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Preference-Based Assessment

# Utility Decrements Associated With Diabetes and Related Complications: Estimates From a Population-Based Study in Germany

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## ABSTRACT

*Objectives:* Health utility decrement estimates for diabetes and complications are needed for parametrization of simulation models that aim to assess the cost-utility of diabetes prevention and care strategies. This study estimates health utility decrements associated with diabetes and cardiovascular and microvascular complications from a population-based German study.

*Methods:* Data were obtained from the population based cross-sectional KORA (Cooperative Health Research in the Augsburg Region) health questionnaire 2016 and comprised n = 1072 individuals with type 2 diabetes and n = 7879 individuals without diabetes. Health utility was assessed through the EQ-5D-5L. We used linear regression models with interaction terms between type 2 diabetes and different cardiovascular and microvascular complications while adjusting for demographic and socio-economic factors and other comorbidities.

*Results:* Type 2 diabetes (β = −0.028, standard error [SE] = 0.014), stroke (β = −0.070, SE = 0.010), cardiac arrhythmia (β = −0.031, SE = 0.006), heart failure (β = −0.073, SE = 0.009), coronary heart disease (β = −0.028, SE = 0.010), myocardial infarction (β = −0.020, SE = 0.011, estimates of main effect), and neuropathy (β = −0.067, SE = 0.020), diabetic foot (β = −0.042, SE = 0.030), nephropathy (β = −0.032, SE = 0.025), and blindness (β = −0.094, SE = 0.056, estimates of interaction terms) were negatively associated with health utility. The interaction term for diabetes x stroke (β = −0.052, SE = 0.021) showed that the utility decrement for stroke is significantly larger in people with type 2 diabetes than in people without diabetes.

*Conclusions:* Diabetes, cardiovascular, and microvascular conditions are associated with significant health utility decrements. Utility decrements for some conditions differ between people with and without type 2 diabetes. These results are of high relevance for the parametrization of decision analytic simulation models and applied health economic evaluations in the field of prevention and management of type 2 diabetes in Germany.

*Keywords:* diabetes complications, type 2 diabetes, utility decrements.

VALUE HEALTH. 2021; 24(2):274–280

## Introduction

Diabetes mellitus is a prevalent and costly disease and a major challenge for healthcare systems across the globe. Previous studies showed that diabetes is associated with excess healthcare utilization and costs, worse labor market outcomes, decreased productivity, and reduced health-related quality of life (HRQL).[1-3] Especially diabetes complications, and in particular microvascular complications, such as retinopathy, nephropathy, and neuropathy, and cardiovascular complications, such as cerebrovascular diseases, coronary heart disease (CHD), and peripheral artery disease, have been identified as a major driver for morbidity and mortality,[4] increased direct and indirect costs,[5-10] and reduced HRQL.[11-13]

Valid utility decrements for diabetes and its complications are crucial to estimate quality-adjusted life years[14] that are used to assess the value of alternative prevention and treatment options in the context of cost-utility analyses. Instruments to assess utility values are, for example, the EQ-5D questionnaire or the Health Utility Index (HUI) questionnaire.[15,16] A review study by Janssen et al showed good validity, reliability, and responsiveness of the EQ-5D in populations with type 2 diabetes.[17] There are studies that estimated EQ-5D utility decrements for diabetes-related conditions in the United States, Australia, Canada, Korea, Singapore, the UK, France, Spain, Belgium, Italy, The Netherlands, and Greece.[12,18] However, until today, no comprehensive set of utility estimates exists for diabetes and related complications for Germany.

Authors of previous studies further acknowledged that the effect of certain events, such as a myocardial infarction, might differ between people with and without diabetes.[18] However, although economic evaluations of prevention strategies for type 2 diabetes require specific utility decrements for people with and

without type 2 diabetes, no previous study estimated those utility decrements from a single data source, which is a requirement to obtain a coherent set of utility estimates across people with and without diabetes.

This study uses data of a large German population-based survey and applies regression models with interaction terms between diabetes and different cardiovascular and microvascular diseases to estimate the health utility decrements associated with those conditions in both people with and without type 2 diabetes.

## Methods

### Study Sample and Study Design

This study is based on data from the population-based, cross sectional KORA (Cooperative Health Research in the Augsburg Region) self-administered and telephone-administered Health Survey 2016. It was conducted in 2016 and invited participants from the MONICA S1 (1984 to 1985, n = 4022), MONICA S2 (1989 to 1990, n = 4940), MONICA S3 (1994 to 1995, n = 4856), and KORA S4 (1999 to 2001, n = 4261) cohorts that were still alive and did not withdraw consent. The study consisted of a general questionnaire and a diabetes-specific questionnaire for participants who indicated in the general questionnaire that they have diabetes. The general questionnaire contained questions on diabetes status, anthropometry, health behavior, history of diseases, and on HRQL. The diabetes-specific questionnaire included questions on the history of diabetes-related complications. Participants who did not answer the postal general or diabetes-specific questionnaire were contacted via phone and data was obtained in a telephone interview.

Of the 11189 eligible KORA participants 9035 (response 80.7%) responded to the general questionnaire (90% sent back the postal questionnaire, and 10% answered to the questions via phone). 7879 participants reported no previous diabetes diagnosis; 1138 (12.6%) participants reported a diabetes diagnosis of which 1072 (94.2%) were determined to have type 2 diabetes. Of those 1072 participants with type 2 diabetes, 778 individuals answered the additional diabetes specific postal questionnaire.

A detailed description of the KORA study design can be found elsewhere.[19] The Ethics Committee of the Bavarian Medical Association approved the KORA Health Survey 2016. All procedures performed were in coherence with the principles expressed in the Declaration of Helsinki and all participants gave written informed consent before participation.

### Measurement of Health Utility

Health utility was assessed by the EQ-5D-5L. The EQ-5D-5L is a multiattribute descriptive system comprising 5 dimensions (mobility, self-care, usual activities, pain or discomfort, and anxiety or depression, each of which has 5 response levels).[15,20,21] The 3125 resulting health states of the EQ-5D-5L descriptive system can be converted into single utility values using country-specific utility value sets. For this study we used the value set of Ludwig et al, which is based on time trade-off valuations and discrete choice experiments in a German population-based sample.[22] The resulting utility values in this value set range from −0.661 for the worst health state (55555) to 1.000 for the best health state (11111). In addition, responses on the EQ-5D-5L visual analogue scale (EQ-VAS) were collected. The EQ-VAS is a thermometer-based scale where participants can mark their health on a continuum from 0 "worst possible health" to 100 "best possible health." Responses on the EQ-VAS cannot be interpreted as utilities. However, as the EQ-VAS might capture different aspects of HRQL deterioration, we used the EQ-VAS as an additional secondary outcome measure.

### Measurement of Diabetes, Related Complications, and Covariates

The status of diabetes (yes or no) was assessed by the question "has a doctor ever told you that you have diabetes?" Type 2 diabetes was determined by the question "which type of diabetes do you have?" (type 1; type 2; gestational diabetes; other), which was asked in the disease-specific questionnaire only. Individuals who did not complete the diabetes-specific questionnaire or who did not answer the question were assumed to have type 1 diabetes if their age at diabetes onset was ≤30 years and were assumed to have type 2 diabetes if their age at diabetes onset was >30 years.

The choice of diabetes complications and other explanatory factors relevant for health utility was informed by the data input requirements of established economic evaluation tools, such as the United Kingdom Prospective Diabetes Study (UKPDS) Outcomes Model, the CDC-RTI Cost-Effectiveness Model, or the CORE Diabetes Model.[23-25]

Demographic, socio-economic, and behavioral factors were age, sex, education (basic, ≤10 years of schooling; medium, 11 to 13 years of schooling; high, ≥14 years of schooling), and smoking status (smoker and nonsmoker). Body mass index (BMI) was calculated from self-reported height and weight.

History of diseases that are not directly linked that were included in the questionnaire, included chronic obstructive pulmonary disease (COPD), cancer, asthma, and chronic bronchitis. History of cardiovascular diseases, which have common risk factors with diabetes, included hypertension, myocardial infarction (MI), stroke, CHD, cardiac arrhythmia, and heart failure (HF).

History of microvascular complications, which are specific to people with diabetes, were only assessed in the diabetes-specific questionnaire and included neuropathy, peripheral vascular disease (PVD), diabetic foot, nephropathy, and blindness. All questions concerning history of diseases asked if a doctor has diagnosed the respective condition or event. In addition, we considered the administration mode for the EQ-5D-5L and VAS (postal questionnaire or telephone interview) as a covariate.

### Statistical Analyses

To efficiently analyze utility decrements for cardiovascular and microvascular complications in people with and without type 2 diabetes, we fitted a multi-variable linear regression model with an interaction effects between diabetes status and the respective cardio or microvascular complication in the full sample. This model can be notated as

$$Y_i = \beta_0 + \beta_{T2D} x_{T2D,\,i} + \boldsymbol{\beta}_{\mathbf{comp}} \boldsymbol{x}_{\mathbf{comp},\,\mathbf{i}} + \boldsymbol{\beta}_{\mathbf{int}} \left( x_{T2D,\,i} * \boldsymbol{x}_{\mathbf{comp},\,\mathbf{i}} \right) + \boldsymbol{\beta}\, \boldsymbol{x}_{\mathbf{i}} + \varepsilon_i$$

where $Y_i$ is the utility value of the individual i, $\beta_{T2D}$ the main effect of type 2 diabetes, $\boldsymbol{\beta}_{\mathbf{comp}}$ the main effects of cardiovascular and microvascular complications (MI, stroke, CHD, cardiac arrhythmia, HF, PVD, diabetic foot, nephropathy, and blindness), $\boldsymbol{\beta}_{\mathbf{int}}$ the interaction terms for the interaction between type 2 diabetes and the cardiovascular or microvascular complications, $\boldsymbol{\beta}\, \boldsymbol{x}_{\mathbf{i}}$ the linear predictor of other covariates (EQ-5D-5L or VAS administration mode, age, sex, education, smoking, BMI, the disease status or history regarding COPD, cancer, asthma, and chronic bronchitis), and $\varepsilon_i$ the error terms, which are assumed to be normally distributed.

Missing values in explanatory variables were imputed using Markov Chain Monte Carlo imputation procedures separately for people with and without type 2 diabetes (n = 10 imputations)

using all explanatory variables included in our regression models. This step also included the imputation of information on microvascular complications in the 296 participants who reported to have type 2 diabetes but did not reply to the diabetes specific questionnaire. This imputation was motivated by the observation that in participants who did not respond to the diabetes-specific questionnaire morbidity was slightly higher and EQ-5D-5L and VAS values were much lower than in people responding to the diabetes-specific questionnaire (see Appendix 1 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2020.09.017). Excluding these people would therefore have resulted in biased utility decrement for type 2 diabetes and complications. Finally, all participants with missing outcome values were excluded from the respective analysis leading to final analysis samples of n = 8755 for the analysis of the EQ-5D-5L and of n = 8013 for the analysis of the EQ-VAS. All analyses were conducted using the glimmix and mianalyze procedure in SAS V.9.4.

### Sensitivity Analyses

In order to test the sensitivity of our results concerning the imputation of information on microvascular complications in the 296 people with type 2 diabetes who did not respond to the diabetes specific questionnaire, we excluded these individuals in an additional analysis.

## Results

### Characteristics of the Cohort

Characteristics of participants without diabetes (n = 7879) and with type 2 diabetes (n = 1072) are presented in Table 1. On average, participants with type 2 diabetes were older, had fewer years of education, a higher BMI, and a higher prevalence of cardiovascular and microvascular complications than individuals without diabetes.

### Health Utility Decrements

Table 2 shows the results from the multivariable regression model with an interaction term between type 2 diabetes and cardiovascular and microvascular diseases. We present coefficients for the main effect of diabetes ($\beta_{T2D}$) and for the main effects of cardiovascular and microvascular diseases ($\beta_{comp}$). In addition, we report the interaction effects of type 2 diabetes and different cardiovascular and microvascular diseases ($\beta_{int}$) and the overall effect of cardiovascular and microvascular diseases in people with diabetes ($\beta_{comp} + \beta_{int}$).

EQ-5D-5L: Type 2 diabetes ($\beta_{T2D} = -0.028$), stroke ($\beta_{comp} = -0.070$), cardiac arrhythmia ($\beta = -0.031$), HF ($\beta = -0.073$), and CHD ($\beta = -0.028$) and neuropathy ($\beta_{int} = -0.067$) (in people with type 2 diabetes was significantly negatively associated with health utility scores. PVD, diabetic foot, nephropathy, and blindness were nonsignificantly negatively associated with health utility in people with type 2 diabetes. The utility decrement for stroke ($\beta_{int} = -0.052$) and HF ($\beta_{int} = -0.034$) was larger in patients with type 2 diabetes than in patients without diabetes.

In addition, older age, female sex, a lower level of education, smoking, a higher BMI, and a history of COPD, cancer, asthma, and chronic bronchitis showed a significant negative association with EQ-5D-5L utility values (all $P < .005$).

EQ-VAS: The utility decrement pattern for the VAS was similar. Type 2 diabetes, hypertension, stroke, HF, CHD, cardiac arrhythmia, and neuropathy and nephropathy were significantly associated with lower VAS values. The largest effects were estimated for stroke and HF. None of the interaction effects between type 2 diabetes and cardiovascular or microvascular complications were statistically significant. As for EQ-5D-5L, older age, female sex, a lower level of education, smoking, a higher BMI, and a history of COPD, cancer, asthma and chronic bronchitis were associated with lower VAS scores (all $P < .005$).

Sensitivity analyses: Excluding the n = 294 participants with type 2 diabetes who did not respond to the diabetes specific questionnaire in our regression, the results suggested smaller utility decrements for type 2 diabetes and for the interaction terms of diabetes and cardiovascular conditions, but very similar main effect estimates for cardiovascular and microvascular diseases.

## Discussion

Knowledge about utility decrements for type 2 diabetes and cardiovascular and microvascular diseases is important for parametrizing decision analytic simulation models and evaluating prevention and treatment strategies for type 2 diabetes. Yet, utility decrements based on German data and preferences are not available. In addition, previous studies failed to provide a comprehensive set of utility decrements for people with and without type 2 diabetes, which are needed to accurately assess the value of diabetes prevention efforts. This study uses data of a large German population-based survey and applies regression models with interaction terms between diabetes and different cardiovascular and microvascular diseases to fill this gap in the literature.

Our results indicate that particularly stroke, HF and cardiac arrhythmia have a strong negative impact on health utility PVD, diabetic foot, nephropathy, and blindness were nonsignificantly negatively associated with health utility in people with type 2 diabetes. The utility decrement for stroke ($\beta_{int} = -0.052$) and HF ($\beta_{int} = -0.034$) was larger in patients with type 2 diabetes than in patients without diabetes.

So far, only one previous study described utility decrements related to chronic diseases, including diabetes and CVD in a population-based German sample.[26] However, this study of Hunger et al was based on people 65 years and older, did not specifically assess microvascular complications, and used the EQ-5D-3L version to asses health utility, which is known to have inferior measurement properties compared to the EQ-5D-5L version.[16,27] The utility decrements in the study of Hunger et al were similar for diabetes (−0.03) and larger for stroke (−0.11) and MI (−0.04) than the utility decrements of our study. Other studies based on EQ-5D-3L data from the US showed utility decrements for diabetes of around −0.03 points.[28,29]

Beaudet et al conducted a review on disutilities used for diabetes complications in diabetes models.[12] The disutilities estimated in our study were mostly within the corridor of decrements reported in this review but at the lower end of the respective confidence intervals. The biggest relative difference in associated utility decrements is apparent for MI. The review shows that the majority of studies report a decrement of −0.04 and higher for MI, whereas the decrement of the main effect for MI in our study was 0.002 in people with type 2 diabetes. These differences might have several reasons. One reason could be that our data are more recent and for some of the conditions the corresponding therapy might have been improved. Thereby, the respective conditions might have become less burdensome. Another possible explanation could be differences in the healthcare systems and the quality of care people receive highlighting the importance of country-specific estimates. Moreover, differences might also have methodologic reasons. Our study differs from other studies that analyzed the utility decrements associated

**Table 1.** Descriptive information on the study population.

| | People without diabetes* (n = 7879) | | People with type 2 diabetes (n = 1072) | |
|---|---|---|---|---|
| | n or mean | % or SD | n or mean | % or SD |
| Data assessment mode | | | | |
| Postal questionnaire | 7146 | 90.5 | 925 | 86.3 |
| Telephone interview | 751 | 9.5 | 147 | 13.7 |
| Mean age (y) | 65.3 | 11.9 | 72.5 | 9.7 |
| Diabetes duration | – | – | 11.5 | 9.6 |
| Female, n (%) | 4299 | 54.4 | 576 | 53.7 |
| Education | | | | |
| Basic, n (%) | 3711 | 47 | 684 | 63.8 |
| Medium, n (%) | 2872 | 36.3 | 277 | 25.8 |
| High, n (%) | 1314 | 16.7 | 111 | 10.4 |
| BMI | 26.7 | 4.7 | 29.7 | 5.2 |
| Smoking, n (%) | 1076 | 13.6 | 120 | 11.2 |
| History of (nondiabetes-associated) diseases | | | | |
| Cancer, n (%) | 892 | 11.3 | 158 | 14.7 |
| Asthma, n (%) | 512 | 6.5 | 97 | 9.1 |
| Chronic bronchitis, n (%) | 487 | 6.2 | 128 | 11.9 |
| COPD, n (%) | 192 | 2.4 | 57 | 5.3 |
| History of cardiovascular diseases | | | | |
| Hypertension, n (%) | 3530 | 44.7 | 834 | 77.8 |
| MI, n (%) | 349 | 4.4 | 116 | 10.8 |
| Cardiac arrhythmia, n (%) | 1184 | 14.9 | 243 | 22.6 |
| HF, n (%) | 513 | 6.5 | 161 | 15 |
| CHD, n (%) | 516 | 6.5 | 172 | 16 |
| Stroke, n (%) | 343 | 4.3 | 125 | 11.6 |
| History of microvascular diseases† | | | | |
| Neuropathy, n (%) | 0 | 0 | 166 | 21.3 |
| PVD, n (%) | 0 | 0 | 46 | 5.9 |
| Diabetic foot, n (%) | 0 | 0 | 55 | 7.1 |
| Nephropathy, n (%) | 0 | 0 | 82 | 10.5 |
| Blindness, n (%) | 0 | 0 | 10 | 1.3 |
| HRQL | | | | |
| EQ-5D-5L (health utility) | 0.88 | 0.18 | 0.78 | 0.27 |
| EQ-VAS | 76.0 | 17.5 | 66.5 | 19.9 |

BMI, body mass index; CHD, coronary heart disease; COPD, chronic obstructive pulmonary disease; VAS, visual analogue scale; HF, heart failure; MI, myocardial infarction; PVD, peripheral vascular disease.
*Excluding also people with other types of diabetes.
†Information only available in n = 778 participants who answered the additional diabetes-specific questionnaire. People without diabetes were assumed not to have these conditions.

with diabetes complications in design features. For example, our sample was from a population-based study, whereas most of the other studies used trial samples. The disadvantage of trial data is that samples often comprise highly selected people who might receive better care. Consequently, complications might be treated better and are therefore less burdensome to patients, limiting the external validity of the estimates. In contrast, an advantage of trial data is that the assessment of complications is very accurate, particularly when they are the primary or secondary outcome of the study, whereas in population-based surveys, such as in our study, the assessment of complications is mostly based on self-reports, which might be biased or incomplete.

A major strength of our study is the simultaneous and therefore coherent estimation of utility decrements in people with and without type 2 diabetes. Such a set of utility decrements is needed to evaluate prevention strategies for type 2 diabetes. In reality, prevention strategies often modify the risk for diabetes and cardiovascular disease at the same time. Our estimates on the main effect and the interaction effects of diabetes with related conditions provide a comprehensive set of marginal utility decrements for such a situation. For example, assume a 45-year old male non-smoker with a BMI of 30 kg/m$^2$, a low level of education, no diabetes, and no history of other diseases. With our utility estimate set, we can determine the baseline utility of this person

**Table 2.** Health utility and VAS decrements associated with type 2 diabetes and cardio- and microvascular conditions.

| | EQ-5D-5L (n = 8755) | | | EQ-VAS (n = 8013) | | |
|---|---|---|---|---|---|---|
| | ß | SE | *P* value | ß | SE | *P* value |
| Intercept | 1.187 | 0.019 | <.0001 | 106.6 | 1.7 | <.0001 |
| Survey mode, telephone (ref: postal)* | −0.044 | 0.007 | <.0001 | 0.0 | – | – |
| Age | −0.003 | 0.000 | <.0001 | −0.3 | 0.0 | <.0001 |
| Female sex (ref: male) | −0.029 | 0.004 | <.0001 | −2.1 | 0.4 | <.0001 |
| Medium education (ref: low education) | 0.009 | 0.004 | .048 | 2.5 | 0.4 | <.0001 |
| High education (ref: low education) | 0.034 | 0.006 | <.0001 | 4.5 | 0.5 | <.0001 |
| Smoking | −0.017 | 0.006 | .004 | −2.1 | 0.5 | .000 |
| BMI | −0.003 | 0.000 | <.0001 | −0.4 | 0.0 | <.0001 |
| COPD | −0.085 | 0.012 | <.0001 | −7.4 | 1.2 | <.0001 |
| Cancer | −0.025 | 0.006 | <.0001 | −4.7 | 0.6 | <.0001 |
| Asthma | −0.032 | 0.008 | <.0001 | −3.5 | 0.7 | <.0001 |
| Chronic bronchitis | −0.047 | 0.008 | <.0001 | −4.8 | 0.8 | <.0001 |
| Type 2 diabetes* | −0.028 | 0.014 | .036 | −3.8 | 1.3 | .003 |
| Hypertension† | 0.005 | 0.004 | .245 | −1.4 | 0.4 | .001 |
| Hypertension*T2D‡ | 0.024 | 0.015 | .101 | 2.5 | 1.4 | .066 |
| Hypertension + hypertension*T2D§ | 0.029 | 0.014 | .037 | 1.1 | 1.3 | .385 |
| MI† | −0.020 | 0.011 | .068 | −2.9 | 1.1 | .006 |
| MI *T2D‡ | 0.023 | 0.023 | .315 | 3.8 | 2.1 | .075 |
| MI + MI *T2D§ | 0.002 | 0.020 | .904 | 0.9 | 1.8 | .640 |
| Stroke† | −0.070 | 0.010 | <.0001 | −7.5 | 1.0 | <.0001 |
| Stroke*T2D‡ | −0.052 | 0.021 | .012 | 1.8 | 2.1 | .379 |
| Stroke + stroke*T2D§ | −0.122 | 0.018 | <.0001 | −5.7 | 1.8 | .002 |
| Cardiac arrhythmia† | −0.031 | 0.006 | <.0001 | −3.8 | 0.6 | <.0001 |
| Cardiac arrhythmia*T2D‡ | 0.001 | 0.016 | .966 | −0.5 | 1.5 | .725 |
| Cardiac arrhythmia + cardiac arrhythmia*T2D§ | −0.030 | 0.015 | .041 | −4.3 | 1.4 | .002 |
| HF† | −0.073 | 0.009 | <.0001 | −8.6 | 0.9 | <.0001 |
| HF*T2D‡ | −0.034 | 0.021 | .107 | 1.2 | 2.0 | .556 |
| HF + HF*T2D§ | −0.107 | 0.019 | <.0001 | −7.4 | 1.8 | <.0001 |
| CHD† | −0.028 | 0.010 | .003 | −3.3 | 0.9 | .000 |
| CHD*T2D‡ | 0.031 | 0.020 | .132 | 0.1 | 1.9 | .965 |
| CHD + CHD*T2D§ | 0.002 | 0.018 | .906 | −3.3 | 1.7 | .055 |
| Neuropathy† | 0.000 | – | – | 0.0 | – | – |
| Neuropathy*T2D‡ | −0.067 | 0.020 | .0017 | −5.1 | 1.7 | .003 |
| Neuropathy + neuropathy*T2D§ | −0.067 | 0.020 | .002 | −5.1 | 1.7 | .003 |
| PVD† | 0.000 | – | – | 0.0 | – | – |
| PVD*T2D‡ | −0.025 | 0.033 | .447 | −0.4 | 2.8 | .893 |
| PVD + PVD*T2D§ | −0.025 | 0.033 | .447 | −0.4 | 2.8 | .893 |
| Diabetic foot† | 0.000 | – | – | 0.0 | – | – |
| Diabetic foot*T2D‡ | −0.042 | 0.030 | .166 | −2.5 | 2.5 | .330 |
| Diabetic foot + diabetic foot*T2D§ | −0.042 | 0.030 | .166 | −2.5 | 2.5 | .330 |
| Nephropathy† | 0.000 | – | – | 0.0 | – | – |
| Nephropathy*T2D‡ | −0.032 | 0.025 | .219 | −4.5 | 2.1 | .037 |
| Nephropathy + nephropathy*T2D§ | −0.032 | 0.025 | .219 | −4.5 | 2.1 | .037 |
| Blindness† | 0.000 | – | – | 0.0 | – | – |
| Blindness*T2D‡ | −0.094 | 0.056 | .091 | −7.2 | 5.7 | .212 |
| Blindness + blindness*T2D§ | −0.094 | 0.056 | .091 | −7.2 | 5.7 | .212 |
| $R^2$ | | 0.175 | | | 0.221 | |

Estimates from a multivariable linear regression model with an interaction term between diabetes and cardiovascular or microvascular complications.
Visual analogue scale (VAS) was only assessed in postal questionnaires.
Health utilities are based on the German tariff of the EQ-5D-5L.
VAS, visual analogue scale; BMI, body mass index; CHD, coronary heart disease; COPD, chronic obstructive pulmonary disease; HF, heart failure; MI, myocardial infarction; PVD, peripheral vascular disease.
*Main effect of diabetes (β_diab).
†Main effect of complication (β_comp).
‡Interaction effect of complication*T2D (β_int).
§Effect of complication in people with diabetes (β_comp + β_int).

(0.962) and assess the utility of an intervention that prevents this person from progressing to a stroke (−0.070), from progressing to type 2 diabetes (−0.028), or from progressing to type 2 diabetes and stroke (−0.122). Our results can be used for model-based economic evaluations in the field of type 2 diabetes in Germany. We previously showed that the updated UKPDS risk equations, which are the epidemiologic foundation of most currently available diabetes models, reasonably predict the onset of cardiovascular morbidity in German patients with diabetes.[30] Together with estimates on the direct healthcare costs associated with type 2 diabetes and incident diabetes complications in Germany, the estimated utility decrements from this study enable full parametrization and use of decision analytic models for economic evaluations of diabetes interventions in Germany.[7]

Beside the above-mentioned strengths and difficulties of our study, some more limitations should be considered. First, our data is cross-sectional. Hence, we could not apply panel data regression methods that can isolate within-person associations as done in previous studies. Alva et al used longitudinal data from the UKPDS and showed that cross-sectional analysis approaches that do not distinguish between within-person and between-person associations might overestimate the effect of complications on health utility.[31] Also, Shao et al showed that fixed effect models applied to a panel data structure result in smaller utility decrements for disease events than an ordinary least square regression model.[32] Therefore, the estimates of our cross-sectional study with a linear regression model might overestimate the true utility decrements associated with diabetes and its complications. Second, we were not able to differentiate between acute complications that occurred within the past 12 months and complications that occurred years ago. Previous studies showed that for most of the complications the utility decrement in the first year is larger than in subsequent years.[13,32] Therefore, our estimates are probably slightly underestimating the effects of acute complications and slightly overestimating the effects of complications in the years after onset or occurrence.

Despite these limitations, this study adds valuable data to the literature. It is the first study that estimates EQ-5D-5L-based utility decrements associated with diabetes and related complications, other chronic conditions, socioeconomic, sociodemographic, and behavioral factors in a German population-based sample. These estimates will be valuable in parametrizing decision analytic simulation models to evaluate prevention and treatment strategies in the field of type 2 diabetes and cardiometabolic disease.

## Supplemental Materials

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.jval.2020.09.017.

## Article and Author Information

**Accepted for Publication:** September 29, 2020

**Published Online:** January 11, 2021

doi: https://doi.org/10.1016/j.jval.2020.09.017

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**Conflict of Interest Disclosures:** The authors reported no conflicts of interest.

**Funding/Support:** The KORA study was initiated and financed by the Helmholtz Zentrum München - German Research Center for Environmental Health, which is funded by the German Federal Ministry of Education and Research (BMBF) and by the State of Bavaria. Furthermore, KORA research was supported within the Munich Center of Health Sciences (MC-Health), Ludwig-Maximilians-Universität, as part of LMUinnovativ.

**Role of the Funder/Sponsor:** The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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