk of mortality differed by age-group shown. Our findings showed that younger adults (aged <40 years) had a higher relative risk of mortality associated with low- and very-low-income status than older age-groups. In Korea, the elderly can receive old-age pensions even if there are some disparities in their coverage (26), leading to a higher chance of receiving treatment and high-quality care. Our findings also suggest that low-SES status might have caused participants to be sicker and to have more premature mortality (27), since low SES is more related to illicit drug use as well as an unusual infection such as tuberculosis, HIV, and viral hepatitis, particularly in younger age-groups (28). In addition, it appears probable that education inequality related to low-SES status and unhealthy lifestyle, i.e., fast food intake, may be associated with cardiometabolic dysfunction such as hypertension, T2D, hyperlipidemia, and obesity in younger populations (29,30). Our findings also showed that the association of low- and very-low-income status with risk of mortality was stronger for men than for women. Differential diabetes management by sex might explain this association. It was suggested that women had better management of diabetes than men at any income group (31). Moreover, women had higher medication adherence compared with men at the same income level (11). Men may be more vulnerable to the harmful effects of low income because of relatively poor disease management and unhealthy lifestyle.

In our study we also investigated the association between changes of income and risk of mortality and found that decline in income was significantly associated with increased risk of mortality. There have been previous studies where an association was observed between declines in income and mortality in the general population. In a U.S. study of 3,937 individuals (aged 23–35 years) greater declines in income and higher income volatility were associated with higher risk of all-cause mortality (HR 1.78; 95% CI 1.03–3.09) (32). In this study, declines in income were defined as income dropping by ≥25% compared with an individual's income from past study visits and lower than the participant's average income from the whole study period. In another U.S. study of 8,714 individuals (aged 51–61 years), negative wealth shocks were associated with increased risk of all-cause mortality (HR 1.50; 95% CI 1.36–1.67) (33). Interestingly,

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Table 4—Change of income status between the two time points (5 years ago vs. baseline) and the corresponding risk of all-cause mortality

Initial income status preceding 5 years (2004–2007)*	Subsequent income status at baseline (2009–2012)*	No. of participants	No. of deaths	Total no. of person-years of follow-up	Mortality rate (per 1,000 person-years)**	Model 1, HR (95% CI)	Model 2, HR (95% CI)	Model 3, HR (95% CI)	Model 4, HR (95% CI)
Quartile 1	Quartile 1	207,368	27,700	20,593,483	13.5	1 (Ref.)	1 (Ref.)	1 (Ref.)	1 (Ref.)
	Quartile 2	101,762	10,792	1,034,868	10.4	0.98 (0.96, 1.01)	1.03 (1.00, 1.05)	1.03 (1.00, 1.05)	1.02 (1.00, 1.04)
	Quartile 3	60,651	6,647	614,510	10.8	0.91 (0.89, 0.94)	0.97 (0.94, 0.99)	0.97 (0.94, 1.00)	0.96 (0.93, 0.99)
	Quartile 4	31,280	4,371	311,424	14.0	0.81 (0.78, 0.83)	0.88 (0.85, 0.91)	0.88 (0.85, 0.91)	0.87 (0.84, 0.90)
Quartile 2	Quartile 1	77,126	8,590	771,454	11.1	1.04 (1.02, 1.07)	1.04 (1.01, 1.07)	1.04 (1.01, 1.07)	1.04 (1.01, 1.07)
	Quartile 2	150,700	15,871	1,522,298	10.4	1 (Ref.)	1 (Ref.)	1 (Ref.)	1 (Ref.)
	Quartile 3	131,018	12,686	1,342,499	9.4	0.92 (0.90, 0.94)	0.93 (0.91, 0.95)	0.94 (0.91, 0.96)	0.93 (0.91, 0.96)
	Quartile 4	34,625	3,825	348,519	11.0	0.79 (0.77, 0.82)	0.83 (0.80, 0.86)	0.83 (0.80, 0.86)	0.83 (0.80, 0.86)
Quartile 3	Quartile 1	67,891	6,717	687,423	9.8	1.07 (1.04, 1.10)	1.07 (1.04, 1.10)	1.06 (1.04, 1.09)	1.06 (1.03, 1.09)
	Quartile 2	78,980	7,489	800,542	9.4	1.08 (1.05, 1.11)	1.07 (1.04, 1.10)	1.07 (1.04, 1.09)	1.06 (1.03, 1.09)
	Quartile 3	240,827	23,129	2,467,982	9.4	1 (Ref.)	1 (Ref.)	1 (Ref.)	1 (Ref.)
	Quartile 4	147,033	14,594	1,507,899	9.7	0.91 (0.89, 0.93)	0.93 (0.91, 0.95)	0.93 (0.91, 0.95)	0.93 (0.91, 0.95)
Quartile 4	Quartile 1	49,620	4,740	502,988	9.4	1.07 (1.04, 1.11)	1.07 (1.04, 1.10)	1.07 (1.04, 1.10)	1.07 (1.04, 1.10)
	Quartile 2	43,904	4,156	444,790	9.3	1.14 (1.11, 1.18)	1.13 (1.10, 1.17)	1.13 (1.09, 1.17)	1.12 (1.08, 1.15)
	Quartile 3	73,853	7,240	747,661	9.7	1.06 (1.03, 1.09)	1.04 (1.02, 1.07)	1.04 (1.02, 1.07)	1.04 (1.02, 1.07)
	Quartile 4	427,216	45,630	4,335,782	10.5	1 (Ref.)	1 (Ref.)	1 (Ref.)	1 (Ref.)

Model 1: adjustment for age and sex. Model 2: additional adjustment for smoking status (never, former, or current), alcohol consumption (never, mild to moderate, or heavy), physical activity (regular exercise or not), BMI (continuous), baseline income status, and health insurance type (employee insured, self-employed insured, or Medical Aid). Model 3: additional adjustment for presence or absence of hypertension, hypercholesterolemia, and chronic kidney disease. Model 4: additional adjustment for plasma glucose concentrations, duration of diabetes (<5 years, ≥5 years), no. of prescriptions for oral antidiabetes medications (<3, ≥3), and insulin prescription history. *Quartile 1 is the lowest income status and quartile 4 is the highest income status. **We calculated mortality rate by dividing the no. of deaths by the total no. of person-years of follow-up. Morality rate is presented per 1,000 person-years.

our study also showed that increase in income was associated with lower risk of mortality in subjects with T2D, even if the amount of increase was not substantial. Results of few studies showed that higher incomes are associated with lower risk of mortality in the general population (14). Our findings may support that improving income status might lead to better health outcomes in those with T2D (34).

There may be several pathways by which sustained low income and declines in income could increase risk of mortality. Low-SES status was reported as an important risk factor for metabolic dysregulation and cardiovascular disease (29,35). Especially in those with T2D, low-SES status can lead to poor preventive care, which may increase risk of diabetes-related comorbidities or complications, which can in turn increase risk of mortality (10). Perceived stress from sustained poverty may be related to mental illness causing unhealthy behaviors such as daily smoking, physical inactivity, unhealthy and unbalanced diets (high-carbohydrate diet, low intake of vegetables), drug or alcohol overuse, and suicidal ideation, all of which can potentially increase mortality risk (29,36,37). Also, chronic stress stemming from low SES might result in insulin resistance and hypertriglyceridemia, leading to cardiovascular disease (38,39). Stressed subjects showed significant reduction of plasma volume, causing increased plasma viscosity that may increase thrombotic risk and cardiovascular mortality (40,41). In South Korea, low-SES status culturally could lead to a harmful perception of the lower position on the social hierarchy (42). Moreover, it can lead to fewer opportunities for education, which might result in a vicious cycle with health inequality (29). Socioeconomic disparities also affected mental health, with, for example, increased suicide rate in South Korea, which was among the highest in the Organization for Economic Co-operation and Development countries (43).

An interesting finding in our study was that the association between cumulative numbers of very-low-income status and mortality risk was much stronger compared with that of cumulative numbers of low-income status. This means that very-low-income status may be associated with more vulnerabilities, even though there were more financial government support, indicating a higher chance of getting medical service via Medical Aid. However, overall healthy behavior education and management for preventing diabetes complications and related mortality risk could have been suboptimal. Although the very-low-income population in Korea can have at least the same or more access to health care service for their medical conditions compared with other higher-income participants, their mortality was higher (44,45), suggesting that other factors might explain the higher mortality. A systematic review showed that socioeconomic inequalities might play a role in inequalities in mortality for adults with type 1 diabetes, even with access to a universal health care system (46). Additionally, our study showed that those with T2D who were not consecutively in the very-low-income category during the study period had similar mortality risks, regardless of the number of years having very-low-income status. In contrast, those with T2D who were consecutively in the very-low-income category had the highest risk of mortality. Persistent lower income could lead to harmful effects on health, which may increase all-cause mortality (47).

This study has notable strengths. We had a very large sample with >1.9 million participants. Therefore, we were able to assess the effect modifications by demographic, lifestyle factors, and comorbidities. We were also able to take account of comorbidities and diabetes durations and treatment in the association between income status and mortality. However, there were a few limitations in this study. First, in this study we used data from the Korean NHIS database. Therefore, the results may not apply to other groups with different cultural, medical, and economic backgrounds. Second, we were unable to separate the type of medical benefits: Medical Aid type 1 (for those incapable of working) and Medical Aid type 2 (for those capable of working). Third, there was a lack of physiologic markers of inflammation and autonomic nervous systems to explain the mechanisms of this association. Fourth, there is no underlying depression or psychiatric disorder information, which might explain the association between low-income status and mortality risk in the study population. Lastly, this study did not include clarification of cause-specific deaths. In future studies investigators should evaluate the differential association of specific causes of death in each age-group and sex.

In conclusion, persistent low-income status and declines in income were associated with increased risk of all-cause mortality in >1.9 million Korean adults with T2D. Our data are important for better understanding of how the pattern and change of income status could impact risk of mortality in those with T2D, particularly for younger adults and males. The findings of this study reinforce the need for increased public awareness of income instability in relation to health in adults with T2D and may be crucial for implementations of health policies and strategies.

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