BMJ Open Diabetes Research & Care

Trends in inpatient admissions and emergency department visits for heart failure in adults with versus without diabetes in the USA, 2006–2017

Jessica L Harding ,[1,2] Stephen R Benoit ,[3] Israel Hora,[3] Lakshmi Sridharan ,[4] Mohammed K Ali,[3,5,6] Ram Jagannathan,[2] Rachel E Patzer,[1] K M Venkat Narayan [5]

To cite: Harding JL, Benoit SR, Hora I, *et al*. Trends in inpatient admissions and emergency department visits for heart failure in adults with versus without diabetes in the USA, 2006–2017. *BMJ Open Diab Res Care* 2021;**9**:e002377. doi:10.1136/bmjdrc-2021-002377

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjdrc-2021-002377).

Received 11 May 2021
Accepted 22 September 2021

ABSTRACT

Introduction Heart failure (HF) is a major contributor to cardiovascular morbidity and mortality in people with diabetes. In this study, we estimated trends in the incidence of HF inpatient admissions and emergency department (ED) visits by diabetes status.

Research design and methods Population-based age-standardized HF rates in adults with and without diabetes were estimated from the 2006–2017 National Inpatient Sample, Nationwide ED Sample and year-matched National Health Interview Survey, and stratified by age and sex. Trends were assessed using Joinpoint.

Results HF inpatient admissions did not change in adults with diabetes between 2006 and 2013 (from 53.9 to 50.4 per 1000 persons; annual percent change (APC): −0.3 (95% CI −2.5 to 1.9) but increased from 50.4 to 62.3 between 2013 and 2017 (APC: 4.8 (95% CI 0.3 to 9.6)). In adults without diabetes, inpatient admissions initially declined (from 14.8 in 2006 to 12.9 in 2014; APC −2.3 (95% CI −3.2 to −1.2)) and then plateaued. Patterns were similar in men and women, but relative increases were greatest in young adults with diabetes. HF-related ED visits increased overall, in men and women, and in all age groups, but increases were greater in adults with (vs without) diabetes.

Conclusions Causes of increased HF rates in hospital settings are unknown, and more detailed data are needed to investigate the aetiology and determine prevention strategies, particularly among adults with diabetes and especially young adults with diabetes.

SIGNIFICANCE OF THIS STUDY

WHAT IS ALREADY KNOWN ABOUT THIS SUBJECT?

⇒ Heart failure (HF) is a major contributor to cardiovascular morbidity and mortality in people with diabetes.
⇒ Whether HF-related hospitalizations among adults with versus without diabetes has changed over time remains unknown.

WHAT ARE THE NEW FINDINGS?

⇒ Rates of HF-related inpatient admissions and ED visits are three to five times higher in adults with versus without diabetes, and this excess risk has increased over time.
⇒ Though absolute rates remain lowest in the youngest age groups, the greatest relative increases in HF-related inpatient admissions and ED visits were observed in young adults with diabetes.
⇒ Increases in HF-related utilization among adults with diabetes was observed in both inpatient and ED settings, suggesting broader underlying causes rather than a shift in treatment setting.

HOW MIGHT THESE RESULTS CHANGE THE FOCUS OF RESEARCH OR CLINICAL PRACTICE?

⇒ Combined with current evidence from clinical trials, findings of this study support the use of intensive and focused prevention and management of diabetes, including the use of SGL2 inhibitors, to reduce the incidence of HF hospitalizations in people with diabetes.
⇒ Future research should focus on the drivers of increases in HF hospitalizations, especially among young people with diabetes.

Check for updates

For numbered affiliations see end of article.

Correspondence to
Dr Jessica L Harding; jessica.harding@emory.edu

INTRODUCTION

People with diabetes are at increased risk for cardiovascular disease (CVD) and associated complications.[1] Although diabetes has become an increasingly common disease, estimated to affect 463 million people worldwide[2] and more than 34 million in the USA,[3] CVD and related mortality in people with diabetes has fallen dramatically in most high-income countries since the 1980s likely due to advances in treatment and better management of risk factors.[4 5] However, the reported declines in CVD among people with diabetes (both incidence and mortality) often do not include heart failure (HF) as an outcome, despite increasing recognition that HF is a major contributor to CVD morbidity, mortality and healthcare costs in people with diabetes.[1 6–11]

In a 2015 paper, Shah *et al*[9] demonstrated that HF is more likely to be an initial manifestation of CVD in people with type 2 diabetes compared with myocardial infarction, stroke and coronary disease. Despite the relative importance of HF in diabetes, few studies have comprehensively examined whether rates of HF in people with diabetes (vs without diabetes) has changed over time. In the USA, one recent study demonstrated that HF inpatient admissions, defined as the primary reason for hospital admission, increased 3.6% per year between 2013 and 2015 following a period of decline.[12] However, to understand the underlying drivers of changes in HF rates and develop subsequent interventions, a comparison with people without diabetes is needed. Such comparisons in atherosclerotic CVD (eg, myocardial infarction and coronary artery disease) have led to narrowing the gap by reducing the excess risk in diabetes populations.[13 14] Furthermore, a more comprehensive approach to understanding the overall HF burden is necessary to inform healthcare planning and resource allocation. This includes consideration of multiple settings in which HF care is likely to occur, as well as consideration of HF as both a primary and contributory cause for hospitalization.

Using nationally representative USA data, we estimated secular trends in the incidence of HF-related inpatient admissions and ED visits among adults with diabetes versus adults without diabetes between 2006 and 2017.

METHODOLOGY

The National Inpatient Sample (NIS) and the Nationwide Emergency Department Sample (NEDS)

We analyzed annual data (2006–2017) from the Agency for Healthcare Research and Quality's NIS and NEDS.[15] NIS and NEDS, the largest all-payer inpatient and ED databases in the USA, includes 7 million and 30 million unweighted annual visits, respectively.[15] Both data sets approximate a 20% stratified sample of discharges and can be weighted to provide nationally representative estimates. Rehabilitation and long-term acute care hospitals are excluded from NIS. Both NIS and NEDS include International Classification of Diseases Clinical Modification (ICD-CM) diagnostic codes as well as patient demographics, hospital characteristics, payment sources, patient disposition and total charges. Both NIS and NEDS data represent hospital discharges, not individual persons, and therefore our analysis does not account for multiple admissions per person.

A hospitalization was considered to be related to HF if at least one ICD-9-CM diagnosis code 428.x between January 2000 and September 2015, or ICD-10-CM diagnosis code I50.x between October 2015 and December 2017, appeared in NIS or NEDS data. This approach is aimed to better capture the overall burden of HF by including HF listed as the primary or contributory cause of the hospitalization. In a sensitivity analysis, we defined HF as the primary cause of hospital admission in NIS and NEDS between January 2006 and September 2015. This analysis was restricted to September 2015 and earlier due to known coding changes implemented in October 2015 that impacted the likelihood of HF being listed as the primary cause of hospital admissions in later years.[16] The 2015 population data (from National Health Interview Survey (NHIS)) were weighted by 0.75 to reflect that only three-quarters of the numerator data was used.[17] To avoid double-counting, we excluded ED visits where the disposition was admission to the hospital because these HF events were accounted for in the inpatient data. Each HF-related admission was considered to be related to diabetes if any of the listed diagnoses also included a diabetes code (ICD-9-CM: 250 .x, 357.2, 366.41; ICD-10-CM: E10, E11 and E13). Comorbidities, adapted from the Charlson Comorbidity Index, among hospitalized patients with HF and with or without diabetes were defined using ICD-9-CM and ICD-10-CM, as appropriate (see online supplemental table 1).

The National Health Interview Survey

Using annual data (2006–2017) from the NHIS, we estimated the number of persons aged ≥18 years with and without diabetes.[18] The NHIS is a household-based survey of the health of the civilian, non-institutionalized USA population.[18] We defined adults with diabetes if the sample adult responded yes to the question, 'other than during pregnancy, have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?'. This survey does not distinguish between diabetes types; but given that type 2 diabetes accounts for 90%–95% of all diabetes cases,[19] we consider the results of this study to be generalizable to people with diagnosed type 2 diabetes. Data from the NHIS were weighted to make estimates representative of the demographic characteristics of the US civilian non-institutionalized population.

Statistical analysis

We reported the crude weighted number of patients with HF at the start (2006), middle (2011) and end (2017) of the study period, stratified by diabetes status, and age group, sex, location (urban, micropolitan and rural), household income (quartiles), USA region (northeast, midwest, south and west) and comorbidities for both NIS and NEDS. The weighted results estimate the number of inpatient admissions and non-admission ED visits in the USA due to HF.

Annual rates were calculated as the number of HF hospitalizations with and without diabetes (as determined from NIS and NEDS), divided by the number of persons with and without diabetes (as determined from NHIS). We reported age-standardized rates of HF per 1000 adults with diabetes and per 1000 adults without diabetes. Age (grouped into 18–44, 45–64, 65–74 and ≥75 years) and sex-specific rates were also calculated. Rates were age standardized using the 2000 USA standard population. Excess risk between diabetes and non-diabetes populations was estimated as rate ratios

Table 1 Characteristics of adults with HF in inpatient (NIS) and ED (NEDS) settings, by diabetes status,* 2006, 2011 and 2017

	Diabetes status	Emergency department (NEDS)**						Inpatient (NIS)					
		2006		2011		2017		2006		2011		2017	
		N	%	N	%	N	%	N	%	N	%	N	%
Weighted total, N		863 816		1 215 499		2 291 311		4 199 309		4 328 315		5 076 844	
Demographic characteristics													
Age group (years)													
18-44	Yes	16 745	5.7	27 349	5.9	56 166	5.8	44 483	2.8	50 329	2.7	68 740	2.9
	No	47 556	8.3	65 266	8.7	120 347	9.1	102 984	3.9	96 885	3.9	124 950	4.6
45-64	Yes	97 036	33.3	164 710	35.5	360 344	37	414 267	26.4	507 741	27.1	672 170	28.2
	No	134 910	23.6	202 597	27	397 474	30.2	468 952	17.8	469 112	19.1	581 875	21.6
65-74	Yes	70 292	24.1	111 663	24.1	252 654	25.9	412 325	26.2	499 910	26.7	690 205	29
	No	95 300	16.7	122 115	16.2	240 782	18.3	479 143	18.2	435 137	17.7	556 425	20.7
≥75	Yes	107 552	36.9	160 043	34.5	305 444	31.3	701 007	44.6	815 249	43.5	952 585	40
	No	294 425	51.5	361 756	48.1	558 100	42.4	1 576 148	60	1 453 952	59.2	1 429 894	53.1
Gender													
Men	Yes	122 793	42.1	205 775	44.4	457 279	46.9	724 625	46.1	908 406	48.5	1 227 515	51.5
	No	249 204	43.6	329 884	43.9	621 073	47.2	1 213 043	46.2	1 143 371	46.6	1 333 365	49.5
Women	Yes	168 800	57.9	257 662	55.6	517 247	53.1	847 414	53.9	964 767	51.5	1 156 150	48.5
	No	322 796	56.4	421 466	56.1	695 466	52.8	1 414 070	53.8	1 311 565	53.4	1 359 705	50.5
Location													
Urban	Yes	217 555	74.8	357 555	77.2	790 845	81.3	1 234 506	78.7	1 469 309	79.9	1 955 570	82.3
	No	422 590	74.1	571 866	76.3	1 054 555	80.4	2 033 634	77.6	1 905 172	79.5	2 193 210	81.7
Micropolitan	Yes	43 821	15.1	63 141	13.6	106 273	10.9	191 267	12.2	210 987	11.5	235 854	9.9
	No	81 791	14.3	101 643	13.6	146 877	11.2	333 365	12.7	276 922	11.6	271 774	10.1
Rural	Yes	29 566	10.2	42 292	9.1	75 427	7.8	143 331	9.1	159 368	8.7	185 925	7.8
	No	65 664	11.5	76 464	10.2	110 611	8.4	254 262	9.7	213 847	8.9	218 230	8.1
Household income													
First quartile (poorest)	Yes	102 414	35.8	172 413	37.9	383 475	40	515 942	33.6	624 720	33.9	826 755	35.2
	No	187 940	33.6	258 795	35.1	470 234	36.4	773 507	30.1	730 924	30.3	819 735	31
Second quartile	Yes	85 225	29.8	125 087	27.5	268 279	28	406 474	26.5	466 148	25.3	639 255	27.2
	No	160 980	28.8	198 215	26.9	355 320	27.5	670 920	26.1	604 367	25.1	714 885	27
Third quartile	Yes	63 322	22.2	98 071	21.5	186 367	19.4	340 853	22.2	447 474	24.3	514 840	21.9
	No	125 866	22.5	165 483	22.4	268 241	20.7	598 751	23.3	593 410	24.6	608 900	23

Continued

Table 1 Continued

	Diabetes status	Emergency department (NEDS)**						Inpatient (NIS)					
		2006		2011		2017		2006		2011		2017	
		N	%	N	%	N	%	N	%	N	%	N	%
Fourth quartile (wealthiest)	Yes	34 886	12.2	59 563	13.1	121 124	12.6	272 696	17.8	302 516	16.4	365 980	15.6
	No	85 056	15.2	114 868	15.6	199 544	15.4	527 656	20.5	480 756	20	504 725	19.1
US region													
Northeast	Yes	33 609	11.5	46 079	9.9	86 556	8.9	320 429	20.4	354 641	18.9	426 350	17.9
	No	81 856	14.3	87 542	11.6	144 018	10.9	501 525	19.1	507 939	20.7	513 079	19.1
Midwest	Yes	85 067	29.2	122 662	26.4	242 622	24.9	393 679	25	474 545	25.3	583 045	24.5
	No	156 589	27.4	193 037	25.7	328 833	25	658 381	25.1	611 503	24.9	644 774	23.9
South	Yes	129 239	44.3	211 335	45.6	462 321	47.4	618 281	39.3	733 689	39.2	971 856	40.8
	No	234 413	41	322 829	42.9	578 959	44	1 061 978	40.4	938 078	38.2	1 059 016	39.3
West	Yes	43 709	15	83 689	18	183 109	18.8	239 693	15.2	310 355	16.6	402 449	16.9
	No	99 333	17.4	148 326	19.7	264 894	20.1	405 343	15.4	397 565	16.2	476 274	17.7
Comorbidities													
Myocardial Infarction	Yes	247 859	16.6	418 179	15.3	629 091	21.1	272 138	17.3	396 389	21.2	568 300	23.8
	No	383 379	15.1	300 754	16.5	619 893	17.5	433 155	16.5	455 611	18.6	548 890	20.4
Peripheral Vascular Disease	Yes	144 798	9.7	218 434	8	440 161	14.8	195 980	12.5	318 289	17	565 005	23.7
	No	166 635	6.6	186 437	10.2	522 821	14.7	216 342	8.2	285 756	11.6	501 535	18.6
Cerebrovascular Disease	Yes	98 752	6.6	187 399	6.8	123 358	4.1	120 054	7.6	184 883	9.9	133 380	5.6
	No	163 958	6.5	125 599	6.9	139 687	3.9	197 503	7.5	228 489	9.3	150 715	5.6
Dementia	Yes	99 882	6.7	299 327	10.9	263 721	8.9	105 888	6.7	177 371	9.5	248 990	10.4
	No	241 362	9.5	140 117	7.7	391 736	11	251 099	9.6	322 289	13.1	362 215	13.4
Chronic Pulmonary Disease	Yes	532 654	35.7	987 082	36	1 178 523	39.6	574 059	36.5	740 773	39.5	972 615	40.8
	No	921 924	36.3	672 799	36.9	1 349 228	38.1	1 016 015	38.7	951 659	38.8	1 101 715	40.9
Rheumatic Disease	Yes	27 135	1.8	86 688	3.2	78 835	2.6	30 915	2	53 319	2.8	70 870	3
	No	64 962	2.6	39 071	2.1	128 802	3.6	76 293	2.9	100 400	4.1	119 205	4.4
Peptic Ulcer Disease	Yes	18 072	1.2	35 223	1.3	33 329	1.1	21 700	1.4	29 251	1.6	35 165	1.5
	No	36 891	1.5	19 024	1	42 069	1.2	44 371	1.7	42 480	1.7	45 205	1.7
Liver Disease Mild	Yes	34 623	2.3	80 354	2.9	125 905	4.2	39 761	2.5	78 917	4.2	119 895	5
	No	67 995	2.7	50 306	2.8	128 975	3.6	77 314	2.9	102 382	4.2	123 860	4.6
Renal Disease Mild to Moderate	Yes	244 008	16.3	576 139	21	1 076 815	36.2	281 640	17.9	717 912	38.3	1 039 750	43.6
	No	263 803	10.4	551 260	30.3	855 003	24.1	308 784	11.8	657 730	26.8	837 925	31.1

Continued

Table 1 Continued

		Emergency department (NEDS)**						Inpatient (NIS)					
		2006		2011		2017		2006		2011		2017	
	Diabetes status	N	%	N	%	N	%	N	%	N	%	N	%
Hemiplegia or Paraplegia	Yes	10 333	0.7	30 742	1.1	37 755	1.3	12 234	0.8	23 801	1.3	43 430	1.8
	No	22 070	0.9	15 487	0.8	46 474	1.3	25 058	1	37 340	1.5	54 355	2
Any malignancy	Yes	51 584	3.5	139 644	5.1	111 149	3.7	68 008	4.3	96 629	5.2	119 180	5
	No	125 689	4.9	66 860	3.7	168 915	4.8	171 192	6.5	172 419	7	187 905	7
Liver Disease moderate to severe	Yes	7 801	0.5	20 780	0.8	34 597	1.2	10 484	0.7	21 739	1.2	37 535	1.6
	No	14 861	0.6	13 485	0.7	33 431	0.9	17 231	0.7	25 950	1.1	37 905	1.4
Renal disease severe	Yes	328 819	22	164 424	6	418 838	14.1	371 670	23.6	238 246	12.7	335 555	14.1
	No	356 566	14	197 091	10.8	212 217	6	407 246	15.5	154 810	6.3	164 155	6.1
HIV/AIDS	Yes	1 971	0.1	9 117	0.3	7 158	0.2	2 378	0.2	3 267	0.2	5 435	0.2
	No	8 966	0.4	3 013	0.2	16 791	0.5	9 239	0.4	8 588	0.3	11 295	0.4
Metastatic solid tumor	Yes	15 407	1	40 665	1.5	36 266	1.2	20 809	1.3	25 695	1.4	39 840	1.7
	No	42 913	1.7	17 100	0.9	58 244	1.6	59 113	2.2	51 215	2.1	67 090	2.5

*HF defined as any diagnosis; **excludes those who were admitted to hospital.
HF, heart failure; NEDS, Nationwide Emergency Department Sample; NIS, National Inpatient Sample.

(RRs). We used SAS-callable SUDAAN (RTI International) to account for the complex sampling design in NIS, NEDS and NHIS, and the Taylor series linearization was used to estimate the variance of the ratio of the numerator and denominator. The delta method was used to compute SEs and 95% CIs for rates and RRs accounting for the weighted design of NIS, NEDS and NHIS.[20]

In 2012, the NIS sampling design was changed, which has implications for trend analyses. Per NIS guidelines, we used NIS-provided trend weights for the years preceding 2012 and the discharge weights beginning in 2012 to make the discharge outcome consistent with the new sampling design.[21]

Joinpoint regression was used to examine trends over time.[22] This software uses permutation tests to identify points where linear trends change significantly in either direction or magnitude and calculates an annual percentage change (APC) for each time period identified. A maximum of two joinpoints were specified. A p value of <0.05 was established as statistical significance.

RESULTS

Characteristics of adults with HF in inpatient (NIS) and ED (NEDS) settings in 2006, 2011 and 2017, and by diabetes status, are described in table 1. In brief, among HF-related inpatient admissions and ED visits between 2006 and 2017, there was an increase in the proportion of men, middle-age adults (aged 45–64 and 65–74 years), adults residing in urban settings, adults reporting low-income households and adults living in the West. This was broadly true for people with and without diabetes. In addition, the proportion of HF hospitalizations, both in ED and inpatient settings, with comorbidities increased in people with and without diabetes with a few exceptions: HF-related hospitalizations with cerebrovascular disease and severe renal disease decreased over time in people with and without diabetes, and the proportion of HF-related hospitalizations with peptic ulcer disease, HIV, malignancy or metastatic solid tumor did not change over time in people with or without diabetes. The increasing proportion of most comorbidities was, generally, higher in people with as compared without diabetes.

National Inpatient Sample

In 2017, rates of HF-related inpatient admissions were more than five times as high in adults with versus without diabetes (RR: 5.1 (95% CI 4.7 to 5.5)), a significant increase from 3.6 (95% CI 3.3 to 4.0) in 2006 (table 2). Overall, between 2006 and 2013, rates of HF-related inpatient admissions did not change among adults with diabetes, and then increased sharply between 2013 and 2017 from 50.4 to 62.3 per 1000 persons (APC: 4.8 (95% CI 0.3 to 9.6) (figure 1A and table 2). Among adults without diabetes, the opposite was observed: between 2006 and 2014, rates declined from 14.8 to 11.7 (APC −2.3 (95% CI −3.2 to −1.2) and plateaued thereafter. Similar patterns were observed in both men and women.

By age, differences were noted (figure 2A and table 2). First, the excess risk associated with diabetes decreased with increasing age. For example, the 2017 RR was 20.2 (95% CI 16.9 to 23.5) versus 2.8 (95% CI 2.5 to 3.2) for those aged 18–44 and ≥75 years, respectively. Second, in adults aged 18–44 years with and without diabetes, rates of HF-related inpatient admissions increased similarly such that there was no significant change in the excess risk associated with diabetes over time. Third, among adults aged 45–64 and 65–74 years with and without diabetes, HF rates increased after a period of decline and the excess risk associated with diabetes increased. Last, among adults aged ≥75 years, rates of HF-related inpatient admissions declined throughout the study period in adults without, but not with, diabetes and the excess risk associated with diabetes increased (from RR of 2.0 to 2.8; APC 2.4 (95% CI 0.6 to 4.2)).

Nationwide Emergency Department Sample

In 2017, rates of HF-related ED visits were more than five times as high in adults with versus without diabetes (RR: 5.2 (95% CI 4.5 to 5.9)), a significant increase from 3.7 (95% CI 3.2 to 4.1) in 2006 (table 3). Overall, between 2006 and 2017, rates of HF-related ED visits increased in adults with (from 11.5 to 43.6 per 1000 persons) and without (from 3.1 to 5.9 per 1000 persons) diabetes (figure 1B and table 3). However, the rate of increase was greater in adults with diabetes, leading to an increase in the excess risk of HF-related ED visits associated with diabetes over.

Increases in HF-related ED visits were observed across all age groups and in adults with and without diabetes (figure 2B and table 3). For all age groups, excluding 65–74 years, the excess risk associated with diabetes did not significantly change over time, indicating increasing rates of HF ED visits were similar in adults with and without diabetes. However, among adults aged 65–74 years, the HF rate increase was greater in adults with diabetes, leading to an increase in the excess risk associated with diabetes over time (from RR of 3.3 to 4.4; APC 2.0 (95% CI 0.7 to 3.3)).

Sensitivity analyses

In a sensitivity analysis, we examined trends in HF inpatient admissions and ED visits between 2006 and 2015 where HF was defined as the primary reason for the admission (online supplemental tables 2 and 3). Overall, in 2015 rates of primary inpatient HF admissions and HF ED visits were 4.7 (95% CI 4.4 to 5.1) and 3.2 (95% CI 2.8 to 3.5) times as high in adults with versus without diabetes, respectively.

Though absolute rates were substantially lower when HF was defined as the primary (vs any) reason for admission, inpatient patterns were similar insofar as the excess risk associated with diabetes, particularly among younger adults, increased over time (online supplemental table 2).

Table 2 Age-standardized inpatient admission rates and rate ratios (RRs)* for HF in adults with versus without diabetes in the USA between 2006 and 2017

		Age-standardized inpatient admission rate (per 1000 people) (95% CI)†			Trend 1‡		Trend 2‡	
		2006	2011	2017	Year	APC (95% CI)	Year	APC (95% CI)
Total population	Diabetes	53.9 (49.4 to 58.3)	54.6 (50.9 to 58.4)	62.3 (58.2 to 66.4)	2006–2013	−0.3 (−2.5 to 1.9)	2013–2017	4.8 (0.3 to 9.6)§
	No diabetes	14.8 (13.7 to 15.8)	12.9 (12.2 to 13.6)	12.2 (11.6 to 12.9)	2006–2014	−2.3 (−3.2 to −1.2)§	2014–2017	1.4 (−2.6 to 5.6)
	RR	3.6 (3.3 to 4.0)	4.2 (3.9 to 4.6)	5.1 (4.7 to 5.5)	2006–2017	2.8 (1.9 to 3.7)§	n/a	
Sex								
Men	Diabetes	54.6 (48.9 to 60.3)	54.8 (50.2 to 59.4)	62.1 (57.2 to 67.1)	2006–2009	−4.7 (−13.4 to 4.9)	2009–2017	3.3 (1.6 to 4.9)§
	No diabetes	16.1 (14.8 to 17.4)	13.9 (13.0 to 14.9)	13.7 (12.9 to 14.6)	2006–2013	−2.4 (−3.7 to −1.2)§	2013–2017	1.2 (−1.3 to 3.7)
	RR	3.4 (2.9 to 3.8)	3.9 (3.5 to 4.4)	4.5 (4.0 to 5.0)	2006–2017	3.1 (1.9 to 4.3)§	n/a	
Women	Diabetes	53.0 (48.0 to 58.1)	54.6 (50.0 to 59.2)	62.5 (57.5 to 67.6)	2006–2013	−1.1 (−3.4 to 1.3)	2013–2017	5.2 (0.2 to 10.5)§
	No diabetes	13.7 (12.6 to 14.7)	12.0 (11.3 to 12.8)	11.0 (10.4 to 11.6)	2006–2017	−1.7 (−2.4 to −1.1)§	n/a	
	RR	3.9 (3.4 to 4.4)	4.5 (4.1 to 5.0)	5.7 (5.1 to 6.3)	2006–2017	2.8 (1.7 to 3.8)§	n/a	
Age group (years)								
18–44	Diabetes	15.2 (12.8 to 17.7)	18.6 (15.9 to 21.2)	22.8 (19.4 to 26.2)	2006–2017	3.9 (1.9 to 6.0)§	n/a	
	No diabetes	1.0 (0.9 to 1.0)	0.9 (0.8 to 1.0)	1.1 (1.1 to 1.2)	2006–2008	−9.4 (−24.2 to 8.1)	2008–2017	3.1 (1.5 to 4.7)§
	RR	15.9 (13.0 to 18.7)	20.7 (17.2 to 24.3)	20.2 (16.9 to 23.5)	2006–2017	2.2 (−0.1 to 4.4)	n/a	
45–64	Diabetes	53.4 (47.7 to 59.2)	52.3 (47.7 to 57.0)	63.4 (57.8 to 69.0)	2006–2008	−10.3 (−23.5 to 5.1)	2008–2017	3.8 (2.5 to 5.1)§
	No diabetes	7.1 (6.6 to 7.5)	6.6 (6.2 to 7.0)	8.0 (7.5 to 8.4)	2006–2012	−1.3 (−3.0 to 0.4)	2012–2017	4.7 (3.1 to 6.3)§
	RR	7.6 (6.6 to 8.5)	7.9 (7.1 to 8.8)	7.9 (7.1 to 8.8)	2006–2017	0.9 (0.2 to 1.7)§	n/a	
65–74	Diabetes	118.9 (104.1 to 133.6)	102.9 (93.6 to 112.2)	122.8 (11.8 to 133.8)	2006–2015	−1.7 (−2.8 to −0.6)§	2015–2017	11.4 (−0.7 to 24.8)
	No diabetes	30.7 (28.1 to 33.3)	25.6 (23.8 to 27.4)	23.4 (22.0 to 24.8)	2006–2013	−4.2 (−5.3 to −3.0)§	2013–2017	1.3 (−1.0 to 3.6)
	RR	3.9 (3.3 to 4.4)	4.0 (3.6 to 4.5)	5.3 (4.7 to 5.8)	2006–2017	2.0 (0.6 to 3.3)§	n/a	
≥75	Diabetes	236.4 (204.3 to 268.5)	245.6 (218.8 to 272.4)	249.6 (221.3 to 277.9)	2006–2017	0.1 (−1.4 to 1.6)	n/a	
	No diabetes	115.7 (105.8 to 125.6)	100.6 (93.5 to 107.7)	88.0 (82.2 to 93.8)	2006–2017	−2.2 (−2.8 to −1.7)§	n/a	
	RR	2.0 (1.7 to 2.4)	2.4 (2.1 to 2.8)	2.8 (2.5 to 3.2)	2006–2017	2.4 (0.6 to 4.2)§	n/a	

Data sources: National Center for Health Statistics, National Health Interview Survey and Agency for Healthcare Research and Quality, National Inpatient Sample.
*RR is rate in diabetes/rate in non-diabetes.
†Years 2006, 2011 and 2017 are displayed in this table for ease of presentation. Rates and 95% CI for other years are presented in figures 1 and 2.
‡Indicates the year in which trends change significantly in either direction or magnitude;.
§p_{trend} <0.05.
APC, annual percentage change; HF, heart failure; n/a, no second trend identified.

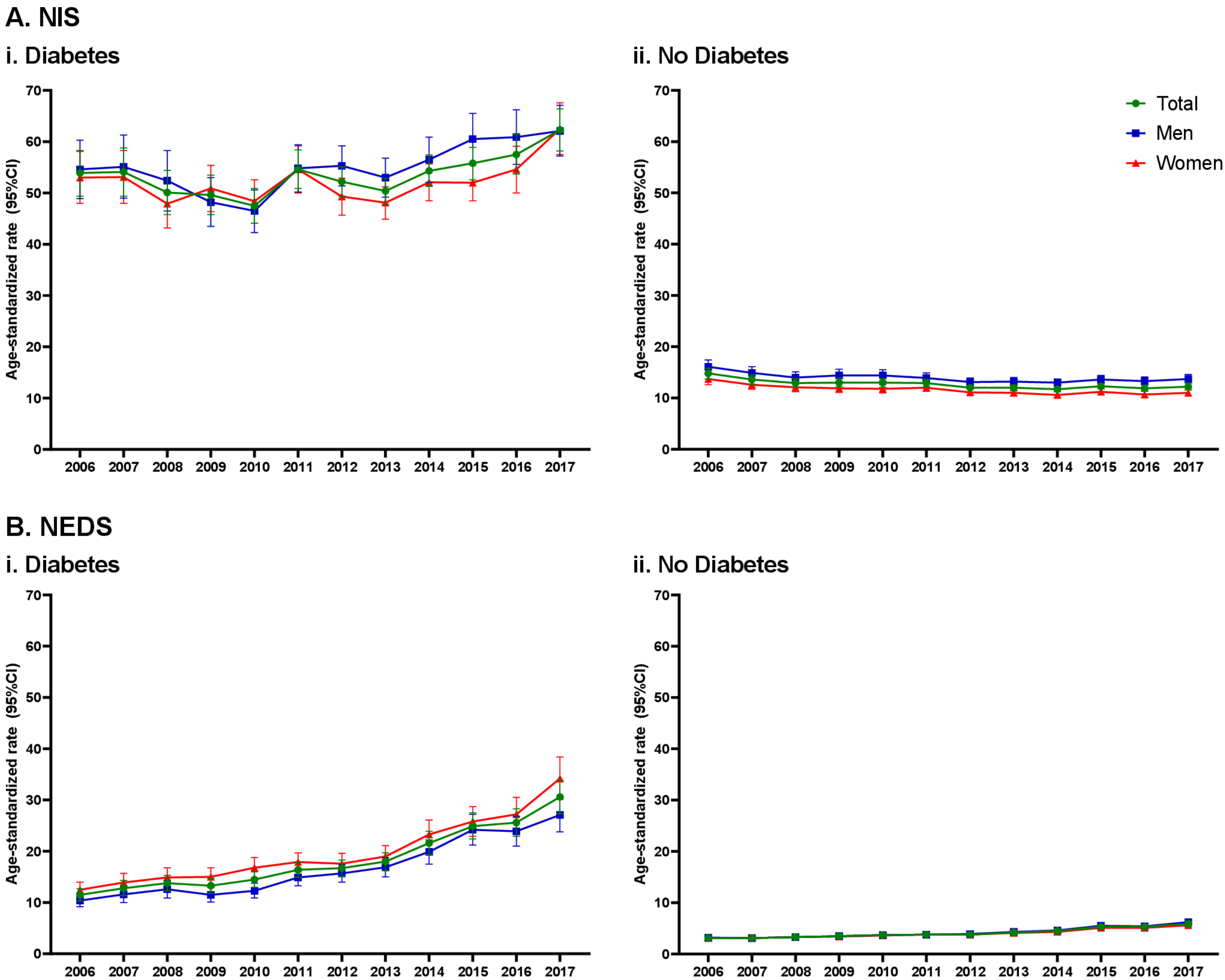

Figure 1 Age-standardized inpatient admission (NIS (A)) and ED visit (NEDS (B)) rates for HF in people with (i) versus without diabetes (ii) in the USA between 2006 and 2017. HF, heart failure; NEDS, Nationwide Emergency Department Sample; NIS, National Inpatient Sample.

This was driven by continued declines in HF rates among people without diabetes throughout the study period, while HF rates among people with diabetes plateaued from approximately 2010 onwards. For HF-related ED visits defined as the primary cause, the excess risk associated with diabetes also increased over time driven by increases in HF rates among people with, but not without, diabetes in the latter study period (online supplemental table 3).

DISCUSSION

In this study, we provide the first comprehensive summary of trends of HF-related inpatient admissions and non-admitted ED visits in the USA among adults with and without diabetes and note several important findings. First, rates of HF-related inpatient admissions and ED visits were three to five times higher in adults with versus without diabetes, and this excess risk has increased over time. Second, while absolute rates remained lowest in the youngest age groups, the greatest relative increases in HF-related inpatient admissions and ED visits were observed in young adults with diabetes. Third, increases in HF-related utilization among adults with diabetes was observed in both inpatient and ED settings, suggesting broader underlying causes rather than a shift in treatment setting.

Our results are consistent with the few studies that have reported changes in HF incidence over time. In the USA, a NIS-based study reported a 3.6% annual decline in HF inpatient admissions among adults ≥35 years with diabetes between 1998 and 2014.[13] This decline was likely driven by significant decreases in the earlier period (ie, 1998–2006) and explains why we, in contrast, observed a non-significant decline in HF-related inpatient admissions from 2006 to 2013. Another study, also using the NIS, reported an overall 38.9% decline in primary HF admissions in people with diabetes between 1995 and 2015.[12] This decline also appeared to be driven by reductions in

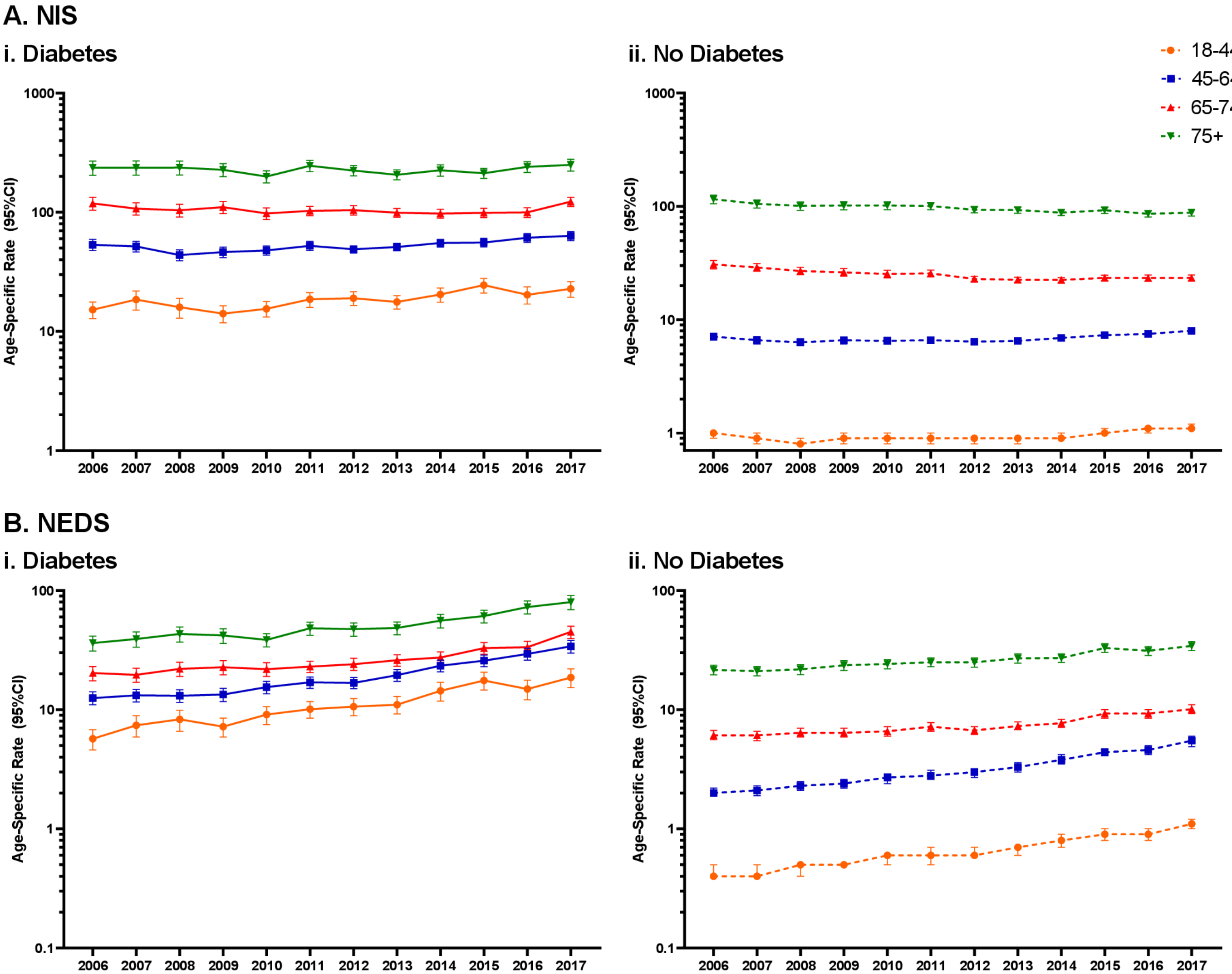

Figure 2 Age-specific inpatient admission (NIS (A)) and ED visit (NEDS (B)) rates for HF in people with (i) versus without diabetes (ii) in the USA between 2006 and 2017. HF, heart failure; NEDS, Nationwide Emergency Department Sample; NIS, National Inpatient Sample.

the earlier study period as non-significant increases were observed between 2013 and 2015.[12] In Spain, a significant 5.4% annual increase in HF hospitalizations was observed between 1997 and 2010 in patients with diabetes, broadly similar to findings in the current study.[23] However, the NIS-based studies and the Spanish study did not compare changes in HF incidence in people with versus without diabetes. This comparison is necessary to understand whether diabetes is an underlying cause of changing HF rates and to develop targeted interventions to reduce the HF burden in this subpopulation. Only one other study has compared rates of HF hospitalizations in people with versus without diabetes. In Sweden, a 29% decrease in HF hospitalization rates, defined as primary of contributory cause, among persons with type 2 diabetes was observed between 1999 and 2013, and this decline was greater than what was observed for people without type 2 diabetes.[24] Unfortunately, data beyond 2013 were not available, and thus, it remains to be elucidated whether the recent increase in HF hospitalizations seen in our US data is also occurring in other populations and settings.

The increasing rates of HF among people with diabetes, especially young adults with diabetes, are consistent with a recent resurgence of other diabetes-related complications in the USA.[25] Between 2010 and 2015, national data show increases in lower extremity amputations (LEAs)[26] and hyperglycaemic crises among adults with diabetes,[27] while long-term declines in end-stage renal disease, acute myocardial infarction (AMI) and stroke have stalled.[25] These trends appear to be driven by increases in young (aged 18–44 years) and middle-aged (aged 45–64 years) adults, among whom the risk of hyperglycaemic crisis, AMI, stroke and LEAs each increased by more than 25% between 2010 and 2015.[25] We add to this growing body of literature that increases in HF also disproportionally affect young people with diabetes at or around the same time. There are several possible reasons to explain this observed increase. First, we have observed a changing

Table 3 Age-standardized ED visit rates and rate ratios (RRs)* for HF in adults with versus without diabetes in the USA between 2006 and 2017

		Age-standardized ED visit rate (per 1000 people) (95% CI)†			Trend 1‡		Trend 2‡	
		2006	2011	2017	Year	APC (95% CI)	Year	APC (95% CI)
Total population	Diabetes	11.5 (10.3 to 12.7)	16.4 (14.9 to 17.9)	43.6 (27.3 to 33.9)	2006–2012	6.0 (3.4 to 8.7)§	2012–2017	12.6 (8.9 to 16.5)§
	No diabetes	3.1 (2.9 to 3.4)	3.8 (3.6 to 4.1)	5.9 (5.4 to 6.4)	2006–2012	4.1 (2.7 to 5.5)§	2012–2017	8.7 (6.1 to 11.3)§
	RR	3.7 (3.2 to 4.1)	4.3 (3.8 to 4.8)	5.2 (4.5 to 5.9)	2006–2017	2.7 (1.9 to 3.5)§	n/a	
Sex								
Men	Diabetes	10.4 (9.2 to 11.7)	14.9 (13.3 to 16.6)	27.1 (23.8 to 30.4)	2006–2010	4.3 (–1.8 to 10.8)	2010–2017	11.8 (9.0 to 14.5)§
	No diabetes	3.2 (2.9 to 3.4)	3.8 (3.5 to 4.1)	6.2 (5.7 to 6.7)	2006–2017	4.1 (1.5 to 6.7)	2012–2017	9.5 (5.6 to 13.5)§
	RR	3.3 (2.8 to 3.8)	3.9 (3.4 to 4.4)	4.4 (3.7 to 5.0)	2006–2017	2.7 (1.5 to 4.0)§	n/a	
Women	Diabetes	12.5 (11.1 to 14.0)	17.9 (16.0 to 19.7)	34.2 (30.1 to 38.4)	2006–2013	6.1 (4.2 to 8.1)§	2013–2017	14.3 (9.1 to 19.6)§
	No diabetes	3.1 (2.8 to 3.4)	3.8 (3.6 to 4.1)	5.6 (5.2 to 6.1)	2006–2012	4.0 (2.6 to 5.4)§	2012–2017	7.8 (5.1 to 10.5)§
	RR	4.0 (3.5 to 4.6)	4.7 (4.1 to 5.2)	6.1 (5.2 to 7.0)	2006–2017	2.7 (1.8 to 3.7)§	n/a	
Age group								
18–44	Diabetes	5.7 (4.6 to 6.8)	10.1 (8.5 to 11.7)	18.6 (15.3 to 22.0)	2006–2012	10.6 (8.5 to 12.8)§	n/a	
	No diabetes	0.4 (0.4 to 0.5)	0.6 (0.5 to 0.7)	1.1 (1.0 to 1.2)	2006–2017	8.9 (7.6, to 10.2)§	n/a	
	RR	12.9 (10.1 to 15.8)	16.7 (13.7 to 19.8)	17.1 (13.4 to 20.8)	2006–2017	1.8 (–0.1 to 3.8)	n/a	
45–64	Diabetes	12.5 (11.0 to 14.1)	17.0 (15.1 to 18.8)	34.0 (29.8 to 38.2)	2006–2012	5.9 (3.6 to 8.3)§	2012–2017	14.7 (11.2 to 18.2)§
	No diabetes	2.0 (1.9 to 2.2)	2.8 (2.6 to 3.1)	5.5 (4.9 to 6.0)	2006–2012	7.0 (5.4 to 8.6)§	2012–2017	12.4 (10.3 to 14.5)§
	RR	6.2 (5.2 to 7.1)	6.0 (5.1 to 6.8)	6.2 (5.2 to 7.2)	2006–2017	0.3 (–0.6 to 1.2)	n/a	
65–74	Diabetes	20.3 (17.5 to 23.0)	23.0 (20.5 to 25.5)	45.0 (39.6 to 50.3)	2006–2014	3.9 (1.8 to 6.1)§	2014–2017	17.3 (7.5 to 28.0)§
	No diabetes	6.1 (5.6 to 6.7)	7.2 (6.6 to 7.8)	10.1 (9.3 to 11.0)	2006–2013	2.7 (0.6 to 4.8)§	2013–2017	9.1 (4.8 to 13.6)§
	RR	3.3 (2.8 to 3.9)	3.2 (2.8 to 3.6)	4.4 (3.8 to 5.1)	2006–2017	2.0 (0.7 to 3.3)§	n/a	
≥75	Diabetes	36.3 (31.0 to 41.5)	48.2 (42.1 to 54.3)	80.0 (69.3 to 90.8)	2006–2013	3.9 (1.0 to 7.0)§	2013–2017	13.4 (6.1 to 21.1)§
	No diabetes	21.6 (19.6 to 23.6)	25.0 (22.9 to 27.2)	34.3 (31.3 to 37.4)	2006–2017	4.5 (3.6 to 5.4)§	n/a	
	RR	1.7 (1.4 to 2.0)	1.9 (1.6 to 2.2)	2.3 (2.0 to 2.7)	2006–2017	1.7 (–0.0 to 3.6)	n/a	

*RR is rate in diabetes/rate in non-diabetes.
†Years 2006, 2011 and 2017 are displayed in this table for ease of presentation. Rates and 95% CI for other years are presented in figures 1 and 2.
‡Indicates the year in which trends change significantly in either direction or magnitude.
§p_{trend} <0.05; sample time (from RR of 3.7 to 5.2; APC 2.7 (95% CI 1.9 to 3.5)). Similar patterns were observed in both men and women.
APC, annual percentage change; ED, emergency department; HF, heart failure; n/a, no second trend identified.

profile of newly identified diabetes cases that are more obese and may have more poorly managed risk factors (eg, blood pressure and lipids) as compared with earlier years, particularly among younger adults.[4] Second, a longer average duration of diabetes may be leading to a shift in risk of complications. Third, the younger age group may include a larger relative proportion of type 1 diabetes who may be at increased risk for HF. However, accumulating evidence suggests that diabetes complication rates may be higher in young adults with type 2 diabetes as compared with type 1 diabetes.[28] Fourth, changes in healthcare policy such as the introduction of high-deductible health plans have led to reductions in early preventive care in people with diabetes.[29 30] Fourth, increased costs of insulin and other diabetes medications may have led patients to cut back on treatment to minimize costs, thus exposing them to increased risk for complications including HF.[31] Last, in 2012, the US Centers for Medicare and Medicaid Services implemented the Hospital Readmissions Reduction Program, which financially penalized hospitals with high 30-day readmission rates for HF.[32] The role of this policy in influencing HF trends in the current study is unclear as NIS and NEDS do not identify hospital readmission. Overall, it is most likely that a combination of these factors explains the increases in HF-related ED visits and hospitalization among US adults with diabetes.

The results of this study offer important implications for public health and healthcare practice. First, in this study, we show that diabetes is associated with an almost fivefold increased risk for HF-related inpatient and non-admission ED visits. The continued increase in the prevalence of diabetes is likely to increase the number of people with HF in the future and will have important implications for both outpatient and hospital burdens, pharmacotherapies and resource allocation. Second, we hypothesize that increasing risk for HF may lead to an increase in subsequent HF-related mortality with some early evidence to support this hypothesis. For example, Cheng *et al*[33] reported an increase in HF-related mortality among young US adults with diabetes between 1988 and 2015, despite mortality rates for several other CVDs declining in that time, and an Australian study reported no change in HF-related mortality despite declines for other CVD outcomes.[34] Third, improved awareness by healthcare providers that diabetes is an important risk factor for HF might stimulate more intensive and focused prevention and management opportunities. For example, post hoc analysis of the Steno-2 trial in Denmark demonstrated a reduction in HF hospitalizations among patients with diabetes receiving intensive (vs conventional) therapy.[35] Furthermore, emerging trial data of sodium-glucose cotransporters 2 (SGLT2) inhibitors show promising findings for HF. For example, randomized trials of SGLT2 inhibitors (vs placebo) have shown a pooled 31% reduction in HF hospitalizations in type 2 diabetes patients at high risk of CVD,[36] as well as improved outcomes among those with existing diabetes and HF.[37] Real-world studies, such as CVD-REAL (Comparative Effectiveness of Cardiovascular Outcomes in New Users of SGLT-2 Inhibitors), have also demonstrated the positive effects of SGLT-2 inhibitors in HF prevention in patients with type 2 diabetes, irrespective of atherosclerotic disease status.[38 39]

This is the largest study to explore rates of HF over time in USA adults with and without diabetes in two nationally representative patient datasets. Nonetheless, there are limitations to be considered. First, NIS and NEDS represent hospital discharges, not individual persons and therefore may include multiple hospital stays for some persons. This may lead to an increase in population-based rates, especially in certain subpopulations at higher risk for recurrence, including those with diabetes.[40] However, the primary objective of this study was to examine changes in HF admissions over time in people with versus without diabetes. To that end, and in the absence of contrary data, we assume that the risk of readmission in people with versus without diabetes remained constant during the study period and readmissions are, therefore, unlikely to impact our key conclusions. Second, because of the inability to differentiate diabetes type in the NHIS survey data, we were not able to report trends in HF by diabetes type. Therefore, all types of diabetes are included in the current analysis with the assumption that the vast majority (~90%–95%) have type 2 diabetes.[41] In addition, the NHIS is self-reported and does not include undiagnosed diabetes and thus likely underestimates the number of people with diabetes in the population. Furthermore, the underlying characteristics of people with diagnosed diabetes could be changing over time. However, there have not been adequate data or studies to characterize such changes. Third, a shift from ICD-9-CM to ICD-10-CM in October 2015 may have affected our observed rates. However, observed changes in trends occurred before this period, and therefore, it is unlikely that this coding shift influenced the overall patterns that we observed in this study. Furthermore, coding changes do not explain differential increases in people with versus without diabetes and in younger versus older adults. Fourth, admissions for hypertensive heart disease with HF were not included in the current analysis. Fifth, NIS and NEDS do not report HF stages and we were unable to explore differential impacts of diabetes on HF stages, though this is an important future direction. Sixth, location (urban/rural) and poverty status, although available in NHIS, were not categorized in the same way in NEDS and NIS, so these factors were excluded from rate calculations. In addition, the race/ethnicity variable in NIS was incomplete prior to 2012, and so trends were not calculated by race/ethnicity. Finally, this is a descriptive observational study designed to assess the relative burden of HF hospitalizations in people with versus without diabetes over time. Future studies with more appropriate datasets (ie, with individual level data) are needed to tease out the underlying mechanisms with which diabetes leads to an increase in HF hospitalization, particularly among young adults.

CONCLUSIONS

In this nationally representative study, we show that: (1) rates of HF-related inpatient admissions increased in adults with, but not without, diabetes and (2) rates of HF-related ED visits increased in adults with and without diabetes, but absolute and relative increases were greater in adults with diabetes; and (3) the greatest relative increases in HF-related inpatient admissions and non-admission ED visits was seen among young adults with diabetes. More detailed and subnational data analyses may help to investigate the aetiology and determine clinical and public health strategies to address these growing burdens.

Author affiliations
[1]Department of Surgery, Emory University School of Medicine, Atlanta, Georgia, USA
[2]Department of Medicine, Emory University School of Medicine, Atlanta, Georgia, USA
[3]Division of Diabetes Translation, Centers for Disease Control and Prevention, Atlanta, Georgia, USA
[4]Division of Cardiology, Emory University School of Medicine, Atlanta, Georgia, USA
[5]Global Diabetes Research Center, Rollins School of Public Health Emory University, Atlanta, Georgia, USA
[6]Department of Family and Preventive Medicine, Emory University School of Medicine, Atlanta, Georgia, USA

Acknowledgements The authors would like to thank the women and men who participated in the National Health Interview Survey (NHIS), as well as all the staff involved at the NCHS and HCUP for study design, data collection and data dissemination.

Contributors JLH designed the study, conducted the analyses, interpreted the results and wrote the manuscript. SRB and IH conducted the analysis, contributed to interpretation and reviewed the manuscript. LS provided clinical input, contributed to interpretation and reviewed the manuscript. RJ, REP and MKA contributed to interpretation and reviewed the manuscript. KMVN conceptualized the manuscript, contributed to interpretation and reviewed the manuscript. JLH is the guarantor of this work and takes responsibility for the integrity of the data and final responsibility for the decision to submit for publication.

Funding Research reported in this publication was supported by the National Institute of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health under Award Number P30DK111024 and the National Institute on Minority Health and Health Disparities grant U01MD010611. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the National Institutes of Health.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval The NHIS, NIS and NEDS databases are publicly available and do not contain direct personal identifiers and are therefore exempt from review by the institutional review boards of the Centers for Disease Control and Prevention and Emory University.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. The data that support the findings of this study are publicly available from the National Center for Health Statistics and the Agency for Healthcare Research and Quality. All data are deidentified.

ORCID iDs
Jessica L Harding http://orcid.org/0000-0002-6664-8630
Stephen R Benoit http://orcid.org/0000-0003-3455-133X
Lakshmi Sridharan http://orcid.org/0000-0002-4855-4892
K M Venkat Narayan http://orcid.org/0000-0001-8621-5405

REFERENCES

1 Authors/Task Force Members, Rydén L, Grant PJ, *et al*. ESC guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD: the task force on diabetes, pre-diabetes, and cardiovascular diseases of the European Society of cardiology (ESC) and developed in collaboration with the European association for the study of diabetes (EASD). *Eur Heart J* 2013;34:3035–87.
2 International Diabetes Federation. *IDF diabetes atlas*. 9th edn. Brussels, Belgium: International Diabetes Federation, 2019. https://www.diabetesatlas.org
3 Centers for Disease Control and Prevention. *National diabetes statistics report*. Atlanta, GA: Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services, 2020. https://www.cdc.gov/diabetes/data/statistics-report/index.html
4 Ali MK, Bullard KM, Saaddine JB, *et al*. Achievement of goals in U.S. diabetes care, 1999-2010. *N Engl J Med* 2013;368:1613–24.
5 Ali MK, Bullard KM, Gregg EW, *et al*. A cascade of care for diabetes in the United States: visualizing the gaps. *Ann Intern Med* 2014;161:681–9.
6 Booth GL, Kapral MK, Fung K, *et al*. Recent trends in cardiovascular complications among men and women with and without diabetes. *Diabetes Care* 2006;29:32–7.
7 Jung CH, Chung JO, Han K, *et al*. Improved trends in cardiovascular complications among subjects with type 2 diabetes in Korea: a nationwide study (2006-2013). *Cardiovasc Diabetol* 2017;16:1.
8 Levi F, Lucchini F, Negri E, *et al*. Trends in mortality from cardiovascular and cerebrovascular diseases in Europe and other areas of the world. *Heart* 2002;88:119–24.
9 Shah AD, Langenberg C, Rapsomaniki E, *et al*. Type 2 diabetes and incidence of cardiovascular diseases: a cohort study in 1·9 million people. *Lancet Diabetes Endocrinol* 2015;3:105–13.
10 Taylor KS, Heneghan CJ, Farmer AJ, *et al*. All-Cause and cardiovascular mortality in middle-aged people with type 2 diabetes compared with people without diabetes in a large U.K. primary care database. *Diabetes Care* 2013;36:2366–71.
11 Vamos EP, Millett C, Parsons C, *et al*. Nationwide study on trends in hospital admissions for major cardiovascular events and procedures among people with and without diabetes in England, 2004-2009. *Diabetes Care* 2012;35:265–72.
12 Honigberg MC, Patel RB, Pandey A, *et al*. Trends in hospitalizations for heart failure and ischemic heart disease among US adults with diabetes. *JAMA Cardiol* 2021;6:354–7.
13 Burrows NR, Li Y, Gregg EW, *et al*. Declining rates of hospitalization for selected cardiovascular disease conditions among adults aged ≥35 years with diagnosed diabetes, U.S., 1998-2014. *Diabetes Care* 2018;41:293–302.
14 Gregg EW, Cheng YJ, Srinivasan M, *et al*. Trends in cause-specific mortality among adults with and without diagnosed diabetes in the USA: an epidemiological analysis of linked national survey and vital statistics data. *Lancet* 2018;391:2430–40.
15 Agency for HealthCare Research and Quality. Nationwide HCUP databases, 2021. Available: https://www.hcup-us.ahrq.gov/databases.jsp
16 Clinical Classifications Software (CCS) for ICD-10-PCS (beta version). Healthcare Cost and Utilization Project (HCUP), 2019Agency for Healthcare Research and Quality, Rockville, MD. Available: www.hcup-us.ahrq.gov/toolssoftware/ccs10/ccs10.jsp [Accessed 7 October 2021].
17 Elixhauser A, Heslin KC, Owens PL. Healthcare cost and utilization project (HCUP) recommendations for reporting trends using ICD-

9-CM and ICD-10-CM/PCS data. Agency for Healthcare Research and Quality, 2017. Available: https://www.hcup-us.ahrq.gov/datainnovations/icd10_resources.jsp
18 National Center for Health Statistics. Survey description, National health interview survey Hyattsville, Maryland, 2017. Available: ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2017/srvydesc.pdf
19 Centers for Disease Control and Prevention. *National diabetes statistics report*. Atlanta, GA: Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services, 2020.
20 Localio AR, Margolis DJ, Berlin JA. Relative risks and confidence intervals were easily computed indirectly from multivariable logistic regression. *J Clin Epidemiol* 2007;60:874–82.
21 Houchens RL RD, Elixhauser A. Using the HCUP national inpatient sample to estimate trends. HCUP methods series report # 2006-05 online. U.S. agency for healthcare research and quality, 2018. Available: http://www.hcup-us.ahrq.gov/reports/methods/methods.jsp
22 National Cancer Institute. Joinpoint trend analysis software, 2018. Available: https://surveillance.cancer.gov/joinpoint/
23 Lara-Rojas CM, Pérez-Belmonte LM, López-Carmona MD, *et al*. National trends in diabetes mellitus hospitalization in Spain 1997-2010: analysis of over 5.4 millions of admissions. *Eur J Intern Med* 2019;60:83–9.
24 Rawshani A, Rawshani A, Franzén S, *et al*. Mortality and cardiovascular disease in type 1 and type 2 diabetes. *N Engl J Med* 2017;376:1407–18.
25 Gregg EW, Hora I, Benoit SR. Resurgence in diabetes-related complications. *JAMA* 2019;321:1867–8.
26 Geiss LS, Li Y, Hora I, *et al*. Resurgence of diabetes-related nontraumatic lower-extremity amputation in the young and middle-aged adult U.S. population. *Diabetes Care* 2019;42:50–4.
27 Benoit SR, Hora I, Pasquel FJ, *et al*. Trends in emergency department visits and inpatient admissions for hyperglycemic crises in adults with diabetes in the U.S., 2006-2015. *Diabetes Care* 2020;43:1057–64.
28 Magliano DJ, Sacre JW, Harding JL, *et al*. Young-onset type 2 diabetes mellitus - implications for morbidity and mortality. *Nat Rev Endocrinol* 2020;16:321–31.
29 Carls G, Huynh J, Tuttle E, *et al*. Achievement of glycated hemoglobin goals in the US remains unchanged through 2014. *Diabetes Ther* 2017;8:863–73.
30 Wharam JF, Zhang F, Eggleston EM, *et al*. Effect of high-deductible insurance on High-Acuity outcomes in diabetes: a natural experiment for translation in diabetes (NEXT-D) study. *Diabetes Care* 2018;41:940–8.
31 Riddle MC, Herman WH. The cost of diabetes Care-An elephant in the room. *Diabetes Care* 2018;41:929–32.
32 Wadhera RK, Joynt Maddox KE, Wasfy JH, *et al*. Association of the hospital readmissions reduction program with mortality among Medicare beneficiaries hospitalized for heart failure, acute myocardial infarction, and pneumonia. *JAMA* 2018;320:2542–52.
33 Cheng YJ, Imperatore G, Geiss LS, *et al*. Trends and disparities in cardiovascular mortality among U.S. adults with and without self-reported diabetes, 1988-2015. *Diabetes Care* 2018;41:2306–15.
34 Sacre JW, Harding JL, Shaw JE, *et al*. Declining mortality in older people with type 2 diabetes masks rising excess risks at younger ages: a population-based study of all-cause and cause-specific mortality over 13 years. *Int J Epidemiol* 2021;50:1362–72.
35 Oellgaard J, Gæde P, Rossing P, *et al*. Reduced risk of heart failure with intensified multifactorial intervention in individuals with type 2 diabetes and microalbuminuria: 21 years of follow-up in the randomised Steno-2 study. *Diabetologia* 2018;61:1724–33.
36 Kumar K, Kheiri B, Simpson TF, *et al*. Sodium-Glucose cotransporter-2 inhibitors in heart failure: a meta-analysis of randomized clinical trials. *Am J Med* 2020;133:e625–30.
37 McMurray JJV, Solomon SD, Inzucchi SE, *et al*. Dapagliflozin in patients with heart failure and reduced ejection fraction. *N Engl J Med* 2019;381:1995–2008.
38 Kosiborod M, Cavender MA, Fu AZ, *et al*. Lower risk of heart failure and death in patients initiated on sodium-glucose cotransporter-2 inhibitors versus other glucose-lowering drugs: the CVD-REAL study (comparative effectiveness of cardiovascular outcomes in new users of sodium-glucose cotransporter-2 inhibitors). *Circulation* 2017;136:249–59.
39 Cavender MA, Norhammar A, Birkeland KI, *et al*. SGLT-2 inhibitors and cardiovascular risk: an analysis of CVD-REAL. *J Am Coll Cardiol* 2018;71:2497–506.
40 Patil S, Shah M, Patel B, *et al*. Readmissions among patients admitted with acute decompensated heart failure based on income Quartiles. *Mayo Clin Proc* 2019;94:1939–50.
41 Centers for Disease Control and Prevention. *National diabetes statistics report*. Atlanta, GA: Centers for Disease Control and Prevention, 2017.