ORIGINAL ARTICLE

Hip and Knee Replacement in Germany and the USA

Analysis of Individual Inpatient Data From German and US Hospitals for the Years 2005 to 2011

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SUMMARY

Background: The number of hip and knee replacement operations is rising in many industrialized countries. To evaluate the current situation in Germany, we analyzed the frequency of procedures in Germany compared to the USA, with the aid of similar case definitions and taking demographic differences into account.

Methods: We used individual inpatient data from Germany (DRG statistics) and the USA (Nationwide Inpatient Sample) to study differences in the age- and sex-adjusted rates of hip and knee replacement surgery and the determinants of trends in case numbers over the years 2005 to 2011.

Results: In 2011, hip replacement surgery was performed 1.4 times as frequently in Germany as in the USA (284 vs. 204 cases per 100 000 population per year; the American figures have been adjusted to the age and sex structure of the German population). On the other hand, knee replacement surgery was performed 1.5 times as frequently in the USA as in Germany (304 [standardized] vs. 206 cases per 100 000 population per year). Over the period of observation, the rates of both procedures increased in both countries. The number of elective primary hip replacement operations in Germany grew by 11%, from 140 000 to 155 300 (from 170 to 190 per 100 000 persons); after correction for demographic changes, a 3% increase remained. At the same time, the rate of elective primary hip replacement surgery in the USA rose by 28%, from 79 to 96 per 100 000 population, with a 13% increase remaining after correction for demographic changes.

Conclusion: There are major differences between Germany and the USA in the frequency of these operations. The observed upward trend in elective primary hip replacement operations was mostly due to demographic changes in Germany; non-demographic factors exerted a stronger influence in the USA than in Germany. With respect to primary knee replacement surgery, non-demographic factors exerted a comparably strong influence in both countries.

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The increase in numbers of hip and knee replacements and the frequency of such surgery in comparison to other countries is the subject of critical discussion in Germany. The overriding impression is that such surgery is performed relatively frequently in Germany when compared to other countries (1–3). Most of the published data on this subject is based on the same primary source, namely OECD indicators (4).

According to OECD reports, 286 hip replacement operations were performed per 100 000 population in Germany in 2011. This places Germany in second place among OECD countries for hip replacement frequency, behind Switzerland. Germany lies in third place for frequency of knee replacements, with 207 operations per 100 000 population (according to OECD figures), behind the USA and Austria (5). Previous years' OECD reports also state high surgery frequencies for Germany (4, 6, 7). However, the extent to which such comparisons can be interpreted is limited, partly because they do not take into account differing demographics and partly because numbers of surgeries are calculated in different ways in different countries.

Unlike OECD reports, this article is not based on statistics prepared by others. Instead, it uses individual inpatient data to compare hip and knee replacements in Germany with those in the USA. Formally and qualitatively comparable patient data from these two countries is available and accessible, so that clinical entities can be precisely defined and evaluated on the basis of individual cases. This article analyzes demographically adjusted differences in frequency and determining factors behind changes in case numbers during the observation period.

Methods

Data

For Germany, nationwide inpatient statistics (DRG statistics), including treatment data on all inpatient cases processed according to the DRG system, were evaluated (8). In 2011, DRG statistics covered approximately 17.7 million patients in 1600 hospitals.

For the USA, the Nationwide Inpatient Sample (NIS) was used. This contains the data on all inpatients in a representative sample of 20% of US hospitals (9),

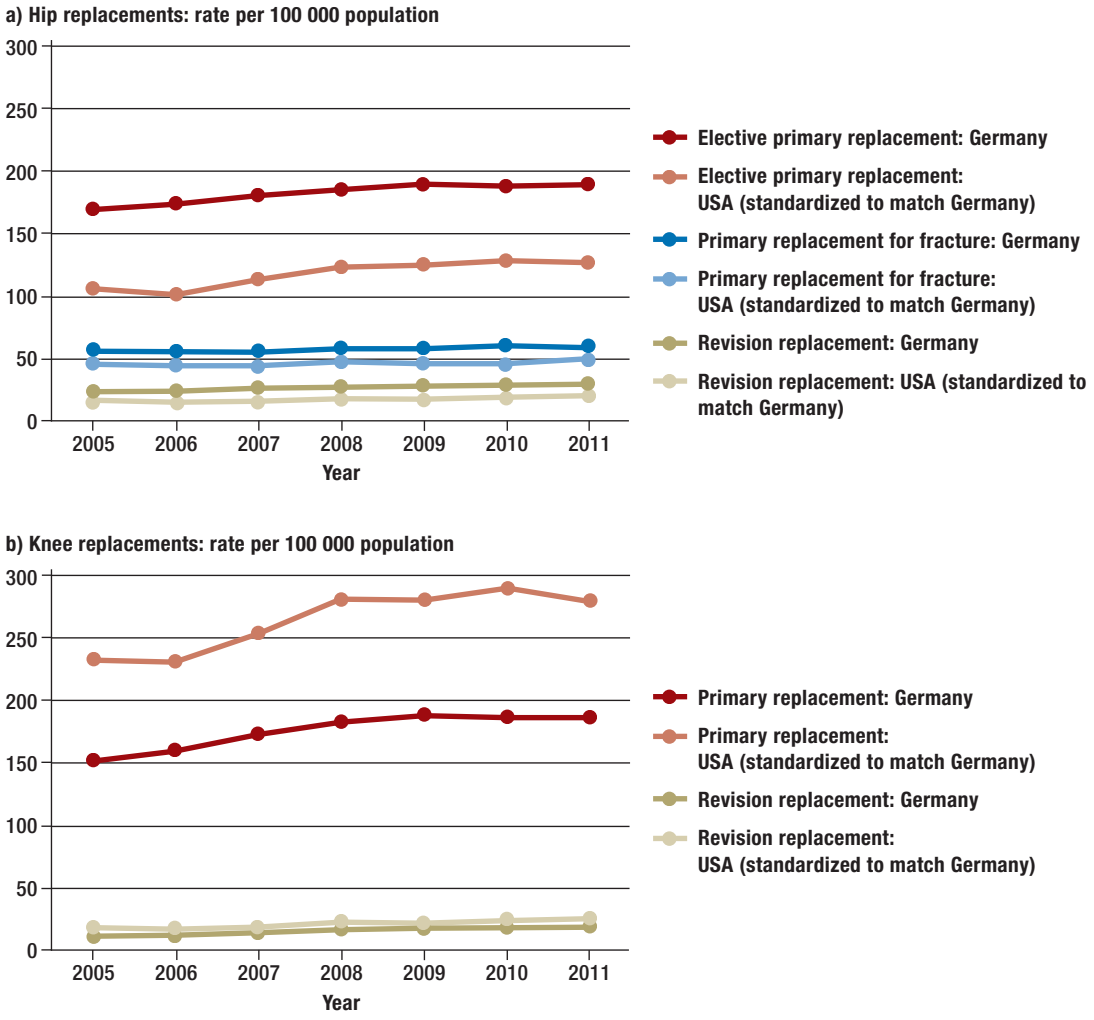
TABLE 1

Demographics and hip and knee replacement frequency in Germany and the USA

	2005	2006	2007	2008	2009	2010	2011
Germany							
Demographics							
Population	82 464 344	82 365 810	82 262 642	82 119 776	81 874 770	81 757 471	81 779 210
Percentage female	51.1%	51.1%	51.0%	51.0%	51.0%	51.0%	50.9%
Percentage aged 65 or older	18.9%	19.5%	19.9%	20.2%	20.5%	20.6%	20.6%
Hip replacements							
Total no.	209 292	213 371	220 114	226 736	231 028	231 740	232 320
Crude rate per 100 000 population	254	259	268	276	282	283	284
Percentage female	64.2%	63.8%	63.2%	62.8%	62.5%	62.3%	62.0%
Percentage aged 65 or older	74.4%	74.5%	74.8%	74.9%	75.1%	74.8%	74.0%
Indication: Elective primary replacement	66.9%	67.1%	67.5%	67.0%	67.3%	66.7%	66.9%
Primary replacement for fracture	22.3%	21.8%	21.1%	21.4%	21.0%	21.5%	21.3%
Revision replacement	9.5%	9.7%	10.0%	10.3%	10.3%	10.4%	10.4%
Other indication*	1.3%	1.4%	1.4%	1.4%	1.4%	1.4%	1.5%
Knee replacements							
Total no.	135 133	142 371	154 404	163 500	168 622	168 511	168 486
Crude rate per 100 000 population	164	173	188	199	206	206	206
Percentage female	68.9%	68.3 %	67.2%	66.5%	66.0%	65.2%	64.8%
Percentage aged 65 or older	74.5%	74.6%	74.2%	73.5%	72.7%	71.3%	70.0%
Indication: Primary replacement	92.8%	92.5%	92.2%	91.6%	91.3%	90.8%	90.5%
Revision replacement	7.2%	7.5%	7.8%	8.4%	8.7%	9.2%	9.5%
USA							
Demographics							
Population	295 753 151	298 593 212	301 579 895	304 374 846	307 006 550	309 330 219	311 591 917
Percentage female	50.8%	50.7%	50.7%	50.7%	50.7%	50.8%	50.8%
Percentage aged 65 or older	12.4%	12.5%	12.6%	12.7%	12.9%	13.1%	13.3%
Hip replacements							
Total no.	381 524	369 884	402 686	436 618	436 284	453 954	465 034
Crude rate per 100 000 population	129	124	134	143	142	147	149
Percentage female	61.4%	61.0%	59.9%	59.4%	59.2%	57.5%	57.5%
Percentage aged 65 or older	67.0%	65.2%	63.9%	63.0%	63.1%	61.3%	61.7%
Indication: Elective primary replacement	61.2%	60.8%	63.2%	63.8%	64.9%	65.6%	64.1%
Primary replacement for fracture	27.1%	27.0%	24.9%	24.2%	23.3%	22.0%	22.7%
Revision replacement	9.9%	9.8 %	9.5%	9.6%	9.3%	9.9%	10.7%
Other indication*	1.8%	2.4%	2.5%	2.4%	2.4%	2.5%	2.5%
Knee replacements							
Total no.	535 369	532 521	591 701	665 543	667 964	712 281	702 415
Crude rate per 100 000 population	181	178	196	219	218	230	225
Percentage female	63.8%	63.4%	63.5%	62.6%	62.6%	62.7%	62.1%
Percentage aged 65 or older	60.3%	59.0%	58.0%	56.8%	57.0%	55.9%	55.3%
Indication: Primary replacement	92.6%	92.9%	92.9%	92.3%	92.7%	92.2%	91.6%
Revision replacement	7.4%	7.1%	7.1%	7.7%	7.3%	7.8%	8.4%

*Hip replacements for other indications are not examined further as they are numerically less significant

FIGURE 1



Germany: crude rates for hip and knee replacements; USA: rates standardized to match German demographics*. *US rates were standardized by sex and five-year age groups to match Germany's demographic structure for each year of the observation period (10) (direct standardization). Standardized rates show how many cases would have occurred in the USA per 100 000 population if the demographic structure were the same as in Germany. They can therefore be compared to German rates. The corresponding figures are shown in *eTables 1 and 2*

providing information on approximately 8 million inpatients for each year of the observation period in 1000 US hospitals.

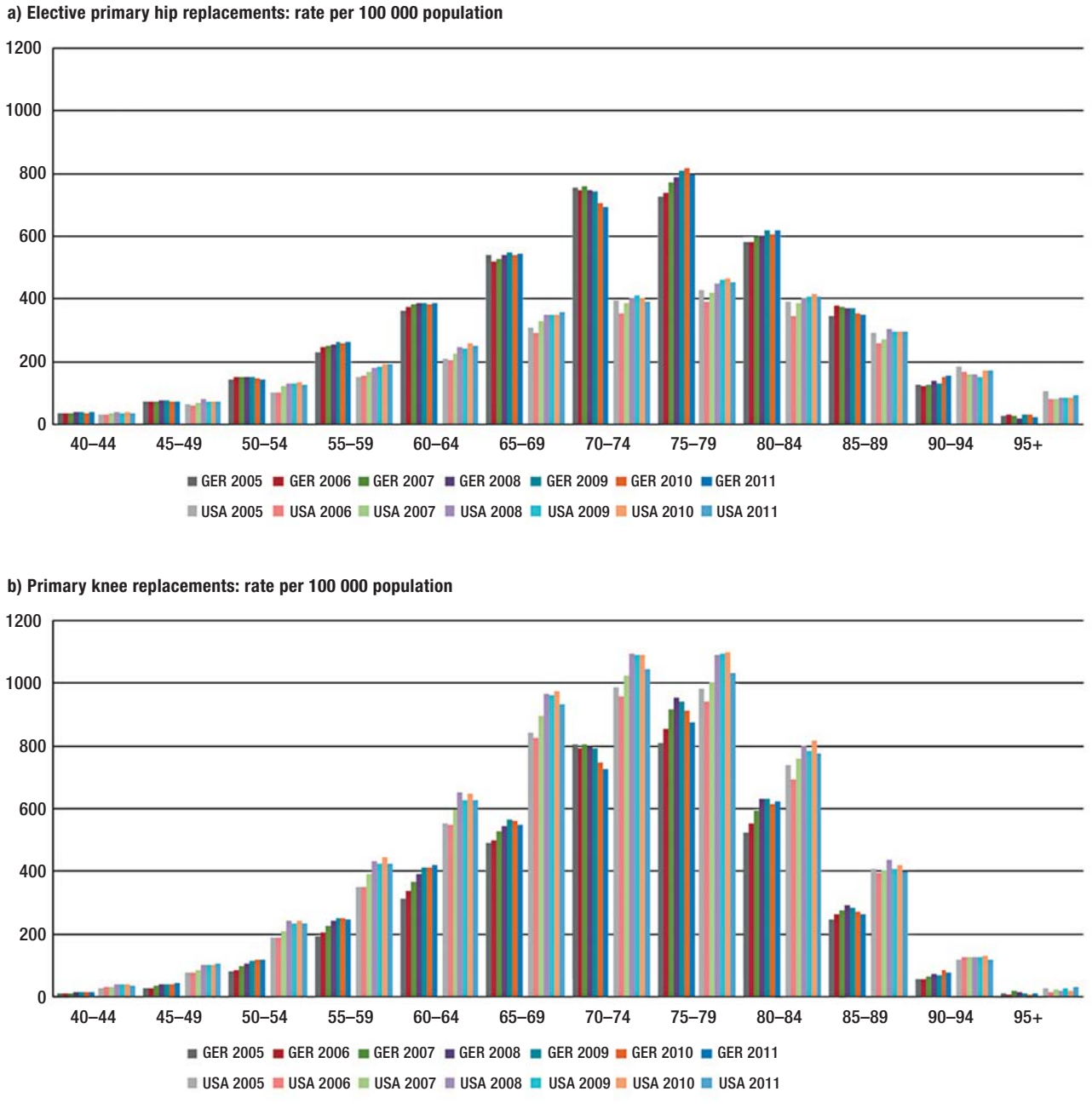
Case definition

The unit of analysis is an inpatient who underwent hip or knee replacement surgery.

In Germany, surgical procedures are coded according to the Surgery and Procedure Coding System (OPS, Operationen- und Prozedurenschlüssel), and diagnoses are coded according to ICD-10-GM (International Classification of Diseases, Tenth Revision, German Modification). In the USA, ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) is used; this includes both diagnoses and procedures.

Case definitions are based on the inclusion criteria for documenting hip and knee replacements according to statutory quality assurance (10) but have been modified, as different classification systems include different levels of detail *(eTable 1)*. These definitions, which provide comparable information on joint replacement surgery in Germany and the USA, were used in the same way for each year of the observation period; this means that longitudinal comparisons are also possible. The definition of hip replacement includes both total and partial joint replacement and is divided into elective primary replacement, primary replacement for fracture, revision replacement, and replacement for other indications. The definition of knee replacement includes both total and partial joint replacement (excluding isolated patella replacement) and is divided into primary replacement and revision replacement. All included patients were aged 20 years and older.

FIGURE 2



Age-specific primary hip and knee replacement rates in Germany and the USA. Only rates for age groups above 40 years are shown due to the low numbers of cases in younger age groups

Analysis

Surgery frequencies were reported on an annual basis for both countries. Because the US data was obtained from a sample, national frequencies were estimated on the basis of the stratified weighting factors stated in the NIS dataset (9). Crude rates per 100 000 population are given in addition to absolute frequencies. Crude rates were calculated by dividing case numbers by the total population for the year (11–13). To enable comparisons to be made between the two countries, annual surgery rates for the USA, standardized for sex and age to match German demographics, were calculated (direct standardization by sex and five-year age groups for each year of the observation period).

Changes over time were analyzed using multiplicative decomposition of the Laspeyres index

(eBox 1). This includes aspects of changes in case numbers between 2005 and 2011 that were determined by demographics, as well as those that were independent of demographics (14, 15).

The demographics-related changes reported in this way can be ascribed to shifts in demographics such as population aging or growth. Changes that were independent of demographics (as shown in figures standardized for age and sex) are the result of other factors affecting the frequency of surgery.

Results

Demographic parameters, crude surgery frequencies

The German and US populations changed in different ways during the observation period. While the US population grew by 5%, the German population fell by 1%. The proportion of those aged over 65 increased in both countries. In 2011 this figure was 21% for Germany and 13% for the USA.

Hip replacement frequency increased in both countries *(Table 1)*. The crude rate per 100 000 population increased from 254 to 284 in Germany and from 129 to 149 in the USA. In terms of indication, in Germany approximately two-thirds of operations were elective primary replacements, 21% were for fracture, and 10% were revision replacements. Distribution in the USA was similar.

Knee replacements also increased during the observation period: from 164 to 206 operations per 100 000 population in Germany and from 181 to 225 per 100 000 population in the USA. In Germany the proportion of revision replacements increased from 7.2% in 2005 to 9.5% in 2011; in the USA it rose from 7.4% to 8.4%.

The proportion of patients aged over 65 was higher in Germany than in the USA for both hip and knee replacements *(Table 1)*.

Comparison standardized for sex and age

Demographics are only part of the reason hip replacement rates are higher in Germany than in the USA. While the crude (i.e. not adjusted for demographics) rate in 2011 was 149 per 100 000 population in the USA, when standardized to match German demographics it was 204. However, with 284 surgeries per 100 000 population, hip replacements were approximately 1.4 times more frequent in Germany even after adjustment for demographic differences.

This difference, which can be seen in all years of the observation period, holds true for primary replacements for fracture and revision replacements as well as for elective primary replacements, although the latter is the most significant indication numerically *(Figure 1a, eTable 2)*. *Figure 2a* shows age-specific rates for primary replacements. The difference was particularly marked in the 70 to 79 age groups: here the German rates were almost twice the US rates.

For knee replacements, the crude rates in the USA were higher than those in Germany. This difference increased further once the US figures were standardized for sex and age to match the German population: in 2011 the standardized rate for the USA was 304 operations per 100 000 population, versus 206 in Germany. Knee replacement was thus 1.5 times more frequent in the USA than in Germany after adjustment for demographic differences. This difference in frequency was present in all years of the observation period *(Figure 1b, eTable 3)*. *Figure 2b* shows that the frequency of primary replacements was higher in the USA than in Germany in almost every age group.

Changes in case numbers

The number of hip replacements increased between 2005 and 2011 in both countries. For elective primary replacements most of the relative increase in Germany—11% (15 300 cases) overall—was caused by demographic factors, namely population aging.

After adjustment for demographics, a 3% increase caused by other factors remains. In the USA the total increase was 28%, significantly greater than in Germany. Demographic factors explain approximately half this increase.

Hip replacements for fracture increased by 15% in Germany due to demographic factors. However, all other determining factors resulted in a decrease of 8%. The net result of these two changes is the actual increase of 6% (2700 cases). In the USA too, non-demographic factors caused a drop in frequency of surgery nearly equal to the increase caused by demographic factors.

The greatest increase in hip replacements concerned revision replacements. In Germany these rose by 22% (4300 cases) overall. The influences of demographic and non-demographic causes were approximately equal. In the USA, revision hip replacements increased by 32% overall; adjustment for demographics leaves an increase of 18% *(Table 2)*.

The number of primary knee replacement operations grew by 22% (27 000 cases) overall in Germany and 30% in the USA. These increases were caused by both demographic and non-demographic factors in both countries; non-demographic factors were slightly more significant in Germany.

The relative increase in knee revision replacements between 2005 and 2011 was 64% (6200 cases) in Germany and 50% in the USA. These sharp increases were mostly caused by non-demographic factors in both countries *(Table 3)*.

Discussion

Analyses that provide international comparisons are useful in ranking and assessing care in the context of differing health care systems. The USA was chosen as an example country with which to compare Germany for this article because appropriate data on individual patients was available, making it possible to perform a methodologically sound comparison.

The results of the research, which is based on independent analysis of individual patient data rather than evaluation of aggregated statistics prepared by

TABLE 2

Changes in hip replacement frequency in Germany and the USA: demographic and non-demographic causes

		2005	2006	2007	2008	2009	2010	2011	Relative changes, 2005 to 2011*		
									Demographic causes	Non-demographic causes	Total
Elective primary hip replacements											
No. in Germany	Total	140 029	143 134	148 519	151 932	155 558	154 528	155 332	7.6%	3.1%	10.9%
	Male	55 827	57 449	60 384	62 137	63 595	63 412	64 103	10.7%	3.7%	14.8%
	Female	84 202	85 685	88 135	89 795	91 963	91 116	91 229	5.6%	2.6%	8.3%
No. in USA	Total	233 599	224 757	254 401	278 522	283 342	297 999	298 174	13.2%	12.8%	27.6%
	Male	101 510	98 984	113 443	126 268	128 345	134 130	134 504	15.0%	15.3%	32.5%
	Female	132 090	125 772	140 958	152 254	154 997	163 869	163 669	11.8%	10.9%	23.9%
Primary hip replacements for fracture											
No. in Germany	Total	46 765	46 606	46 519	48 435	48 529	49 816	49 456	14.7%	–7.8%	5.8%
	Male	10 887	11 087	11 285	12 217	12 702	13 490	13 702	26.3%	–0.4%	25.9%
	Female	35 878	35 519	35 234	36 218	35 827	36 326	35 754	11.2%	–10.4%	–0.3%
No. in USA	Total	103 317	99 932	100 337	105 852	101 817	99 755	105 707	10.6%	–7.5%	2.3%
	Male	27 807	26 859	28 319	29 559	28 707	28 652	30 433	17.9%	–7.2%	9.4%
	Female	75 510	73 073	72 019	76 293	73 110	71 104	75 274	7.9%	–7.6%	–0.3%
Revision hip replacement											
No. in Germany	Total	19 819	20 745	22 095	23 267	23 756	24 063	24 136	10.6%	10.1%	21.8%
	Male	7554	7889	8480	9080	9335	9454	9485	15.8%	8.5%	25.6%
	Female	12 265	12 856	13 615	14 187	14 421	14 609	14 651	7.4%	11.2%	19.5%
No. in USA	Total	37 713	36 288	38 079	41 946	40 499	44 913	49 746	11.6%	18.2%	31.9%
	Male	15 415	15 323	16 064	17 772	16 911	18 679	21 176	14.3%	20.2%	37.4%
	Female	22 298	20 965	22 015	24 173	23 588	26 234	28 570	9.8%	16.7%	28.1%

**Calculated using multiplicative decomposition of the Laspeyres index by sex and five-year age groups. Figures shown are percent relative changes in indices. Example for reference: the number of elective primary hip replacements in Germany increased from 140 029 in 2005 to 155 332 in 2011. The index of the increase due to demographic causes is 1.076 (+7.6%); the index of the increase due to non-demographic causes is 1.031 (+3.1%). Multiplying these two indices together gives a total index of 1.109 (+10.9%), which corresponds to the relative difference between 140 029 and 155 332

others, show that hip replacements are performed more frequently in Germany than in the USA even after adjustment for differing demographics. However, the frequency of knee replacements was significantly lower in Germany than in the USA.

The number of operations performed increased during the observation period in both countries. For hip replacements, the overall increases were slightly smaller in Germany than in the USA. Most of the increase in elective primary replacements in Germany can be explained by demographic factors.

After adjustment for demographic factors, there was actually a decrease in primary replacements for fracture in older age groups. This may be related to changes in treatment strategies. The increase in revision replacements may have been a consequence of earlier increases in the primary replacement rate. Significantly higher increases that were unrelated to demographics were observed in the USA, where the baseline figures for elective primary replacements and revision replacements were lower, than in Germany.

Knee replacements also increased in Germany during the observation period, although there was a slight downward trend in 2010 and 2011. Non-demographic factors play a greater role in changes in knee replacement case numbers than for hip replacements. Revision knee replacements were performed approximately 1.6 times more frequently in 2011 than in 2005, independently of the effects of population aging; this can be seen as a consequence of earlier increases in primary replacements.

In the USA there were particularly sharp increases in total knee replacements from 2006 to 2008. These were caused by both demographic and non-demographic factors.

These results seem plausible when compared to other frequency figures reported on the basis of case numbers. Case numbers calculated for Germany using DRG statistics are comparable to those found in statutory quality assurance if differing definitions are taken into account (16).

There is also a good level of agreement with estimates based on health insurer data (17, 18), if entities defined in comparable ways are compared with each other. US publications, too, come to similar estimates of national frequencies for the USA (19–21).

Reliable knowledge can only be obtained from international comparisons if certain methodological requirements are met: in addition to taking into account countries' differing demographics, clinical entities must be referred to appropriately, without overlooking the differing features of individual classification systems. Analyses can only be performed on the basis of representative, comparative individual patient data. Calculating numbers of procedure codes without using individual patient data can result in significant data distortion due to multiple counting of individual cases.

The USA was chosen as an example country with which to compare Germany for this extensive case-related analysis because appropriate data was available. It was not possible to provide comparisons based on individual patient data from other industrialized countries in this study. However, published rates for other countries have also been collated and are compared in *eTables 4 and 5*. The crude frequency of hip replacements in Germany is higher than in Sweden, Norway, the Netherlands, England and Wales, or Australia but lower than in Switzerland. For knee replacements, German rates are similar to those of Switzerland. However, lower rates are reported for England and Wales, the Netherlands, Denmark, and Norway, while higher rates are reported for Australia. Almost all data sources show that surgery numbers increase over time. Günther et al. (22) have also collated rates for various countries and conclude that Germany is in the top third of industrialized countries for both hip and knee replacements. However, it must be remembered that the extent to which crude figures can be interpreted is severely limited by demographic differences. Of all the countries examined, Germany has the highest proportion of inhabitants aged 65 or older *(eTables 4 and 5)*.

The causes of the differences in hip and knee replacement frequency in Germany compared to the USA found in this research that are independent of demographics can only be a subject of speculation. It is possible that differences between health care systems affect access to joint replacement surgery. Because the USA has a higher proportion of uninsured individuals and significantly higher copayments for inpatient treatment, lower numbers of surgeries would be expected, as seen for hip replacements. This is not true of knee replacements, however. Differences in risk factor epidemiology may play a role here. For example, the proportion of overweight individuals, who are at greater risk of needing knee replacement, is higher in the USA than in Germany (23).

Changes in case numbers over time did not result from demographic factors alone in either country. Changes in numbers of elective primary replacements that are not caused by demographic factors may be the result of epidemiological factors. For example, in both Germany and the USA there is evidence of an increase in the prevalence of arthritis (24–26). However, it is also likely that surgery is being indicated more frequently as a result of medical and technical advances. In particular, the lower risks of surgery (e.g. thanks to less aggressive surgery and anesthesiology techniques) should be considered; these make it possible to provide such care even for patients with moderately increased risk. A change in demand by patients is also a possible cause, due to such surgery being seen as less risky, for example. Frequently discussed changes in supply by care providers, e.g. as a result of DRG introduction, may account for a further portion of changes unrelated to demographics but explain no more than some of the overall increase.

Limitations

Due to the availability of suitable data, this article compares surgery frequencies in Germany and the USA only.

TABLE 3

Changes in knee replacement frequency in Germany and the USA: demographic and non-demographic causes

		2005	2006	2007	2008	2009	2010	2011	Relative changes, 2005 to 2011*		
									Demographic causes	Non-demographic causes	Total
Primary knee replacements											
No. in Germany	Total	125 437	131 670	142 302	149 769	153 990	153 020	152 553	8.3%	12.3%	21.6%
	Male	38 968	41 628	46 639	50 164	52 265	53 145	53 681	12.4%	22.5%	37.8%
	Female	86 469	90 042	95 663	99 605	101 725	99 875	98 872	6.4%	7.5%	14.3%
No. in USA	Total	495 999	494 881	549 670	614 462	619 335	656 815	643 500	15.3%	12.5%	29.7%
	Male	177 478	179 438	198 608	227 175	229 426	242 842	241 759	17.5%	15.9%	36.2%
	Female	318 521	315 443	351 062	387 287	389 909	413 972	401 742	14.1%	10.6%	26.1%
Revision knee replacements											
No. in Germany	Total	9696	10 701	12 102	13 731	14 632	15 491	15 933	8.4%	51.6%	64.3%
	Male	3094	3456	3979	4560	5140	5486	5646	12.8%	61.8%	82.5%
	Female	6602	7245	8123	9171	9492	10 005	10 287	6.4%	46.5%	55.8%
No. in USA	Total	39 370	37 639	42 032	51 081	48 628	55 466	58 915	14.3%	30.9%	49.6%
	Male	16 358	15 522	17 433	21 549	20 340	22 614	24 241	16.4%	27.3%	48.2%
	Female	23 011	22 118	24 599	29 532	28 288	32 853	34 674	12.8%	33.6%	49.6%

*Calculated using multiplicative decomposition of the Laspeyres index by sex and five-year age groups. Figures shown are percent relative changes in indices. Example for reference: the number of primary knee replacements in Germany increased from 125 437 in 2005 to 152 553 in 2011. The index of the increase due to demographic causes is 1.083 (+8.3%); the index of the increase due to non-demographic causes is 1.123 (+12.3%). Multiplying these two indices together gives a total index of 1.216 (+21.6%), which corresponds to the relative difference between 125 437 and 152 553

In order to rank these results better, further comparisons should be made with other industrialized countries, to the extent that individual patient data is available.

The non-demographic causes of differing surgery frequencies in the countries investigated cannot be analyzed more closely on the basis of the selected study design. In addition, it should be noted that there are differences between the German and US health care systems which must be borne in mind when interpreting the results.

Summary

In cross-sectional analysis there are considerable differences between the frequencies of both hip and knee replacements in Germany and the USA. While more people undergo hip replacement surgery in Germany, the frequency of knee replacements was significantly higher in the USA.

The number of operations performed increased in both countries during the observation period, from different baseline levels. In Germany, changes in numbers of primary hip replacements were mostly caused by demographic factors, while larger increases unrelated to demographics were observed in the USA. Non-demographic factors affected numbers of primary knee replacements to similar extents in both countries.

This analysis cannot determine whether too many or too few joint replacements are performed in Germany or the USA. Long-term studies must investigate the extent of any overtreatment, undertreatment, or incorrect treatment; such studies must measure medical benefit in terms of target parameters such as functional outcome or quality of life. In light of the results of this research, general statements that too many joint replacements are performed in Germany should be interpreted with care. Discussion of changes in case numbers over time must take greater account of the effect of demographic factors.

Conflict of interest statement
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KEY MESSAGES

- After adjustment for differing demographics, in 2011 hip replacement surgery was 1.4 times more frequent in Germany, with 284 cases per 100 000 population, than in the USA (figure standardized to match Germany: 204 cases per 100 000 population).
- The number of hip replacements increased between 2005 and 2011 in both countries. Most of the increase in elective primary replacements in Germany can be explained by demographic factors: the increase independent of demographics over seven years was only 3.1%. In the USA the increase independent of demographics was considerably greater, from a lower baseline level.
- In 2011 knee replacements were 1.5 times more frequent in the USA (standardized rate: 304 cases per 100 000 population) than in Germany (206 cases per 100 000 population).
- Knee replacements also increased in both countries, and there was a slight downward trend in Germany in 2010 and 2011. Over the seven-year observation period, the increase in primary knee replacements that was independent of demographics was 12.3% in Germany and 12.5% in the USA.

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eTABLE 1

Case definitions

Hip replacements		
	Germany	**USA**
Diagnosis classification system	International statistical classification of diseases and related health problems, Tenth Revision, German Modification (ICD-10-GM)	International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) Diagnosis Codes
Procedure classification system	Surgery and Procedure Coding System (OPS)	International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) Procedure Codes
PR-THR, inclusion procedure: primary replacement	5–820.0* Total replacement 5–820.2* Total replacement, special 5–820.3* Femoral head replacement 5–820.4* Dual head replacement 5–820.6* Femoral head cap 5–820.8* Resurfacing 5–820.9* Short-stem femoral head replacement 5–820.x* Other	81.51 Total hip replacement 81.52 Partial hip replacement 00.85 Resurfacing hip, total, acetabulum and femoral head 00.86 Resurfacing hip, partial, femoral head 00.87 Resurfacing hip, partial, acetabulum
PR-THR-REV, inclusion procedure: revision replacement	5–821.1* Revision femoral head replacement 5–821.2* Revision acetabulum replacement 5–821.3* Revision total cemented replacement 5–821.4* Revision total uncemented replacement 5–821.5* Revision total hybrid (partially cemented) replacement 5–821.6* Revision total replacement, special 5–821.f* Revision dual head replacement 5–821.g* Revision resurfacing replacement 5–821.j* Revision femoral neck-preserving femoral head replacement	81.53 Revision of hip replacement, not otherwise specified 00.70 Revision of hip replacement, both acetabular and femoral components 00.71 Revision of hip replacement, acetabular component 00.72 Revision of hip replacement, femoral component 00.73 Revision of hip replacement, acetabular liner and/or femoral head only
D-THR-FRAC, inclusion diagnosis: fracture	S32.4 Acetabulum fracture S72.00 Femoral neck fracture, unspecified S72.01 Femoral neck fracture, intracapsular section S72.03 Femoral neck fracture, subcapital S72.04 Femoral neck fracture, midcervical, transcervical, further unspecified S72.05 Femoral neck fracture, base, cervicotrochanteric section S72.08 Femoral neck fracture, other parts S72.1 Pertrochanteric fracture S72.2 Subtrochanteric fracture	808.0 Acetabulum, closed 808.1 Acetabulum, open 820.00 Intracapsular section, unspecified 820.02 Midcervical section 820.03 Base of neck 820.09 Other 820.10 Intracapsular section, unspecified 820.12 Midcervical section 820.13 Base of neck 820.19 Other 820.20 Trochanteric section, unspecified 820.22 Subtrochanteric section 820.30 Trochanteric section, unspecified 820.32 Subtrochanteric section 820.8 Unspecified part of neck of femur, closed 820.9 Unspecified part of neck of femur, open V54.13 Aftercare for healing traumatic fracture of hip V54.15 Aftercare for healing traumatic fracture of upper leg
D-THR-OTH, inclusion diagnosis: other indication	M84.15 Malunion of fracture [pseudoarthrosis] (pelvic region and thigh) M96.0 Pseudoarthrosis following fusion or arthrodesis T84.1 Mechanical complication caused by internal osteosynthetic device in bone of extremity T84.6 Infection and inflammatory reaction caused by internal osteosynthetic device (any location)	733.81 Malunion of fracture 733.82 Nonunion of fracture 996.49 other mechanical complication of other internal orthopedic device, implant, and graft 996.67 Due to other internal orthopedic device, implant and graft V45.4 Arthrodesis status
1. Elective primary hip replacement (THR)	IF procedure IN PR-THR AND diagnosis NOT IN (D-THR-FRAC OR D-THR-OTH) AND age >19 THEN THR =1	
2. Revision hip replacement (THRR)	IF procedure IN PR-THR-REV AND THR<>1 AND age >19 THEN THRR =1	
3. Primary hip replacement for fracture (THRF)	IF procedure IN PR-THR AND diagnosis IN D-THR-FRAC AND diagnosis NOT IN D-THR-OTH AND THRR <>1 AND age >19 THEN THRF =1	
4. Hip replacement: other indication (THRO)	IF procedure IN PR-THR AND diagnosis IN D-THR-OTH AND THRR <>1 AND THRF <>1 AND age >19 THEN THRO =1	

Knee replacements		
Procedure classification system	Surgery and Procedure Coding System (OPS)	International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) Procedure Codes
PR-TKR, inclusion procedure: primary replacement	5–822.0* Unicondylar sled prosthesis 5–822.1* Bicondylar resurfacing, uncoupled, no patella replacement 5–822.2* Bicondylar resurfacing, uncoupled, with patella replacement 5–822.3* Bicondylar resurfacing, partially coupled, no patella replacement 5–822.4* Bicondylar resurfacing, partially coupled, with patella replacement 5–822.6* Hinged prosthesis, no patella replacement 5–822.7* Hinged prosthesis, with patella replacement 5–822.9* Special prosthesis 5–822.a* Replacement with increased flexion, no patella replacement 5–822.b* Replacement with increased flexion, with patella replacement 5–822.d* Bicompartmental partial replacement, no patella replacement 5–822.e* Bicompartmental partial replacement, with patella replacement	81.54 Total knee replacement Bicompartmental Partial knee replacement Tricompartmental Unicompartmental (hemijoint)
PR-TKR-REV, inclusion procedure: revision replacement	5–823.1* Revision unicondylar sled prosthesis 5–823.2* Revision bicondylar resurfacing 5–823.3* Revision hinged prosthesis replacement 5–823.4 Revision special prosthesis .40 Same type .41 Partial revision of femoral component .42 Partial revision of tibial component .4x Other 5–823.b* Revision replacement with increased flexion 5–823.f* Revision bicompartmental partial replacement 5–823.g* Removal of bicompartmental partial replacement	81.55 Revision of knee replacement, not otherwise specified 00.80 Revision of knee replacement, total (all components) 00.81 Revision of knee replacement, tibial component 00.82 Revision of knee replacement, femoral component 00.84 Revision of total knee replacement, tibial insert (liner)
1. Primary knee replacement (TKR)	IF procedure IN PR-TKR AND age >19 THEN TKR =1	
2. Revision knee replacement (TKRR)	IF procedure IN PR-TKR-REV AND TKR<>1 AND age >19 THEN TKRR =1	

eBOX 1

Formula for multiplicative index decomposition

$$Index = Index_R \cdot Index_B = \frac{\sum_{i=1}^{32}(B_{i,2011} \cdot R_{i,2011})}{\sum_{i=1}^{32}(B_{i,2011} \cdot R_{i,2005})} \cdot \frac{\sum_{i=1}^{32}(B_{i,2011} \cdot R_{i,2005})}{\sum_{i=1}^{32}(B_{i,2005} \cdot R_{i,2005})}$$

R = Risk (of surgery)
P = Population
i = 5-year age group for each sex

eTABLE 2

Hip replacement frequency in Germany and the USA, standardized for sex and age

	2005	2006	2007	2008	2009	2010	2011
Hip replacement: total							
No., Germany	209 292	213 371	220 114	226 736	231 028	231 740	232 320
No., USA	381 524	369 884	402 686	436 618	436 284	453 954	465 034
Rate per 100 000 population: Germany	254	259	268	276	282	283	284
Rate per 100 000 population: USA	129	124	134	143	142	147	149
Rate per 100 000 population: USA, standardized to match Germany*	173	167	181	195	195	200	204
Hip replacement: elective primary							
No., Germany	140 029	143 134	148 519	151 932	155 558	154 528	155 332
No., USA	233 599	224 757	254 401	278 522	283 342	297 999	298 174
Rate per 100 000 population: Germany	170	174	181	185	190	189	190
Rate per 100 000 population: USA	79	75	84	92	92	96	96
Rate per 100 000 population: USA, standardized to match Germany*	106	101	114	123	125	129	128
Hip replacement: primary for fracture							
No., Germany	46 765	46 606	46 519	48 435	48 529	49 816	49 456
No., USA	103 317	99 932	100 337	105 852	101 817	99 755	105 707
Rate per 100 000 population: Germany	57	57	57	59	59	61	60
Rate per 100 000 population: USA	35	33	33	35	33	32	34
Rate per 100 000 population: USA, standardized to match Germany*	46	45	46	48	46	47	50
Hip replacement: revision							
No., Germany	19 819	20 745	22 095	23 267	23 756	24 063	24 136
No., USA	37 713	36 288	38 079	41 946	40 499	44 913	49 746
Rate per 100 000 population: Germany	24	25	27	28	29	29	30
Rate per 100 000 population: USA	13	12	13	14	13	15	16
Rate per 100 000 population: USA, standardized to match Germany*	17	16	17	19	18	20	22

*US rates were standardized by sex and five-year age groups to match Germany's demographic structure for each year of the observation period (10) (direct standardization). Standardized rates show how many cases would have occurred in the USA per 100 000 population if the demographic structure were the same as in Germany. They can therefore be compared to German rates.

The total of elective primary hip replacements, primary hip replacements for fracture, and revision replacements is slightly lower than the figure shown for total hip replacements, as hip replacements for other indications are not shown here

eTABLE 3

Knee replacement frequency in Germany and the USA, standardized for sex and age

	2005	2006	2007	2008	2009	2010	2011
Knee replacement: total							
No., Germany	135 133	142 371	154 404	163 500	168 622	168 511	168 486
No., USA	535 369	532 521	591 701	665 543	667 964	712 281	702 415
Rate per 100 000 population: Germany	164	173	188	199	206	206	206
Rate per 100 000 population: USA	181	178	196	219	218	230	225
Rate per 100 000 population: USA, standardized to match Germany*	251	248	273	302	302	313	304
Knee replacement: primary							
No., Germany	125 437	131 670	142 302	149 769	153 990	153 020	152 553
No., USA	495 999	494 881	549 670	614 462	619 335	656 815	643 500
Rate per 100 000 population: Germany	152	160	173	182	188	187	187
Rate per 100 000 population: USA	168	166	182	202	202	212	207
Rate per 100 000 population: USA, standardized to match Germany*	233	231	254	280	280	289	279
Knee replacement: revision							
No., Germany	9696	10 701	12 102	13 731	14 632	15 491	15 933
No., USA	39 370	37 639	42 032	51 081	48 628	55 466	58 915
Rate per 100 000 population: Germany	12	13	15	17	18	19	19
Rate per 100 000 population: USA	13	13	14	17	16	18	19
Rate per 100 000 population: USA, standardized to match Germany*	18	17	19	23	22	24	25

*US rates were standardized by sex and five-year age groups to match Germany's demographic structure for each year of the observation period (10) (direct standardization). Standardized rates show how many cases would have occurred in the USA per 100 000 population if the demographic structure were the same as in Germany. They can therefore be compared to German rates

eTABLE 4

Frequency of primary hip replacements in various industrialized countries

Country	Source	Dataset	Year	Entity	Cases per 100 000 population	Percentage of population aged 65 or older	Features of case definition
Australia	Australian Orthopaedic Association National Joint Replacement Registry: Annual Report 2012. Adelaide: AOA National Joint Replacement Registry 2012.	Registry (completeness not stated)	2011	Primary hip replacement	151	14%	Replacement for fracture not excluded
England and Wales	National Joint Registry for England and Wales: 9th Annual Report 2012. Herfordshire: National Joint Registry 2012.	Registry (completeness: 93%)	2011	Primary total hip replacement	117	16%	Total replacement only
The Netherlands	Otten R, van Roermund PM, Picavet HS: [Trends in the number of knee and hip arthroplasties: considerably more knee and hip prostheses due to osteoarthritis in 2030]. Ned Tijdschr Geneeskd. 2010; 154: A1534. [Article in Dutch]	Hospital data (complete collation)	2005	Primary total hip replacement for arthritis	127	14%	Total replacement only
Norway	Bergen H: Report June 2010. Centre of excellence of joint replacements. Haukeland: Nasjonalt Register for Leddproteser 2010.	Registry (completeness: 95%)	2009	Elective primary hip replacement	138	15%	
Sweden	Garellik G, Karrholm J, Rogmark C, Rolfson O, Herberts P: Swedish Hip Arthroplasty Register. Annual Report 2011. Göteborg: Swedish Hip Arthroplasty Register 2012.	Registry (completeness: 96 to 98%)	2011	Elective primary hip replacement	156	18%	
Switzerland	Bundesamt für Gesundheit (BAG): Qualitätsindikatoren der Schweizer Akutspitäler 2011. Bern: Bundesamt für Gesundheit 2013.	Hospital data (complete collation)	2011	Elective primary hip replacement, age >19 (CH-IQI V3.1 I.1.1.F)	221	17%	Replacement for tumor excluded
Switzerland	Falbrede I, Widmer M, Kurtz S, Schneidmüller D, Dudda M, Röder C: Verwendungsraten von Prothesen der unteren Extremität in Deutschland und der Schweiz. Ein Vergleich der Jahre 2005–2008. Orthopäde 2011; 40: 793–801.	Hospital data (complete collation)	2008	Primary hip replacement	263	17%	Replacement for fracture not excluded

Figures shown here are published frequencies for elective primary hip replacements (total or partial hip replacements excluding replacements for fracture and revision replacements) for the years within the observation period of our study. Where no rates per 100 000 population were provided, these were calculated on the basis of absolute frequencies and the population size for the year in question. The corresponding crude rates used in this article for 2011 are 190 cases per 100 000 population for Germany and 96 for the USA.

Differing demographic structures must be taken into account when comparing crude rates. Percentages of the population aged 65 or older are given for reference. For 2011, this figure is 21% for Germany and 13% for the USA.

The following differences in case definitions must be borne in mind: primary replacements for fracture are not always excluded; some figures are for total hip replacements only

eTABLE 5

Frequency of primary knee replacements in various industrialized countries

Country	Source	Dataset	Year	Entity	Cases per 100 000 population	Percentage of population aged 65 or older	Features of case definition
Australia	Australian Orthopaedic Association National Joint Replacement Registry: Annual Report 2012. Adelaide: AOA National Joint Replacement Registry 2012.	Registry (completeness not stated)	2011	Primary knee replacement	200	14%	
Denmark	Danish Knee Arthroplasty Register: Annual Report 2010. Aarhus: Danish Knee Arthroplasty Register 2010.	Registry (completeness: 92%)	2009	Primary knee replacement	163	16%	
England and Wales	National Joint Registry for England and Wales: 9th Annual Report 2012. Herfordshire: National Joint Registry 2012.	Registry (completeness: 93%)	2011	Primary knee replacement	142	16%	
The Netherlands	Otten R, van Roermund PM, Picavet HS: [Trends in the number of knee and hip arthroplasties: considerably more knee and hip prostheses due to osteoarthritis in 2030]. Ned Tijdschr Geneeskd. 2010; 154: A1534. [Article in Dutch]	Hospital data (complete collation)	2005	Primary total knee replacement for arthritis	89	14%	Total replacements only
Norway	Bergen H: Report June 2010. Centre of excellence of joint replacements. Haukeland: Nasjonalt Register for Leddproteser 2010.	Registry (completeness: 95%)	2009	Primary knee replacement	93	15%	
Switzerland	Falbrede I, Widmer M, Kurtz S, Schneidmüller D, Dudda M, Röder C: Verwendungsraten von Prothesen der unteren Extremität in Deutschland und der Schweiz. Ein Vergleich der Jahre 2005–2008. Orthopäde 2011; 40: 793–801.	Hospital data (complete collation)	2008	Primary knee replacement	175	17%	

Figures shown here are published frequencies for primary knee replacements (total or partial replacements excluding revision replacements) for the years within the observation period of our study. Where no rates per 100 000 population were provided, these were calculated on the basis of absolute frequencies and the population size for the year in question. The corresponding crude rates used in this article for 2011 are 187 cases per 100 000 population for Germany and 207 for the USA.
Differing demographic structures must be taken into account when comparing crude rates. Percentages of the population aged 65 or older are given for reference. For 2011, this figure is 21% for Germany and 13% for the USA. Differences in case definitions must be borne in mind