Effect of socioeconomic deprivation on outcomes of diabetes complications in patients with type 2 diabetes mellitus: a nationwide population-based cohort study of South Korea

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ABSTRACT

Introduction This study aimed to examine the effect of socioeconomic deprivation on the outcomes of diabetes complications in patients with type 2 diabetes mellitus (T2DM).

Research design and methods We conducted a cohort study using claims data and 2005 national census data. We included 7510 patients newly diagnosed with T2DM from 2004 to 2012 and aged 40 years or above. We excluded participants who had onset of diabetes complications and hospitalization within 1 year after initial onset T2DM, aged less than 40 years and with missing covariates. We used the regional socioeconomic deprivation index and classified study participants into five categories according to the quintile distribution. We calculated the adjusted HR and 95% CI for hospitalization related to diabetes complications and all-cause mortality by applying Cox proportional hazards model and the adjusted subdistribution hazards model.

Results The percentages of participants in the first quintile (least deprived) to fifth quintile (most deprived) were 27.0%, 27.9%, 19.5%, 14.8%, and 10.8% for socioeconomic deprivation; 25.4%, 28.8%, 32.4%, 34.6%, and 37.6% for hospitalization due to diabetes complications; 5.7%, 7.2%, 2.5%, 2.9%, and 3.6% for deaths from diabetes complications; 1.3%, 2.1%, 2.9%, 2.5%, and 2.1% for deaths from all causes; 34.6%, and 37.6% for hospitalization due to diabetes complications; 5.7%, 7.2%, 9.7%, 9.7%, and 13.1% for deaths from all causes, respectively. Participants with higher socioeconomic deprivation had a higher HR for hospitalization and mortality from all-cause and diabetes complications. These associations were the strongest among men and participants in their 40s in hospitalization related to diabetes complications, 50s in diabetes complications-specific mortality and 50s and 60s in all-cause mortality.

Conclusions Patients with T2DM with high socioeconomic deprivation had higher hospital admission and mortality rates for diabetes complications than those with low deprivation. We cannot fully explain the effect of socioeconomic deprivation on diabetes outcomes. Therefore, further studies are needed in order to find underlying mechanisms for these associations.

INTRODUCTION

Diabetes is estimated to affect about 415 million adults worldwide; 5.5 million deaths are caused by diabetes in 2015. The prevalence rate of diabetes continues to rise and is expected to reach 10.4% by 2040.1 Patients with type 2 diabetes mellitus (T2DM) have a high risk of complications such as heart disease, stroke, renal disease, and retinopathy.2–5 Although the mortality rate among people with diabetes is decreasing, they remain at a significantly higher risk of developing these complications than people without diabetes.6 Individuals living in low-income households, as well as those...
with low socioeconomic status, have a higher risk of diabetes complications than those of other socioeconomic groups.7–10 Low socioeconomic status is associated with many factors known to contribute to poor health outcomes, including decreased access to recommended preventive care, low care utilization, poor metabolic control and psychological pain.10 In addition, previous studies have proven that the results of diabetes complications differ according to an individual’s socioeconomic status and from neighborhood to neighborhood.11–16

Socioeconomic deprivation encompasses the current individual socioeconomic status and social relationships, community-level characteristics and gradients of socioeconomic position at the individual and community level.10,17,18 Socioeconomic position is a complex structure based on socially derived economic factors that determine the relative status of an individual or group within a society. The differences in socioeconomic status between the social strata can lead to inequalities in health.13,19,20

Although many studies have assessed the association of socioeconomic deprivation with the incidence of diabetes complications and mortality due to diabetes, their study populations were mostly Western. This study aimed to examine the effect of socioeconomic deprivation on diabetes complications outcomes among Korean patients with T2DM.

METHODS

Study population

This study used a random sample of claims data from the Korean National Health Insurance Service, which included information about approximately 1 million patients. The data included unique anonymous number for each patient with age, sex, type of insurance, and a list of diagnoses according to the International Classification of Diseases version 10 (ICD-10). The dataset also contained claimed medical costs, prescribed drugs, and medical history.

We conducted a cohort study of patients newly diagnosed with T2DM (ICD-10 code: E11, except for E11.9), using a 2.5% stratified random sample. From 13,893 patients diagnosed as having T2DM from 2004 to 2012, we excluded patients with a pre-existing diagnosis of T2DM, diabetes complications, and the use of diabetes medication from 2002 to 2003. Accordingly, we selected 9,536 with newly diagnosed T2DM. Then, we excluded 2,026 patients who were aged <40 years, died of diabetes complications within 1 year after the onset of T2DM, or had missing covariates. Finally, 7,510 patients were enrolled in the study.

Predictor variables

Data from the national census conducted in 2005 were used to assess the socioeconomic deprivation index. The data were a 2% random sample from the nationwide population and publicly accessible through the Microdata Service System provided by Statistics Korea.

We focused mainly on socioeconomic deprivation indices in 250 regions using the 2005 Korean census data. Areas with relatively large and heterogeneous populations, ranging from 12,000 to 630,000, which are administratively defined in Korea as regions, were used as space units for analysis.21 A region is defined as the smallest city-state unit that can implement autonomous policies and the lowest statistical unit with official data. For area-level deprivation measures, the degree of urbanicity, which is designated by the government (metropolitan, urban, and rural), and a socioeconomic deprivation index was assigned to each region. The socioeconomic deprivation index was generated by modifying the Townsend and Carstairs index, which has been used in previous studies,21,22 and calculated by Kim and colleagues’ methodology.21 For every region, we calculated the proportion of households: (1) living in an apartment, (2) without a car, (3) congested (>1.5 people/ room), (4) with a woman homeowner, (5) renting a home and (6) under substandard living conditions (without hot water supply, a flush toilet, or modern kitchen). In addition, we calculated the proportion of adults older than 25 years who were: (7) unemployed among high school graduates, (8) unemployed among the economically active, (9) employed manually and (10) who were older than 65 years. All proportions were z-standardized; we did not include home ownership and unemployment rate in further analysis since the factor analysis with varimax rotation showed that these factors differ from the others. Finally, we averaged z-standardized scores of the eight remaining proportions (households living in an apartment, households without cars, crowded conditions, women homeowners, and individuals with educational level lower than high school graduation among adults over 25 years of age) to constitute a regional deprivation index. A positive and high score implied a higher level of deprivation. We classified study participants into five categories according to the quintile distribution of the regional deprivation index (first quintile being least and fifth quintile most deprived).

Age was classified into four groups: 40–49, 50–59, 60–69, and ≥70 years. Household income was estimated using the health insurance premium and divided into tertiles. Medical aid was defined as non-payment of health insurance premiums, low income as the bottom 20% of health insurance premiums, middle income as 20%–80% of the premiums, and high income as the top 20% of premiums. The Charlson comorbidity index (CCI) was calculated for 1 year before the onset of T2DM. We included the use of insulin during the follow-up period in the analysis.

Outcome variables

We used ICD-10, fee-for-service, and prescribed drug codes to assess the incidence of T2DM, diabetes complications, hospital admissions, and mortality from diabetes complications including neurovascular disease, cardiovascular disease, end-stage renal disease, proliferative retinopathy, lower extremity arterial disease, diabetic
foot, and autonomic neuropathy (online supplementary eTable 1). Mortality due to diabetes complication was defined as the occurrence of death 1 year following the onset of T2DM.

**Statistical analysis**
The baseline characteristics of the study population were analyzed descriptively using the χ² test, t-test, and analysis of variance. Thereafter, we calculated the adjusted HR and 95% CI for hospitalization related to diabetes complications and all-cause mortality by applying Cox proportional hazards model, and the adjusted subdistribution HR (sHR) and 95% CI for diabetes complications-specific mortality by applying Cox proportional subdistribution hazards model. In this model, we adjusted for these regional and individual characteristics: sex, age, household income, types of insurance, CCI, disability status, use of insulin treatment, classification of hospital visited, and year of onset of T2DM. The follow-up time was calculated from the onset of T2DM to the time of death due to diabetes complications, loss to follow-up, death from another cause, or to the end of the study on 15 December 2013 for those who did not have complications or did not die. Hence, the follow-up time was equivalent to the duration of diabetes. The number of hospital admissions and mortality rate due to diabetes complications, stratified by socioeconomic deprivation, were measured from the time of diagnosis, using the overall survival after 1 year of T2DM onset as the event variable. Lastly, we conducted subgroup analyses by sex and age. The rates of events were calculated as the number of events per 1000 person-years along with the 95% CI using the standard life table analysis technique. All statistical analyses were performed using SAS V.9.4 and R V.3.6 (The R Development Core Team, Vienna, Austria). Statistical significance was defined as p<0.05.

**RESULTS**
Figure 1 shows the socioeconomic deprivation scores according to the 250 regions. The deeper color represents a higher socioeconomic deprivation score than the light color. Socioeconomic deprivation scores ranged from −5.16 to 8.72.

Table 1 shows the overall demographic characteristics of the study population. We observed a total of 7510 participants with T2DM. The percentages of participants from the first quintile to the fifth quintile of socioeconomic deprivation were 27.0% (n=2027), 19.5% (n=1467), 14.8% (n=1111), and 10.8% (n=809). According to socioeconomic deprivation groups from the first to the fifth quintile, 25.4% (n=514), 28.8% (n=603), 32.4% (n=476), 34.6% (n=384), and 37.6% (n=304) were hospitalized due to diabetes complications; 1.3% (n=26), 2.1% (n=44), 2.5% (n=36), 2.9% (n=32), and 3.6% (n=29) died from diabetes complications; and 5.7% (n=115), 7.2% (n=151), 9.7% (n=142), 10.8% (n=809), 11.2% (n=93), 12.1% (n=100), 13.1% (n=106) died from all causes, respectively (online supplementary eTable 2).

Figure 2 shows the cumulative incidence function of diabetes complications-specific mortality, other-cause mortality, and hospitalization with diabetes complications assessed using Gray’s test according to socioeconomic deprivation with competing risks. The cumulative diabetes complications mortality and hospital admission rates for the fifth quintile group were higher than those for other groups (Gray’s test: p=0.0015). The diabetes complications-related mortality rates per 1000 patient-years were 1.83 (95% CI 1.26 to 2.67), 2.91 (95% CI 2.16 to 3.91), 3.47 (95% CI 2.50 to 4.80), 4.04 (95% CI 2.86 to 5.71), and 5.10 (95% CI 3.54 to 7.34) from the first quintile to the fifth quintile, respectively (online supplementary eTable 3).

Table 2 shows the adjusted HRs of outcomes using Cox proportional subdistribution hazards models according to socioeconomic deprivation and covariates. The second (HR 1.15, 95% CI 1.02 to 1.30), third (HR 1.28, 95% CI 1.13 to 1.45), fourth (HR 1.42, 95% CI 1.24 to 1.62) and fifth (HR 1.48, 95% CI 1.28 to 1.71) quintile of socioeconomic deprivation had higher HRs for hospitalization related to diabetes complications compared with the first quintile. For mortality from diabetes complications, the sHRs of the third (sHR 1.72, 95% CI 1.03 to 2.87), fourth (sHR 2.07, 95% CI 1.22 to 3.51) and fifth (sHR 2.38, 95% CI 1.39 to 4.07) quintile were higher than those of the first quintile. The third (HR 1.64, 95% CI 1.28 to 2.11), fourth (HR 1.62, 95% CI 1.24 to 2.11), and...
### Table 1: The overall characteristics of the study population

| Variables                      | Total | First quintile (least) | Second quintile | Third quintile | Fourth quintile | Fifth quintile (most) | P value |
|-------------------------------|-------|------------------------|-----------------|----------------|-----------------|-----------------------|---------|
| **Sex**                       |       |                        |                 |                |                 |                       |         |
| Men                           | 4455  | 59.3                   | 1237            | 61.0           | 1271            | 60.6                  | 0.013   |
| Women                         | 3055  | 40.7                   | 790             | 39.0           | 825             | 39.4                  |         |
| **Age (years)**               |       |                        |                 |                |                 |                       | <0.001  |
| 40–49                         | 2273  | 30.3                   | 678             | 33.4           | 662             | 31.6                  |         |
| 50–59                         | 2519  | 33.5                   | 701             | 34.6           | 694             | 33.1                  |         |
| 60–69                         | 1773  | 23.6                   | 440             | 21.7           | 486             | 23.2                  |         |
| 70+                           | 945   | 12.6                   | 208             | 10.3           | 254             | 12.1                  |         |
| **Household income**          |       |                        |                 |                |                 |                       | <0.001  |
| First tertile                 | 2898  | 38.6                   | 686             | 33.8           | 750             | 35.8                  |         |
| Second tertile                | 1983  | 26.4                   | 543             | 26.8           | 527             | 25.1                  |         |
| Third tertile                 | 2629  | 35.0                   | 798             | 39.4           | 819             | 39.1                  |         |
| **Types of insurance**        |       |                        |                 |                |                 |                       | <0.001  |
| Self-employed insured or NHI | 6767  | 90.1                   | 1891            | 93.3           | 1933            | 92.2                  |         |
| Medical aid                   | 743   | 9.9                    | 136             | 6.7            | 163             | 7.8                   |         |
| **Charlson Comorbidity Index**|       |                        |                 |                |                 |                       | 0.172   |
| 0                             | 3724  | 49.6                   | 1032            | 50.9           | 1070            | 51.0                  |         |
| 1                             | 2457  | 32.7                   | 650             | 32.1           | 674             | 32.2                  |         |
| 2+                            | 1329  | 17.7                   | 345             | 17.0           | 352             | 16.8                  |         |
| **Disability**                |       |                        |                 |                |                 |                       | 0.461   |
| Healthy                       | 6892  | 91.8                   | 1871            | 92.3           | 1939            | 92.5                  |         |
| Severe                        | 158   | 2.1                    | 43              | 2.1            | 39              | 1.9                   |         |
| Mild                          | 460   | 6.1                    | 113             | 5.6            | 118             | 5.6                   |         |
| **Onset of diabetes complications** |       |                        |                 |                |                 |                       | 0.461   |
| No                            | 537   | 7.2                    | 139             | 6.9            | 166             | 7.9                   |         |
| Yes                           | 6973  | 92.8                   | 1888            | 93.1           | 1930            | 92.1                  |         |
| **Insulin treatment**         |       |                        |                 |                |                 |                       | 0.765   |
| No                            | 7067  | 94.1                   | 1908            | 94.1           | 1967            | 93.8                  |         |
| Yes                           | 443   | 5.9                    | 119             | 5.9            | 129             | 6.2                   |         |
| **Hospital classification**   |       |                        |                 |                |                 |                       | <0.001  |
| General hospital              | 995   | 13.2                   | 290             | 14.3           | 326             | 15.6                  |         |
| Hospital                      | 407   | 5.4                    | 96              | 4.7            | 113             | 5.4                   |         |
| Clinic                        | 5597  | 74.5                   | 1546            | 76.3           | 1543            | 73.6                  |         |
| Others                        | 511   | 6.8                    | 95              | 4.7            | 114             | 5.4                   |         |
| **Year of onset type 2 diabetes** |       |                        |                 |                |                 |                       | 0.070   |
| 2004                          | 1967  | 26.2                   | 528             | 26.0           | 529             | 25.2                  |         |
| 2005                          | 1863  | 24.8                   | 524             | 25.9           | 521             | 24.9                  |         |
| 2006                          | 1195  | 15.9                   | 309             | 15.2           | 372             | 17.7                  |         |
| 2007                          | 564   | 7.5                    | 173             | 8.5            | 156             | 7.4                   |         |
| 2008                          | 801   | 10.7                   | 188             | 9.3            | 197             | 9.4                   |         |
| 2009                          | 444   | 5.9                    | 120             | 5.9            | 120             | 5.7                   |         |
| 2010                          | 268   | 3.6                    | 75              | 3.7            | 75              | 3.6                   |         |
| 2011                          | 280   | 3.7                    | 75              | 3.7            | 88              | 4.2                   |         |
| 2012                          | 128   | 1.7                    | 35              | 1.7            | 38              | 1.8                   |         |
| **Total**                     | 7510  | 100.0                  | 2027            | 27.0           | 2096            | 27.9                  |         |

NHI, National Health Insurance.
Figure 2 Cumulative incidence function of DCSM and OCM and hospitalization with diabetes complications according to socioeconomic deprivation.

Figure 3 shows the results of the subgroup analyses of adjusted sHR for diabetes-specific mortality using Cox proportional subdistribution hazards model and for hospitalization related to diabetes complications and all-cause mortality using Cox proportional hazards model. Among men, those in the second, third, fourth, and fifth quintile of socioeconomic deprivation had higher HR for hospitalization compared with those in the first quintile. Among women, however, only those in the fourth and fifth quintile showed significantly higher HR for hospitalization than those in the first quintile. For mortality from fifth (HR 2.05, 95% CI 1.57 to 2.68) quintile had higher HR for all-cause mortality than the first quintile. The HR of the second quintile for all cause and the sHR of the second quintile for diabetes complications-specific mortality were not statistically significant.

Table 2 The adjusted subdistribution HRs of outcomes using Cox proportional hazards models with competing risks according to socioeconomic deprivation and covariates

| Variables                          | Socioeconomic deprivation |
|------------------------------------|---------------------------|
|                                    | First quintile (least)    | Second quintile          | Third quintile          | Fourth quintile         | Fifth quintile (most)   |
|                                    | Reference                 | HR (95% CI)              | HR (95% CI)             | HR (95% CI)             | HR (95% CI)             |
| Hospitalization with diabetes complications | 1.00                      | 1.15 (1.02 to 1.30)     | 1.28 (1.13 to 1.45)     | 1.42 (1.24 to 1.62)     | 1.48 (1.28 to 1.71)     |
| Mortality with diabetes complications | 1.00                      | 1.60 (0.98 to 2.60)     | 1.72 (1.03 to 2.87)     | 2.07 (1.22 to 3.51)     | 2.38 (1.39 to 4.07)     |
| All-cause mortality                | 1.00                      | 1.22 (0.96 to 1.56)     | 1.64 (1.28 to 2.11)     | 1.62 (1.24 to 2.11)     | 2.05 (1.57 to 2.68)     |

Analysis was adjusted for the following covariates: sex, age, household income, types of insurance, Charlson Comorbidity Index, disability, onset of diabetes complications, insulin treatment, hospital classification, and year of onset type 2 diabetes.
diabetes complications in men, the fourth and fifth quintile had higher sHR than the first quintile. There were no statistically significant differences among women. Similar trends were observed for all-cause mortality. Among the participants in their 40s, only the third, fourth, and fifth quintile group had higher HRs for hospitalization than the first quartile group. However, similar trends were observed for the group of participants in only their 50s in diabetes complications-specific and in their 50s and 60s in all-cause mortality.

**DISCUSSION**

This study examined the effect of socioeconomic deprivation on mortality from diabetes complications among patients with T2DM under the national health insurance system of Korea. Patients with T2DM with high socioeconomic deprivation had a significantly higher rate of diabetes-related outcomes and all-cause mortality than those with low socioeconomic deprivation, after controlling for a variety of covariates. Moreover, these associations were the strongest among men and participants in their 40s in hospitalization related to diabetes complications, 50s in diabetes complications-specific mortality, and 50s and 60s in all-cause mortality.

Neighborhoods or communities can play an important role in the health status of residents through the availability of healthcare and general attitude to health and health behaviors. In South Korea, there is a difference in regional characteristics between the metropolitan and rural areas due to the surge in economic growth and modernization, and migration of population from rural to urban areas. Previous studies reported that rural areas had lower income, more unmet medical needs, higher proportion of people aged 65 years or above, poor accessibility to healthcare service, and underutilization of health service manpower compared with metropolitan areas. However, the degree of urbanity can neither explain our age subgroup results nor the fact that there were no significant differences in older patients. A study in the UK showed similar inverse association between socioeconomic status and the prevalence of T2DM in the middle years of life. This factor may not be able to explain the relationship between the prevalence of diabetes and the socioeconomic status, and it may even underestimate this relationship.

Previous studies have shown that deprivation level is associated with prevalence of T2DM, chronic diabetes complications, mortality, and hospitalization due to diabetes complications. The Whitehall study and the WHO multinational study showed that people of lower socioeconomic status had 1.7 times higher all-cause mortality and 2.1 times higher mortality from cardiovascular disease than those in higher classes. A Swedish study showed that low neighborhood socioeconomic
status is associated with 1.1 times higher OR for coronary heart disease in men and 1.2 times in women. In patients with diabetes, factors such as low income, low education, and living in poor areas are related to higher smoking rates, less frequent blood sugar monitoring, less exercise, and poor access to primary and professional care. Therefore, patients with diabetes living in economically disadvantaged areas are likely to have a high risk of hospitalization and mortality from all causes and diabetes complications. It is a reasonable hypothesis that these factors may partly or substantially explain our findings. However, this is an ecological study based on aggregated data at area level, and our results cannot distinguish between contextual and compositional effects.

The observed associations are stronger in men than in women. The differences in biology, culture, lifestyle, environment, and socioeconomic status between men and women may lead to differences in predisposition, development, and clinical presentation of cardiovascular diseases. Previous studies have reported that genetic effects, epigenetic mechanisms, nutritional factors, and sedentary lifestyle affect the risk and complications of diabetes differently in both sexes. We believe that men are likely to engage in unhealthy behavior such as binge drinking, heavy smoking, and consumption of non-nutritious foods. Together with high socioeconomic deprivation, these factors have a synergistic effect on hospital admission and mortality due to diabetes complications.

In the subgroup analysis according to age groups, participants in their 50s showed a strong relationship between socioeconomic deprivation and mortality from diabetes complications and all-cause mortality. A previous study demonstrated that a high proportion of working-age people are still dying from diabetes. One possible explanation is that young patients are likely to be obese, have higher insulin resistance, and more aggressive treatment may be needed to control blood sugar levels. Another possibility may be the increased attention paid to medication prescribed to older people to control their blood sugar, suggesting the need to improve blood sugar management in young patients. Moreover, this could be the result of a survival effect, as people with diabetes in lower socioeconomic groups die prematurely due to complications such as cardiovascular disease.

Some limitations of this study are worth mentioning. First, other important covariates may have been omitted, such as clinical data regarding body mass index, blood pressure, fasting glucose level, and hemoglobin A1c level; education level; health behaviors such as alcohol consumption, smoking, and physical activity; and other individual social factors. Although such factors are strongly associated with diabetes complications outcomes, they were not included because of the limited information available in the claims data. Moreover, we could not consider long-standing diabetes that went undiagnosed. Second, we could not consider the consistency of individual socioeconomic deprivation within any region because of the lack of information. We could not differentiate between contextual and compositional effects because our findings are based on aggregated data at area level. This might have caused the inconsistent results between men and women, age groups, and household income levels. Therefore, caution is needed when interpreting these results. Further studies need to consider both area-level and individual-level socioeconomic deprivation as factors that influence diabetes outcomes. Third, we could not measure diabetes severity. However, we tried to account for diabetes severity by including the use of insulin and CCI in our analysis. Fourth, although regional characteristics were adjusted using some regional information, we could not fully control regional factors because of the limitation of the data. Finally, we could not validate our study modeling approach and diagnosis of outcomes. To overcome this, we defined the diagnosis of outcomes using both ICD-10 and medicine codes.

The present findings are valuable because of the following strengths of our study. First, we used a stratified random sample of a large and comprehensive national-level dataset, which included patients with diabetes with a long follow-up period, thus securing the external validity of the study. Second, as this study was an observational longitudinal cohort study, the association between the independent variables and survival is more confirmative than it would have been if obtained using a cross-sectional study. Finally, we considered a subdistribution hazard model because the naive Kaplan-Meier analysis with competing events as censored observations may be biased. This model yields a measure of association that reflects both the association of diabetes with a cause-specific death and the contribution of competing events by actively maintaining individuals with and without diabetes in the risk set.

In conclusion, patients with T2DM with high socioeconomic deprivation had higher hospitalization and mortality rates due to diabetes complications than those with low deprivation. This effect was strongest among men and participants in their 50s. Although we cannot fully explain the effect of socioeconomic deprivation on diabetes outcomes, we believe that the difference in social and economic factors, as well as in medical factors, may play a key role. Health policy makers and professionals should consider these factors when formulating preventive strategies for adverse diabetes outcomes.
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Data are available on reasonable request. The data can be accessed on the National Health Insurance Data Sharing Service homepage of the National Health Insurance Service (http://nhis.nhisin.or.kr). Applications to use the NHS data will be reviewed by the inquiry committee of research support and, once approved, raw data will be provided to the applicant with a fee.

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REFERENCES
1. Ogurtsova K, da Rocha Fernandes JD, Huang Y, et al. IDF diabetes atlas: global estimates for the prevalence of diabetes for 2015 and 2040. Diabetes Res Clin Pract 2017;128:40–50.
2. Roger VL, Go AS, Lloyd-Jones DM, et al. Heart disease and stroke statistics–2012 update: a report from the American Heart Association Circulation 2012;125:e2–220.
3. Donahoe SM, Stewart GC, McCabe CH, et al. Diabetes and mortality following acute coronary syndromes. JAMA 2007;298:765–75.
4. Ritz E, Orth SR. Nephropathy in patients with type 2 diabetes mellitus. N Engl J Med 1999;341:11–33.
5. Solomon SD, Chew E, Duh EJ, et al. Diabetic retinopathy: a position statement by the American Diabetes association. Diabetes Care 2017;40:412–8.
6. Harding JL, Pavkov ME, Magliano DJ, et al. Global trends in diabetes complications: a review of current evidence. Diabetologia 2019;62:3–16.
7. Connolly V, Unwin N, Sherriff P, et al. Diabetes prevalence and socioeconomic status: a population based study showing increased prevalence of type 2 diabetes mellitus in deprived areas. J Epidemiol Community Health 2000;54:173–7.
8. Evans JM, Newton RW, Ruta DA, et al. Socio-Economic status, obesity and prevalence of type 1 and type 2 diabetes mellitus. Diabet Med 2000;17:478–80.
9. Wild S, Macleod F, McKnight J, et al. Impact of deprivation on cardiovascular risk factors in people with diabetes: an observational study. Diabet Med 2006;25:194–9.
10. Brown AF, Ettner SL, Piette J, et al. Socioeconomic position and health among persons with diabetes mellitus: a conceptual framework and review of the literature. Epidemiol Rev 2004;26:63–77.
11. Walker JJ, Livingstone SJ, Colhoun HM, et al. Effect of socioeconomic status on mortality among people with type 2 diabetes. Diabetes Care 2011;34:1127.
12. Jackson CA, Jones NRV, Walker JJ, et al. Area-Based socioeconomic status, type 2 diabetes and cardiovascular mortality in Scotland. Diabetologia 2012;55:2938–45.
13. Saydah SH, Imperatore G, Beckles GL. Socioeconomic status and mortality. Diabetes Care 2013;36:49.
14. Dalsgaard E-M, Skrivar MV, Sandbaek A, et al. Socioeconomic position, type 2 diabetes and long-term risk of death. PLoS One 2015;10:e0124829.
15. Booth GL, Hux JE. Relationship between avoidable hospitalizations for diabetes mellitus and income level. JAMA Internal Medicine 2003;163:101–6.
16. Bachmann MO, Eachus J, Hopper CD, et al. Socio-Economic inequalities in diabetes complications, control, attitudes and health service use: a cross-sectional study. Diabet Med 2003;20:921–9.
17. Seeman TE, Crimmins E. Social environment effects on health and aging. Ann N Y Acad Sci 2001;954:88–117.
18. Pickert KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. J Epidemiol Community Health 2001;55:111–22.
19. Rabi DM, Edwards AL, Southern DA, et al. Association of socioeconomic status with diabetes prevalence and utilization of diabetes care services. BMC Health Serv Res 2006;6:124–24.
20. Galobardes B, Shaw M, Lawlor DA, et al. Indicators of socioeconomic position (Part 1). J Epidemiol Community Health 2006;60:7–12.
21. Kim M-H, Subramanian SV, Kawachi I, et al. Association between childhood fatal injuries and socioeconomic position at individual and area levels: a multilevel study. J Epidemiol Community Health 2007;61:135–40.
22. Kim M-H, Jung-Choi K, Jun H-J, et al. Socioeconomic inequalities in suicidal ideation, parasuicides, and completed suicides in South Korea. Soc Sci Med 2010;70:1254–61.
23. Kim Y-M, Kim M-H. [Health inequalities in Korea: current conditions and implications]. J Prev Med Public Health 2007;40:431–8.
24. Kwon TH, Jun KH. Rural-Urban migration and the social mobility of individuals in the Republic of Korea: an analysis of life history data. Korea J Popul Dev 1999;19:13–34.
25. Palley HA. Social policy and the elderly in South Korea: Confucianism, modernization, and development. Asian Surv 1992:32:787–801.
26. Chan CT, Caine EO, You S, et al. Changes in South Korean urbanicity and suicide rates, 1992 to 2012. BMJ Open 2015;5:e009451.
27. Park J, Kim K. The residential location choice of the elderly in Korea: a multilevel logit model. J Rural Stud 2016;44:261–71.
28. Cheong K-S, Choi M-H, Cho B-M, et al. Suicide rate differences by sex, age, and urbanicity, and related regional factors in Korea. J Prev Med Public Health 2012;45:70–7.
29. Heo J, Oh J, Kim J, et al. Poverty in the midst of plenty: unmet needs and distribution of health care resources in South Korea. PLoS One 2012;7:e51004.
30. Lee SE, Yeon M, Kim C-W, et al. The association among individual and contextual factors and unmet healthcare needs in South Korea: a multilevel study using national data. J Prev Med Public Health 2016;49:308–22.
31. Larrañaga I, Aroa pitia JM, Rodriguez JL, et al. Socio-Economic inequalities in the prevalence of type 2 diabetes, cardiovascular risk factors and chronic diabetic complications in the Basque country, Spain. Diabet Med 2005;22:1047–53.
32. Joshy G, Porter T, Le Lievre C, et al. Prevalence of diabetes in New Zealand general practice: the impact of deprivation. J Epidemiol Community Health 2009;63:386–90.
33. Roper NA, Bilous RW, Kelly WF, et al. Excess mortality in a population with diabetes and the impact of material deprivation. J Epidemiol Community Health 2009;63:386–90.
34. Booth GL, Hux JE. Relationship between avoidable hospitalisations for diabetes mellitus and income level. Arch Intern Med 2003;163:101–6.
35. Grintsova O, Maier W, Kelly WF, et al. Association between socioeconomic status and utilization of diabetes care services. BMJ Health Serv Res 2006;6:124–24.
36. Bottle A, Millett C, Xie Y, et al. Quality of primary care and hospital admissions for diabetes mellitus in England. J Ambul Care Manage 2008;31:226–38.
37. Chakiat Äsa, Li X, Bennet L, et al. Neighborhood deprivation and inequalities in coronary heart disease among patients with diabetes mellitus: a multilevel study of 334,000 patients. Health Place 2012;18:877–82.
38. Chaturvedi N, Jarrett J, Shipley MJ, et al. Socioeconomic gradient in morbidity and mortality in people with diabetes: a cohort study findings from the Whitehall study and the who multinational study of vascular disease in diabetes. BMJ 1998;316:100–5.
39 Connolly V, Kesson CM. Socio-Economic status and membership of the British diabetic association in Scotland. *Diabet Med* 1996;13:898–901.

40 Beckles GL, Engelgau MM, Narayan KM, et al. Population-Based assessment of the level of care among adults with diabetes in the U.S. *Diabetes Care* 1998;21:1432–8.

41 Karter AJ, Ferrara A, Darbinian JA, et al. Self-Monitoring of blood glucose: language and financial barriers in a managed care population with diabetes. *Diabetes Care* 2000;23:477–83.

42 Shi L, Starfield B. Primary care, income inequality, and self-rated health in the United States: a mixed-level analysis. *Int J Health Serv* 2000;30:541–55.

43 Regitz-Zagrosek V, Oertelt-Prigione S, EUGenMed T, Group CCS, et al. EUGenMed Cardiovascular Clinical Study Group. Gender in cardiovascular diseases: impact on clinical manifestations, management, and outcomes. *Eur Heart J* 2016;37:24–34.

44 Kautzky-Willer A, Harreiter J, Pacini G. Sex and gender differences in risk, pathophysiology and complications of type 2 diabetes mellitus. *Endocr Rev* 2016;37:278–316.

45 El-Kebbi IM, Cook CB, Ziemer DC, et al. Association of younger age with poor glycemic control and obesity in urban African Americans with type 2 diabetes. *Arch Intern Med* 2003;163:69–75.

46 Benoit SR, Fleming R, Philips-Tsimikas A, et al. Predictors of glycemic control among patients with type 2 diabetes: a longitudinal study. *BMC Public Health* 2005;5:36.

47 Chiu C-J, Wray LA. Factors predicting glycemic control in middle-aged and older adults with type 2 diabetes. *Prev Chronic Dis* 2010;7:A08

48 Andersen PK, Geskus RB, De Witte T, et al. Competing risks in epidemiology: possibilities and pitfalls. *Int J Epidemiol* 2012;41:861–70.

49 Lau B, Cole SR, Gange SJ. Competing risk regression models for epidemiologic data. *Am J Epidemiol* 2009;170:244–56.