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ORIGINAL ARTICLE

Costs of COVID-19 pandemic associated with diabetes in Europe: a health care cost model

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ABSTRACT

Objective: Diabetes is associated with progression to severe COVID-19. The objective of this study was to estimate to what extent the increased risk among people with diabetes could impact the secondary care costs of COVID-19 throughout Europe during the first wave of the COVID-19 pandemic from January to June 2020.

Methods: Applying a health care cost model based on inputs from data published in international peer-reviewed journals, identified via a rapid literature review this study aimed to estimate the total secondary sector costs of COVID-19. Estimates of unit costs were based on data from Denmark, France, Spain and the UK. We calculated average costs per patient without diabetes and according to four diabetes categories based on risk of hospitalization, admission to intensive care unit, ventilator support and length of hospital stay.

Results: The estimated cost per hospital admission during the first wave of COVID-19 in Europe ranged between EUR 25,018 among people with type 2 diabetes in good glycaemic control to EUR 57,244 among people with type 1 diabetes in poor glycaemic control, reflecting higher risk of intensive care, ventilator support and longer hospital stay according to diabetes category, while the corresponding cost for people without diabetes was estimated at EUR 16,993. The total direct costs of secondary care of COVID-19 in Europe were estimated at EUR 13.9 billion. Thus, 23.5% of the total costs accounted for treating people with diabetes.

Conclusions: This study highlights the importance of a greater focus on prevention and adequate treatment of diabetes and the need for special attention to avoid infection with COVID-19 to the extent possible among those already diagnosed with diabetes.

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Introduction

The first confirmed cases of coronavirus disease 2019 (COVID-19) were reported in Europe on 31 January 2020[1], and on 11 March 2020, in part due to the rapid escalation of cases in the European region, the World Health Organization declared the outbreak of COVID-19 a global pandemic[2]. In the first half of 2020, COVID-19 has led to more than 2.4 million confirmed cases in Europe and presumably many more unconfirmed cases. As of 30 June 2020, 190,000 cases of death associated with confirmed COVID-19 have been registered in this region[3], however, counting only confirmed deaths due to COVID-19 likely underestimates the number of deaths attributable to the pandemic[4]. During the first six months, also referred to as the first wave, of the pandemic, Europe has experienced higher prevalence and mortality from COVID-19 compared to many Asian and African countries[5]. The difference is partly due to different lockdown strategies, as an aggressive lockdown strategy has proven effective to reduce both prevalence and mortality of infectious diseases[6–8]. The downside of a lockdown, especially for people with diabetes, is that it also impacts routine visits, which can result in complications that are not dealt with in a timely manner[9,10]. Diabetes is the term given to a group of serious, chronic diseases which are characterized by hyperglycaemia. The prevalence of diagnosed diabetes in European adult populations ranges between 4.6% in Ireland and 14.9% in Portugal; there is a total of 60 million people with diabetes in Europe, corresponding to a European average of 9.2%[11].

Approximately 10% of people with diabetes have type 1 diabetes, while 90% have type 2 diabetes[11]. A large proportion of people with diabetes are not achieving good

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glycaemic control, potentially leading to comorbidities e.g. damage to the heart, blood vessels, kidneys, eyes and nerves; and dysfunction of the immune system[12,13]. Due to compromised immunity, people with diabetes are in general more susceptible to infection and to the risk of severe outcomes due to infection. Specifically, with poor glycaemic control the risk of infections and serious infections rise[13,14].

The correlation between diabetes and COVID-19 is not yet fully understood. No study has, to our knowledge, suggested that people with diabetes are at higher risk of contracting COVID-19 infection. However, recent studies suggest that people with diabetes and poorly controlled blood glucose who contract COVID-19 are more likely to have severe and fatal outcomes[15–25]. This includes higher rates of admission to hospitals and intensive care units (ICUs) and increased need of invasive mechanical ventilation (IMV).

Recognizing that people with diabetes are more likely to experience a more severe course of COVID-19, we aimed to assess the increased direct hospital costs associated with treating COVID-19 patients with diabetes throughout Europe. Moreover, we highlight the consequences of poor glycaemic control in people with diabetes and the resultant increased economic burden of treating people with diabetes and COVID-19.

Methods

This study applied a health care cost model estimating the direct costs of secondary care (i.e. hospital costs) of COVID-19 in the first half of 2020 in Europe by the four aforementioned diabetes categories. Here, Europe is defined as the countries of EU 27, along with Iceland, Norway, Switzerland, Liechtenstein and the United Kingdom. Total direct costs of secondary care were defined as publicly funded hospital service usage, including hospital admissions, admissions to ICUs and support by IMV during ICU stays (henceforth referred to as ICU + IMV). Other potential costs such as primary care costs, i.e. visits to a general practitioner, and indirect costs, e.g. productivity loss during illness, were not calculated. The health care cost model applied in this study is based on a parallel methodology as a health care cost model estimating the direct costs of secondary care according to BMI categories. The manuscript for this article is currently in press[26].

In the first wave of the pandemic, the number of people testing positive for COVID-19 throughout Europe depended largely on the testing strategy applied in each country. Therefore, we used country-specific data for hospital admissions as a starting point for the health care cost model and did not take into account COVID-19 patients who were not hospitalized.

To obtain knowledge on the risk of severe disease among people with diabetes hospitalized due to COVID-19 which could be used in the health care cost model, a rapid literature review was performed. We searched PubMed on 1 July 2020 using the key terms “COVID-19” or “coronavirus infection” or “SARS-CoV-2” and “diabetes”. Peer-reviewed articles written in English published between 1 January 2020 and 30 June 2020 were included in the initial title and abstract screening. Articles estimating risk of general hospitalization, risk of admission to ICU and risk of admission to ICU + IMV due to COVID-19 among people with diabetes were included.

Data published in international peer-reviewed journals were used as inputs into the health care cost model. We prioritized articles from Europe estimating age- and sex-adjusted risks. In cases where we identified additional useful knowledge from other countries, e.g. the US and China, those were also included.

Input to the health care cost model

Based on the rapid literature review and the identified information, we defined the model dimensions regarding groups of people with diabetes as follows: type 1 diabetes in good glycaemic control, type 1 diabetes in poor glycaemic control, type 2 diabetes in good glycaemic control, type 2 diabetes in poor glycaemic control. Glycaemic control is commonly assessed by measuring glycated haemoglobin (HbA1c), fasting plasma glucose or 2-h plasma glucose. This study applied findings on glycaemic control obtained from studies identified in the rapid literature review as an input to the health care cost model. Hence, the definition of glycaemic control applied in the health care cost model ultimately depends on the definitions applied in the underlying studies that were identified by the rapid literature review.

To model the population sizes, we applied the estimated distribution between type 1 and type 2 diabetes from the International Diabetes Federation (IDF) Diabetes Atlas: 10% with diabetes type 1 and 90% with type 2[11]. Potentially varying prevalence rates in different age groups was not considered in this study. Other types of diabetes e.g. gestational diabetes, and secondary diabetes are much less common and were therefore not taken into account for the purpose of this study.

Estimates of risk of hospitalization, risk of ICU admission and IMV were obtained from the rapid literature review and ORs from the literature were adjusted into RRs. For each of the four diabetes categories, we ensured that the resulting risk of severe outcomes by diabetes type and glycaemic control status was coherent with both the reported risk associated with the type of diabetes and the reported risk associated with being in good or poor glycaemic control.

Admissions and type of treatment

The distribution and number of people hospitalized were calculated based on the number of people admitted to hospital for COVID-19 treatment in Europe from 1 January 2020 until 30 June 2020 obtained from[27] (720,547) and the increased risk of hospitalization among people with diabetes compared to people without diabetes (OR = 1.8 (1.6–2.2)) obtained from Reilev et al.[25]. The risk of admission to ICU among hospitalizations was calculated based on data from McKeigue[28], estimating crude RRs of 4.9 (3.3–7.3) and 2.6 (2.3–2.9) for people with type 1 diabetes and type 2 diabetes, respectively, compared with people without diabetes. Thus, not distinguishing between good and poor glycaemic control. Risks of treatment in ICU, including IMV, were calculated based on data from Smith et al.[29] estimating that the crude rate for people with diabetes in poor glycaemic control was significantly higher compared with people in good glycaemic control (31.5 vs. 17.8%; $p=.045$), thus assuming the same risk for people with diabetes in good/poor glycaemic control independent of type of diabetes. Here, poor glycaemic control was defined as having HbA1C $\geq$7.5% measured in hospital[29].

Unit costs

Publicly available cost data from Denmark, France, Spain and the UK were used to estimate costs of hospitalization, admission to ICU and treatment via ICU + IMV[30–37]. For the remaining 28 countries, costs were estimated using a cost index from Eurostat based on per capita costs for inpatient curative and rehabilitative care[38].

All results are presented in euros (EUR, 2020 price level). Cost estimates from Denmark and the UK were converted to EUR using an exchange rate (as of 18 June 2020) of 1.11 for pounds sterling (GBP) and 0.13 for Danish krone (DKK).

Health care cost model

The health care cost model determined the cost per patient and the total direct costs of secondary care by country and diabetes category (Figure 1). By adding the country-specific costs across diabetes categories and countries, one can estimate the total estimated costs of secondary care of COVID-19 in Europe and for people with diabetes.

The total direct costs of secondary care were calculated from the costs per patient and the number of admitted patients by country and diabetes category. The number of admitted patients was estimated by multiplying the number of admissions due to COVID-19 per country, the relative risk of hospital admission with COVID-19 by diabetes category and the distribution of population by diabetes category and country.

The costs per patient by diabetes category and country were calculated by multiplying the cost per bed day by country and the average number of bed days per admitted patient. The average number of bed days was estimated by multiplying the risk of admission to ICU and ICU + IMV by diabetes category, and the expected number of bed days in general hospital, ICU and ICU + IMV when admitted to the specific unit by diabetes category.

Results

Rapid literature review

Initially, 803 articles were identified (Figure 2). During title and abstract screening, 26 of the 803 publications were selected for full-text review, and 15 were included in the rapid review. Articles that did not estimate relevant outcomes (see method section) and articles not peer-reviewed were excluded during the review.

Seven of the included studies were from Europe and nine were from US or China. Three studies were systematic reviews while the rest were either cohort studies or case-control studies including between 174 and 23,804 COVID-19 patients. In Supplementary Table 1, an overview of the studies identified in the rapid literature review is presented.

Admissions and type of treatment

Based on the increased risk of hospitalization due to COVID-19 among people with diabetes, we estimated that 1.4% of all patients admitted to hospital with COVID-19 had type 1 diabetes and 12.4% had type 2 diabetes. Table 1 summarizes the modelled distribution of people in the four diabetes categories, and the modelled distribution and number of people with diabetes among patients hospitalized with COVID-19.

Applying the risk of admission to ICU, Table 2 shows the resulting calculated risks of all four diabetes categories and for people without diabetes. It shows that people with diabetes had a 24.6–75.8% estimated risk of admission to ICU depending on type of diabetes and glycaemic control, while people without diabetes had a 13.3% risk of ICU admission[25]. We estimated that 15% (110,151) of the admitted patients are admitted to ICU, and of these, 20% (22,136) are people with diabetes. We further estimated that 10% (75,533) will need ventilation during their ICU admission, and hereof, 20% (15,154) are people with diabetes (for country-specific admissions, see Supplementary Table 5). Table 2 further shows that 11.9–55.9% of people with diabetes who were admitted to hospital received ICU + IMV treatment. The corresponding rate for people without diabetes was 9.1%.

Cost per bed type

The average weighted cost per diem (24 h) across all European countries for admission to general hospital, ICU and ICU + IMV were EUR 883, EUR 1925 and EUR 3183, respectively.

Country-specific costs for all countries are presented in Supplementary Table 2.

Cost per average hospital admission according to diabetes category

Table 3 shows the modelled cost per average hospital admission for the four different diabetes categories and the reference group (no diabetes). The average cost across all countries ranges from EUR 16,993 for treating people without diabetes to EUR 57,244 for treating people with diabetes type 1 in poor glycaemic control. The country-specific modelled average costs per patient are presented in Supplementary Table 3.

Risk of ICU admission was higher for people with diabetes and especially for people with diabetes in poor glycaemic control. Since admission to ICU was significantly more expensive than a general hospital admission, the costs per average hospital admission due to COVID-19 were considerably higher for people with diabetes in poor glycaemic control

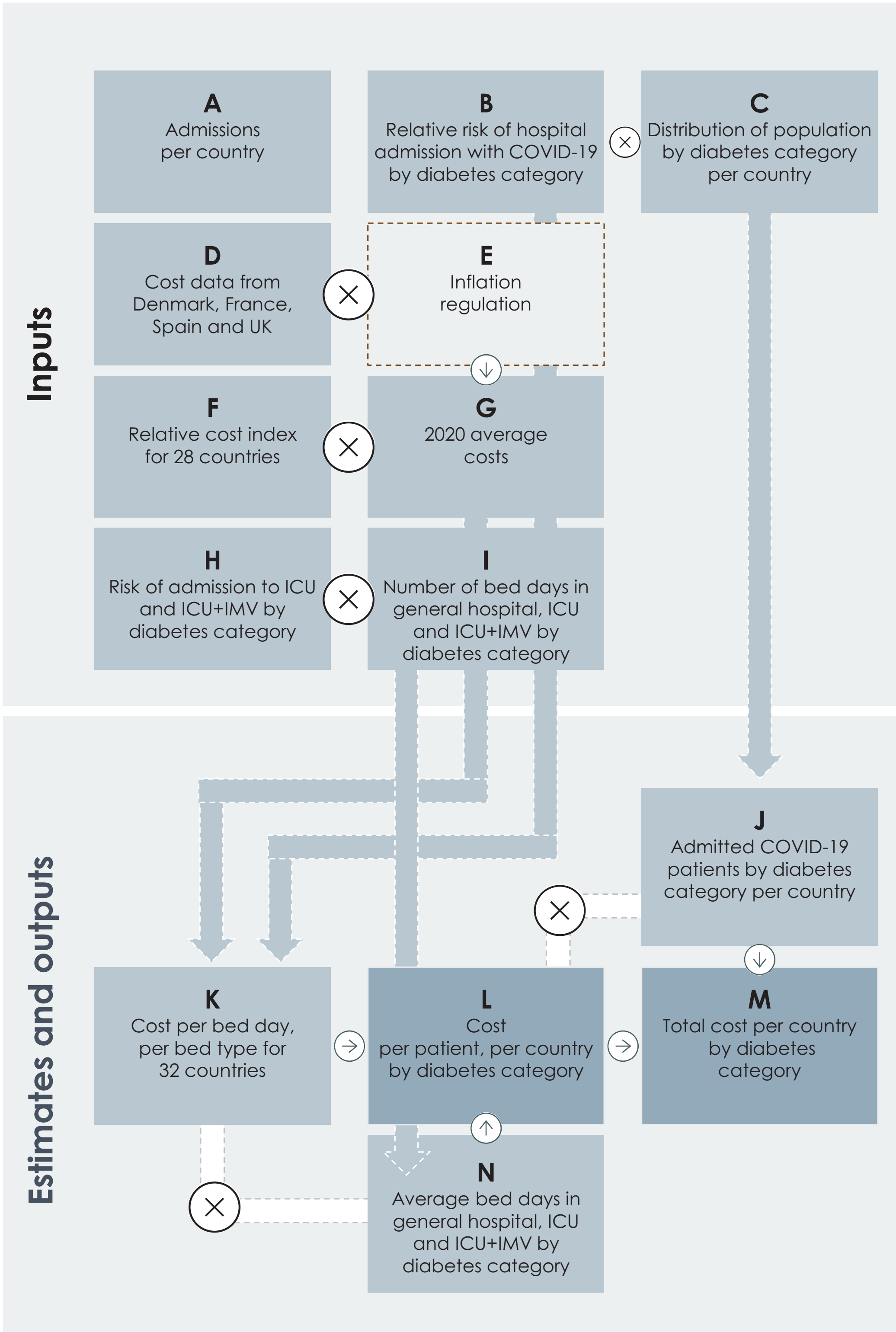

Figure 1. Economic model outline.

compared with people with diabetes in good glycaemic control.

Based on the calculated absolute costs per patient presented in Table 3, Table 4 reports relative costs showing that the average hospital cost of treating a person with type 1 diabetes in poor glycaemic control was 97% higher than the average hospital cost of treating a person with type 1 diabetes in good glycaemic control (i.e. 57,244/28,997 EUR). Moreover, Table 4 shows that the average hospital cost of treating a person with type 2 diabetes in poor glycaemic control was 84% higher than the average hospital cost of treating a person with type 2 diabetes in good glycaemic control (i.e. 46,130/25,018 EUR). Finally, it shows that the average hospital cost of treating a person with diabetes was

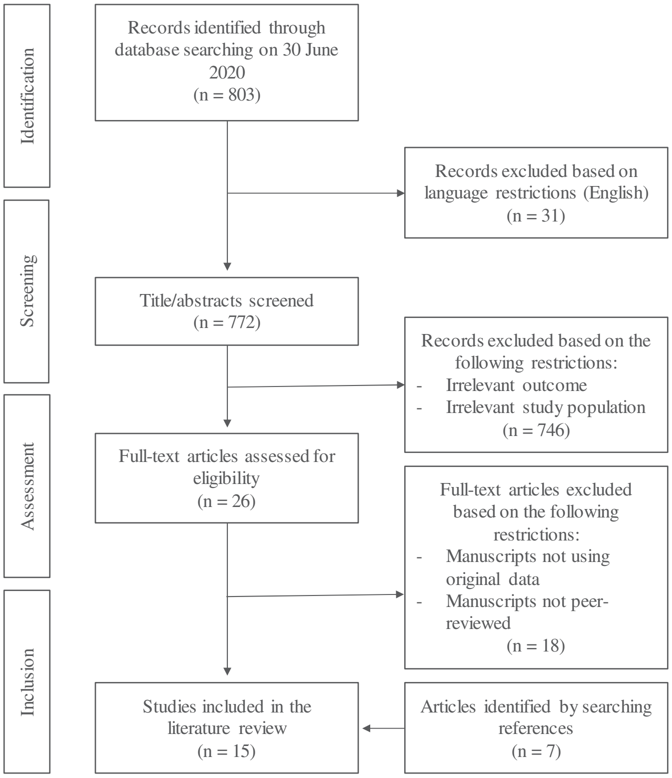

Figure 2. Flow chart for the rapid literature search.

103% higher than the hospital cost of treating a person without diabetes.

Total direct secondary care costs

The direct costs of secondary care of COVID-19 in Europe reported in Table 5 were estimated by summing the country-specific total direct costs of secondary care (reported in Supplementary Table 4) with a resulting estimated total cost of EUR 13.9 billion. The total costs of treating people with diabetes were EUR 3.3 billion, while the total costs of treating people without diabetes were 10.6 billion. Treatment in a medical department accounted for more than half of the total costs, ICU treatment without IMV accounted for 15% and ICU + IMV treatment accounted for one-third of the total costs.

The total direct costs of secondary care of COVID-19 associated with type 1 diabetes were estimated at EUR 0.5 billion, which corresponds to 3.4% of the total costs (Table 6). Likewise, the costs associated with type 2 diabetes were estimated at EUR 2.8 billion, accounting for 20.20% of the total costs. In comparison, the estimated prevalence of type 1 and type 2 diabetes in the European population is 0.9 and 8.3%, respectively. Moreover, the estimated costs of treating people with diabetes in good glycaemic control accounted for 10.2%, while the share of people with diabetes in good

Table 1. Input parameters regarding number of hospitalizations due to COVID-19 in Europe across four diabetes categories and for people without diabetes.

	Type 1 diabetes		Type 2 diabetes		All diabetes	No diabetes	Total
	Good glycaemic control	Poor glycaemic control	Good glycaemic control	Poor glycaemic control			
Prevalence in Europe (%)[a]	0.3	0.7	5.2	3.1	9.2	90.8	100
Distribution of hospitalizations according to diabetes categories (%)[b]	0.4	1.0	7.5	4.4	13.2	86.8	100
Total number of people hospitalized in Europe (N), January–June 2020[c]	2656	6869	54,028	31,701	95,255	625,292	720,547

[a]Diabetes prevalence in the European population was based on data from the IDF Diabetes Atlas[11], McKnight et al.[39], and de Pablos-Velasco et al.[40]
[b]The distribution of hospitalization were calculated based on Reilev et al.[25]
[c]Total number of people hospitalized in Europe was based on data from the University of Washington Institute for Health Metrics and Evaluation[27]. The distribution of number of people hospitalized between diabetes categories were calculated based on IDF diabetes Atlas[11] and risk of hospitalization obtained from Reilev et al.[25].

Table 2. Percentage of people admitted to ICU and ICU + IMV, compared with all people admitted to hospital with COVID-19, for each diabetes category and for people without diabetes.

	Type 1 diabetes		Type 2 diabetes		No diabetes
	Good glycaemic control	Poor glycaemic control	Good glycaemic control	Poor glycaemic control	
Admission to ICU among hospitalizations (%)[a,c]	36.9	75.8	24.6	50.6	13.3
Treatment in ICU including IMV among hospitalizations (%)[b,c]	15.3	55.9	11.9	43.1	9.1

Note: Crude estimates from the literature were converted to shares within each diabetes category.
[a]Rate of admission to ICU for people with diabetes were obtained from McKeigue et al.[28] and from Reilev et al.[25] for people without diabetes.
[b]Rate of treatment in ICU including IMV were obtained from Smith et al.[24].
[c]The risk of admission to ICU among hospitalizations was calculated based on data from crude RRs for people with type 1 diabetes and type 2 diabetes, respectively, compared with people without diabetes. Thus, not distinguishing between good and poor glycaemic control. Risks of treatment in ICU, including IMV, were calculated based on the crude rate for people with diabetes in poor glycaemic control that was significantly higher compared with people in good glycaemic control, thus assuming the same risk for people with diabetes in good/poor glycaemic control, independent of type of diabetes.
Abbreviations. ICU, intensive care unit; IMV, invasive mechanical ventilation.

Table 3. Cost (EUR) per patient of an average hospital stay, by diabetes category and for people without diabetes.

	Type 1 diabetes		Type 2 diabetes		No diabetes
	Good glycaemic control	Poor glycaemic control	Good glycaemic control	Poor glycaemic control	
Denmark	34,011	77,074	27,874	60,026	18,883
France	24,224	46,439	21,058	37,644	14,287
Spain	29,031	58,579	24,984	47,121	17,026
United Kingdom	31,489	62,115	27,124	49,990	18,398
Average (weighted)	28,997	57,244	25,018	46,130	16,993

Note: The cost (EUR) of the average hospital stay by diabetes category per patient is modelled on the RR for general hospital admission, ICU and ICU + IMV.
Abbreviations. EUR, euro; RR, risk ratios; ICU, intensive care unit; IMV, invasive mechanical ventilation.

Table 4. Relative costs for diabetes categories.

	Type 1 diabetes		Type 2 diabetes		All (weighted) diabetes
	Good glycaemic control	Poor glycaemic control	Good glycaemic control	Poor glycaemic control	
Relative costs for diabetes categories compared with no diabetes (%)	171	337	147	271	203
Relative costs within diabetes categories		+97% compared with type 1 diabetes in good glycaemic control		+84% compared with type 2 diabetes in good glycaemic control	+103% compared with no diabetes

Note: The relative costs were calculated from Table 3.

Table 5. Total costs (EUR, millions) of COVID-19 in Europe, by diabetes category and type of admission.

	Cost for people with type 1 diabetes		Cost for people with type 2 diabetes		Total cost for people with diabetes	Total cost for people without diabetes	Total cost
	Good glycaemic control	Poor glycaemic control	Good glycaemic control	Poor glycaemic control			
Total	77	392	1,339	1,467	3,275	10,634	13,908
Medical department	38	99	772	458	1,367	6,159	7,527
ICU	17	90	228	278	612	1,445	2,057
ICU + IMV	22	204	339	731	1,295	3,029	4,325

Abbreviations. EUR, euro; ICU, intensive care unit; IMV, invasive mechanical ventilation.

Table 6. Total costs, cost share and prevalence in European population for people without diabetes, with type 1 diabetes, with type 2 diabetes, with diabetes in good glycaemic control and with diabetes in poor glycaemic control.

	Total type 1 diabetes	Total type 2 diabetes	Total in good glycaemic control	Total in poor glycaemic control	All diabetes	No diabetes	Total (All diabetes + No diabetes)
Total cost (million EUR)	469	2806	1416	1859	3275	10,634	13,908
Cost share (%)	3.4	20.2	10.2	13.4	23.5	76.5	100
Prevalence (%)	0.9	8.3	5.4	3.8	9.2	90.8	100

glycaemic control in the European population is 5.4%. Treatment of people with diabetes in poor glycaemic control cost EUR 1.9 billion, which is 13.4% of the total costs, while the prevalence of people with diabetes in poor glycaemic control in the European population is only 3.8% (Table 6). The disproportional factor for share of costs were hence 3.7, 2.4, and 3.6 times compared to the prevalence in the population for the three groups, respectively.

Alternative scenarios

The total costs were driven by people with diabetes having additional risk of hospital admission and increased risk of severe outcomes while in hospital, leading to higher rates of admission to ICU and ICU + IMV and to longer hospital stays overall. If people with diabetes had the same risk of being admitted to hospital, to ICU and to ICU + IMV as those without diabetes, the total direct secondary care costs of COVID-19 in Europe would have been EUR 12.5 billion, or EUR 1.3 billion lower than was the case with the increased risk.

If people with type 2 diabetes had the same risk of being admitted to hospital and admitted to ICU + IMV as those without diabetes, the total direct secondary care costs of COVID-19 in Europe would have been EUR 12.6 billion. The health care costs are hence 10.7% higher than they would have been if people with type 2 diabetes had the same risk of severe COVID-19 as people without type 2 diabetes.

Sensitivity analysis

Since COVID-19 is a novel disease, there is still much uncertainty related to calculating the true secondary sector health care costs. The results represent the most likely single point estimate; however, we have also computed lower and upper bound estimates for the total cost. The range for total direct secondary care costs is EUR 10.8–21.3 billion. The lower estimate reflects a reduced risk of hospitalization (RR: 1.54) and reduced risk of ICU for people with diabetes across diabetes groups (2.06–3.26), but an unchanged increased risk of ventilator treatment[25,28,41]. The estimate also includes a 20% decrease in per diem costs across admission type (regular, ICU and ICU + IMV), whereas the high estimate reflects an increased risk of hospitalisation (RR: 2.03) and increased risk of ICU for people with diabetes across diabetes groups (2.06–7.31), but an unchanged increased risk of ventilator treatment[25,28,41]. The estimate also includes a 20% increase in per diem costs across admission type (regular, ICU and ICU + IMV).

Discussion

To our knowledge, no other study has investigated the impact of the increased risk of severe disease course of COVID-19 among people with diabetes on the costs of secondary care of COVID-19 treatment throughout Europe.

In this study, we found that both type 1 and type 2 diabetes and poorly controlled diabetes is associated with excess costs of treating people for COVID-19 in selected countries in Europe.

We estimated that people with type 1 diabetes accounted for 3.4% of the total costs of treating people hospitalized for COVID-19 in the first half of 2020 despite comprising only 0.9% of the population. People with type 2 diabetes accounted for 20.2% of the total costs of treating people for COVID-19 and make up only 8.3% of the population. Furthermore, people with poorly controlled diabetes were at higher risk for severe outcomes associated with COVID-19, resulting in increased secondary care costs. People with diabetes who were in poor glycaemic control accounted for 13.4% of the total costs of treating people for COVID-19 despite constituting only 3.8% of the population. Our study therefore supplements current well-established knowledge that poorly controlled diabetes is costly[42–44].

Although data regarding the association of COVID-19 and diabetes control is limited, previous studies, investigating the association of diabetes control and other infections such as SARS and influenza have suggested that people with diabetes in poor glycaemic control have an increased risk of complications[45,46], in line with the findings of the association between COVID-19 and diabetes control.

Studies of COVID-19 and diabetes have indicated that people with diabetes have an increased risk of requiring admission to ICU and treatment via ICU + IMV compared with people without diabetes; however, to our knowledge no studies have indicated that people with diabetes have a higher or lower risk of acquiring COVID-19. The magnitude of any such increased or decreased risk has not been established and, therefore, it was not considered in this study. Thus, the only cost driver of the present study was increased risk of severe outcomes due to COVID-19, i.e. risk of hospitalization, risk of admission to ICU, treatment via ICU + IMV and a prolonged hospital stay for people with diabetes while in hospital for COVID-19 treatment.

Other possible cost drivers are comorbidities and complications among people with diabetes. People with diabetes and comorbidities are expected to have more severe outcomes of COVID-19 compared to people with diabetes without comorbidities. This will drive up costs for people with diabetes and comorbidities due to longer stay time in hospital and because people will most likely need treatment for one or more of the comorbidities and COVID-19 simultaneously. We have not explicitly included factors related to comorbidities in the cost model, since other studies find that there is a strong link between diabetes in poor glycaemic control and comorbidities and/or complications; hence, those people may also be more likely to experience more severe outcomes of COVID-19[47]. Since much of the risk for severe outcomes of COVID-19 is included in the outcomes for poor glycaemic control, we do not include the independent contributions from comorbidities and complications, since this would result in a high risk of double counting. It could, however, contribute further to the precision of the cost estimates if the factors were examined separately.

A number of additional factors could potentially increase the costs of hospital admissions due to COVID-19. The health care cost model in the present study included only costs on usual admissions to general hospital or ICU. However, during the COVID-19 pandemic, hospitals have created special COVID-19 units or transformed other hospital beds to ICU beds with requirements that could be associated with higher costs. Moreover, this study calculated only direct costs of secondary care of COVID-19. However, the total costs of COVID-19 would be even higher if primary care costs and indirect costs (e.g. loss of productivity during illness, outpatient costs during the recovery phase) were included.

Some studies have indicated that people with diabetes have a significantly higher mortality rate due to COVID-19 compared with people without diabetes[20,21,25]. Specifically, a study from the UK found that people with type 1 diabetes had more than a threefold mortality risk compared with people without diabetes, while people with type 2 diabetes had a twofold mortality risk[21]. These results support our finding that type 1 diabetes is associated with more severe outcomes from COVID-19 than type 2 diabetes. Although the increased risk of mortality was not included in the health care cost model in this study, naturally the risk of fatal outcomes could potentially impact the direct and indirect costs of COVID-19.

The pandemic has to a large degree paused the health care system and thereby, for example, reduced the number of routine assessments for people with diabetes but without COVID-19[48]. It remains to be seen whether the long-term effect of this will worsen health outcomes for people with diabetes. In order to mitigate worse diabetes control due to the lockdown measures during the pandemic and at the same time protect people with diabetes against being infected, one could implement a greater use of new technologies such as telemedicine, arrange for supplies of medicines to be readily and routinely available and make use of online communication platforms and other measures to address key issues such as diagnosis/monitoring and adherence.

The COVID-19 pandemic has had a great impact on public health and the health care systems throughout Europe during the first half of 2020. But the pandemic was far from over[3], and several epidemiology experts anticipated the second wave of COVID-19 infections[49] which we have seen occur. The number of infections and deaths have increased throughout Europe once again in the autumn of 2020[3]. Our study suggests that diabetes contributes significantly to the cost of COVID-19 care. Both the costs and the number of people dying from COVID-19 would potentially be lower if diabetes were prevented to a higher extent than it currently is and, specifically, if more people with diabetes were in good glycaemic control across all European countries.

Strengths and limitations

The results presented in this study were based on the current carefully selected, recently published peer-reviewed studies regarding severe outcomes of COVID-19 for selected European countries. The study was based on a large sample of data for hospital admissions across Europe and validated cost data from the four reference countries. However, the risk of severe outcomes among people with diabetes is not yet fully understood. The inputs to the health care cost model from the rapid literature review were not completely adjusted for confounding factors, and it cannot, therefore, be stated whether diabetes is an independent risk factor related to the severe outcomes of COVID-19, or whether it is a confounding factor. Evaluation of cost is limited to the four categories of type 1 and type 2 diabetes in good or poor glycaemic control and does not include information about complications and comorbidities of diabetes, which could likely influence the cost evaluation. Due to the novelty of COVID-19, most of the existing literature on diabetes and COVID-19 does not distinguish between type 1 and type 2 diabetes nor is an explicit age distribution available. The health care cost model therefore applied the estimated distribution between type 1 and type 2 diabetes from the International Diabetes Federation (IDF) Diabetes Atlas: 10% with diabetes type 1 and 90% with type 2[11]. Additionally, different definitions of good and poor glycaemic control were applied across publications. As a result, application of these estimates to other European countries should be done with caution. To further improve the study, one could base the input on observation data and subsequent cost calculation. This could improve the accuracy of the utility use of COVID-19 patients across the four diabetes categories, but since it is still a novel disease, there were no such data available.

In conclusion, this study reports that the average cost of secondary care for people with diabetes and COVID-19 is higher compared with people with COVID-19 without diabetes. Moreover, this study highlights the importance of greater focus on prevention and adequate treatment of diabetes and the need for special attention to avoid infection with COVID-19 to the extent possible among those already diagnosed with diabetes.

Transparency

Declaration of funding

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Declaration of financial/other relationships

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