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All-cause mortality in adults with and without diabetes – Analysis of statutory health insurance claims data in Germany 2013-2014

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Keywords: Diabetes mellitus, Mortality, Epidemiology, Surveillance, Claims data

Abstract

Objectives

Little is known about the age-specific excess mortality pattern of people with diagnosed diabetes in Germany. Thus, our goal was to determine the excess mortality in diagnosed diabetes overall and stratified by age and sex based on claims data.

Design

Routine data analysis using a claims dataset from all statutory health insured persons in Germany in 2013, which accounts for about 90% of the population.

Participants

We included persons who lived in Germany, were insured at least 360 days, were not self-paying any health services and were aged 30 years or older leading to a total number of 47.3 million insured persons for analyses.

Exposure

Diabetes was determined by ICD-10 codes E10 to E14, which were documented in 2013 in at least two quarters on an outpatient setting or at least once on an inpatient setting.

Outcome measures

The vital status in the study population was drawn from the claims dataset for the year 2014. We derived the excess mortality estimated as an age-adjusted mortality rate ratio (MRR) by sex and for age groups using a Poisson model.

Main Results

We found age-adjusted MRRs (95% CI) for diabetes of 1.52 (1.51 to 1.52) for women and 1.56 (1.56 to 1.56) for men. These figures declined with increasing age and were highest for age 30 to 34 years with 6.76 (4.99 to 9.15) for women and 6.87 (5.46 to 8.64) for men and lowest for age 95 years and older with 1.13 (1.10 to 1.15) for women and 1.11 (1.05 to 1.17) for men.

Conclusions

For the first time, we derived deeply age-stratified figures on excess mortality in diabetes for Germany. Establishing a sustainable analysis of excess mortality is aimed at within the framework of diabetes surveillance.

Strengths and limitations of this study

- The study is based on documented data of all statutorily insured patients accounting for about 90% of the German population.
- Mortality rates derived from the study data showed very good agreement with data from official death statistics covering the entire German population.
- For the first time, this analysis allowed to assess detailed age-related patterns in women and men in the German population.
- Our results are robust with respect to variation of the case definition of diabetes.
- The study data are limited to documented diagnoses, i.e. no information about undiagnosed morbidity is available.

Introduction

Diabetes mellitus is a chronic metabolic disease of high public health impact in Germany and worldwide.[1] According to the Global Burden of Disease Study 2017 diabetes ranks among the top 10 leading causes of death globally.[2] Available treatment with insulin and glucose lowering drugs has greatly reduced the risk of acute complications and premature mortality. Nevertheless, persons with diabetes still have a higher age-adjusted risk of death compared to persons without diabetes mainly because of an increased risk of micro- and macrovascular complications.[3]

Monitoring diabetes-associated mortality over time is an important part of national diabetes surveillance activities, as the age-specific excess risk of death among persons with diabetes compared to those without diabetes serves as an indicator of quality of diabetes care. Some countries, such as Sweden, Denmark and Scotland have established national diabetes registers, and along with a legal basis for individual health data linkage, these data allow a reliable assessment of diabetes-associated mortality in comparison to the general population[4 5] or population-based controls.[6] Results from these countries consistently demonstrate a significantly higher risk of death in association with diabetes, but greatly vary with regard to the overall magnitude of excess risk as well as sex differences. A recent meta-analysis of diabetes-associated all-cause-mortality based on 86 prospective cohorts showed a higher pooled adjusted relative risk of death among women than men (1.93 vs. 1.74).[7] The studies from Sweden as well as a further study from Australia have been age disaggregated, indicating that excess mortality among persons with type 2 diabetes significantly decreases with increasing chronological age.[6 8]

In Germany, a national diabetes surveillance system is currently being established at the Robert Koch Institute as the national public health institute. One of the main goals is to cover the diabetes-associated mortality continuously (www.diabsurv.rki.de). Over the past 20-years a number of epidemiological studies in Germany have provided estimates of mortality rate ratios (MRRs) comparing mortality rates among persons with and without diabetes. The results from these studies vary due to differences in study design and study populations, methodological issues, regional vs. national data, follow-up time, and insight from age- and sex-stratified analyses is limited due to the

small number of observations.[9] In addition to these population-based estimates, a recent study estimated diabetes-associated MRRs for the population 65-90 years of age in Germany based on mathematical modeling using official death statistics, and prevalence and incidence estimates derived from statutory health insurance (SHI) claims data.[10]

Information on mortality has recently been added to a SHI claims dataset with complete records of all insured persons, which is accessible to health researchers in Germany. The present study for the first time used outpatient and inpatient SHI claims data drawn from this dataset to analyse observed mortality rates for adults in Germany with and without diagnosed diabetes. Our main aim was to provide estimates of MRRs associated with diabetes within strata of narrow age bands and sex.

Methods

Source of data

We used the SHI claims research dataset hosted by the German Institute for Medical Documentation and Information (DIMDI).[11] According to the Data Transparency Regulation Act (DaTraV) 2012 this dataset has been made accessible to authorized health researchers. Originally, these data were collected within the scope of the German morbidity-based risk-adjustment scheme.[12] The dataset includes medical data from approximately 70 million people covered by SHI, which are about 90% of the German population. The DaTraV data contain complete data on outpatient and inpatient diagnoses as well as prescribed drugs and the vital status.[11] Therefore, the data can be analyzed across all sectors of care and providers within the SHI system. For reasons of data protection, there is no direct access to these stored individual data. Analyses are limited to aggregate data, which can be requested from the DIMDI data processing centre. A research question needs to be submitted together with an analytical scheme or a syntax query for data analysis. The request has to be approved by the data processing centre and the aggregated results are checked and transmitted to the applicant.

We developed an SQL script for the analysis of mortality rates among persons with and without diabetes based on DaTraV datasets 2013 and 2014. As described in detail

below, the SQL script had to take into account several specifics of the data, including assessment of vital status and the case definition for diabetes.[13]

Study population

Information from more than 70 million SHI persons was available for the year 2013 (Figure 1). In addition to the individual SHI identification number, the year of birth and sex were checked for unique assignment to the insured person. Persons with an insured period of less than 360 days, persons who cover at least partly their own health expenditure and persons with main residence abroad were excluded from the analysis, because this may have precluded documentation of diabetes within the year 2013.

After these exclusions but mainly due to an insurance period of less than 360 days, about 65.8 million persons were considered eligible for analysis. In addition, persons aged younger than 30 years were excluded for data protection reasons due to the small number of deaths among persons with diabetes in these age groups. The final study population hence comprised a total of 47.3 million persons (Figure 1). Of these, 6.5 million persons with diabetes fulfilled the case definition for diabetes and 40.8 million persons were defined as having no diabetes. As the flow chart reveals, 0.29 million persons in the population with diabetes and 0.48 million persons in the population without diabetes died in 2014 (Figure 1).

Patient and public involvement

No patient involved.

Figure 1 Flow chart of selection of study population with excluding criteria and sample sizes

Definition of diabetes

We used the International Classification of Diseases (ICD-10) codes E10.- to E14.- to define diabetes:

- E10.- Type 1 diabetes mellitus

- E11.- Type 2 diabetes mellitus
- E12.- Malnutrition related diabetes mellitus
- E13.- Other specified diabetes mellitus, for example diabetes related to pancreatic insufficiency
- E14.- Unspecified diabetes mellitus.

In the outpatient setting, documentation of an additional ICD-tag "G" is required to indicate a confirmed diagnosis of diabetes. In the present analysis, this additional requirement was applied to all data originating in the outpatient setting, in order to increase the validity of the case definition for diabetes. Furthermore, an outpatient diagnosis of diabetes had to be documented in at least two quarters of the year for validation reasons. This definition is related to the m2Q criterion, which was originally used for reimbursement and is also recommended for epidemiological studies [14]. In the case of inpatient-documented diagnosis, one primary or secondary diagnosis of diabetes in the year 2013 was sufficient to identify a diabetes case.

In order to examine the impact of potential misclassification on the results, we conducted sensitivity analyses applying modified case definitions for diagnosed diabetes based on less stringent criteria: first, documentation of at least one confirmed outpatient diagnosis or one inpatient diagnosis in 2013 ("m1Q criterion"), and secondly, documentation of only one confirmed outpatient diagnosis in 2013 without any documented inpatient diagnosis.

Assessment of mortality

We calculated the mortality rates based on the vital status in 2014, since in the event of death no diagnoses for the year of death are available in the dataset.[11] The reason for this approach is that the SHI claims dataset was originally created only for morbidity-adjusted reimbursement of SHI companies and diagnoses in the year of death were not transmitted. Therefore, we used the difference of the year 2014 and the year of birth to calculate the age groups.

In order to examine whether assessment of vital status in the SHI claims dataset produced plausible results, we compared the observed overall mortality rates as total counts per 100,000 persons across age groups and stratified by sex with the corresponding mortality rates from the official cause of death statistics in Germany for

the year 2014.[15] As illustrated in Figure 2 mortality rates per 100,000 persons based on data from both sources showed high consistency in both sexes and in nearly all age groups, with only minor deviations among middle-aged men and women 85 years of age and older.

Figure 2 Age-specific mortality rates per 100,000 persons stratified by sex for the year 2014 as obtained from official cause of death statistics (Destatis) and claims data (Datrav). The blue line indicates results from official statistics; the green line indicates results from the DaTraV dataset.

Statistical analysis

We estimated age- and sex-specific MRRs and 95% confidence intervals using Poisson regression. We applied the GENMOD procedure implemented in the statistical software SAS (Version 9.4 for Windows) [16]. Due to the aggregated count data of our study population, we applied a count model for MRR estimations. We preferred a Poisson model to a log-binomial model or negative binomial model, as the Poisson distribution provides a good approximation to the underlying binomial distribution due to increasing sample size and better convergence properties [16]. One central assumption of the model is equality of mean and variance, which is often not fulfilled for count data. In our analyses, we had to handle a large sample size, which tends to result in a lower variance with respect to the mean value, what is called underdispersion and could lead to biased, smaller standard errors. Therefore, we used the residual deviance as scale parameter.

We estimated MRRs separately for both sexes and over 5-year age groups for adults in the age range 30 to 95 years and older. We also calculated age-adjusted MRRs stratified by sex based on the 5-year age groups.

In order to assess the impact of modified case definitions on the study results, we conducted two sensitivity analyses calculating the age-adjusted MRRs for men and women as described above.

Results

Description of the study population

Compared to men, women were overrepresented in the population without diabetes, whereas proportions of men and women were similar in the population with diabetes (Table 1). Accordingly, the diabetes prevalence among women (12.8%) was lower than in men (14.9%). As expected, the population with diabetes had a higher mean age compared to the population without diabetes. On average, women were older than men among persons with and without diabetes. In terms of absolute numbers, more women than men died in 2014 in the population with and without diabetes. However, age-specific and age-standardized mortality rates per 1,000 persons were consistently higher among men than women in both populations. In both sexes, mortality rates per 1,000 persons were markedly higher among individuals with than without diabetes (Table 1).

Table 1 Descriptive characteristics of the study population by diabetes status and sex (DaTraV, age ≥ 30 years)

	No diabetes		Diabetes	
	Women	Men	Women	Men
Population size in M. (2013)	22,5	18,3	3,3	3,2
Proportion (%) 2013	55.1	44.9	50.8	49.2
Mean age in years 2013	55.9	53.6	71.5	67.9
Number of deaths 2014	254,408	220,305	148,491	140,024
Mortality rate per 1,000 persons*	12.00	12.74	19.96	21.91
Mortality rate per 1,000 persons across age groups*				
30 to 34 years	0.30	0.62	2.03	4.26
35 to 39 years	0.45	0.87	1.86	4.38
40 to 44 years	0.77	1.40	3.75	5.31
45 to 49 years	1.29	2.34	4.62	7.64
50 to 54 years	2.23	4.13	6.95	10.18
55 to 59 years	3.41	6.73	9.19	14.55
60 to 64 years	5.21	10.71	11.18	19.84
65 to 69 years	7.80	15.44	15.42	25.84
70 to 74 years	11.63	22.35	22.56	38.24
75 to 79 years	19.15	33.64	35.17	55.34
80 to 84 years	40.02	62.14	62.97	89.99
85 to 89 years	83.06	111.42	113.91	144.18
90 to 94 years	157.24	191.04	194.06	229.21
95 years and older	270.33	303.74	304.13	336.90

*age-standardized to the German population 2013 using all displayed age groups

Main Analysis

Figure 3 MRRs for persons with diabetes compared to persons without diabetes by sex and age groups. Overall estimates are adjusted using all displayed age groups.

MRR estimates in association with diagnosed diabetes as obtained from Poisson regression are depicted in Figure 3. For both sexes, the age-specific MRR estimates decreased with increasing chronological age from 6.76 among women and 6.87 among men in the youngest age group to 3.12 among women and 2.46 among men aged 50-54 years to 1.13 among women and 1.11 among men aged 95 years and older. Except for persons younger than 40 years of age, MRR estimates in association with diabetes were higher among women than men. In particular, among persons 50-79 years, the MRR was between 1.26 and 1.12 significantly times higher among women than men.

Overall adjusted MRR estimates were comparable for women and men (1.52 vs. 1.56). Constraining our analysis to persons below 90 years of age reversed the overall age-adjusted MRRs regarding sex with still comparable estimates of 1.66 for women and 1.61 for men.

Sensitivity analyses

An excess risk of death in association with diabetes among men and women was confirmed in two sensitivity analyses applying less stringent case definitions for diabetes (Table 2).

Compared to the main analysis, where the case definition for diabetes required documentation of a confirmed diabetes diagnosis in at least two quarters of the year 2013 for outpatient data or one inpatient diagnosis of diabetes in 2013, the first case definition in Table 2 additionally includes persons with only one confirmed outpatient diagnosis of diabetes in 2013. This means that about 0.5 million persons were added to the population with diabetes and at the same time removed from the population without diabetes compared to the numbers used for the main analysis as shown in Figure 1. Results of this sensitivity analysis were similar to those of the main analysis, with only slightly lower overall MRR estimates of 1.51 among women and 1.55 among men. In contrast, markedly attenuated overall MRR estimates were obtained in the second sensitivity analysis, where the case definition for diabetes was based on the

documentation of only one confirmed outpatient diagnosis. Still, the age-adjusted MRRs resulting from this case definition showed a significantly nearly 20% higher risk of death in men and women with diagnosed diabetes compared to those without diagnosed diabetes (Table 2).

Table 2 Sensitivity analyses applying modified diabetes case definitions: number of persons by diabetes status and age-adjusted MRRs stratified by sex (DaTraV, age ≥ 30 years).

	Women		Men	
	N (no diabetes / diabetes)	MRRs (95% CI)	N (no diabetes / diabetes)	MRRs (95% CI)
Sensitivity analysis 1*	22.3 M/ 3.6 M	1.51 (1.51 to 1.51)	18.1 M/ 3.4 M	1.55 (1.55 to 1.55)
Sensitivity analysis 2#	22.3 M/ 0.25 M	1.19 (1.18 to 1.20)	18.1 M/ 0.21 M	1.20 (1.19 to 1.21)

* Documentation of at least one outpatient (confirmed) or inpatient diagnosis of diabetes in 2013
# Documentation of only one outpatient (confirmed) diagnosis of diabetes in 2013. Deviations from figures in figure 1 are due to rounding.

Discussion

Main findings

To the best of our knowledge, we present for the first time deeply age-stratified MRR estimates in association with diagnosed diabetes among men and women 30 years of age and older in Germany based on SHI claims data covering about 90% of the population. Overall, men and women with diabetes had an about 50% higher age-adjusted risk of death compared to adults without diabetes. Across strata of increasing age, the diabetes-associated MRRs considerably decreased with slightly higher estimates among women than men in the population aged 40-80 years. Results persisted in sensitivity analyses applying modified case definitions for diabetes, with the exception of markedly reduced albeit still significantly higher diabetes-associated risk of death based on the least stringent case definition for diabetes requiring only one outpatient diagnosis for diabetes throughout the year 2013.

Our findings regarding age-related decreases in diabetes-associated MRRs partly agree with results from two previous nationwide studies in Germany.[10 17] A population-based cohort study based on 12-year-mortality follow-up of adults participating in the German National Health Interview and Examination Survey 1998 (GNHIES98) reported decreasing age-specific diabetes-associated MRRs in both sexes as well as overall age-adjusted MRR estimates of similar magnitude as in the present study.[17] In this previous analysis no sex differences in MRRs from all causes in association with diagnosed type 2 diabetes were observed, although significantly detection of a sex differential may have been precluded by a limited number of deaths among adults with diabetes. Tönnies et al. calculated type-2-diabetes-associated MRR applying an illness-death model, with estimates on diabetes prevalence and incidence derived from SHI claims data and mortality rates of the general population from official death statistics. These authors reported age-related decreases in MRRs, but considerably higher overall age-adjusted MRR estimates, with higher estimates among women than men (3.0 vs. 2.3).[10] For comparison with this previous study which focused on the population 65-90 years of age in Germany we limited our analyses to the population aged 65-90 years and found no differences in MRRs between women and men (1.47 versus 1.48).

Consistent with our results, nationwide studies in several other countries based on diabetes registers or diabetes surveillance systems have reported a higher diabetes-associated risk of all-cause mortality compared to general population or population based controls.[4-6 8 18]

The Swedish national diabetes register and the Australian diabetes surveillance showed that the excess risk of death in association with diagnosed type 2 diabetes declined with increasing chronological age.[6 8] Although the present study could not differentiate by type of diabetes, these results are in line with our findings, since type 2 diabetes accounts for the vast majority of diabetes cases among older adults. The age-related decline in diabetes-associated excess risk of all-cause mortality might be due to the different onsets of diabetes on the life span and the associated disease durations. It may reflect increases in competing risk of death in older age groups as well as survival disadvantage in association with increased diabetes duration. In addition, the

number of severe comorbidities in people with and without diabetes converges with increasing age.

With regard to sex differences in diabetes-associated relative risk or excess risk of all-cause mortality, previous studies from other countries showed conflicting findings.[4 5 8] Our age-specific estimates of diabetes-associated MRRs showed higher risk estimates among women than among men for persons aged 50-79. This higher risk among women declined with increasing age and diminished in the oldest age groups. This consistent pattern is comparable to a study from Australia for 2004-2010 which showed higher standardized mortality ratios (SMRs) in women than in men especially for persons aged 50-79 years and very similar SMRs for women and men aged 80 years or older (1.03 and 0.98).[8] A recently conducted systematic review and meta-analysis including 49 studies with 86 prospective cohorts showed a combined MRR of 1.93 for women and 1.74 for men with a pooled women-to-men RRR of 1.13.[7] However estimates across studies ranged from 1.24 to 3.67 in women and from 1.32 to 3.13 in men, pooled women-to-men RRR varied from 0.64 to 1.74.[7] Overall, differences in study results regarding a sex differential in excess risk of diabetes-associated all-cause mortality might, at least in part, be explained by differences in the age range, underestimation of older people, time of follow-up and applied methods for risk estimation.

Prospective population-based studies are needed to obtain a deeper insight into the role of sex difference in diabetes-associated mortality risks by taking relevant risk factors such as lifestyle behavior and co-morbidities into account.

Practical implications

Our findings confirm that diagnosed diabetes in Germany is still associated with a significantly elevated, several times higher risk of death among men and women, in particular in younger and middle age. This emphasizes the need for effective primary and secondary prevention. Further improvements in the early detection of diabetes, particularly in younger ages, alongside with evidence based treatments, could contribute to a reduction in excess mortality.

Our results open the perspective to close an important gap in diabetes surveillance in Germany, as the SHI claims dataset appears to be suitable for close monitoring of

diabetes-associated excess risk of death, which is a key indicator in the national diabetes surveillance system. In addition, the dataset will permit calculation of closely related indicators, including the absolute number of deaths in association with diabetes, and composite indicators of disease burden, including healthy life years and the number of years lost in association with diabetes. Thus, including SHI claims data dataset will harness the potential for improved health information systems as a basis for the surveillance of diabetes and other noncommunicable diseases (NCD).

Strengths and limitations

The main strength of our analysis is the completeness of the dataset, since about 90% of the German population is covered by SHI. Mortality rates derived from the SHI claims dataset showed good agreement with data from official death statistics, which underlines the potential for generalization of our results. Our findings from sensitivity analyses support the validity of the data. We consistently showed an excess risk of all-cause mortality in association with diagnosed diabetes based on varying case definitions for diabetes.

Taken together, our results demonstrate that the DaTraV dataset could essentially contribute to close current gaps in diabetes surveillance with an overall good documentation quality of diabetes and the advantage to consider inpatient as well as outpatient data for case definition.

A great disadvantage of routine datasets based solely on documented diagnoses is that no information about undiagnosed morbidity can be drawn. National surveys with an additional HbA1c measurement in blood samples of participants show a relevant proportion of undiagnosed diabetes. Although this proportion has decreased over time, it is still relatively high [19] and at the same time is related to a slightly higher excess mortality than diagnosed diabetes.[17 20] For this reason the current routine data analysis is likely to underestimate the excess mortality in diabetes.

There are a number of limitations which arise from the specific construction of the DaTraV dataset, which originally served economic but not research purposes. We had to determine cases of diabetes in the data in 2013 only, in order to identify persons who died in 2014 among persons with and without diabetes. This implies that those who died with newly documented diabetes in 2014 are not detectable in the data as

diabetes cases and hence will be counted as persons without diabetes. We cannot exclude that this also contributed to an underestimation of diabetes-associated excess mortality. Since diabetes is a chronic disease, and long-term complications account for the majority of diabetes-associated deaths, we assume that this had only little impact on our results. The planned revision of the Data Transparency Regulations in Germany could help to overcome current shortcomings.

Furthermore, the currently missing stratification of the dataset according to geographic region and social status or social deprivation should be possible in the future, hence we will be able to analyze and compare mortality trends within Germany as well as at a national level with other countries.

The present study included adults 30 years of age and older, and type 2 diabetes is likely to account for most cases of documented diabetes. Nevertheless, it will be important to overcome current limitations to differentiate between major types of diabetes in claims data. The main problem is the frequent coding of an unspecific diabetes (ICD-10: E14.-) or even diagnoses that are mutually exclusive (E10.- and E11.-) in the data.[21] A recent analysis of the here used dataset has demonstrated that including information on medication may improve assignment of unspecific diabetes codes to type 2 diabetes.[22] Among children and adolescents type 1 diabetes is the predominant type of diabetes. As insulin treatment is required here, documented insulin use is an essential part of the case definition for type 1 diabetes, and also helps to clarify diabetes definition.[23]

Conclusions

Diabetes-related risk of death is a key indicator for monitoring diabetes epidemiology and quality of diabetes care. Establishing sustainable time trends for this indicator as part of the national diabetes surveillance system in Germany is of great need, but was so far precluded by the lack of a valid and timely accessible dataset. Results of the present study demonstrate that analysis of SHI claims data may provide a solution in closing this information gap. Further research is needed to analyze and to improve the quality of the data, in particular with regard to case definitions. In this case, the SHI claims data could also serve to calculate and monitor the absolute number of diabetes-associated deaths as well as composite indicators of disease burden, such as diabetes-

associated healthy life years and years of life lost. Stratification of SHI claims data according to geographic region and social status or social deprivation will be possible in the future, hence we will be able to analyze and compare diabetes-associated mortality trends within Germany but also with international developments.[3] This will strengthen surveillance activities for the prevention and control of diabetes and other major NCD at a national level and also enhance international collaboration in diabetes and NCD surveillance and burden of disease estimates.

Footnotes

Contributors: CS, JB and CH designed the study. CS, LR and JB performed the analysis. CS, CSN and JB wrote the initial version of the manuscript. LR, RP and TZ revised the manuscript. All authors read and approved the final manuscript. All authors had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. CS is the lead author and guarantor.

Transparency declaration: The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Competing interests: All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work, no financial relationships with any organisations that might have an interest in the submitted work in the previous three years no other relationships or activities that could appear to have influenced the submitted work.

Ethics approval: This study was not approved by a research ethics committee, because our study did not meet the criteria for human subjects research.

Data sharing: The SQL code for requesting aggregated data and statistical codes available from the corresponding author at schmidtchri@rki.de.

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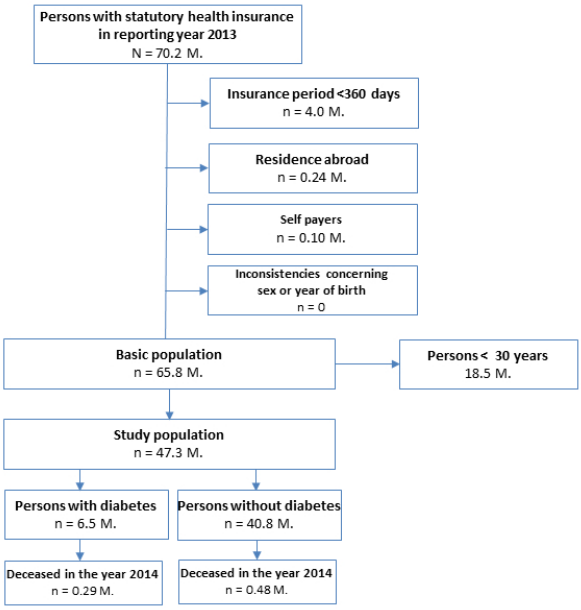

Figure 1 Flow chart of selection of study population with excluding criteria and sample sizes.

Figure 1 Flow chart of selection of study population with excluding criteria and sample sizes

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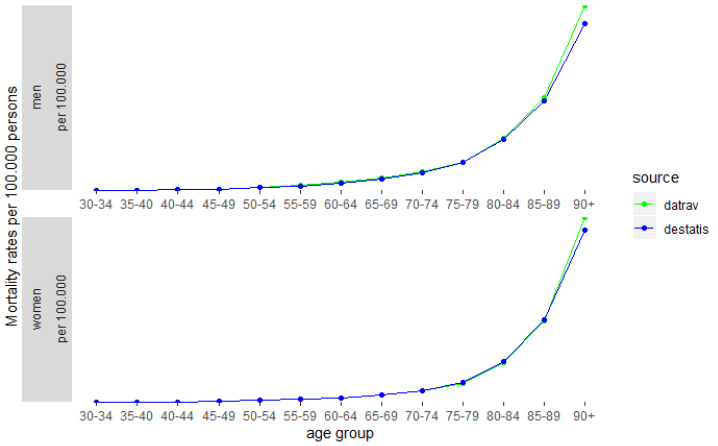

Figure 2 Age-specific mortality rates per 100,000 persons stratified by sex for the year 2014 as obtained from official cause of death statistics (Destatis) and claims data (Datrav). The blue line indicates results from official statistics; the green line indicates results from the DaTraV dataset.

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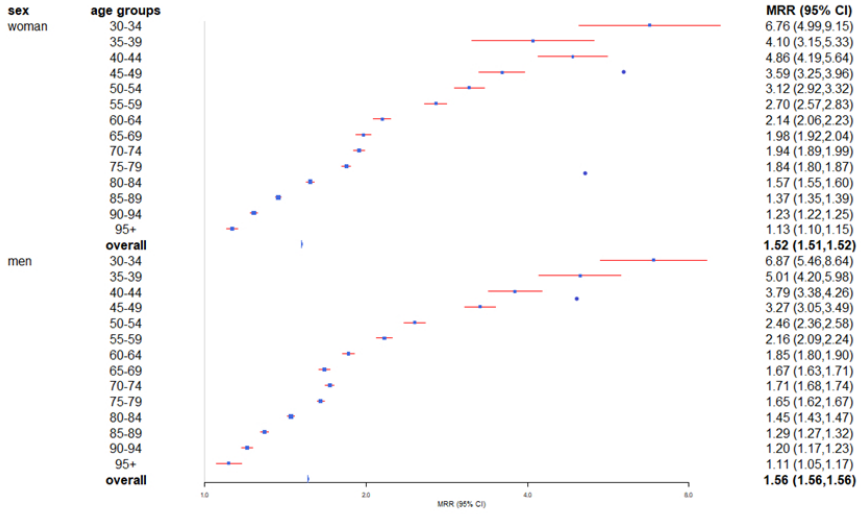

Figure 3 MRRs for persons with diabetes compared to persons without diabetes by sex and age groups. Overall estimates are adjusted using all displayed age groups.

Figure 3 MRRs for persons with diabetes compared to persons without diabetes by sex and age groups. Overall estimates are adjusted using all displayed age groups.

254x190mm (96 x 96 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4,5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	2,5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2,5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6, 7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5,6
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	8,11
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-10
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	10

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10,11
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11,12
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15,16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	15,16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Excess mortality in adults with documented diabetes in Germany – Routine data analysis of all insurance claims in Germany 2013-2014

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Excess mortality in adults with documented diabetes in Germany – Routine data analysis of all insurance claims in Germany 2013-2014

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Abstract

Objectives

Little is known about the age-specific excess mortality pattern of people with diagnosed diabetes in Germany. Thus, our goal was to determine the excess mortality in diagnosed diabetes overall and stratified by age and sex based on claims data.

Design

Routine data analysis using a claims dataset from all statutory health insured persons in Germany in 2013, which accounts for about 90% of the population.

Participants

We included persons who lived in Germany, were insured at least 360 days, were not self-paying any health services and were aged 30 years or older leading to a total number of 47.3 million insured persons for analyses.

Exposure

Diabetes was determined by ICD-10 codes E10 to E14, which were documented in 2013 in at least two quarters on an outpatient setting or at least once on an inpatient setting.

Outcome measures

The vital status in the study population was drawn from the claims dataset for the year 2014. We derived the excess mortality estimated as an age-adjusted mortality rate ratio (MRR) by sex and for age groups using a Poisson model.

Main Results

We found age-adjusted MRRs (95% CI) for diabetes of 1.52 (1.51 to 1.52) for women and 1.56 (1.56 to 1.56) for men. These figures declined with increasing age and were highest for age 30 to 34 years with 6.76 (4.99 to 9.15) for women and 6.87 (5.46 to 8.64) for men and lowest for age 95 years and older with 1.13 (1.10 to 1.15) for women and 1.11 (1.05 to 1.17) for men.

Conclusions

We derived deeply age-stratified figures on excess mortality in diabetes for Germany. Establishing a sustainable analysis of excess mortality is aimed at within the framework of diabetes surveillance.

Strengths and limitations of this study

- This is the first study in Germany, which analyses excess mortality of diabetes on the basis of routine data covering almost the entire German population.
- The completeness of the study data in terms of deaths and documented diagnosis allows calculating nearly unbiased and deep stratified diabetes-related mortality.
- We have not distinguished the type of diabetes because routine data contain implausible double diagnoses of type 1 and type 2 diabetes in the same person.
- The study data are limited to documented diagnoses, i.e. no information about undiagnosed morbidity is available.
- In principle, the study data allows a continuous assessment of changes in mortality, which is suitable for public health surveillance.

Introduction

Diabetes mellitus is a chronic metabolic disease of high public health impact in Germany and worldwide.[1] According to the Global Burden of Disease Study 2017 diabetes ranks among the top 10 leading causes of death globally.[2] Available treatment with insulin and glucose lowering drugs has greatly reduced the risk of acute complications and premature mortality. Nevertheless, persons with diabetes still have a higher age-adjusted risk of death compared to persons without diabetes mainly because of an increased risk of micro- and macrovascular complications.[3]

Monitoring diabetes-related mortality over time is an important part of national diabetes surveillance activities, as the age-specific excess risk of death among persons with diabetes compared to those without diabetes serves as an indicator of quality of diabetes care. Some countries, such as Sweden, Denmark and Scotland have established national diabetes registers, and along with a legal basis for individual health data linkage, these data allow a reliable assessment of diabetes-related mortality in comparison to the general population[4 5] or population-based controls.[6] Results from these countries consistently demonstrate a significantly higher risk of death in association with diabetes, but greatly vary with regard to the overall magnitude of excess risk as well as sex differences. A recent meta-analysis of diabetes-related all-cause mortality based on 86 prospective cohorts showed a higher pooled adjusted relative risk of death among women than men (1.93 vs. 1.74).[7] The studies from Sweden as well as a further study from Australia have been age disaggregated, indicating that excess mortality among persons with type 2 diabetes significantly decreases with increasing chronological age.[6 8]

In Germany, a national diabetes surveillance system is currently being established at the Robert Koch Institute as the national public health institute. One of the main goals is to cover the diabetes-related mortality continuously (www.diabsurv.rki.de). Over the past 20-years a number of epidemiological studies in Germany have provided estimates of mortality rate ratios (MRRs) comparing mortality rates among persons with and without diabetes. The results from these studies vary due to differences in study design and study populations, methodological issues, regional vs. national data, follow-up time, and insight from age- and sex-stratified analyses is limited due to the

small number of observations.[9] In addition to these population-based estimates, a recent study estimated diabetes-related MRRs for the population 65-90 years of age in Germany based on mathematical modeling using official death statistics, and prevalence and incidence estimates derived from statutory health insurance (SHI) claims data.[10] Due to partly conflicting findings stated above, further research is needed to increase knowledge on diabetes-related excess mortality, especially with respect to differences in magnitude by age, sex, region and time trend.

Information on mortality has recently been added to a SHI claims dataset with complete records of all insured persons in Germany. As almost 90% of the population is covered by statutory health insurance, this data source has enormous potential for public health research, including detailed analyses of mortality patterns. The present study for the first time used outpatient and inpatient SHI claims data drawn from this dataset to analyse observed mortality rates for adults in Germany with and without diagnosed diabetes. Up to now, diabetes-related MRRs from the age of 30 years in 5-years age bands have not been available for the German population. Against this background our main aim was to provide for the first time estimates of MRRs related to diabetes within strata of narrow age bands and sex for Germany and thus adds important knowledge in diabetes-related excess mortality. Deeply stratified mortality rates based on valid data are important for the surveillance of diabetes in Germany, as they allow a comparison over time and with other countries.

Methods

Source of data

We used the SHI claims research dataset hosted by the German Institute for Medical Documentation and Information (DIMDI).[11] According to the Data Transparency Regulation Act (DaTraV) 2012 this dataset has been made accessible to authorized health researchers. Originally, these data were collected within the scope of the German morbidity-based risk-adjustment scheme.[12] The dataset includes medical data from approximately 70 million people covered by SHI, which are about 90% of the German population. The DaTraV data contain complete data on outpatient and inpatient diagnoses as well as prescribed drugs and the vital status.[11] Therefore, the data can be analyzed across all sectors of care and providers within the SHI system. For

reasons of data protection, there is no direct access to these stored individual data. Analyses are limited to aggregate data, which can be requested from the DIMDI data processing centre. A research question needs to be submitted together with an analytical scheme or a syntax query for data analysis. The request has to be approved by the data processing centre and the aggregated results are checked and transmitted to the applicant.

We developed an SQL script for the analysis of mortality rates among persons with and without diabetes based on DaTraV datasets 2013 and 2014. As described in detail below, the SQL script had to take into account several specifics of the data, including assessment of vital status and the case definition for diabetes.[13]

Study population

Information from more than 70 million SHI persons was available for the year 2013 (Figure 1). In addition to the individual SHI identification number, the year of birth and sex were checked for unique assignment to the insured person. Persons with an insured period of less than 360 days, persons who cover at least partly their own health expenditure and persons with main residence abroad were excluded from the analysis, because this may have precluded documentation of diabetes within the year 2013.

After these exclusions but mainly due to an insurance period of less than 360 days, about 65.8 million persons were considered eligible for analysis. In addition, persons aged younger than 30 years were excluded for data protection reasons due to the small number of deaths among persons with diabetes in these age groups. The final study population hence comprised a total of 47.3 million persons (Figure 1). Of these, 6.5 million persons with diabetes fulfilled the case definition for diabetes and 40.8 million persons were defined as having no diabetes. As the flow chart reveals, 0.29 million persons in the population with diabetes and 0.48 million persons in the population without diabetes died in 2014 (Figure 1).

Patient and public involvement

No patient involved.

Definition of diabetes

We used the International Classification of Diseases (ICD-10) codes E10.- to E14.- to define diabetes:

- E10.- Type 1 diabetes mellitus
- E11.- Type 2 diabetes mellitus
- E12.- Malnutrition related diabetes mellitus
- E13.- Other specified diabetes mellitus, for example diabetes related to pancreatic insufficiency
- E14.- Unspecified diabetes mellitus.

In the outpatient setting, documentation of an additional ICD-tag "G" is required to indicate a confirmed diagnosis of diabetes. In the present analysis, this additional requirement was applied to all data originating in the outpatient setting, in order to increase the validity of the case definition for diabetes. Furthermore, an outpatient diagnosis of diabetes had to be documented in at least two quarters of the year for validation reasons. This definition is related to the m2Q criterion, which was originally used for reimbursement and is also recommended for epidemiological studies [14]. In the case of inpatient-documented diagnosis, one primary or secondary diagnosis of diabetes in the year 2013 was sufficient to identify a diabetes case.

In order to examine the impact of potential misclassification on the results, we conducted sensitivity analyses applying modified case definitions for diagnosed diabetes based on less stringent criteria: first, documentation of at least one confirmed outpatient diagnosis or one inpatient diagnosis in 2013 ("m1Q criterion"), and secondly, documentation of only one confirmed outpatient diagnosis in 2013 without any documented inpatient diagnosis.

Assessment of mortality

We calculated the mortality rates based on the vital status in 2014, since in the event of death no diagnoses for the year of death are available in the dataset.[11] The reason for this approach is that the SHI claims dataset was originally created only for morbidity-adjusted reimbursement of SHI companies and diagnoses in the year of death were not transmitted. Therefore, we used the difference of the year 2014 and the year of birth to calculate the age groups.

In order to examine whether assessment of vital status in the SHI claims dataset produced plausible results, we compared the observed overall mortality rates as total counts per 100,000 persons across age groups and stratified by sex with the corresponding mortality rates from the official cause of death statistics in Germany for the year 2014.[15] As illustrated in Figure 2 mortality rates per 100,000 persons based on data from both sources showed high consistency in both sexes and in nearly all age groups, with only minor deviations among middle-aged men and women 85 years of age and older.

Statistical analysis

We estimated age- and sex-specific MRRs and 95% confidence intervals using Poisson regression. We applied the GENMOD procedure implemented in the statistical software SAS (Version 9.4 for Windows) [16]. Due to the aggregated count data of our study population, we applied a count model for MRR estimations. We preferred a Poisson model to a log-binomial model or negative binomial model, as the Poisson distribution provides a good approximation to the underlying binomial distribution due to increasing sample size and better convergence properties [16]. One central assumption of the model is equality of mean and variance, which is often not fulfilled for count data. In our analyses, we had to handle a large sample size, which tends to result in a lower variance with respect to the mean value, what is called underdispersion and could lead to biased, smaller standard errors. Therefore, we used the residual deviance as scale parameter.

We estimated MRRs separately for both sexes and over 5-year age groups for adults in the age range 30 to 95 years and older. We also calculated age-adjusted MRRs stratified by sex based on the 5-year age groups.

In order to assess the impact of modified case definitions on the study results, we conducted two sensitivity analyses calculating the age-adjusted MRRs for men and women as described above.

Results

Description of the study population

Compared to men, women were overrepresented in the population without diabetes, whereas proportions of men and women were similar in the population with diabetes (Table 1). Accordingly, the diabetes prevalence among women (12.8%) was lower than in men (14.9%). As expected, the population with diabetes had a higher mean age compared to the population without diabetes. On average, women were older than men among persons with and without diabetes. In terms of absolute numbers, more women than men died in 2014 in the population with and without diabetes. However, age-specific and age-standardized mortality rates per 1,000 persons were consistently higher among men than women in both populations. In both sexes, mortality rates per 1,000 persons were markedly higher among individuals with than without diabetes (Table 1).

Table 1 Descriptive characteristics of the study population by diabetes status and sex (DaTraV, age ≥ 30 years)

	No diabetes		Diabetes	
	Women	Men	Women	Men
Population size in M. (2013)	22,5	18,3	3,3	3,2
Proportion (%) 2013	55.1	44.9	50.8	49.2
Mean age in years 2013	55.9	53.6	71.5	67.9
Number of deaths 2014	254,408	220,305	148,491	140,024
Mortality rate per 1,000 persons*	12.00	12.74	19.96	21.91
Mortality rate per 1,000 persons across age groups*				
30 to 34 years	0.30	0.62	2.03	4.26
35 to 39 years	0.45	0.87	1.86	4.38
40 to 44 years	0.77	1.40	3.75	5.31
45 to 49 years	1.29	2.34	4.62	7.64
50 to 54 years	2.23	4.13	6.95	10.18
55 to 59 years	3.41	6.73	9.19	14.55
60 to 64 years	5.21	10.71	11.18	19.84
65 to 69 years	7.80	15.44	15.42	25.84
70 to 74 years	11.63	22.35	22.56	38.24
75 to 79 years	19.15	33.64	35.17	55.34
80 to 84 years	40.02	62.14	62.97	89.99
85 to 89 years	83.06	111.42	113.91	144.18
90 to 94 years	157.24	191.04	194.06	229.21
95 years and older	270.33	303.74	304.13	336.90

*age-standardized to the German population 2013 using all displayed age groups

Main Analysis

MRR estimates in association with diagnosed diabetes as obtained from Poisson regression are depicted in Figure 3. For both sexes, the age-specific MRR estimates decreased with increasing chronological age from 6.76 among women and 6.87 among men in the youngest age group to 3.12 among women and 2.46 among men aged 50-54 years to 1.13 among women and 1.11 among men aged 95 years and older. Except for persons younger than 40 years of age, MRR estimates in association with diabetes were higher among women than men. In particular, among persons 50-79 years, the MRR was between 1.26 and 1.12 significantly times higher among women than men.

Overall adjusted MRR estimates were comparable for women and men (1.52 vs. 1.56). Constraining our analysis to persons below 90 years of age reversed the overall age-adjusted MRRs regarding sex with still comparable estimates of 1.66 for women and 1.61 for men.

Sensitivity analyses

An excess risk of death in association with diabetes among men and women was confirmed in two sensitivity analyses applying less stringent case definitions for diabetes (Table 2).

Compared to the main analysis, where the case definition for diabetes required documentation of a confirmed diabetes diagnosis in at least two quarters of the year 2013 for outpatient data or one inpatient diagnosis of diabetes in 2013, the first case definition in Table 2 additionally includes persons with only one confirmed outpatient diagnosis of diabetes in 2013. This means that about 0.5 million persons were added to the population with diabetes and at the same time removed from the population without diabetes compared to the numbers used for the main analysis as shown in Figure 1. Results of this sensitivity analysis were similar to those of the main analysis, with only slightly lower overall MRR estimates of 1.51 among women and 1.55 among men. In contrast, markedly attenuated overall MRR estimates were obtained in the second sensitivity analysis, where the case definition for diabetes was based on the documentation of only one confirmed outpatient diagnosis. Still, the age-adjusted MRRs resulting from this case definition showed a significantly nearly 20% higher risk

of death in men and women with diagnosed diabetes compared to those without diagnosed diabetes (Table 2).

Table 2 Sensitivity analyses applying modified diabetes case definitions: number of persons by diabetes status and age-adjusted MRRs stratified by sex (DaTraV, age ≥ 30 years).

	Women		Men	
	N in million (no diabetes / diabetes)	Mortality rate ratios (95% CI)	N in million (no diabetes / diabetes)	Mortality rate ratios (95% CI)
Sensitivity analysis 1*	22.3 / 3.6	1.51 (1.51 to 1.51)	18.1 / 3.4	1.55 (1.55 to 1.55)
Sensitivity analysis 2#	22.3 / 0.25	1.19 (1.18 to 1.20)	18.1 / 0.21	1.20 (1.19 to 1.21)

* Documentation of at least one outpatient (confirmed) or inpatient diagnosis of diabetes in 2013
# Documentation of only one outpatient (confirmed) diagnosis of diabetes in 2013. Deviations from figures in figure 1 are due to rounding.

Discussion

Main findings

To the best of our knowledge, we present for the first time deeply age-stratified MRR estimates in association with diagnosed diabetes among men and women 30 years of age and older in Germany based on SHI claims data covering about 90% of the population. Overall, men and women with diabetes had an about 50% higher age-adjusted risk of death compared to adults without diabetes. Across strata of increasing age, the diabetes-related MRRs considerably decreased with slightly higher estimates among women than men in the population aged 40-80 years. Results persisted in sensitivity analyses applying modified case definitions for diabetes, with the exception of markedly reduced albeit still significantly higher diabetes-related risk of death based on the least stringent case definition for diabetes requiring only one outpatient diagnosis for diabetes throughout the year 2013.

Our findings regarding age-related decreases in diabetes-related MRRs partly agree with results from two previous nationwide studies in Germany.[10 17] A population-based cohort study based on 12-year-mortality follow-up of adults participating in the

German National Health Interview and Examination Survey 1998 (GNHIES98) reported decreasing age-specific diabetes-related MRRs in both sexes as well as overall age-adjusted MRR estimates of similar magnitude as in the present study.[17] In this previous analysis no sex differences in MRRs from all causes in association with diagnosed type 2 diabetes were observed, although significantly detection of a sex differential may have been precluded by a limited number of deaths among adults with diabetes. Tönnies et al. calculated type-2-diabetes-related MRR applying an illness-death model, with estimates on diabetes prevalence and incidence derived from SHI claims data and mortality rates of the general population from official death statistics. These authors reported age-related decreases in MRRs, but considerably higher overall age-adjusted MRR estimates, with higher estimates among women than men (3.0 vs. 2.3).[10] For comparison with this previous study which focused on the population 65-90 years of age in Germany we limited our analyses to the population aged 65-90 years and found no differences in MRRs between women and men (1.47 versus 1.48. The study by Jacobs et al.[18] calculated, on the basis of the DaTraV dataset as well, the excessive deaths for women and men over 40 years of age in Germany. As no such data were available for Germany at that time, Jacobs et al. took the mortality rates from the Danish National Diabetes Register. The study found absolute excess deaths related to diabetes of 81,703 for women and 92,924 for men. In contrast, using the same methods but the estimated MRRs for Germany in our study, we found considerably fewer absolute excess deaths of 49,136 for women and 53,872 for men.

Consistent with our results, nationwide studies in several other countries based on diabetes registers or diabetes surveillance systems have reported a higher diabetes-related risk of all-cause mortality compared to general population or population- based controls but differ in magnitude.[4-6 8 19]

The Swedish national diabetes register and the Australian diabetes surveillance showed that the excess risk of death in association with diagnosed type 2 diabetes declined with increasing chronological age.[6 8] Although the present study could not differentiate by type of diabetes, these results are in line with our findings, since type 2 diabetes accounts for the vast majority of diabetes cases among older adults. The age-related decline in diabetes-related excess risk of all-cause mortality might be due to

the different onsets of diabetes on the life span and the associated disease durations. It may reflect increases in competing risk of death in older age groups as well as survival disadvantage in association with increased diabetes duration. In addition, the number of severe comorbidities in people with and without diabetes converges with increasing age.

With regard to sex differences in diabetes-related relative risk or excess risk of all-cause mortality, previous studies from other countries showed conflicting findings.[4 5 8] Our age-specific estimates of diabetes-related MRRs showed higher risk estimates among women than among men for persons aged 50-79. This higher risk among women declined with increasing age and diminished in the oldest age groups. This consistent pattern is comparable to a study from Australia for 2004-2010 which showed higher standardized mortality ratios (SMRs) in women than in men especially for persons aged 50-79 years and very similar SMRs for women and men aged 80 years or older (1.03 and 0.98).[8] A recently conducted systematic review and meta-analysis including 49 studies with 86 prospective cohorts showed a combined MRR of 1.93 for women and 1.74 for men with a pooled women-to-men RRR of 1.13.[7] However estimates across studies ranged from 1.24 to 3.67 in women and from 1.32 to 3.13 in men, pooled women-to-men RRR varied from 0.64 to 1.74.[7] Overall, differences in study results regarding a sex differential in excess risk of diabetes-related all-cause mortality might, at least in part, be explained by differences in the age range, underestimation of older people, time of follow-up and applied methods for risk estimation.

Prospective population-based studies are needed to obtain a deeper insight into the role of sex difference in diabetes-related mortality risks by taking relevant risk factors such as lifestyle behavior, adherence to prescribed therapy and co-morbidities into account.

Practical implications

Our findings confirm that diagnosed diabetes in Germany is still associated with a significantly elevated, several times higher risk of death among men and women, in particular in younger and middle age. This emphasizes the need for effective primary and secondary prevention. Further improvements in the early detection of diabetes,

particularly in younger ages, alongside with evidence-based treatments, could contribute to a reduction in excess mortality.

Our results open the perspective to close an important gap in diabetes surveillance in Germany, as the SHI claims dataset appears to be suitable for close monitoring of diabetes-related excess risk of death, which is a key indicator in the national diabetes surveillance system. In addition, the dataset will permit calculation of closely related indicators, including the absolute number of deaths in association with diabetes, and composite indicators of disease burden, including healthy life years and the number of years lost in association with diabetes.[20] Thus, including SHI claims data dataset will harness the potential for improved health information systems as a basis for the surveillance of diabetes and other noncommunicable diseases (NCD).

Strengths and limitations

The main strength of our analysis is the completeness of the dataset, since about 90% of the German population is covered by SHI. Mortality rates derived from the SHI claims dataset showed good agreement with data from official death statistics, which underlines the potential for generalization of our results. Our findings from sensitivity analyses support the validity of the data. We consistently showed an excess risk of all-cause mortality in association with diagnosed diabetes based on varying case definitions for diabetes.

Taken together, our results demonstrate that the DaTraV dataset could essentially contribute to close current gaps in diabetes surveillance with an overall good documentation quality of diabetes and the advantage to consider inpatient as well as outpatient data for case definition.

A great disadvantage of routine datasets based solely on documented diagnoses is that no information about undiagnosed morbidity can be drawn. National surveys with an additional HbA1c measurement in blood samples of participants show a relevant proportion of undiagnosed diabetes. Although this proportion has decreased over time, it is still relatively high [21] and at the same time is related to a slightly higher excess mortality than diagnosed diabetes.[17 22] For this reason the current routine data analysis is likely to underestimate the excess mortality in diabetes. In general, another

limitation of routine data is that this data cannot identify the ethnicity of individuals. An ethnic risk profile is being discussed for diabetes in particular.[23]

There are a number of limitations which arise from the specific construction of the DaTraV dataset, which originally served economic but not research purposes. We had to determine cases of diabetes in the data in 2013 only, in order to identify persons who died in 2014 among persons with and without diabetes. This implies that those who died with newly documented diabetes in 2014 are not detectable in the data as diabetes cases and hence will be counted as persons without diabetes. We cannot exclude that this also contributed to an underestimation of diabetes-related excess mortality. Since diabetes is a chronic disease, and long-term complications account for the majority of diabetes-related deaths, we assume that this had only little impact on our results. The planned revision of the Data Transparency Regulations in Germany could help to overcome current shortcomings.

Furthermore, the currently missing stratification of the dataset according to geographic region and social status or social deprivation should be possible in the future, hence we will be able to analyze and compare mortality trends within Germany as well as at a national level with other countries.

The present study included adults 30 years of age and older, and type 2 diabetes is likely to account for most cases of documented diabetes. Nevertheless, it will be important to overcome current limitations to differentiate between major types of diabetes in claims data. The main problem is the frequent coding of an unspecific diabetes (ICD-10: E14.-) or even diagnoses that are mutually exclusive (E10.- and E11.-) in the data.[24] A recent analysis of the here used dataset has demonstrated that including information on medication may improve assignment of unspecific diabetes codes to type 2 diabetes.[25] Among children and adolescents type 1 diabetes is the predominant type of diabetes. As insulin treatment is required here, documented insulin use is an essential part of the case definition for type 1 diabetes, and also helps to clarify diabetes definition.[26]

Conclusions

Diabetes-related risk of death is a key indicator for monitoring diabetes epidemiology and quality of diabetes care. Establishing sustainable time trends for this indicator as part of the national diabetes surveillance system in Germany is of great need, but was so far precluded by the lack of a valid and timely accessible dataset. Results of the present study demonstrate that analysis of SHI claims data may provide a solution in closing this information gap. Further research is needed to analyze and to improve the quality of the data, in particular with regard to case definitions. In this case, the SHI claims data could also serve to calculate and monitor the absolute number of diabetes-related deaths as well as composite indicators of disease burden, such as diabetes-related healthy life years and years of life lost. Stratification of SHI claims data according to geographic region and social status or social deprivation will be possible in the future, hence we will be able to analyze and compare diabetes-related mortality trends within Germany but also with international developments.[3] This will strengthen surveillance activities for the prevention and control of diabetes and other major NCD at a national level and also enhance international collaboration in diabetes and NCD surveillance and burden of disease estimates.

Footnotes

Contributors: CS, JB and CH designed the study. CS, LR and JB performed the analysis. CS, CSN and JB wrote the initial version of the manuscript. LR, RP and TZ revised the manuscript. All authors read and approved the final manuscript. All authors had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. CS is the lead author and guarantor.

Transparency declaration: The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Competing interests: All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work, no financial relationships with any organisations that might have an interest in the submitted work in the previous three years no other relationships or activities that could appear to have influenced the submitted work.

Ethics approval: This study was not approved by a research ethics committee, because our study did not meet the criteria for human subjects research.

Data sharing: The SQL code for requesting aggregated data and statistical codes available from the corresponding author at schmidtchri@rki.de.

Figure 1 Flow chart of selection of study population with excluding criteria and sample sizes.

Figure 2 Age-specific mortality rates per 100,000 persons stratified by sex for the year 2014 as obtained from official cause of death statistics (Destatis) and claims data (Datrav). The blue line indicates results from official statistics; the green line indicates results from the DaTraV dataset.

Figure 3 MRRs for persons with diabetes compared to persons without diabetes by sex and age groups. Overall estimates are adjusted using all displayed age groups.

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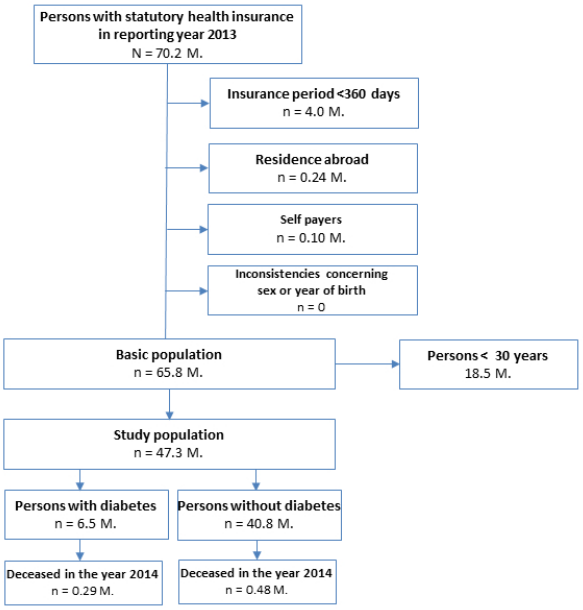

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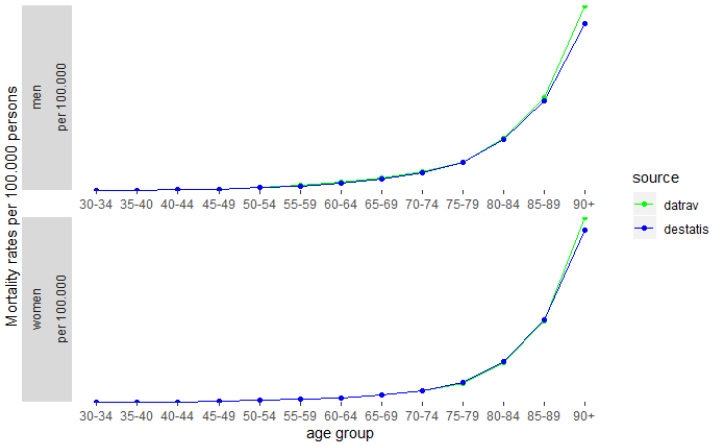

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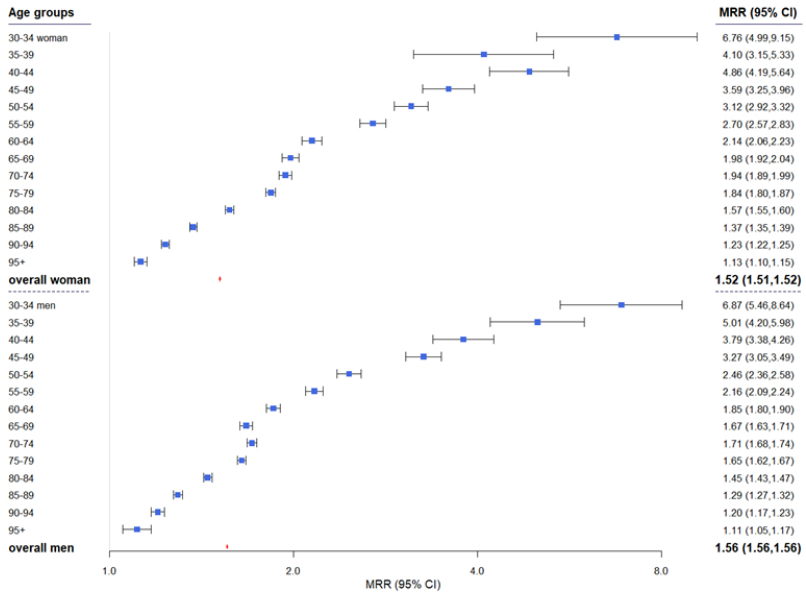

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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4,5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	2,5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2,5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6, 7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5,6
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	8,11
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-10
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	10

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10,11
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11,12
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15,16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	15,16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.