ABSTRACT

Introduction We aim to project the number of people with diagnosed type 1 diabetes in Germany between 2010 and 2040.

Research design and methods We first estimate the age-specific and sex-specific incidence and prevalence of type 1 diabetes in Germany in 2010 using data from 65 million insurees of the German statutory health insurance. Then, we use the illness-death model to project the prevalence of type 1 diabetes until 2040. We alter the incidence and mortality underlying the illness-death model in several scenarios to explore the impact of possible temporal trends on the number of people with type 1 diabetes.

Results Applying the prevalence from 2010 to the official population projections of Germany's Federal Statistical Office yields a total number of 252,000 people with type 1 diabetes in Germany in 2040 (+1% compared with 2010). Incorporating different annual trends of the incidence and mortality in the projection model results in a future number of people with type 1 diabetes between 292,000 (+18%) and 327,000 (+32%).

Conclusions For the first time in Germany, we provide estimates for the incidence, prevalence, and number of people with diagnosed type 1 diabetes for the whole German population between 2010 and 2040. The relative increase of the people with type 1 diabetes ranges from 1% to 32% in 2040 compared with 2010. The projected results are mainly influenced by temporal trends in the incidence. Ignoring these trends, that is, applying a constant prevalence to population projections, probably underestimates future chronic disease numbers.

INTRODUCTION

Worldwide, chronic disease burden rises dramatically.1 As one of the most common chronic diseases in Germany, diabetes mellitus causes suffering among diagnosed people as well as tremendous costs for the overall population.1–4 Without a structured self-management plan, monitoring blood glucose level, physical activity, diet and, most important, without daily insulin treatment, people with type 1 diabetes (T1D) are at high risk of premature death.5 Although defined as autoimmune disease with an onset at ages younger than 35 years,6,7 the disease is nowadays prevalent among the whole age range.1,7,8 In 2009 in Germany, estimates of the prevalence of T1D for girls and boys younger than 19 years were 0.17% to 0.19%, respectively. The prevalence among women and men aged between 20 and 79 years was estimated between 0.28% and 0.39% and among elderly, that is, older than 80 years, between 0.47% and 0.50%.9,10 Reports of the total number of people with T1D in Germany range from 256,000 to 375,000 in 2009 and 2016, respectively.2,9 Approximately 7200 people per year are newly diagnosed.2,9 Similar to trends observed over the past decades, the T1D incidence and prevalence are expected to rise further.1

Despite the high relevance of T1D and its considerable health and economic consequences,5 representative studies that investigate the population-wide current and future disease burden in Germany are sparse.1,2 The generalizability of previous studies to Germany is impaired due to their focus on particular age ranges and/or their restriction to data from selected health
insurances, and cohorts. Additionally, although there is evidence that diabetes type-specific interventions help in reducing complications and mortality, many existing analyses do not distinguish the diabetes types. This makes the need for type-specific analyses of the current and future burden of T1D even more compelling.

In this article, we provide nationally representative estimates of the age-specific and sex-specific T1D incidence in Germany in 2010. Furthermore, we project the age-specific and sex-specific prevalence and the number of people diagnosed with T1D from 2010 to 2040.

**METHODS**

Based on published data from 65 million insurees of the German statutory health insurance, we first estimated the age-specific and sex-specific incidence of diagnosed T1D in Germany in 2010 for all ages between 0 and 100 years. Using mathematical relations between prevalence, incidence, and mortality based on the illnes-death model (IDM), we projected the future age-specific prevalence of T1D between 2010 and 2040. In this second step, we compared several scenarios regarding possible temporal trends in the incidence and mortality. To calculate the number of people with diagnosed T1D in each year, we finally multiplied the projected prevalence to the projected distribution of the German population issued by the German Federal Statistical Office (FSO). The following paragraphs provide more details about these three steps.

All methods were implemented using the free statistical software R, V.4.1.0 (The R Foundation for Statistical Computing). The source code and data for running the analysis are published in the open-access repository Zenodo. We only used published data on aggregated level.

**Definition of type 1 diabetes**

To define T1D, we refer to the International Classification of Diseases (ICD) coding provided in the underlying claims data which is commonly used to specify a particular type of diabetes. The aggregated prevalence data, provided by the German Institute for Medicine Documentation and Information in 2012, contains information from about 65 million policyholders from the inpatient and outpatient sector insured for at least 360 days per year by one of the German statutory health insurances. This represents >80% of Germany’s overall resident population. Accordingly, the data can be considered a unique and suitable information source that enables nationwide representative estimates of diagnosed diabetes in Germany. For instance, the Robert Koch Institute features the same data for estimating the overall incidence of diabetes in Germany. Generally, the ICD-code E10.- specifies a T1D diagnosis. Since in some cases, the data report multiple diagnoses for the same individual, the combination of the ICD-codes E14.- (unspecified diabetes mellitus) and E10.- also resulted in the assignment to T1D. Any other ICD coding or unclear code combination were excluded.

**Estimation of the age-specific T1D incidence in 2010**

To estimate the age-specific and sex-specific T1D incidence in Germany in 2010, we applied a partial differential equation (PDE), which describes the relation between prevalence, incidence and mortality as a function of age and calendar time (see online supplemental material). This requires prevalence input data for 2 years, information on the general mortality, and on the mortality rate ratio (MRR), that is, the ratio of the mortality rates of people with versus without T1D. The aforementioned claims data provide aggregated, age-specific and sex-specific information on the number of people in Germany along with their respective diabetes status (ie, diagnosed with T1D vs no T1D) for the two consecutive years 2009 and 2010. Knowing that the prevalence is the proportion of a particular population found to be affected by a certain condition (here, T1D vs no T1D) at a specific time (here, 2009 and 2010), we analogously calculated the overall and the age-stratified T1D prevalence for each sex for 2009 and 2010 using our input data. To do so, we divided the number of T1D diagnoses in Germany by the total German population number for both years on overall and age-specific level, respectively. We obtain the general mortality of the German population as of 2010 from the population projections of the German FSO. Due to unavailability of the T1D-related MRR in Germany, we align with other diabetes-related work, and refer to age-specific and sex-specific estimates from Denmark as the two countries’ MRRs are claimed highly comparable. Due to inconsistencies in coding of diagnoses, we approximated the course of the T1D incidence in Germany for ages 35+ years (see online supplemental material). For that purpose, and due to a lack of appropriate alternative data from Germany, we used information from the Danish National Diabetes Register. In Denmark, the T1D incidence rate in ages 35+ years decreases logarithmically with age. This resembles the German diabetes burden estimated in previous studies, where the proportion of T1D among all diabetes types peaks among the youth and decreases with increasing age. Since the erroneous coding occurred among older ages and since often latent autoimmune diabetes in adults (LADA) commonly showing in patients over 35 years is diagnosed as T1D, the chosen age cut-off seems reasonable.

**Projection of the age-specific T1D prevalence and future number of people with T1D**

We use the aforementioned PDE to project the age-specific and sex-specific prevalence of T1D in Germany between 2010 and 2040 (see online supplemental material). Solving the PDE returns the age-specific prevalence for each year depending on the incidence and MRR. Since information on current and future trends
of the incidence and mortality are scarce in Germany, we assumed five hypothetical scenarios that have been discussed in previous projections of T1D and T2D in Germany. Scenario 1, a ‘simple’ sex-specific and age-specific prevalence extrapolation, assumes a constant age-specific prevalence between 2015 and 2040 and neither reflects on the incidence nor on the mortality. In scenarios 2–5, we alter the temporal trends of the incidence and MRR. We consider scenario 2 as baseline scenario, assuming constant incidence and mortality. In the future, it is likely that the mortality rate among people with T1D will decrease faster than among people without T1D due to probable advancements in medical care. Consequently in scenarios 3–5, we anticipate that the MRR decreases by 2% per year as observed in Denmark. Furthermore, scenario 3 assumes a constant incidence rate, while scenarios 4 and 5 assume an annual increase and decrease of 0.5%, respectively.

We obtain the number of people with T1D in Germany between 2010 and 2040 for all ages between 0 and 100 by multiplying the projected prevalence from the PDE with the number of people from the population projections of the FSO. The FSO releases several variants wherein they assume different future birth rates, life expectancies at birth, and migration. We consider a rather realistic version (variant B1L2M1) which assumes declining fertility (B1: birth rate of 1.4 children per woman), moderate developments in life expectancy (L2: life expectancy of 84.4 and 88.1 years for men and women, respectively), and low long-term net migration (M1: 147000 people per year). This aligns with Tönnies et al. and Voeltz et al., who also examine this variant in their projections of type 2 diabetes (T2D) in Germany.

**Sensitivity analyses**

Model assumptions and data sparsity might hamper the projection of future prevalence. Precise information about temporal trends of the incidence and mortality in Germany are lacking. Since these rates can emerge very heterogeneously, we assessed further, relatively extreme scenarios which may cover possible unexpected developments. First, we evaluated an annual decrease in the incidence of 5% as observed among older ages in Denmark between 1996 and 2016. In contrast to a lower incidence, researchers postulated that the SARS-CoV-2 virus might damage cells in the pancreas that produce insulin, which may notably increase the risk of new-onset T1D. Although data on a relation between SARS-CoV-2 and T1D remain heterogeneous, assessed a 5% annual increase in the incidence as observed in European children younger than 5 years between 2005 and 2020. In addition, we performed a Monte Carlo simulation with 500 bootstraps to account for possible sampling error of the input values and to calculate 95% CIs (see online supplemental material). Furthermore, we assess the impact of alternative variants of the FSO population projections (see online supplemental material).

**RESULTS**

**Estimated incidence**

Figure 1 visualises the age-specific and sex-specific estimates of the German T1D incidence in 2010. Across all ages, the T1D incidence is estimated higher for men than women. For both sexes, the incidence peaks between 5 and 15 years of age with approximately 0.17 for men and 0.12 for women per 1000 person-years. For all following ages, the estimated course declines.

**Projected prevalence**

Figure 2 shows the estimated age-specific and sex-specific prevalence for Germany in 2009 and 2010. For any age below 80 years, the prevalence of T1D is higher among men compared with women. Among the elderly, the relationship between prevalence and sex does not remain that obvious.

Figure 3 shows the projected age-specific and sex-specific T1D prevalence for five scenarios of the incidence and MRR from 2010 to 2040 assuming moderately increasing life expectancy. For almost any age, the prevalence of T1D for men is slightly higher than for women. Particularly noteworthy is the shift in the course of the prevalence. In 2040, the prevalence is estimated to peak at around 40 years of age for both sexes, while the prevalence decreases among older age groups compared with 2010. Compared with scenario 1 assuming a constant prevalence, results for all other scenarios suggest a substantial increase in the overall prevalence for men and women (online supplemental figure S2). The different variants of the FSO had no remarkable influence on the prevalence projection (online supplemental figure S4).
Projected number of people with T1D

Figure 4 and table 1 show the projected number of people with T1D in Germany in 2010 and 2040 and approximate CIs for several scenarios of the incidence and MRR. Coherently, as for the prevalence, the number of men diagnosed with T1D is higher than the number of women throughout the overall projection horizon. Assuming that the prevalence remains as in 2010 (scenario 1), overall numbers are projected to increase by 1% to a total of 252,000 people with T1D in 2040. For scenarios 2–5, the number of people with T1D in Germany in 2040 is projected to increase by 44,000 people (+18%) to 78,800 people (+32%) compared with 2010. Compared with a relatively linear course for scenario 1, the course of the estimated case numbers for scenarios 2–5 resembles a J-shaped growth pattern in the first few years and then grows linearly for men and women alike. The FSO population variants had minor impact (see online supplemental material).

Sensitivity of the results

Additionally, we assessed an annual change of the incidence of −5% and +5%. Comparing 2010 and 2040, we obtain a decrease of the population with T1D of −27,500 (−11%) and an increase of almost 300,000 (+121%), respectively. Possible sampling error of the input values had minor impact and led to deviations of 5%–7% for women and men (see online supplemental material).

DISCUSSION

The aim of this study was to project the number of people with T1D in Germany between 2010 and 2040. For this purpose, we first estimated the age-specific and sex-specific incidence in 2010. Then, we projected the age-specific and sex-specific prevalence and the number of individuals with T1D for each year until 2040. Overall, our results indicate a general increase in the future burden of T1D.
Comparing different scenarios of disease-specific rates, we found considerable differences in the projected population with T1D. In scenario 1, we estimated an increase in the population with T1D of 1% in 2040 compared with 2010. In this scenario, we simply applied the constant sex-specific and age-specific prevalence of T2D from 2010 to future population distributions projected by the German FSO. Although this approach is commonly used for chronic disease projections, it appears that ignoring temporal trends in the prevailing epidemiological situation likely leads to misleading results since the future development of a disease is influenced by various disease-specific aspects. More precisely, disregarding potential changes in mortality and incidence as is done in scenario 1 may provoke an underestimation of future T1D cases in Germany. Contrastingly, reflecting on changes in epidemiological indicators such as mortality and incidence likely produces more reliable projection results. This was done in scenarios 2–5, where the use of the PDE enables to additionally account for disease-specific information when modeling the future prevalence of T1D. Considering scenarios 2–5, which take temporal trends in the incidence and mortality into consideration, results ranged from 44,000 (+18%) to 78,800 (+32%) additional people with T1D in 2040. Unfortunately, there are no data available to validate our projected results and/or pinpoint the most plausible scenario. Nonetheless, the general increase observable across all scenarios highlights the importance of intensified diabetes-related public health management and the need for more resources.
### Table 1  Number of people with T1D (in thousands) in Germany in 2010 and 2040 for variant B1L2M1, 95% CIs for case numbers in 2040 as well as absolute and relative change comparing 2010 vs 2040

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Annual trend in MRR (%)</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>−2</th>
<th>−2</th>
<th>−2</th>
<th>−2</th>
<th>−2</th>
<th>−2</th>
<th>(constant prevalence)</th>
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<tbody>
<tr>
<td>Men</td>
<td>Annual trend in incidence (%)</td>
<td>0</td>
<td>−0.1</td>
<td>−0.5</td>
<td>+0.1</td>
<td>+0.5</td>
<td>+5</td>
<td>−5</td>
<td>0</td>
<td>−0.1</td>
<td>−0.5</td>
<td>+0.1</td>
<td>+0.5</td>
<td>+5</td>
</tr>
<tr>
<td>2010</td>
<td>137</td>
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<td>137</td>
<td>137</td>
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<tr>
<td>2040</td>
<td>149</td>
<td>148</td>
<td>143</td>
<td>151</td>
<td>156</td>
<td>266</td>
<td>104</td>
<td>162</td>
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<td>155</td>
<td>163</td>
<td>169</td>
<td>281</td>
<td>115</td>
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<tr>
<td>95% CI</td>
<td>133 to 154</td>
<td>131 to 152</td>
<td>127 to 147</td>
<td>134 to 155</td>
<td>139 to 160</td>
<td>237 to 260</td>
<td>92 to 112</td>
<td>145 to 160</td>
<td>143 to 159</td>
<td>139 to 154</td>
<td>146 to 162</td>
<td>151 to 167</td>
<td>251 to 268</td>
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<td>11</td>
<td>5</td>
<td>13</td>
<td>19</td>
<td>129</td>
<td>−33</td>
<td>24</td>
<td>23</td>
<td>18</td>
<td>26</td>
<td>32</td>
<td>144</td>
<td>−22</td>
</tr>
<tr>
<td>Relative change</td>
<td>+9%</td>
<td>+8%</td>
<td>+4%</td>
<td>+10%</td>
<td>+14%</td>
<td>+94%</td>
<td>−24%</td>
<td>+18%</td>
<td>+17%</td>
<td>+13%</td>
<td>+19%</td>
<td>+23%</td>
<td>+105%</td>
<td>−16%</td>
</tr>
<tr>
<td>Women</td>
<td>2010</td>
<td>111</td>
<td>111</td>
<td>111</td>
<td>111</td>
<td>111</td>
<td>111</td>
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<td>111</td>
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</tr>
<tr>
<td>2040</td>
<td>143</td>
<td>142</td>
<td>136</td>
<td>144</td>
<td>150</td>
<td>258</td>
<td>98</td>
<td>151</td>
<td>149</td>
<td>144</td>
<td>152</td>
<td>158</td>
<td>267</td>
<td>105</td>
</tr>
<tr>
<td>95% CI</td>
<td>128 to 143</td>
<td>127 to 141</td>
<td>122 to 137</td>
<td>129 to 144</td>
<td>134 to 149</td>
<td>230 to 247</td>
<td>88 to 102</td>
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<td>135 to 144</td>
<td>130 to 139</td>
<td>137 to 147</td>
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<tr>
<td>Absolute change</td>
<td>32</td>
<td>31</td>
<td>26</td>
<td>33</td>
<td>39</td>
<td>147</td>
<td>−13</td>
<td>40</td>
<td>38</td>
<td>33</td>
<td>41</td>
<td>47</td>
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<tr>
<td>Relative change</td>
<td>+29%</td>
<td>+28%</td>
<td>+23%</td>
<td>+30%</td>
<td>+35%</td>
<td>+132%</td>
<td>−11%</td>
<td>+36%</td>
<td>+35%</td>
<td>+30%</td>
<td>+37%</td>
<td>+42%</td>
<td>+141%</td>
<td>−5%</td>
</tr>
<tr>
<td>2040</td>
<td>292</td>
<td>289</td>
<td>279</td>
<td>295</td>
<td>307</td>
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<td>202</td>
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<td>299</td>
<td>315</td>
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<tr>
<td>95% CI</td>
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<td>258 to 293</td>
<td>248 to 284</td>
<td>262 to 298</td>
<td>273 to 309</td>
<td>466 to 507</td>
<td>180 to 213</td>
<td>280 to 305</td>
<td>278 to 303</td>
<td>268 to 293</td>
<td>283 to 308</td>
<td>293 to 318</td>
<td>490 to 518</td>
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</tr>
<tr>
<td>Absolute change</td>
<td>44</td>
<td>41</td>
<td>31</td>
<td>47</td>
<td>58</td>
<td>276</td>
<td>−46</td>
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<td>67</td>
<td>79</td>
<td>300</td>
<td>−28</td>
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<tr>
<td>Relative change</td>
<td>+18%</td>
<td>+17%</td>
<td>+12%</td>
<td>+19%</td>
<td>+24%</td>
<td>+111%</td>
<td>−18%</td>
<td>+26%</td>
<td>+25%</td>
<td>+27%</td>
<td>+32%</td>
<td>+121%</td>
<td>−11%</td>
<td>+1%</td>
</tr>
</tbody>
</table>

MRR, mortality rate ratio; T1D, type 1 diabetes.
allocated to diabetes healthcare. Moreover, it emphasizes the need for research on primary prevention of T1D and effective interventions to reduce its incidence.27

Environmental and lifestyle changes may explain the rapid increase of the number of people with T1D worldwide.13 28 The relatively short projection period makes changes in the genetic background of populations an unlikely cause. For instance, lifestyle factors that lead to rapid growth and large gains in weight particularly in the first years of life are more likely causing the increasing incidence. Factors such as accelerated autoimmune processes contribute to a growing T1D incidence in childhood.22 Besides, factors that initiate the autoimmune destruction of beta cells are also discussed, for example, fetal and neonatal factors. Another hypothesis for the increase in the incidence is the reduced exposure to microbial antigens.22 Overall, to gain a better understanding of drivers of the T1D burden, future studies could include these environmental factors in the evaluation to shed light on possible causes.

With regard to the methodological approach, our results underline the advantage of the IDM as theoretical background as it allows to incorporate temporal trends in disease-specific rates which impact the epidemiological trends of a disease.10 23 Comparing multiple future scenarios, we showed that the incidence rate is a major driver of future numbers. A blunt extrapolation, that is, applying the observed prevalence in 2010 to the population projections, is unlikely to project accurate future numbers.10 23 Ignoring disease-specific rates probably leads to underestimation of an upcoming disease situation, and consequently, underestimates the importance of public health management, healthcare facilities, education of specialists, and the like.

In addition to the increasing T1D burden, our projection indicates a shift of the prevalence peak toward older ages. Concomitant, although historically believed, T1D may not remain a disease of childhood. In line with Ostrowskas et al29 our results contradict a shift of the onset of T1D toward younger ages as explanation for the increasing temporal trend among children.

Comparison with previous studies

Worldwide, T1D incidence varies largely. In the great majority of countries, it has steadily increased over the past and its growth is expected to continue. In 2021, the International Diabetes Federation (IDF) estimates that 1211900 children and adolescents younger than 20 years were diagnosed with T1D and reports an annual growth of 149500 children worldwide.5 Direct health expenditures related to diabetes are close to US$1 trillion and are projected to exceed this by 2030. Strikingly, current evidence suggests that the IDF figures are still substantially underestimated.30 Using data from the Childhood Diabetes Registry of Saxony, Germany, Manuwald et al10 report an increase in the T1D incidence among children and adolescents in Germany from 17.1 to 24.7 per 100000 person-years between 1999 and 2019. Continuing this trend, they project a growth to 34.8 per 100000 person-years in 2030. Based on medical data from Baden-Wuerttemberg and Saxony and the national diabetes registry of North Rhine-Westphalia, Rosenbauer et al6 report a national T1D incidence among adults of 6.1 per 100000 person-years between 2014 and 2016. Their prevalence estimate equals 445 and 544 per 100000 individuals with slightly lower figures for women compared with men. This equals a number of 341 000 adults with T1D in 2016, which is estimated to grow to 4150 adults annually. Notably, these studies neglect relevant age groups, the role of disease-specific rates or are based on limited data. Contrarily, one of the main strengths of our prevalence input data is its completeness in terms of covering all age groups as well as all health insurances in the German statutory health insurance.

Limitations

Although the reasons remain unclear, ICD codes are often inaccurately captured in administrative data in Germany (such as our prevalence input data).9 12 31 Impeding a valid differentiation of the diabetes types.31 Indeed, research confirms that limited diagnostic accuracy, that is, sensitivity and specificity, from aggregated routine data may lead to unstable or implausible estimation results.32 33 Potential misclassifications and double diagnoses in our setting may have occurred when a diagnosis was changed after more precise specification of a person’s health state by different care providers or clinicians. For instance, and controversially discussed, the ICD coding specifies LADA as E10.-34-36 although its pathogenesis only gradually resembles the one of T1D. Moreover, since T1D is more common to develop at younger ages, it can be assumed that many unspecific cases among the older population could be attributed to T2D.13 31 Consequently, these false positive diagnoses might explain questionable estimates among older ages. On the contrary, unspecific diabetes diagnosis among children very likely mask a T1D case.13 31 To filter out such inaccuracies observed among older ages and since our focus is on T1D developed during childhood, we adapted the log-linear trend from Denmark to the German T1D incidence in 2010. Including misspecifications, unclear or double diagnoses, or cases masked by the unspecific diabetes coding E14.-, may lead to an additional increase in the prevalence of T1D.13 31 Alternatively, previous studies advise the additional integration of medication to validate that the coding accurately reflects T1D prevalence rates from 2010.31 since for patients with T1D it is necessary to inject insulin to control blood glucose levels. This method is of help for children and adolescents, in adulthood however it is inapplicable.31 This falls beyond the scope of our article and is left open for future research.

Since the future course of the incidence and mortality is unknown, we explored the impact of trends in incidence and mortality by considering several scenarios. This highlights the need for long-term, country-specific and diabetes type-specific studies to obtain confidence
about future T1D cases. Assuming that medical aid and the treatment of diabetes will improve further, a decline in the mortality seems likely. Evidence for continuous declines in mortality is found in several countries such as the USA, Canada, Finland, Sweden and Denmark.\(^2\)\(^3\)\(^7\)\(^8\)\(^9\)\(^10\)\(^11\)\(^12\)\(^13\) Contrastingly, the T1D incidence and its development are heterogeneously distributed across countries.\(^1\)\(^5\)\(^6\)\(^7\)\(^8\) Despite a universally reported growth, evidence from some regions suggests a slowing in this increase.\(^5\)\(^2\)\(^8\) Against this reporting, pooled estimates for Europe show a continuous annual 3.4% growth, indicating a doubling of the incidence within 20 years.\(^2\) In Germany, the T1D incidence among children has increased threefold in the past decades.\(^1\) In line with the trend over the past 20 years, other studies assume a 40% increase in the incidence of T1D in children and adolescents for the next 10 years.\(^2\)\(^2\) Overall, declining mortality and increasing incidence as in scenario 3 seems most plausible. Considering that the claims data reflect the medical situation a decade ago, it does neither comprise latest happenings such as the SARS-CoV-2 pandemic nor other recent developments that may have affected the disease situation.\(^3\)\(^9\) It appears that a SARS-CoV-2 diagnosis is associated with an increased risk of new-onset T1D.\(^2\)\(^4\)\(^5\) With our scenario in the sensitivity analysis assuming a 5% annual increase in the incidence, we account for extreme events such as the impact of SARS-CoV-2. In that scenario, we project an increase in the future T1D burden in 2040 in Germany of up to 121% additional T1D cases compared with 2010. Evidently, other unexpected events such as the global climate, energy or inflation crisis, future developments of migration, or changes in diagnostic criteria may alter future trends of the T1D incidence and mortality.\(^1\)\(^6\)\(^7\)\(^8\)\(^9\)\(^10\)\(^11\)\(^12\)\(^13\)\(^14\)\(^15\)\(^16\)\(^17\) Further, there are medical and non-medical issues that make particular ethnic groups more or less vulnerable to diabetes. Routine data and particularly aggregated prevalence data from administrative origin do not provide any identification possibility of the individual’s ethnicity.\(^1\)\(^3\)\(^5\)\(^7\)\(^8\)\(^9\)\(^10\)\(^11\)\(^12\)\(^13\)\(^15\)\(^16\)\(^17\) Assessing the impact therefore goes beyond scope of our study, but could be addressed in the future.

Due to data scarcity in Germany, we referred to information on the incidence and MRR from Denmark for our initial T1D incidence estimation and prevalence projection. The motivation to use Danish data is threefold. First, it is based on the national diabetes register which has a coverage of 100% due to compulsory reporting and which accurately differentiates the diabetes types.\(^1\)\(^3\)\(^5\)\(^7\)\(^8\)\(^9\)\(^10\)\(^11\)\(^12\)\(^13\)\(^15\)\(^16\)\(^17\) Second, previous studies concerning diabetes surveillance in Germany refer to Danish data.\(^1\)\(^3\)\(^5\)\(^7\)\(^8\)\(^9\)\(^10\)\(^11\)\(^12\)\(^13\)\(^15\)\(^16\)\(^17\) Third, for countries that are comparable in terms of their disease burden and healthcare systems, such as Denmark and Germany, deviations of disease-specific rates should remain minimal.\(^1\)\(^3\)\(^5\)\(^7\)\(^8\)\(^9\)\(^10\)\(^11\)\(^12\)\(^13\)\(^15\)\(^16\)\(^17\) Obviously, modelling the T1D situation over a 30-year horizon from 2010 until 2040 using prevalence data from 2010 and borrowed information from Denmark requires some assumptions. Our analysis and the reliability of our results would be strengthened if more recent, validated data from Germany were available. Moreover, information on T1D directly measured in the German population would be more appropriate to generate reliable national projections. As final remark with regard to an accurate diabetes surveillance in Germany, we claim that more detailed, precise, and timely data regarding diabetes in general and T1D in particular is urgently needed.

CONCLUSION

This is the first study addressing the current and future age-specific T1D incidence and prevalence for the whole German population for all ages from 0 to 100 years between 2010 and 2040. Using the IDM and data from 65 million people in Germany, we show that temporal trends in the incidence and mortality mainly drive the future number of individuals with T1D. Our projection suggests a substantial increase in the incidence, prevalence, and in the number of people diagnosed with T1D ranging from 4000 (+1%) to 78,800 (+32%) additional cases in Germany in 2040 vs 2010.
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