

## Research: Health Economics

# Societal costs of diabetes mellitus in Denmark

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### Abstract

**Aim** To provide comprehensive real-world evidence on societal diabetes-attributable costs in Denmark.

**Methods** National register data are linked on an individual level through unique central personal registration numbers in Denmark. All patients in the Danish National Diabetes Register in 2011 ( $N = 318\,729$ ) were included in this study. Complication status was defined according to data from the Danish National Hospital Register. Diabetes-attributable costs were calculated as the difference between costs of patients with diabetes and the expected costs given the annual resource consumption of the diabetes-free population.

**Results** Societal costs attributable to diabetes were estimated to be at least 4.27 billion EUR in 2011, corresponding to 14,349 EUR per patient-year. A twofold higher healthcare resource usage was found for patients with diabetes as compared with the diabetes-free population. Attributable costs, grouped according to different components, were 732 million EUR for primary and secondary care services, 153 million EUR for pharmaceutical drugs, 851 million EUR for nursing services, 1.77 billion EUR in lost productivity and 761 million EUR for additional costs. A steep increase in diabetes-attributable costs was found for patients with major complications compared with patients without complications across all cost components. For attributable healthcare costs this increase was estimated to be 6,992 EUR per person-year after controlling for potential confounders.

**Conclusions** Nearly half of the total costs of patients with diabetes can be attributed directly to their diabetes. The majority of costs are incurred among patients with major complications pointing to the importance of secondary preventive efforts among patients with diabetes.

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### Introduction

Globally, healthcare systems are facing the challenge of an exponential increase in the prevalence of chronic diseases [1]. This puts a heavy economic burden on society as new successful but costly treatments lead to an increase in care for more people as life expectancy increases.

With ~ 371 million people diagnosed globally [2] and evidence of rapidly increasing prevalence [3–6], diabetes mellitus is one of the most burdensome chronic diseases. Diabetes is associated with shorter lifetime, reduced quality of life and economic burdens on the patient and society as a result of healthcare, pharmaceutical drugs, nursing, reduced labour market participation and premature mortality [1,7–10].

We aimed to present new evidence of the relationship between costs of patients with diabetes, with and without complications, compared with the diabetes-free population based on data from all relevant national registers in Denmark [11]. Categorizing patients according to their complication progression into no complications, minor complications and major complications, is a novel method intended to inform decision-makers of a complex problem in an intuitive and easily interpretable way. Our results provide an economic rationale for secondary prevention, which is important to recognize with increasing numbers of patients with the chronic condition of diabetes. Furthermore, the results may contribute to an awareness among decision-makers regarding the allocation of budgets which can impede shifts of resources between sectors.

### Subjects and methods

#### Study population

Denmark offers unique opportunities for register-based research in epidemiology and healthcare [11]. The present

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**What's new?**

- Real-world evidence on the attributable costs of diabetes is calculated from individual register data and categorized according to complication progression.
- The study shows evidence of twofold higher healthcare resource usage in patients with diabetes compared with the diabetes-free population.
- The societal diabetes-attributable costs of diabetes in Denmark 2011 were estimated to be ~ 4.27 billion EUR, corresponding to 14,349 EUR per patient year.
- Nearly 60% of diabetes-attributable costs were ascribed to the 25% of patients with major complications.
- Steep gradients of increasing costs with increasing complications were evidenced across all cost components.

study is part of a large-scale register-based observational investigation, the Diabetes Impact Study 2013, investigating the epidemiological, health economic and socio-economic aspects of diabetes in Denmark.

The study population was identified from the Danish National Diabetes Register, adjusted for shortcomings [12], resulting in a period prevalence of  $n = 318,729$ . Person-time was quantified as number of person-years, defined as 365 person-days ( $n = 297,378$ ). Patient data were combined with data from the Danish National Patient Register [13], the Danish National Prescription Registry [14], the Danish National Health Service Register [15], the Danish Civil Registration System [16] and registers at Statistics Denmark. Municipal statements were used where register data were not available. Data were linked between registers using the unique Danish Personal Identification Number, assigned to each Danish citizen [16].

**Analysis**

Person-time was stratified by gender and current age (in 5-year age intervals) into three complication status groups: no complications, minor complications and major complications. Documentation on diagnoses and procedural codes across complication status groups can be found in Table S1.

The cost of illness framework was applied with a societal cost perspective, including both direct and indirect costs, but excluding intangible costs such as psychosocial effects [10,17]. The analytical time window was the calendar year, 2011. Costs (market values excluding value added tax) [17]) were defined as opportunity costs valued as alternative forgone use. The following cost components were evaluated on an individual person level from national register data: 1)

healthcare services in primary and secondary care including ambulant treatment and emergency room visits; 2) nursing services in own home/assisted facilities and nurse home visits; 3) pharmaceutical drug consumption; and 4) lost productivity including lower annual income, absenteeism and premature mortality, calculated using the human capital approach [17]. Additional cost components (prevention, education, psychological assistance, use of self-monitoring of blood glucose appliances, insulin pumps, medical appliances, patients' (and informal care givers') own time and depreciation of capital) were conservatively estimated from Statistics Denmark data and the literature. The measurement of cost components is shown in Table S2.

Attributable costs measure the excess costs of patients with diabetes' total healthcare consumption compared with the annual resource consumption of the diabetes-free population, stratified according to gender and age. This approach means that our attributable cost estimates reflect the cost of care of patients with diabetes including issues not directly associated with diabetes, and not solely the cost of diabetes care. This was applied because earlier studies document that adding up diabetes-specific diagnoses/services underestimates the attributable costs compared with a case-control method [18,19].

For healthcare services, patients with diabetes were compared with the diabetes-free population ( $n = 5,261,714$  in 2011) stratified by gender and 5-year age groups. For pharmaceutical drugs, nursing and the labour market, comparisons were made between patients with diabetes and a matched cohort of the diabetes-free population, consisting of five control subjects per patient with diabetes, matched by age, gender and residence at date of diagnosis ( $n = 1,462,872$ ). As a result of data limitations from source registers, some cost components were calculated per person (pharmaceutical drugs, nursing, productivity loss) and some per person-years (healthcare costs). In calculations across the different sectors, person-years were applied.

Direct associations between cost components and complication status groups were explored in a multivariate linear regression analysis, controlling for potential confounders (gender, age, highest attained education level, ethnicity, year of death and region of residence). The dependent variables were: total and attributable healthcare cost (EUR per person-years) in primary and secondary care; total net pharmaceutical drug costs; and total costs for home nursing (EUR per year) in 2011, defined per group according to the independent variables. The definitions of these variables are given in Table S3. T-tests were performed and the significance valued at the 1% level.

Costs were further analysed according to first ascertainment source in the Danish National Diabetes Register as we have previously seen that up to 20% of registrants in the Danish National Diabetes Register are included only as a result of frequent blood glucose measurements and may not have diabetes [12].

## Results

Estimates for total and attributable costs and costs per person-year across cost components, gender and complication status groups are shown in Tables 1–3. Estimates excluding possible ‘false-positive’ patients are shown in Tables S4 and S5. All cost estimates are presented in Euro (EUR).

### Healthcare

Total healthcare costs were estimated to be 1.64 billion Euro, corresponding to 5509 EUR per person-year. On average, a patient with diabetes consumed approximately twice the healthcare resources compared with a diabetes-free person (1.2, 1.8 and 2.8 times the healthcare resource use of a diabetes-free person for patients with no, minor or major complications, respectively) with higher gradients found among younger patients as compared with the elderly, among male patients as compared with female patients, and for secondary care as compared with primary care. A patient going from no complications to minor or major complications incurred increased healthcare costs of 1782 and 7534 EUR per person-year, respectively, even after controlling for potential confounders (Table S6).

The total attributable healthcare costs of diabetes were estimated to be 732 million EUR, divided between the no complication, minor complication and major complication groups as follows: 93, 147 and 492 million EUR, respectively. The greatest absolute cost burden was observed in the age group of 60–74 years, mainly because of the sheer volume of patients in these age groups.

Average attributable costs per person-year for healthcare were 2460 EUR (2,128 EUR for women and 2,772 EUR for men). The costs for patients with minor complications were 4.5 times higher and for patients with major complications 12 times higher than for patients without complications. Patients with major complications, representing 25% of all patients, consumed almost 50% of total healthcare resources. Differences in attributable healthcare costs between a patient with no complications and a patient with minor or major complications of 1617 and 7388 EUR per person-year, respectively, were found, after controlling for potential confounders (Table S7).

Observed patterns in healthcare resource consumption are shown in Fig. 1 and may be summarized as follows: 1) gradients between complication status groups were especially marked for secondary care, where the largest costs also lay; 2) men consumed more resources in all secondary care services than women, whereas the opposite was true for primary care; and 3) attributable cost per person-year decreased with age, mainly as a result of the diabetes-free population experiencing an increase in cost with age.

### Pharmaceutical drugs

Pharmaceutical drug consumption amounted to 256 million EUR in 2011, corresponding to 860 EUR per person. Differences in the costs between no complications and minor and major complications, respectively, were 257 and 329 EUR per year, after controlling for potential confounders (Table S8). The pharmaceutical drug consumption of patients with diabetes was 2.5 times higher than that of the diabetes-free population: 153 million Euro were found to be attributable to diabetes. Attributable costs per person-year were 516 EUR (476 EUR for women and 553 EUR for men), and were 310, 750 and 788 EUR per person-year for the no complication, minor complication and major complication groups, respectively. This shows a significant increase in pharmaceutical drug costs when patients progressed from uncomplicated diabetes to minor complications, whereas later progression to major complications did not impose a marked increase. For women, the increase from minor to major complications was 2% and for men 10%. The higher attributable costs among men were the result of differences in pharmaceutical drug consumption between genders in the control group, whereas consumption was approximately equal for each gender among patients with diabetes.

Attributable costs were highest among the young, and declined with age (Fig. 2). This pattern is mainly the result of patients with diabetes having more or less the same pharmaceutical drug consumption across age groups, whereas there was increasing consumption with age among the control subjects.

### Nursing

Costs for nursing for patients with diabetes in 2011 amounted to 1.91 billion EUR, corresponding to 6,433 EUR per person. Total attributable nursing costs amounted to 851 million corresponding to 2,863 EUR per person-year (3,675 EUR for women and 2,098 EUR for men). When the attributable costs were divided between the no complication, minor complication and major complication groups, the costs were 268, 2,386 and 8,970 EUR, respectively, per patient. Attributable costs per patient hence increased 33-fold when patients progressed from uncomplicated diabetes to diabetes with major complications.

The probability of living in a nursing home for patients with diabetes was 45% greater compared with the matched diabetes-free population. For men (in particular those aged  $\geq 75$  years) negative attributable costs were evidenced, reflecting that men in these older age groups, who have no complications, use fewer nursing resources than aged-matched men in the diabetes-free population. Patients with diabetes received on average 50% more home nursing visits than the matched diabetes-free population. The difference in total costs for home nursing between patients with no complications and those with minor and major complications were estimated to

**Table 1** Total diabetes resource use (total costs) and costs per person-year for the entire diabetes population according to complication status and gender

Cost item	Total costs (EUR)				Total cost per person-years (EUR)			
	ALL	C0	C1	C2	ALL	C0	C1	C2
<b>Healthcare costs</b>	1,638,237,935	553,933,413	319,439,149	764,865,373	5,509	3,361	5,508	10,257
Women	741,592,485	302,682,783	139,460,753	299,448,949	5,140	3,445	5,670	9,409
Men	896,645,450	251,250,630	179,978,396	465,416,424	5,857	3,265	5,388	10,889
<b>Primary care</b>	221,176,905	110,599,788	42,068,988	68,508,128	744	671	725	919
Women	113,618,643	63,234,638	19,779,391	30,604,615	787	720	804	962
Men	107,558,262	47,365,151	22,289,598	37,903,514	703	616	667	887
<b>Secondary care</b>	1,417,061,030	443,333,624	277,370,161	696,357,244	4,765	2,690	4,782	9,339
Women	627,973,841	239,448,145	119,681,362	268,844,335	4,352	2,725	4,866	8,447
Men	789,087,188	203,885,480	157,688,799	427,512,910	5,154	2,650	4,721	10,002
<b>Pharmaceutical drug costs</b>	255,799,680	102,638,292	62,354,493	90,806,895	860	623	1,075	1,218
Women	124,231,968	56,257,489	28,124,315	39,850,163	861	640	1,143	1,252
Men	131,567,712	46,380,803	34,230,178	50,956,732	859	603	1,025	1,192
<b>Nursing costs</b>	1,913,057,725	486,635,500	319,986,457	1,106,435,768	6,433	2,953	5,517	14,838
Women	1,181,279,919	347,648,931	197,983,759	635,647,229	8,187	3,957	8,050	19,973
Men	731,777,784	138,986,589	122,002,705	470,788,491	4,780	1,806	3,652	11,015
<b>Nursing home</b>	850,952,193	211,354,084	128,233,596	511,364,513	2,862	1,282	2,211	6,858
Women	537,556,556	151,368,523	82,046,366	304,141,667	3,726	1,723	3,336	9,556
Men	313,395,637	59,985,561	46,187,229	207,222,847	2,047	780	1,383	4,848
<b>Nursing in own home</b>	682,300,980	207,788,535	123,110,097	351,402,347	2,294	1,261	2,123	4,713
Women	421,328,648	149,028,783	75,136,381	197,163,484	2,920	1,696	3,055	6,195
Men	260,972,332	58,759,753	47,973,716	154,238,863	1,705	764	1,436	3,609
<b>Home nurse in own home</b>	379,804,552	67,492,881	68,642,764	243,668,907	1,277	410	1,183	3,268
Women	222,394,715	47,251,626	40,801,011	134,342,079	1,541	538	1,659	4,221
Men	157,409,815	20,241,275	27,841,759	109,326,781	1,028	263	833	2,558
<b>Productivity loss</b>	1,770,021,767	584,202,697	360,442,062	825,377,008	5,952	3,545	6,214	11,069
Women	550,569,259	245,373,990	101,862,861	203,332,408	3,816	2,793	4,142	6,389
Men	1,219,452,507	338,828,707	258,579,201	622,044,600	7,965	4,403	7,741	14,553
<b>Lost income</b>	912,272,022	413,992,645	184,680,345	313,599,033	3,068	2,512	3,184	4,206
Women	317,068,466	190,042,378	47,083,003	79,943,085	2,198	2,163	1,914	2,512
Men	595,203,557	223,950,267	137,597,342	233,655,947	3,888	2,910	4,119	5,467
<b>Lost productivity in 2011 as a result of premature mortality</b>	32,477,477	3,584,403	5,659,401	23,233,674	109	22	98	312
Women	8,209,904	884,182	1,901,945	5,423,777	57	10	77	170
Men	24,267,574	2,700,221	3,757,456	17,809,896	159	35	112	417
<b>Lost productivity in 2011 as a result of premature deaths before 2011</b>	723,048,722	122,775,598	144,419,340	455,853,784	2,431	745	2,490	6,113
Women	187,784,170	35,195,124	44,329,134	108,259,911	1,302	401	1,802	3,402
Men	535,264,552	87,580,474	100,090,205	347,593,872	3,496	1,138	2,996	8,132
<b>Absence</b>	102,223,545	43,850,051	25,682,976	32,690,518	344	266	443	438
Women	37,506,720	19,252,307	8,548,779	9,705,634	260	219	348	305
Men	64,716,826	24,597,745	17,134,197	22,984,884	423	320	513	538
<b>Total additional costs</b>	1,096,979,996	285,846,918	193,084,112	618,048,966	3,689	1,734	3,329	8,288
Women	499,242,465	152,580,215	81,802,942	264,859,308	3,460	1,737	3,326	8,322
Men	597,737,531	133,266,704	111,281,170	353,189,657	3,904	1,732	3,331	8,263
<b>Education, prevention, psychological assistance etc.</b>	23,510,431	13,124,212	4,710,462	5,675,757	79	80	81	76
Women	11,433,432	7,005,481	1,995,657	2,432,294	79	80	81	76
Men	12,076,999	6,118,731	2,714,805	3,243,462	79	80	81	76
<b>SMBG and pumps</b>	66,392,321	38,767,809	13,283,599	14,340,912	223	235	229	192
Women	32,467,058	20,693,596	5,627,794	6,145,668	225	236	229	193
Men	33,925,263	18,074,213	7,655,806	8,195,243	222	235	229	192
<b>Medical appliances</b>	57,486,656	0	0	57,486,656	193	0	0	771
Women	24,635,388	0	0	24,635,388	171	0	0	774
Men	32,851,268	0	0	32,851,268	215	0	0	769
<b>Patients' and informal care givers' time</b>	345,542,010	183,886,084	66,482,029	95,173,897	1,162	1,116	1,146	1,276
Women	167,107,269	98,155,258	28,166,096	40,785,915	1,158	1,117	1,145	1,282
Men	178,434,741	85,730,825	38,315,933	54,387,982	1,166	1,114	1,147	1,272
<b>Depreciation</b>	604,048,579	50,068,814	108,608,022	445,371,743	2,031	304	1,873	5,973
Women	263,599,318	26,725,880	46,013,396	190,860,043	1,827	304	1,871	5,997
Men	340,449,260	23,342,934	62,594,626	254,511,701	2,224	303	1,874	5,955
<b>Total for all cost items</b>	6,674,097,103	2,013,256,821	1,255,306,273	3,405,534,010	22,443	12,216	21,643	45,670
Women	3,096,916,097	1,104,543,408	549,234,630	1,443,138,059	21,465	12,572	22,331	45,345
Men	3,577,180,985	908,713,433	706,071,649	1,962,395,903	23,365	11,809	21,137	45,912

C0, no complications; C1, minor complications; C2, major complications; SMBG, self-monitoring of blood glucose.

**Table 2** Diabetes attributable costs and attributable costs per person-year for the diabetes population according to complication status and gender

Cost item	Total attributable cost (EUR)				Total attributable cost per person-year (EUR)			
	ALL	C0	C1	C2	ALL	C0	C1	C2
<b>Healthcare costs</b>	731,520,509	93,151,921	146,557,644	491,810,944	2,460	565	2,527	6,595
Women	307,076,026	56,324,754	65,757,805	184,993,467	2,128	641	2,674	5,813
Men	424,444,483	36,827,167	80,799,839	306,817,477	2,772	479	2,419	7,178
<b>Primary care</b>	23,775,938	8,071,606	4,630,869	11,073,463	80	49	80	149
Women	9,466,709	3,358,214	2,032,360	4,076,136	66	38	83	128
Men	14,309,229	4,713,392	2,598,509	6,997,327	93	61	78	164
<b>Secondary care</b>	707,744,571	85,080,316	141,926,775	480,737,481	2,380	516	2,447	6,447
Women	297,609,317	52,966,541	63,725,445	180,917,331	2,063	603	2,591	5,685
Men	410,135,255	32,113,775	78,201,329	299,820,150	2,679	417	2,341	7,015
<b>Pharmaceutical drug costs</b>	153,372,738	51,151,437	43,493,499	58,727,802	516	310	750	788
Women	68,729,716	25,830,792	18,958,706	23,940,218	476	294	771	752
Men	84,643,022	25,320,645	24,534,793	34,787,584	553	329	734	814
<b>Nursing costs</b>	851,426,972	44,157,419	138,412,494	668,857,059	2,863	268	2,386	8,970
Women	530,191,480	55,119,865	94,574,667	380,496,948	3,675	627	3,845	11,956
Men	321,235,491	-10,962,446	43,837,827	288,360,111	2,098	-142	1,312	6,746
<b>Nursing home</b>	271,179,210	-22,733,872	29,375,665	264,537,417	912	-138	506	3,548
Women	214,979,658	8,249,313	31,006,921	175,723,425	1,490	94	1,261	5,521
Men	56,199,552	-30,983,185	-1,631,255	88,813,992	367	-403	-49	2,078
<b>Nursing in own home</b>	307,899,167	47,914,035	59,025,923	200,959,210	1,035	291	1,018	2,695
Women	180,996,612	39,487,891	36,882,579	104,626,142	1,254	449	1,500	3,287
Men	126,902,555	8,426,144	22,143,344	96,333,067	829	110	663	2,254
<b>Home nurse in own home</b>	272,348,594	18,977,256	50,010,906	203,360,433	916	115	862	2,727
Women	134,215,210	7,382,661	26,685,167	100,147,381	930	84	1,085	3,147
Men	138,133,384	11,594,594	23,325,738	103,213,051	902	151	698	2,415
<b>Productivity loss</b>	1,770,021,767	584,202,697	360,442,062	825,377,008	5,952	3,545	6,214	11,069
Women	550,569,259	245,373,990	101,862,861	203,332,408	3,816	2,793	4,142	6,389
Men	1,219,452,507	338,828,707	258,579,201	622,044,600	7,965	4,403	7,741	14,553
<b>Lost income</b>	912,272,022	413,992,645	184,680,345	313,599,033	3,068	2,512	3,184	4,206
Women	317,068,466	190,042,378	47,083,003	79,943,085	2,198	2,163	1,914	2,512
Men	595,203,557	223,950,267	137,597,342	233,655,947	3,888	2,910	4,119	5,467
<b>Lost productivity in 2011 due to premature mortality</b>	32,477,477	3,584,403	5,659,401	23,233,674	109	22	98	312
Women	8,209,904	884,182	1,901,945	5,423,777	57	10	77	170
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Women	187,784,170	35,195,124	44,329,134	108,259,911	1,302	401	1,802	3,402
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<b>Absence</b>	102,223,545	43,850,051	25,682,976	32,690,518	344	266	443	438
Women	37,506,720	19,252,307	8,548,779	9,705,634	260	219	348	305
Men	64,716,826	24,597,745	17,134,197	22,984,884	423	320	513	538
<b>Total additional costs</b>	760,778,770	257,979,629	132,635,083	370,164,058	2,558	1,565	2,287	4,964
Women	352,528,414	137,705,130	56,192,816	158,630,468	2,443	1,567	2,285	4,984
Men	408,250,356	120,274,499	76,442,267	211,533,590	2,667	1,563	2,288	4,949
<b>Education, prevention, psychological assistance etc.</b>	23,510,431	13,124,212	4,710,462	5,675,757	79	80	81	76
Women	11,433,432	7,005,481	1,995,657	2,432,294	79	80	81	76
Men	12,076,999	6,118,731	2,714,805	3,243,462	79	80	81	76
<b>SMBG and pumps</b>	66,392,321	38,767,809	13,283,599	14,340,912	223	235	229	192
Women	32,467,058	20,693,596	5,627,794	6,145,668	225	236	229	193
Men	33,925,263	18,074,213	7,655,806	8,195,243	222	235	229	192
<b>Medical appliances</b>	57,486,656	0	0	57,486,656	193	0	0	771
Women	24,635,388	0	0	24,635,388	171	0	0	774
Men	32,851,268	0	0	32,851,268	215	0	0	769
<b>Patients' and informal care givers' time</b>	345,542,010	183,886,084	66,482,029	95,173,897	1,162	1,116	1,146	1,276
Women	167,107,269	98,155,258	28,166,096	40,785,915	1,158	1,117	1,145	1,282
Men	178,434,741	85,730,825	38,315,933	54,387,982	1,166	1,114	1,147	1,272
<b>Depreciation</b>	267,847,352	22,201,524	48,158,993	197,486,835	901	135	830	2,648
Women	116,885,267	11,850,795	20,403,270	84,631,202	810	135	830	2,659
Men	150,962,085	10,350,729	27,755,723	112,855,634	986	135	831	2,640
<b>Total for all cost items</b>	4,267,120,755	1,030,643,103	821,540,781	2,414,936,871	14,349	6,254	14,164	32,386
Women	1,809,094,895	520,354,532	337,346,855	951,393,509	12,539	5,923	13,716	29,894
Men	2,458,025,860	510,288,571	484,193,927	1,463,543,362	16,055	6,631	14,495	34,241

C0, no complications; C1, minor complications; C2, major complications; SMBG, self-monitoring of blood glucose.

**Table 3** Total person-years for the entire diabetes population according to complication status and gender

Person years	All	No complications	Minor complications	Major complications
Total	297,378	164,809	58,000	74,568
Women	144,281	87,860	24,595	31,826
Men	153,097	76,950	33,405	42,742

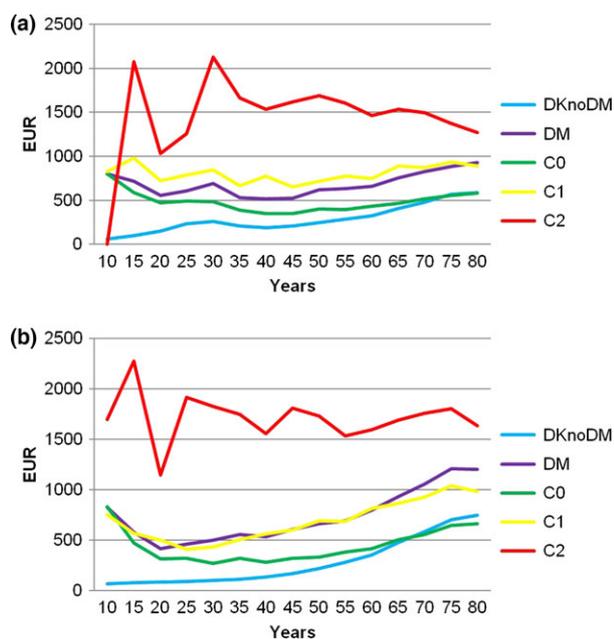
be 299 and 722 EUR per year, respectively, after controlling for potential confounders (Table S9).

**Productivity**

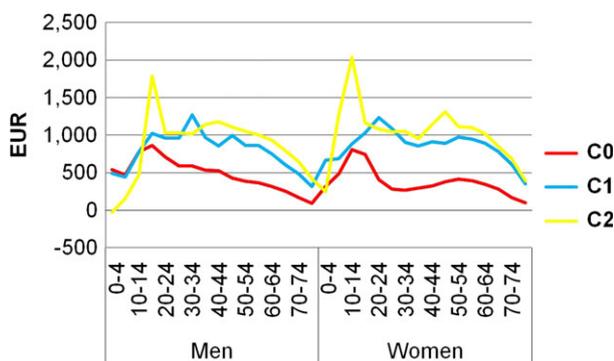
In total, the productivity loss amounted to 1.77 billion EUR, assuming patients with diabetes of working age earned the

same income as the diabetes-free population of the same age, gender and education level, died at the same age and had not experienced any excess days of absence attributable to disease.

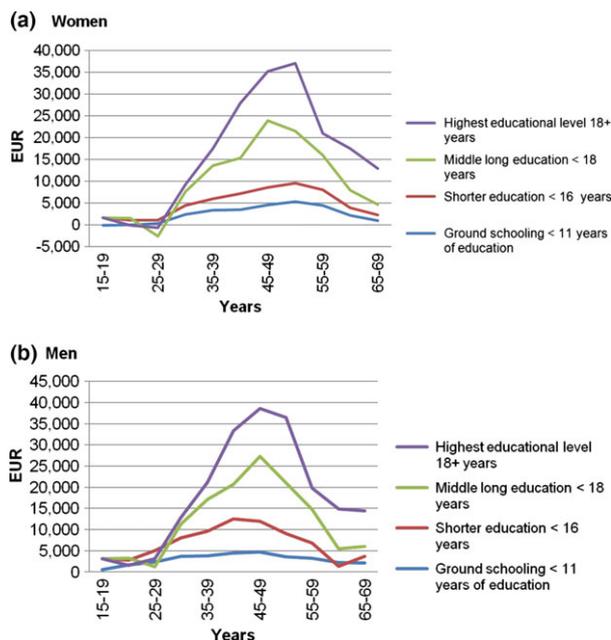
Patients with diabetes on average received a lower annual gross income than matched control subjects after controlling for education level. This reflected that a higher percentage of control subjects had jobs requiring high-level skills, e.g. almost twice as many control subjects held jobs in managerial positions, whereas patients with diabetes had a 22% higher unemployment rate and more than twice as many had retired early (12% compared with 5.4%). Differences in income level increased with education level and complication status group, with a maximum annual difference among patients with major complications belonging to the highest education level group of 25,229 EUR for men and 24,104 EUR for women in the age group 55–59 years. The annual difference in mean gross income according to age in four education level groups is shown for the no complications group, with men and women separately in Fig. 3.



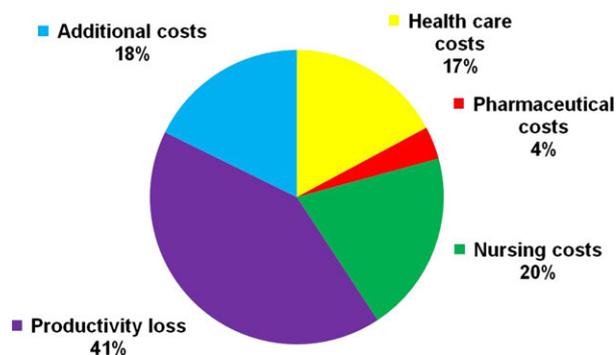
**FIGURE 1** Total cost of secondary care for the diabetes-free population (DKnoDM) and patients with diabetes (DM) by complication state (C0: no, C1: minor and C2: major) for (a) women and (b) men.



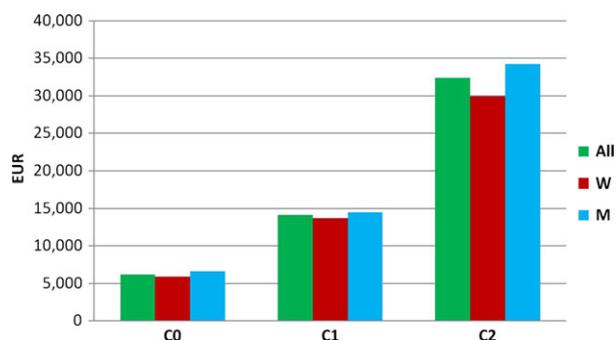
**FIGURE 2** Diabetes-attributable cost for pharmaceuticals by age, gender and complication status (C0: no, C1: minor and C2: major).



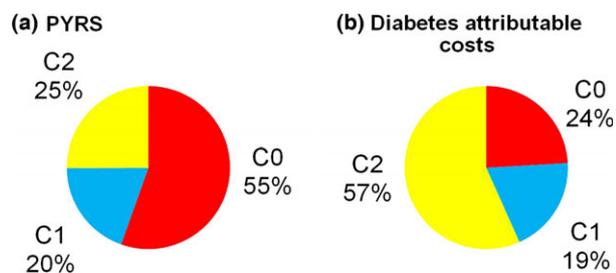
**FIGURE 3** Annual difference in mean gross income according to age and education level for (a) women and (b) men with no diabetes complications.



**FIGURE 4** Relative distribution of the components of diabetes-attributable costs.



**FIGURE 5** Diabetes attributable costs according to complication status (C0: no complications; C1: minor complications; C2: major complications) and gender.



**FIGURE 6** Relative distribution of person years (a) and diabetes attributable costs (b) according to complication status (C0: no complications; C1: minor complications; C2: major complications).

The total attributable difference in annual gross income was 912 million EUR. The main share (46%) of the total productivity loss was attributable to productivity losses among patients with no complications, because of the volume of people of working age. Lost productivity in 2011 as a result of premature death from diabetes was 32.4 million EUR calculated from 1,567 premature deaths corresponding to 52% of the total number of deaths among patients with diabetes of working age and to 1% of the total diabetes population in the working age group. Production foregone in 2011 as a result of premature deaths from

diabetes encountered before 2011 (with production foregone as a result of the diabetes-attributable deaths until the age of 69 years used as proxy estimate) was estimated to be 723 million EUR, and excess days of absence from work were estimated to be 102 million EUR in 2011.

#### Additional costs

Additional costs attributable to diabetes were estimated to be 761 million EUR corresponding to 2,558 EUR per person-year.

#### Total attributable costs

The total costs of diabetes in Denmark in 2011 were estimated to be 6.67 billion EUR (22,443 EUR per person-year), of which 4.27 billion EUR (14,349 EUR per person-year) were attributable to diabetes. The relative distribution between cost components is shown in Fig. 4, and the absolute distribution is shown in the Figure S1.

The total diabetes-attributable costs were divided between the no complication, minor complication and major complication groups as follows: 6,254, 14,164 and 32,386 EUR per person-year, respectively (Fig. 5).

The relative distribution of total attributable costs according to complication status and number of person-years showed that 25% of patients with diabetes consumed nearly 60% of attributable costs (Fig. 6).

#### Discussion

We found that patients with diabetes consumed approximately twice the healthcare resources consumed by people without diabetes. This is less than that documented in earlier studies [20], indicating that the population with diabetes is becoming less resource-demanding in the healthcare sector per person-year, probably as a result of improvements in prognosis [21,22]. Compared with the diabetes-free population, patients with diabetes incurred their resource use earlier in life, while later in life they required more specialized care. When patients with diabetes developed complications, the healthcare and nursing costs increased markedly. Men in particular used fewer healthcare services before complications, whereas later they were more likely than women to progress to major complications with a need for specialized care. We show a marked increase in healthcare costs with increasing complications, even after controlling for relevant confounders. These findings correspond to those of other studies, which document major costs related to diabetes complications [23,24]. This highlights the cost-saving potential of preventing complications among patients with diabetes and hence the importance of secondary prevention. Acknowledging that more people are living for longer with diabetes because of prognosis improvements, and that these epidemiological trends cannot be turned around in the short or medium term [21,22], the importance of prevention of expensive complications is highlighted. We

found that patients' morbidity characteristics were the most important predictors of diabetes-attributable costs. Interestingly, however, the multivariate analysis, showed significant cost differences according to region of residence, education level and year of death. This latter finding indicates that the high attributable costs for younger patients with diabetes might, to some degree, be attributable to death *per se*, irrespective of the cause of death. This methodological issue should be further investigated. Likewise, underlying associations between patients' characteristics and their morbidity patterns are important to investigate further in order to target prevention and treatment efforts. These issues will be dealt with in future work.

Regarding pharmaceutical drug consumption, the greatest increase in costs was found to be between patients with no complications and those with minor complications. Clinically, this might be explained by patients with minor complications being heavily medicated to prevent progression to major complications. Gender differences point to women being more proactive in receiving pharmaceutical drugs earlier in their diabetes (with fewer complications) than men. Nursing costs were found to be concentrated among patients with major complications, corresponding to recent structural changes in Denmark with respect to nursing services being offered. Patients with diabetes were more costly than the diabetes-free population, in particular with respect to visits by a home nurse. Results clearly show evidence for different labour market patterns among patients with diabetes compared with the control subjects, and increasing loss in productivity among patients with diabetes was seen with an increase in complication levels. When controlling for education level, it was evident that the main extent of the income disparities could not be accounted for by the fact that the diabetes incidence was higher among people with lower income. We therefore expect the difference to be attributable to the influence of the ability of the person with diabetes to work, thus resulting in a lower annual income. Even though diabetes mainly affects older people in society, looking at patient volume, we show major costs to society as well as to the individual in relation to productivity.

The exclusion of patients registered in the Danish National Diabetes Register solely because of frequent blood glucose measurements (63,647 person-years) [12] resulted in a reduction in patients with no complications. Total attributable costs were decreased by 9% (to 3.9 billion EUR), but attributable cost per person-year increased. We conclude therefore that estimates for patients with no complications might be underestimated.

The chosen approach with a 1-year time window has its limitations, but it allowed a descriptive analysis of the population in this year [25]. It would be advantageous to include more years to facilitate analysis of trends over time. Our data did not allow a distinction between Type 1 and Type 2 diabetes, which would be advantageous taking the different aetiology into consideration. Our findings across

age groups indicate high attributable costs among children and teenagers, reflecting that the diabetes-free population in these age groups consumes markedly less healthcare, nursing services and pharmaceutical drugs.

Categorizing patients according to their development of complications; i.e. no complications, minor complications and major complications, is a novel method within this field. We aimed to contribute to this field with an easily understandable outline of the cost pattern for a very complex disease, providing decision-makers with the necessary guidance for future investments in diabetes.

The presented cost distributions by component and by complication status are presumably not only valid in a Danish setting but could be transferred to other countries and chronic diseases.

Based on all available data in Danish national health registers for all patients with diabetes in 2011, the costs attributable to diabetes were estimated to be at least 4.27 billion EUR, corresponding to 14,349 EUR per person-year. We show a steep increase in attributable costs for patients with major complications compared with patients without complications across all cost components, also when potential confounders are controlled for. Our results underline the universal message of cost increases with increased complications, providing an economic rationale for secondary prevention.

Evidence of cost distributions within diabetes can guide future efforts in specific sectors, or targeted patient groups, based on expected cost savings.

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#### Competing interests

None declared.

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## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Table S1.** Grouping of diagnoses and interventions used for classifying hospital activities by complication status of relevance for diabetes, and with respect to diagnostic specificity for diabetes.

**Table S2.** Cost units and methods of calculation for cost components.

**Table S3.** Definition of variables included in the multivariate analysis

**Table S4.** Total diabetes-attributable costs and attributable costs per person-year for all diabetes patients, excluding patients included in the National Diabetes Register as a result of frequent blood glucose measurements.

**Table S5.** Distribution of person-years by complication status and gender for all diabetes patients, excluding patients included in the National Diabetes Register as a result of frequent blood glucose measurements.

**Table S6.** Multivariate analysis of total healthcare costs (EUR per person-year).

**Table S7.** Multivariate analysis of total attributable healthcare costs (EUR per person-year).

**Table S8.** Multivariate analysis of total net pharmaceutical costs (EUR per year).

**Table S9.** Multivariate analysis of total costs for nursing in own home (EUR per year).

**Figure S1** Absolute distribution of diabetes-attributable costs by cost components.

**Supplementary references.**