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Prevalence and temporal trend of known diabetes mellitus

Results of the German Health Interview and Examination Survey for Adults (DEGS1)

Background and purpose

Diabetes mellitus is a chronic metabolic disease, which is characterised by increased blood sugar concentrations as a result of an absolute or relative lack of insulin. An absolute lack of insulin characterises "type-1 diabetes", which manifests itself mainly during childhood or adolescence. It is caused by an autoimmune destruction of the insulin-producing beta cells of the pancreas [1]. A relative lack of insulin characterises "type-2 diabetes", which primarily occurs in adulthood. Here, the impaired glucose metabolism results from a reduced insulin effect in conjunction with inadequately compensating insulin secretion. In addition to genetic predisposition, the main risk factors include a diet related to the "Western" lifestyle, lack of exercise and associated excess weight [1, 2]. A relative lack of insulin can also develop for the first time during pregnancy, which generally subsequently disappears ("gestational diabetes"). However, a high risk remains of developing a manifest type-2 diabetes in later life [1].

Long-term increased blood sugar concentrations in the case of as-yet undiagnosed diabetes or an inadequately controlled diagnosed diabetes leads to damage of the blood vessels and peripheral nerves. This results in an increased risk of cardiovascular diseases such as heart attack and stroke, as well as of kidney failure, blindness and foot amputations [1, 3]. These health complications, in addition to the diabetes itself, lead to a lesser quality of life and reduced life expectancy of those affected [3, 4], as well as to high costs for the health care system [5].

International analyses show that the number of adults with diabetes worldwide has more than doubled in the last three decades [6]. This trend mainly reflects the increase in type-2 diabetes [2]. It is assumed that the disease has not yet been diagnosed in approximately half of those affected [7].

German studies on prevalence estimates of known diabetes are based mostly on data from regional studies, health insurance companies or general practices assessed at least 5–10 years ago (see summary in **Tab. 6**). Nationwide, population-based data on known diabetes were provided most recently via the telephone surveys "German Health Update" (GEDA) 2009 [8, 9] and GEDA 2010 [10]. There are only isolated studies on undiagnosed diabetes [11].

On the basis of data from the Health Interview and Examination Survey conducted from 2008 to 2011, the following article presents up-to-date, representative estimates regarding lifetime prevalence of known diabetes in the resident population of Germany aged 18–79 years. The temporal trend is shown in comparison with the last Health Interview and Examination Survey from 1997 to 1999. The results are presented and discussed in the context of previous studies in Germany. For the purpose of assessing the prevalence and temporal trend of undiagnosed diabetes, laboratory data that are comparable over time are required. This is currently being cross-calibrated for both surveys and is therefore not included as part of the paper.

Methods

Study design

The "German Health Interview and Examination Survey for Adults" (DEGS) is part of the health monitoring system at the Robert Koch Institute (RKI). The concept and design of DEGS are described in detail elsewhere [12, 13, 14, 15, 16]. The first wave of the survey (DEGS1) was conducted from 2008 to 2011 and

Tab. 1 Lifetime prevalence (percent, 95% confidence interval) of known diabetes according to gender and age groups. $N_{unweighted}$=7,080

Age group in years	18–39	40–49	50–59	60–69	70–79	Overall
Gender						
Female	3.7 (2.5–5.5)	4.5 (3.0–6.8)	4.0 (2.6–6.0)	10.7 (8.2–13.8)	21.8 (17.6–26.7)	7.4 (6.5–8.5)
Male	0.9 (0.3–2.3)	2.0 (1.1–3.7)	7.3 (5.3–10.1)	17.0 (13.1–21.7)	22.0 (17.6–27.2)	7.0 (6.0–8.1)
Overall	2.3 (1.5–3.4)	3.2 (2.3–4.6)	5.7 (4.4–7.2)	13.8 (11.4–16.6)	21.9 (18.7–25.5)	7.2 (6.5–8.0)

comprised interviews, examinations and tests [17, 18]. The target population comprises the residents of Germany aged 18–79 years. DEGS1 has a mixed design, which allows for both cross-sectional and longitudinal analyses. For this purpose, a random sample from local population registries was drawn to complete the sample of participants of the "German National Health Interview and Examination Survey 1998" (GNHIES98) who re-participated. A total of 8,152 persons participated, including 4,193 first-time invitees (response rate: 42%) and 3,959 revisiting participants of the GNHIES98 (response rate: 62%). In all, 7,238 persons visited one of the 180 examination centres, and 914 were interviewed only. The net sample allows for representative cross-sectional and trend analyses for the age range of 18–79 years (n=7,988, including 7,116 in examination centres) in comparison with GNHIES98 ((n=7,124) [16]. The data of the revisiting participants are suitable for longitudinal analyses.

The cross-sectional analyses on known diabetes are based on the data of 7,116 participants aged 18–79 years who completed the examination part of DEGS1. In an additional analysis, the diabetes prevalence established in this sample was compared with that in the total net sample (n=7,988), which also contained data from those surveyed by interview only. The participants of GNHIES98 (n=7,124) were included in the temporal comparison. Participants with missing data regarding diabetes diagnosis were excluded from the analyses, provided they were not taking anti-diabetics (DEGS1: n=36; GNHIES98: n=25).

Definition of known diabetes

Lifetime prevalence of known diabetes was established using the following case definition:

- Answering yes to the question "Have you ever been diagnosed with diabetes by a doctor?" as part of a standardised, computer-aided and physician-administered interview or
- Taking of anti-diabetics having been documented as part of an automated assessment of medication taken within the past 7 days.

The physician-administered interview did not include any direct questions on the type of diabetes. However, the proportion of type-1 diabetes was estimated by gathering the following additional information:

- Age at diagnosis <30 years, and
- Insulin treatment immediately after diagnosis, and
- Current insulin treatment.

In addition, women with a diagnosis of diabetes before the age of 50 years were asked in the DEGS1 whether they were pregnant at the time of diagnosis. The proportion of gestational diabetes was estimated by linking with additional information as follows:

- Diagnosis during pregnancy, and
- Not currently taking anti-diabetics, and
- No existing diabetes in the past 12 months (n=32) or in the case of missing data (n=6) or in the case of unclear answer (n=4) with regard to diabetes existing within the past 12 months: HbA1c <6.5% and glucose <7.0 mmol/l (fasting)/<11.1 mmol/l (non-fasting).

One participant that stated"diagnosis during pregnancy" was pregnant when interviewed. Because of additional information (diagnosis 3 years ago, diabetes existing in the past 12 months, current treatment with insulin and treatment immediately after diagnosis by tablet), type-2 diabetes rather than gestational diabetes was assumed in this case.

Statistical analysis

The cross-sectional and trend analyses were conducted using a weighting factor, which corrects sample deviations from the population structure (as of 31 December 2010) with regard to age, sex, region and nationality, as well as type of community and education [16]. A separate weighting factor was created for the examination part. Calculation of the weighting factor also considered the re-participation probability of the GNHIES98 participants based on a logistic regression model. For the purpose of conducting trend analyses, the data from GNHIES98 were age-adjusted to the population structure as of 31 December 2010. A non-response analysis and a comparison of selected indicators with data from census statistics indicated a high level of sample representativeness for the resident population of Germany aged 18–79 years [16]. In order to take into account both the weighting and the correlation of the participants within a community, the confidence intervals and p values were determined using the survey procedures for complex samples in SAS 9.2. Differences with p values of <0.05 were considered to be statistically significant.

Estimates of the lifetime prevalence of diabetes in cross-sectional and trend analyses are presented for the population aged 18–79 years in general, as well as stratified by gender. Additional stratification variables in the cross-sectional analyses are age, socioeconomic status, residential region and health insurance company. Socioeconomic status was determined using an index that includes information regarding school education and vocational training, professional status and net household income (weighted by household needs) and which allows classification into either the low, middle or high

status group [19]. The residential region was stratified into new federal states (including Berlin) and old federal states for the purpose of comparisons with previous surveys. For further regional differentiation, the old federal states were sub-divided into North (Schleswig-Holstein, Hamburg, Lower Saxony, Bremen), Central (North Rhine-Westphalia, Hesse, Rhineland Palatinate, Saarland) and South (Bavaria, Baden-Wuerttemberg). Health insurance companies were categorised into statutory health insurance, private health insurance as comprehensive health insurers and other health care provision (benefit aid, foreign health insurance, other entitlement, no health insurance/self-payer). In addition and analogous to earlier telephone surveys, the statutory health insurance providers were sub-divided into local health insurance funds (AOK), substitute health insurance funds, company health insurance funds and other statutory health insurance funds. By comparing non-adjusted and age-adjusted logistical regression models, the influence of age on the relationship between the respective stratification variable and prevalence of diabetes was evaluated.

Results

Prevalence of known diabetes

In total, 591 of the 7,080 participants of the DEGS1 examination part stated they had been diagnosed with diabetes by a doctor at some point. **Tab. 1** shows the corresponding lifetime prevalence of known diabetes for the population aged 18–79 years of 7.2% overall (women: 7.4%; men: 7.0%). For both sexes the prevalence increases substantially with age from under 5% amongst those under 50 years of age to around 22% in the 70- to 79-year-olds.

An analysis of the total net sample, which also included participants surveyed by means of interview only, yielded comparable results with 677 of the 7,934 participants included having a diabetes diagnosis or a lifetime prevalence overall of 7.4% (women: 7.5%; men: 7.2%).

The prevalence of type-1 diabetes was ascertained as being around 0.1% (n=8). This corresponds to a proportion of 1.1% of the total prevalence of known diabetes. The prevalence of gestational diabetes amongst women amounted to 1.2% (n=42). This corresponds to a proportion of 16.3% of the total prevalence of known diabetes amongst women.

Tab. 2 reflects a significantly higher lifetime prevalence of known diabetes for women and men of low socioeconomic status than for those of high socioeconomic status. This difference is more strongly pronounced in women than in men. While women of middle socioeconomic status also show a significantly higher prevalence than those of high socioeconomic status, there is no differ-

Abstract · Zusammenfassung

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Prevalence and temporal trend of known diabetes mellitus. Results of the German Health Interview and Examination Survey for Adults (DEGS1)

Abstract

The first wave of the "German Health Interview and Examination Survey for Adults" (DEGS1, 2008–2011) allows for up-to-date, representative prevalence estimates of known diabetes amongst the 18- to 79-year-old resident population of Germany. Temporal trends can be shown by comparing the survey findings with those of the "German National Health Interview and Examination Survey 1998" (GNHIES98). The definition of known diabetes was based on self-reports in physician-administered interviews that asked respondents if they had ever been diagnosed with diabetes by a doctor or were on anti-diabetic medication. Overall, diabetes had been diagnosed in 7.2% of the adults (7.4% of the women; 7.0% of the men). The prevalence increased substantially with advancing age and was higher in persons of low than of high socioeconomic status. Prevalence varied depending on the type of health insurance held and was highest amongst those insured with AOK health insurance funds. In comparison with GNHIES98, there was a 38% increase in prevalence, of which approximately one third is to be attributed to demographic ageing. In the context of other nationwide studies, the results indicate a figure of at least 4.6 million 18- to 79-year-olds having been diagnosed with diabetes at some point. Planned analyses of undiagnosed diabetes will contribute to the interpretation of the observed increase in the prevalence of known diabetes.

Keywords

Diabetes mellitus · Germany · Adults · Health survey · Prevalence

Prävalenz und zeitliche Entwicklung des bekannten Diabetes mellitus. Ergebnisse der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1)

Zusammenfassung

Die erste Welle der „Studie zur Gesundheit Erwachsener in Deutschland" (DEGS1, 2008–2011) ermöglicht aktuelle, repräsentative Prävalenzschätzungen des bekannten Diabetes in der 18- bis 79-jährigen Wohnbevölkerung. Im Vergleich zum „Bundes-Gesundheitssurvey 1998" (BGS98) lässt sich die zeitliche Entwicklung darstellen. Die Definition des bekannten Diabetes beruht auf Selbstangaben zu einem jemals ärztlich festgestellten Diabetes in ärztlichen Interviews oder der Einnahme von Antidiabetika. Insgesamt wurde bei 7,2% der Erwachsenen (7,4% der Frauen; 7,0% der Männer) jemals ein Diabetes diagnostiziert. Die Prävalenz steigt mit zunehmendem Alter deutlich an und ist bei niedrigem Sozialstatus höher als bei hohem Sozialstatus. Die Prävalenz variiert je nach Krankenversicherungsart und ist für Versicherte der Allgemeinen Ortskrankenkasse (AOK) am höchsten. Im Vergleich zum BGS98 zeigt sich ein Prävalenzanstieg um 38%, wovon etwa ein Drittel auf die demografische Alterung zurückzuführen ist. Die Ergebnisse weisen im Kontext mit anderen bundesweiten Studien auf aktuell mindestens 4,6 Mio. 18- bis 79-Jährige mit einer Diabetesdiagnose hin. Geplante Analysen zum nicht diagnostizierten Diabetes werden zur Interpretation des beobachteten Prävalenzanstiegs des bekannten Diabetes beitragen.

Schlüsselwörter

Diabetes mellitus · Deutschland · Erwachsene · Gesundheitssurvey · Prävalenz

Tab. 2 Lifetime prevalence (percent, 95% confidence interval) of known diabetes according to gender and socioeconomic status. $N_{unweighted}$=7,012

Socioeconomic status	Low	Middle	High
Gender			
Female	11.6 (8.6–15.5)	7.4 (6.3–8.7)	3.0 (2.0–4.5)
Male	10.1 (7.5–13.5)	6.1 (5.1–7.4)	6.2 (4.6–8.3)
Overall	10.9 (8.8–13.5)	6.8 (6.0–7.7)	4.8 (3.7–6.0)

Socioeconomic status: index that includes information on school and vocational education, professional position and net household income (weighted by household needs)

Tab. 3 Lifetime prevalence (percent, 95% confidence interval) of known diabetes according to gender and residential area. $N_{unweighted}$=7,080

Residential area	Old federal states				New federal states
	Overall	North	Central	South	
Gender					
Female	7.1 (6.0–8.4)	7.1 (4.6–10.9)	7.7 (6.3–9.4)	6.3 (4.6–8.6)	8.7 (6.7–11.3)
Male	6.9 (5.7–8.2)	6.3 (4.3–9.3)	7.5 (5.6–10.0)	6.3 (4.7–8.4)	7.5 (5.9–9.4)
Overall	7.0 (6.2–7.9)	6.7 (5.2–8.7)	7.6 (6.3–9.2)	6.3 (5.1–7.8)	8.1 (6.9–9.5)

Old federal states: North: Schleswig-Holstein, Hamburg, Lower Saxony, Bremen; Central: North Rhine-Westphalia, Hessen, Rhineland Palatinate, Saarland; South: Bavaria, Baden-Wuerttemberg

ence in prevalence between men of middle and high socioeconomic status. These results were also observed in the age-adjusted model.

In the stratification of the lifetime prevalence of known diabetes according to residential area, as shown in **Tab. 3,** there tends to be a higher prevalence for the new federal states than for the old federal states, which is more pronounced amongst women than men. Further stratification of the old federal states into North, Central and South indicates that there tends to be a higher prevalence in the Central region compared to the North or South. These observed trends, however, are not statistically significant. They remain in the age-adjusted model but are even less pronounced.

Tab. 4 shows differences in the lifetime prevalence of known diabetes depending on the type of health insurance. Statutory health insurees have a higher prevalence overall (7.5%) than those privately insured (3.8%). Amongst persons insured in statutory schemes, those covered through AOK have the highest prevalence at 9.0%, whereas those covered through company health insurance funds have the lowest prevalence at 5.9%. This pattern is also evident in the gender-stratified analysis, although the prevalence difference is less pronounced between the various statutory health insurance funds amongst women and between the statutory and the private funds amongst men. This pattern is also observed in the age-adjusted model, although the differences are less pronounced.

Trends in known diabetes

In **Tab. 5,** the lifetime prevalence of known diabetes from the earlier examination survey is compared with that from DEGS1. The lifetime prevalence observed on the basis of the GNHIES98 data (weighted to 1997 population structure) was 5.2% overall (women: 5.7%; men: 4.7%). This resulted in a significant absolute increase in prevalence over time of 2.0% (women: 1.7%; men: 2.3%) and a relative increase of 38% (women: 30%; men: 49%). A significant increase also exists after taking the demographic ageing of the population into account (weighted to 2010 population structure). This is 1.4% absolute (women: 1.3%; men: 1.6%) and 24% relative (women: 21%; men: 30%). Consequently, an absolute increase of 0.6% (women: 0.4%; men: 0.7%) and relative increase of 14% (women: 9%; men: 19%) can be attributed to demographic ageing.

Extrapolations of the GNHIES98 data show that approximately 10 years ago a total of 3.3 million of 18- to 79-year-olds living in Germany had at some point been diagnosed with diabetes. By contrast, according to the estimations based on DEGS1 data, diabetes has been diagnosed at some point in a total of 4.6 million people in this age group.

Discussion

According to the current DEGS1 data, 7.2% or 4.6 million of the 18- to 79-year-old population of Germany have at some point been diagnosed with diabetes. The lifetime prevalence of known diabetes increases substantially with age and is higher amongst those of low socioeconomic status than high socioeconomic status. Prevalence is higher in persons insured in statutory health insurance schemes—especially those insured with AOK—than it is amongst those with private medical insurance. In addition, there are indications of regional differences, especially with regard to a tendency toward a higher prevalence in the new federal states compared to the old ones. In comparison to GNHIES98, the prevalence of known diabetes has increased by 38%. An increase of 14% is to be attributed to the demographic ageing of the population.

Prevalence of known diabetes

The most recent health surveys conducted at population level as telephone interviews, GEDA 2009 and GEDA 2010, yielded a pooled lifetime prevalence of 8.7% or a figure of 5.9 million adults aged 18 years and above having been diagnosed with diabetes at some point. Limiting the GEDA data to the age range of 18–79 years results in a prevalence of 8.2%, which exceeds the observed prevalence of 7.2% in DEGS1. Conversely, a diabetes prevalence in the age group over 80 years observed in GEDA and other studies, similar in size to that in the 70–79-year age range [20, 21, 22, 23, 24, 25, 26], results in a figure of only 5.5 million adults over 18 years with known diabetes when the data are transposed onto DEGS1. This difference in size of the estimates between DEGS1 and GEDA is presumably a result of the difference in sample composition due to a different sam-

Tab. 4 Lifetime prevalence (percent, 95% confidence interval) of known diabetes according to gender and health insurance fund. $N_{unweighted}$=6,938

Health insurance fund	Statutory health insurance funds					Private health insurance funds (PKV)	Other health care provision
	Overall	Local health insurance funds (AOK)	Substitute health insurance funds (EKK)	Company health insurance funds (BKK)	Other statutory insurance		
Gender							
Female	7.8 (6.7–9.0)	8.6 (6.6–11.2)	7.3 (5.7–9.2)	6.8 (4.7–9.9)	8.9 (5.7–13.6)	1.2 (0.3–3.9)	4.7 (2.4–9.3)
Male	7.2 (6.1–8.5)	9.5 (7.4–12.0)	6.7 (5.0–8.8)	5.0 (3.2–7.7)	7.0 (4.5–10.5)	5.0 (2.8–8.7)	4.7 (2.6–8.4)
Overall	7.5 (6.7–8.4)	9.0 (7.5–10.8)	7.0 (5.9–8.3)	5.9 (4.4–7.8)	7.9 (5.7–10.8)	3.8 (2.2–6.5)	4.7 (3.1–7.0)

Tab. 5 Lifetime prevalence (percent, 95% confidence interval) of known diabetes according to gender compared over time. $N(DEGS1)_{unweighted}$=7,080, $N(GNHIES98)_{unweighted}$=7,099

Survey	GNHIES98[a]	GNHIES98[b]	DEGS1[b]
Gender			
Female	5.7 (4.8–6.7)	6.1 (5.1–7.2)	7.4 (6.5–8.5)
Male	4.7 (4.1–5.4)	5.4 (4.7–6.3)	7.0 (6.0–8.1)
Overall	5.2 (4.6–5.9)	5.8 (5.1–6.5)	7.2 (6.5–8.0)

[a]Weighted to population distribution as of 31 December 1997
[b]Weighted to population distribution as of 31 December 2010

pling procedure (local population registry sample vs. private households available via landline) and a different survey method (personal physician-administered interview vs. telephone interview). For a direct comparison, the DEGS1 data were consequently compared exclusively with the GNHIES98 data, which are the most recent data gathered by a comparable method.

The nationwide surveys conducted on a postal-written basis by the Bertelsmann Healthcare Monitor indicate a prevalence for known diabetes of 8.0% in the 18–79-year age range for 2008 [27]. This prevalence is therefore between the lifetime prevalence established in DEGS1 (2008–11) at 7.2% and that of GEDA (2008–10) at 8.2%. On the other hand, the AOK Hesse/KV Hesse sample points to a prevalence of 9.8% for insured persons of all age groups for 2009 [5] (18- to 79-year-olds, excluding in-patient care cases: 10.2%), which is higher than the prevalence found in GEDA (2008–2010) for adults aged 18 years and above at 8.7% (18- to 79-year-olds: 8.2%). This expected difference is, however, in agreement with the present observations from DEGS1 and other current analyses [27, 28], according to which persons insured with AOK have the highest prevalence of diabetes when compared to those otherwise insured. In addition to deviations in age structure, which can largely be taken into account in age-standardised analyses, differences in educational status and in the existence of co-morbidities play a role here [29].

The results of further studies regarding known diabetes in Germany that are shown in **Tab. 6** are not comparable with the current results because the study periods were before the DEGS1 period. Regarding the relatively high prevalence of known diabetes in the patient samples of general practices, it should be noted that more people with diagnosed diabetes are to be expected amongst the practice patients than in the general population. Overall and similarly to DEGS1, the studies summarised in **Tab. 6**—in addition to the aforementioned differences depending on the type of health insurance—point toward a clear increase in prevalence with increasing age, especially from the age of 50 years onwards [8, 20, 21, 22, 23, 24, 25, 26, 28, 30, 31, 32, 33, 34, 35, 36, 37], as well as social differences [8, 27] and regional trends [8, 10, 27, 32] in the prevalence of diabetes.

Data regarding the prevalence of type-1 diabetes are only to be found in a few patient samples [25, 37, 38]. The proportion of type-1 diabetes of the respective overall prevalence of known diabetes in these samples is between approximately 3% and 6% and is therefore higher than the DEGS1 figure of about 1%. Given this difference in size, the rather conservative estimation of type-1 diabetes prevalence in DEGS1 by using the available information, along with variations in study design, has to be taken into account. Data on the prevalence of gestational diabetes were not reported in any of the studies summarised in **Tab. 6**.

Temporal trends in known diabetes

The first time series for Germany regarding the prevalence of known diabetes is based on data from the diabetes register of the former GDR, which existed between 1960 and 1989. For this period, a continual increase in prevalence from 0.6% to 4.1% was observed, which was mostly attributable to the increase in prevalence in the over 50-year age group [20, 39]. Data on the prevalence trend in the old federal states do not exist for this period.

For the subsequent period until about 2000, based on the data from population-based studies, there is no evidence of a further increase in prevalence. No trend in diabetes prevalence was observed either in the surveys conducted as part of the German Cardiovascular Prevention Study in the old federal states for 25- to 69-year-olds between 1984–1986 and 1990–1991 [31] or in the KORA/MONICA surveys in the Augsburg region for 25- to 64-year-olds between 1984–1985 and 1999–2001 or for 25- to 74-year-olds between 1989–1990 and 1999–2001 [35]. Similarly, the comparison of data from the nationwide examination surveys

Tab. 6 Overview of studies in Germany with data on the prevalence of known diabetes in adults

Study population		Period (Standardisation)	Definition of diabetes	Prevalence of diabetes
Nationwide interview and examination survey				
DEGS1; 18–79 years, N=7.080 (**Tab. 4**, **Tab. 5**)	Representative survey of resident population in Germany	2008–2011 (31/12/2010)	Self-report on physician-diagnosed diabetes or anti-diabetic medication	Overall: 7.2% (women: 7.4%, men: 7.0%) Type-1: 0.1%, Gestational diabetes/ women: 1.2% AOK: 9.0%; EKK: 7.0%; BKK: 5.9%; other statutory insurance: 7.9%; PKV: 3.8%; other provision: 4.7%
GNHIES98; 18–79 years, N=7.099 (**Tab. 5**) [30][a]		1997–1999 (31/12/1997)		Overall: 5.2% (women: 5.7%, men: 4.7%)
East/West Health Survey 91, representative survey of residential population in the new and old federal states; 25–69 years, N≈7.450 [30]		1990–1992 (1991)	Self-report on diabetes diagnosis	Women: 4.7%, men: 5.0%
German Cardiovascular Prevention Study, representative survey of residential population in the old federal states; 25–69 years, N≈5.000 (per survey) [31]		1990/91, 1987/88, 1984–1986 (1984)		1990/1991: women: 4.1%, men: 4.6% 1987/1988: women: 3.8%, men: 5.3% 1984–1986: women: 4.6%, men: 4.5%
Nationwide telephone survey				
GEDA 2010; 18+ years, N=22.050 [10]	Representative survey of German speaking resident population in Germany available via land-line telephone	2009/2010 (31/12/2008)	Self-report on physician-diagnosed diabetes	Overall: 8.6% (women: 8.8%; men: 8.5%)
GEDA 2009; 18+ years, N=21.262 [8, 9]		2008/2009 (31/12/2007)		Overall: 8.8% (women: 9.3%, men: 8.2%)
GSTel03; 18+ years, N=8.318 [8, 9]		2002/2003 (31/12/2001)		Overall: 6.1% (women: 6.8%, men: 5.4%)
GSTel03, GSTel04 (pooled); 18+ years, N=15.354 [28]		2002–2004 (31/12/2001)		Overall: 6.5% AOK: 10.1%; EKK: 5.6%; BKK: 4.7%; other statutory insurance: 6.6%; PKV: 4.8%
Nationwide postal survey				
Bertelsmann Healthcare Monitor, representative survey of German-speaking resident population in Germany; 18–79 years, N=15.089 (N≈1.500 per survey) [27]		2004–2008	Self-report on diabetes diagnosis (≥1 physician visit per quarter or regular use of medication	Overall 6.9% (women: 5.8%, men: 8.0%) 2008: 8.0%, 2007: 7.2%, 2006: 6.5%, 2005: 6.4%, 2004: 6.2% AOK: 11.4%; Barmer: 8.5%; DAK: 6.5%; BKK: 5.9%; TKK: 5.8%; PKV: 4.6%; IKK: 3.9%; other provision: 5.2%
Registry data				
Diabetes register of the former GDR; All age groups, total population [20, 39]		1960–1989	Physician-diagnosed diabetes	1989: 4.1% 1987: 4.0% 1960: 0.6%
Diabetes register of the former GDR; All age groups, population of East Berlin [47]		1960–1989		1988: 3.8% (women: 4.5%, men: 3.0%) 1970: 2.5%
Regional study				
Rural Health Study, sample from randomly selected north-east German rural communities; 18+ years, N=1.246 (2004/08), N=2.155 (1994), N=3.603 (1973) [48]		2004/2008, 1994, 1973 (2004/08)	Self-report on diabetes diagnosis	2004/2008: women: 12.4%, men: 12.8% 1994: women: 10.9%, men: 6.8% 1973: women: 3.5%, men: 3.1%
DIAB-CORE Consortium including GNHIES98 (1997–99) and the regional studies CARLA (2002–06), DO-GS (2003/04), HNR (2000–03), KORA S4 (1999–2001), SHIP (1997–2001); 45–74 years, N=15.071 [32]		1997–2006 (31/12/2007)	Self-report on diabetes diagnosis or anti-diabetic medication and age at diagnosis >30 Years	Type-2: 8.6% GNHIES98: 8.2%; CARLA: 12.0%; DO-GS: 9.3%; HNR: 7.2%; KORA: 5.8%; SHIP: 10.9%
KORA F4 (follow-up), cohort study in the Augsburg region; 35–59 years, N=1.653 [33]		2006–2008 (31/12/2007)	Self-report on physician-diagnosed diabetes or anti-diabetic medication (verified)	Overall: 2.2% (women: 2.3%, men: 2.2%)
KORA S4, survey in the Augsburg region; 55–74 years, N=1.353 [34]		1999–2001 (31/12/2000)		Overall: 8.7% (Women: 8.0%, Men: 9.3%)

Tab. 6 Overview of studies in Germany with data on the prevalence of known diabetes in adults (Continued)

Study population	Period (Standardisation)	Definition of diabetes	Prevalence of diabetes
MONICA/KORA, surveys in the Augsburg region; 25–64 years (19984/85), 25–74 years (subsequent surveys), N≈2.000 (per survey) [35]	1999–2001, 1994/95, 1989/90, 1984/85 (31/12/2000)	Self-report on physician-diagnosed diabetes or anti-diabetic medication	25–64 years: 1999–2001: women: 2.7%, men: 2.5% 1994/1995: women: 2.5%, men: 3.0% 1989/1990: women: 2.3%, men: 3.6% 1984/85: women: 2.0%, men: 2.7% 25–74 years: 1999–2001: women: 3.5%, men: 3.7% 1994/1995: women: 3.7%, men: 4.1% 1989/90: women: 3.6%, men: 4.6%
EPIC-Potsdam, baseline examination of a cohort study in the Potsdam region; 35–59 years, N≈27.500 [11]	1994–1998 (2007)	Self-report on physician-diagnosed diabetes or diabetic therapy	Women: 2.6%, men: 3.7%
Sample from randomly selected towns and rural areas in 5 federal states; 18–70 years, N=2.150 [36]	1993–1996	Self-report on diabetes diagnosis or diabetes therapy	Overall: 6.3%
Study on early detection of diabetes in Munich; All age groups, N≈790.000 [49]	1967/1968	Self-report on diabetes diagnosis	Overall: 2.0%
Health insurance fund data			
AOK Hesse/KV Hesse Statutory Health Insurance Sample; All age groups, N≈300.000 per annum [5]	2000–2009 (31/12/2009)	Physician-diagnosed diabetes (in ≥3 of 4 quarters) or prescription of anti-diabetic medication (≥2 per annum or 1 per annum plus diabetes diagnosis or plus glucose- or HbA1c-measurement in the same quarter)	2009: 9.8% 2000: 7.5%
AOK Hesse/KV Hesse Statutory Health Insurance Sample; All age groups, N≈300.000 per annum [50]	2000–2007 (31/12 of the previous year)		2007: 8.9% 2000: 6.5%
AOK Hesse/KV Hesse Statutory Health Insurance Sample; All age groups, N≈300.000 per annum [21, 22]	1998–2004 (31/12 of the previous year)		2004: 7.9% (women: 8.1%, men 7.6%) 2001: 6.9% (women: 7.4%, men: 6.5%) 1998: 5.9%
Sample of insured persons from six statutory health insurance funds; All age groups, N=14.7 million [23]	1999	Diabetes diagnosis or prescription of anti-diabetic medication	Overall: 6.5%
Sample of insured persons from the AOK-Dortmund; All age groups, N=6.478 [24]	1988 (1988)	Physician-diagnosed diabetes (in ≥2 of 4 quarters) or prescription of anti-diabetic medication (≥4 per annum) or blood glucose measurement (in ≥3 of 4 quarters)	Overall: 4.8% (women: 5.5%, men: 4.1%)
Patient data			
GEMCAS, national sample of patients from general practices; 18+ years, N=35.869 (N=1.511 practices) [25]	2005 (2003)	Physician-diagnosed diabetes	Overall: 11.8% Type-1: 0.7%, Type-2: 11.1%
DETECT study, national sample of patients from general practices; 18+ years, N=55.518 (N=3.188 practices) [37]	2003	Physician data on diabetes diagnosis on day of study or anti-diabetic medication	Overall: 15.2% Type-1: 0.5%, Type-2: 14.7%
ESTHER, sample of patients from health check-ups in general practices in the Saarland; 50–74 years, N=9.953 [51]	2000–2002	Physician-diagnosed diabetes or anti-diabetic medication	Overall: 13.8%
HYDRA-study, national sample of patients from general practices/internists in private practice; 16+ years, N=43.549 (N=1.912 practices) [26]	2001	Physician data on diabetes diagnosis on day of study	Overall:15.6% (women: 13.7%, men: 18.5%)
SESAM 2, sample of patients from general practices in Saxony; 2–102 years, N=8.877 (N=270 practices) [38]	1999/2000 (2000)	Physician-diagnosed diabetes	Overall: 9.2% Type-1: 0.3%, Type-2: 6.2%, Other types: 1.8%, types not further specified: 1.0%

[a]Deviation in the data in Thefeld et al. [30] from **Tab. 5** is a result of the non-consideration of anti-diabetic medication in the definition of diabetes

shows no increase in prevalence for the 25- to 69-year-old population between 1990–1992 and 1997–1999 [30]—neither for the new nor for the old federal states [40]. Furthermore, no trend can be seen in an extension of this comparison over time that includes the data from the telephone health surveys of 2002–2005 [40].

A comparison of the DEGS1 data with those from GNHIES98 as described in the results section, indicates, in agreement with other current investigations, an increase in the prevalence of known diabetes within the last decade. The increase for the 18- to 79-year-old population amounts to 38% on the basis of the examination surveys performed between 1997–1999 and 2008–2011 and 29% on the basis of the Bertelsmann Healthcare Monitor survey between 2004 and 2008 [27]. For adults aged 18 years and above, an increase of 43% can be observed based on the telephone surveys between 2002–2003 and 2008–2010 and 49% based on the AOK Hesse/KV Hesse sample of insured persons between 2000 and 2009 [5]. A greater increase is evident in men than in women: In the examination surveys this amounts to 49% versus 30%, in the telephone surveys 54% versus 34% and in the sample of insured persons 57% versus 40%. In addition, data analysis of the examination surveys shows—in accordance with the results of the AOK Hesse/KV Hesse sample of insured persons [5]—that approximately one third of the increase observed can be attributed to demographic ageing within the observation period.

Projections of the prevalence of known type-2 diabetes for the year 2030—which are calculated on the basis of the diabetes prevalence data of population-based regional studies and of GNHIES98 (DIABCORE Consortium), diabetes incidence and mortality data from the Augsburg region (KORA S4/F4) and the Federal Statistical Office population forecast—show an increase of approximately 1.5 million persons for the 55- to 74-year-olds alone (+64%) compared to today [41]. A more pronounced increase of almost 1 million people was projected for men (+79%) than for women at over 0.5 million people (+47%).

Factors relevant to the interpretation of the prevalence of known diabetes

The magnitude of known diabetes is dependent on the ratio of diagnosed-to-undiagnosed cases. Isolated analyses to estimate this ratio lead to different results owing to differing study populations and study periods and especially owing to varying diagnosis criteria. Results of the oral glucose tolerance test as part of the KORA Study in the Augsburg region indicate a prevalence of undiagnosed diabetes (defined as fasting glucose ≥7.0 mmol/l or glucose following the oral glucose tolerance test ≥11.1 mmol/l) that is just as high as that of diagnosed diabetes [33, 34]. On the contrary, preliminary evaluations from DEGS1, in which no oral glucose tolerance test was conducted but in which laboratory values exist for fasting glucose (48% of the sample) or random glucose and for HbA1c, indicate a prevalence of undiagnosed diabetes (defined as HbA1c ≥6.5% or fasting-glucose ≥7.0 mmol/l or random-glucose ≥11.1 mmol/l) [42] that is more than three times lower than that of known diabetes. In earlier studies in which no oral glucose tolerance test was conducted, the prevalence of undiagnosed diabetes based on various criteria was also substantially lower than the prevalence of diagnosed diabetes [25, 30, 36].

The ratio of diagnosed-to-undiagnosed diabetes can shift over the course of time. Thus, improved screening methods, increased attention by doctors (for example through the introduction of disease management programmes) and improved knowledge about symptoms on the part of the patients all lead to the earlier discovery of persons with diabetes. Consequently, the proportion of diagnosed cases increases whilst the proportion of undiagnosed cases falls. Thus, data on the trend in undiagnosed diabetes, which are gathered over time using comparable methods, are essential for the interpretation of the trends observed in known diabetes. However, there are no such data yet for Germany [11]. Planned comparative analyses of DEGS1 and GNHIES98 will be able to provide an indication of this for the first time.

The prevalence of known diabetes—and also that of undiagnosed diabetes—is furthermore dependent on the incidence and mortality rates. The incidence rate is closely linked with behaviour (such as diet, physical activity and associated body weight) and living conditions (such as personal or regional economic factors, air pollution), which play a role in the development of diabetes [2]. This means that the observed increase in obesity [43], the main risk factor for diabetes, will probably as a consequence lead to an increase in the incidence of diabetes. In addition to general life expectancy, the mortality rate of persons with diabetes is associated with treatment intensity or rather treatment success. Thus, given a higher general life expectancy and improved treatment possibilities, a higher prevalence would also be expected. So far, population-based data on incidence and mortality—other than from the diabetes register of the former GDR—are only available from the Augsburg region [44, 45].

The monitoring data of the RKI will also be able to contribute towards estimating nationwide diabetic incidence and mortality and temporal trends therein.

Strengths and limitations

The strengths of this study lie in the population representativeness of the prevalence estimates for the German resident population aged 18–79 years, and in the comparability of the prevalence figures at two points in time more than 10 years apart due to identical sampling and definition of known diabetes. Estimates of prevalence and extrapolations for the population are made possible by weighting the results with complex weighting factors, which take into account the complex design of the study, the non-response, and re-participation of the GNHIES98 participants [15, 16]. The limitations of this study are that the population aged 80 years and above and certain groups of people (especially care-home residents and severely ill persons) could not be included representatively in the examination survey. In addition, no comprehensive assessment of disease development is possible since the estima-

tions here are limited to already diagnosed diabetes. Furthermore, the definition of known diabetes is mainly based on self-reports by participants, which could, however, be evaluated as a relatively valid source for the purpose of ascertaining diagnosed diabetes [46].

Conclusion and outlook

The results of DEGS1 and of other recent nationwide surveys indicate a figure of at least 4.6 million 18- to 79-year-old adults in Germany having been diagnosed with diabetes at some point. Particularly affected are persons aged 50 years and older, as well as people with a low socioeconomic status. Within the last decade, the number of adults with known diabetes has increased by 38%, of which approximately one third can be attributed to the demographic ageing of the population. Planned analyses on the temporal trend in undiagnosed diabetes and on the incidence and mortality rates will contribute to the interpretation of these results.

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