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ORIGINAL ARTICLE

Lifetime Risk of Total Knee Replacement and Temporal Trends in Incidence by Health Care Setting, Socioeconomic Status, and Geographic Location

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Objective. **To estimate the lifetime risk of total knee replacement (TKR) and examine temporal trends in TKR incidence in the state of Victoria, Australia.**
Methods. **We performed a retrospective analysis of a population-based longitudinal cohort of patients (ages ≥40 years) who received a primary TKR in Victoria from 1999–2008. Hospital separations and life tables were used to estimate lifetime risk. Temporal changes in TKR incidence were examined according to health care setting (public versus private), socioeconomic status (SES), and geographic location (regional versus metropolitan).**
Results. **There were 43,570 incidents of primary TKRs identified over the study period. In 2008, the lifetime risk of surgery was 10.4% (95% confidence interval [95% CI] 10.13–10.64%) for men and 11.9% (95% CI 11.63–12.13%) for women. TKRs increased steadily over the study period in private hospitals (overall increase of 90%) with a smaller growth in procedure numbers for public hospitals (overall increase of 40%). From 2002–2003 onward, the low SES tertile showed a lower incidence of TKR compared to the middle and high SES groups, with incidence rates of 1.09 (95% CI 1.04–1.15), 1.22 (95% CI 1.17–1.28), and 1.20 (95% CI 1.16–1.25) per 1,000 population, respectively (based on 2007–2008 figures). Increased numbers of TKRs were also found to be occurring among people residing in regional areas of Victoria (from 1.12 [95% CI 1.04–1.31] to 1.84 [95% CI 1.72–2.02] per 1,000 population).**
Conclusion. **Increases in lifetime risk of TKR were evident. Although improved access to TKR for those living in regional areas was observed, sustained disparities relating to health care setting and SES warrant further investigation.**

INTRODUCTION

Lifetime risk of total knee replacement (TKR) refers to the probability of having knee replacement surgery over an individual's lifetime. Although data on the incidence of TKR may be instructive for researchers, the estimation of "lifetime risk" produces more tangible information for health professionals and policymakers to assess utilization and unmet need in the community and make decisions about the allocation of resources. Examining changes in lifetime risk over time can inform population health strategies and potentially facilitate the uptake of primary and secondary prevention strategies within populations. Where studies from the US have estimated the lifetime risk of symptomatic hip and knee osteoarthritis (OA) (1,2), 2 recent studies also have investigated the lifetime risk of TKR. Using a primary care database, Culliford et al (3) estimated the lifetime risk of TKR in the UK to range from 8–11% for women ages 50–70 years and from 6–8% for men in this age group. Over a 15-year period from 1991–2006, lifetime risk of TKR increased substantially for women (+6.9%) and men (+4.4%) (3), although potential explanations for this finding were not provided. Weinstein et al (4) used national health survey data from 2005–2008 and estimated that the cumulative lifetime risk of a 25-year-old to have a TKR in the US was 7.0% (95% confidence interval [95% CI] 6.1–7.8%) for men and 9.5% (95%

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Significance & Innovations

- Lifetime risk is a measure of disease risk with potential utility for the public, health professionals, and policymakers. For this study, lifetime risk of total knee replacement (TKR) was used to estimate the probability of having knee replacement surgery over an individual's lifetime.
- Lifetime risk of TKR increased over the 9-year study period to 10.4% for men and 11.9% for women.
- Sustained disparities in access to TKR relating to health care setting and socioeconomic status were observed, although the incidence of people receiving knee replacement surgery in more remote areas increased over time.

CI 8.5–10.5%) for women. Because these studies represent the only available data on lifetime risk of TKR, whether risk of knee replacement surgery is similar in other developed countries and how risk may change over time remain unknown.

A range of factors could affect access to TKR over time and potentially contribute to changes in lifetime risk of knee replacement surgery. These include insurance coverage or health care setting (5), socioeconomic status (SES) (6,7), and geographic location (8,9). The aims of this retrospective, population-based longitudinal cohort study were to quantify the lifetime risk of having a TKR in Victoria, Australia over time and describe temporal changes in the incidence of TKR according to health care setting (public versus private hospitals), SES, and geographic location.

MATERIALS AND METHODS

Data sources. We used data from the Victorian Admitted Episodes Dataset (VAED), a hospital admissions data set maintained by the Victorian State Department of Health to provide casemix funding to hospitals and support health service planning. It includes routinely collected patient-level data on all public and private hospital episodes within the state of Victoria, which has a population of approximately 5.5 million people (10). Records are internally linked to identify all hospital admissions for a single patient over time using a combination of probabilistic and stepwise deterministic linkage methods at the Department of Health. Following ethics approval from the Monash University Ethics Committee, we obtained data from the VAED on all patients with a hospital episode that included the clinical specialty codes for orthopedics or rheumatology. We also obtained population-level data on the age- and sex-specific Victorian population (11), the population by socioeconomic groupings from the Australian Bureau of Statistics (ABS) Socio-Economic Index for Areas (SEIFA) (12), the population by regional and metropolitan residence (13), and life tables for the study period (14) from the ABS.

Participant inclusion criteria. We included participants in our cohort if they met the following criteria: had a hospital episode between January 1, 1999 and December 31, 2008, received a primary TKR procedure (see Supplementary Appendix A, available in the online version of this article at http://onlinelibrary.wiley.com/doi/10.1002/acr.22122/abstract) during the study period, and were age ≥40 years at the time of their TKR episode (since TKRs are rarely undertaken in patients ages <40 years [0.4%]). TKRs were identified using International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM) operative procedure codes.

Covariates of interest. Data on individual age, sex, country of birth, and hospital type (public or private) were extracted from the VAED. Age at the time of the hospital admission for TKR was categorized into 10-year groupings (40–49, 50–59, 60–69, 70–79, and ≥80 years). Patient comorbidities were defined using ICD-10-AM codes (15), incorporating a lookback period through any hospital admission 1 year prior to the TKR admission (16). A diagnosis of OA or rheumatoid arthritis (RA) at the time of the TKR admission was defined using ICD-10-AM codes; 99% of primary TKRs in Australia are performed for these 2 diagnoses (17).

Each patient's Statistical Local Area of Residence (SLA) at the time of the hospital admission was linked to the Australian SEIFA (12); Australian 2001 Census data were used for patients admitted until June 2002, and Australian 2006 Census data were used for patients admitted after June 2002. The SEIFA measure is an Australia-wide index of SES based on geographic area of residence. The Index of Economic Resources score, one of 4 area-based measures of SES, was utilized for this study. This index score is a continuous number based on the sum of weighted characteristics (income, employment, and housing status) of economic resources in each geographic area. The economic resources score was chosen because it was thought to most closely reflect economic capacity to purchase health insurance. For cases with missing SLA data (15.6%), we used a simple mean imputation of the economic resources scores (12) from all nonmissing cases. We then grouped the scores into tertiles based on the distribution of the scores throughout the Australian population.

Each patient's SLA was also linked to the Australian Standard Geographical Classification (ASGC) Remoteness Structure to derive a measure of geographic access to health care. The ASGC classifies census districts into 5 categories of remoteness (major cities, inner regional cities, outer regional cities, remote locations, and very remote locations) based on the road distance to the nearest urban center. We grouped major and inner regional cities into a single category and outer regional, remote, and very remote locations into another category for our analyses. The latter regions align closely with districts of medical workforce shortage assigned by the Australian Department of

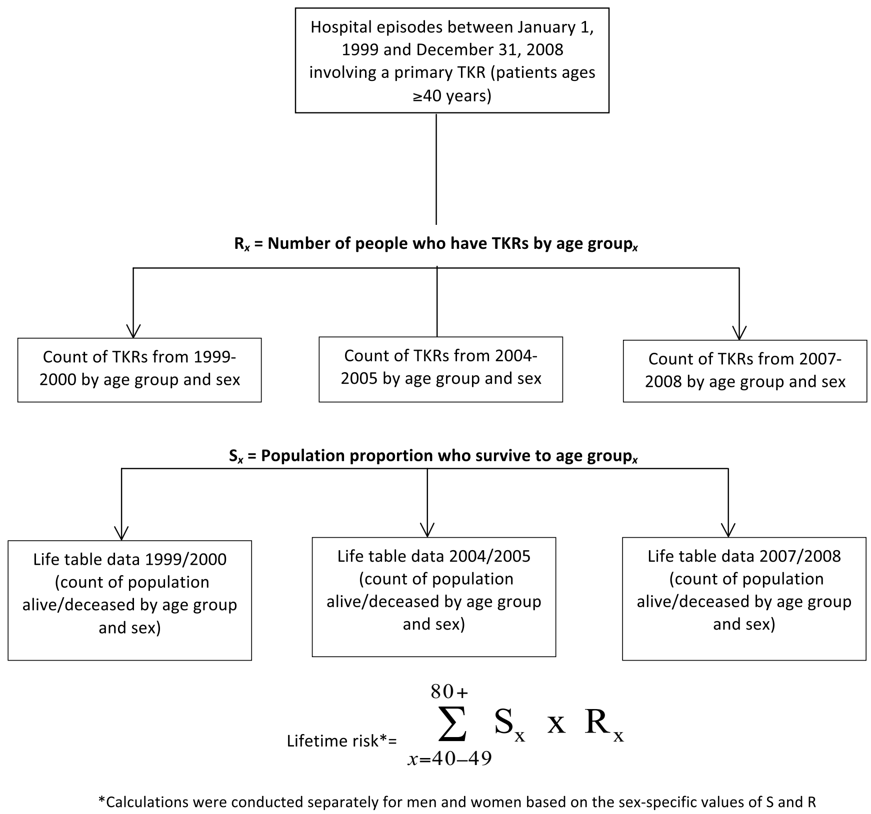

Figure 1. Schematic diagram of lifetime risk calculations. TKR = total knee replacement.

Health and Ageing (18) and were thought to be a good proxy for limited access to care. For cases with missing SLA data (15.6%), we conducted a nearest neighbor imputation, sorting data by admission date, separation date, and hospital.

Statistical analysis. Chi-square analyses were undertaken for comparisons between all categorical variables. For a hypothetical cohort of 100,000 people in Victoria, the number of years of life lived at each year of age is estimated by the ABS using all-cause mortality rates for the Victorian population. These methods have been described elsewhere (14). The lifetime risk of TKR was calculated for each age group by dividing the total number of incident TKRs by the total number of people expected to be alive at the beginning of the interval (Figure 1). Lifetime risk within each 10-year age group and overall lifetime risk were calculated at 3 time periods (1999–2000, 2003–2004, and 2007–2008). Separate risk calculations were undertaken for men and women due to known sex differences in arthritis prevalence and TKR rates (3,17,19). CIs (95%) were estimated using a Poisson model, since this is the recommended method for rate-based analyses (20).

The most recent financial year in our data set (2007–2008) was used for single-year estimates and temporal trends were estimated using the entire time period (1999–2008). We calculated the annual incidence of TKR over the study period according to factors potentially related to disparities in care, including health care setting, SES, and geographic location. Since population data for socioeconomic groupings were not available in each year, data from the previous census year were used (for example, the denominator for 1999/2000 and 2000/2001 was 1996 census data and for 2001/2002 to 2005/2006 was 2001 census data). CIs for incidence rates were calculated according to methods described elsewhere (21). All statistical analyses were performed using Microsoft Excel 2010 and Stata, version 12.1 (StataCorp).

RESULTS

Characteristics of the cohort. There were 43,570 incidents of primary TKRs identified over the study period. The number of TKR procedures in the VAED was consistent with data reported to the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) by individual hospitals, indicating complete case ascertainment (data available upon request from the corresponding author).

The descriptive characteristics of the cohort are reported in Table 1. Although the Victorian population age ≥40 years increased by 18% from 1999–2008, the number of primary TKRs increased by 84% over the same period. The majority of procedures were performed for women (59.0%). Those who had a TKR were more likely to be from the middle and high SES tertiles (38.7% and 34.4%, respectively) and less likely to be from the low SES tertile (26.9%). As expected, given the geographic distribution of the population, most TKRs were performed for people

Table 1. Descriptive characteristics of the cohort compared to the Victorian population

	Total knee replacement (n = 43,570), no. (%)	Victorian population, no. (%)*
Year of procedure		
1999	3,051 (7.0)	1,995,869 (9.1)
2000	3,179 (7.3)	2,042,315 (9.3)
2001	3,812 (8.8)	2,091,738 (9.5)
2002	4,126 (9.5)	2,136,334 (9.7)
2003	4,448 (10.2)	2,180,901 (9.9)
2004	4,495 (10.3)	2,223,767 (10.1)
2005	4,951 (11.4)	2,268,845 (10.3)
2006	4,918 (11.3)	2,314,302 (10.5)
2007	4,959 (11.4)	2,361,366 (10.7)
2008	5,631 (12.9)	2,409,467 (10.9)
Age group, years		
40–49	1,196 (2.8)	722,134 (32.8)
50–59	6,369 (14.6)	599,815 (27.2)
60–69	13,390 (30.7)	410,278 (18.6)
70–79	16,765 (38.5)	299,850 (13.6)
≥80	5,850 (13.4)	170,414 (7.7)
Sex		
Male	17,873 (41.0)	1,055,959 (47.9)
Female	25,697 (59.0)	1,146,531 (52.1)
Country of birth†		
Australian born	30,864 (70.8)	3,454,470 (69.3)
Non–Australian born	12,706 (29.2)	1,526,997 (30.7)
Geographic region†		
Metro/inner regional	39,872 (91.5)	4,729,483 (94.9)
Outer regional/ remote	3,698 (8.5)	251,984 (5.1)
Socioeconomic status tertile‡		
High	15,006 (34.4)	1,459,901 (29.3)
Middle	16,840 (38.7)	2,027,126 (40.7)
Low	11,724 (26.9)	1,494,439 (30.0)
Musculoskeletal conditions		Not available
Osteoarthritis	41,633 (95.6)	
Rheumatoid arthritis	1,023 (2.3)	
Other	1,212 (2.8)	
Hospital setting		Not available
Private hospital	28,077 (64.4)	
Public hospital	15,493 (35.6)	

* Figures are based on the population average age ≥40 years over the time period (10).
† Based on the entire population of Australia, since age-specific data were not available (11).
‡ Based on the entire population of Australia, since age-specific data were not available (11). Tertiles of economic resources scores were used to derive these categories.

living in metropolitan or inner regional areas (91.5%). People residing in outer regional/rural locations were more likely to be treated in a public hospital (48.7% versus 34.3% from metropolitan/inner regional residences; $P < 0.01$) and more likely to be from the lowest socioeconomic group (48.6% versus 24.9% from metropolitan/inner regional residences; $P < 0.01$).

Most patients (95.6%) had a concomitant diagnosis of OA and few had RA (2.3%). Overall, almost 16% of the cohort had hypertension (n = 6,851), 6.3% had uncomplicated diabetes mellitus (n = 2,743), 5.8% were current smokers (n = 2,506), 2.4% had hyperlipidemia (n = 1,026), 1.9% had chronic lung disease (n = 827), and 1.2% had chronic heart failure (n = 508). When compared to people from middle and high socioeconomic groups, people from low socioeconomic backgrounds were more likely to have diabetes mellitus (6.8% versus 6.1%; $P = 0.01$), be obese (2.4% versus 2.0%; $P = 0.01$), be smokers (6.3% versus 5.5%; $P < 0.01$), and have hyperlipidemia (2.6% versus 2.2%; $P = 0.03$).

Lifetime risk of primary TKR. As shown in Figure 2, the lifetime risk of TKR was examined at 3 time points (1999–2000, 2003–2004, and 2007–2008). For a person age 40–49 years, the mortality-adjusted lifetime risk rose from 7.83% for both men (95% CI 7.55–8.03%) and women (95% CI 7.59–8.01%) in 1999–2000 to 10.49% (95% CI 10.13–10.65%) for men and 11.94% (95% CI 11.63–12.13%) for women in 2007–2008. The widest gap between women and men was evident in 2004–2005 (Figure 2). The lifetime risk of TKR increased across all age categories for both women and men from 1999/2000 to 2007/2008. For women ages 60–69 years, the lifetime risk of ever having a TKR increased from 4.64% in 1999/2000 to 5.89% in 2004/2005 and to 6.09% in 2007/2008. For men ages 60–69 years, the lifetime risk increased from 4.439% in 1999/2000 to 4.73% in 2004/2005 and to 4.81% in 2007/2008 (Table 2).

Temporal changes in the incidence of primary TKR. Substantial differences in the incidence of TKR according to health care setting were identified. In 1999–2000, a slightly higher incidence of TKR was seen for private hospitals compared to public hospitals (Figure 3). Although the incidence of TKR in private hospitals increased steadily over the study period, the incidence in public hospitals plateaued. By 2004–2005, the incidence of TKR in the private hospitals was double that of the public hospitals (1.4 [95% CI 1.34–1.42] per 1,000 population

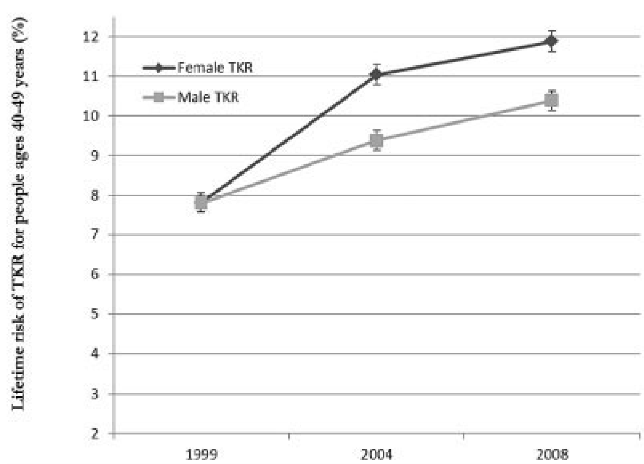

Figure 2. Temporal changes in lifetime risk of receiving total knee replacement (TKR) by sex.

Table 2. Risk of future primary knee replacement in 1999–2000, 2004–2005, and 2007–2008 according to age in women and men

	Women, %				Men, %			
	50–59 years	60–69 years	70–79 years	Ever	50–59 years	60–69 years	70–79 years	Ever
1999/2000 current age, years								
40–49	0.8	2.4	5.4	7.8	0.6	2.0	4.6	7.8
50–59		1.6	4.5	6.8		1.4	3.9	6.8
60–69			2.8	4.6			2.3	4.4
70–79				0.8				0.9
2004/2005 current age, years								
40–49	1.3	3.7	7.5	10.8	0.8	2.8	5.6	9.1
50–59		2.4	6.1	9.1		1.9	4.7	7.8
60–69			3.5	5.9			2.5	4.7
70–79				1.6				1.2
2007/2008 current age, years								
40–49	1.7	4.6	8.4	11.9	1.0	3.5	6.4	10.4
50–59		2.9	6.6	9.8		2.4	5.2	8.6
60–69			3.6	6.1			2.5	4.8
70–79				1.7				1.3

versus 0.7 [95% CI 0.65–0.72] per 1,000 population for public hospitals). In 1999, 53.2% and 42.0% of people in the lowest and highest SES tertiles, respectively, had their TKR performed in public hospitals. In 2008, 45.4% and 34.3% of people in the lowest and highest SES tertiles, respectively, had their TKR performed in public hospitals.

There was some evidence of SES disparities in the incidence of TKR over the study period. From 2002–2003 to 2004–2005, the low SES tertile demonstrated the lowest incidence of TKR each year compared with the middle and high SES tertiles (Figure 4). In 2005–2006, the incidence of TKR was similar for the low SES (0.99 per 1,000 population; 95% CI 0.94–1.04) and high SES tertiles (1.02 per 1,000 population; 95% CI 0.98–1.02). However, in subsequent years, the incidence of TKR was again lowest for the low SES tertile. In 2006–2007, the incidence was 0.99 (95% CI 0.94–1.04) per 1,000 population in the lowest SES group compared to 1.15 (95% CI 1.10–1.20) per 1,000 population in the middle SES group. In 2007–2008, the incidence was 1.09 (95% CI 1.04–1.15) per 1,000 population in the lowest SES group compared to 1.22 (95% CI 1.17–1.28) per 1,000 population in the middle SES group.

Although the incidence of TKR for patients residing in metropolitan/inner regional locations increased slightly over the study period (from 0.7 [95% CI 0.63–0.72] per 1,000 population to 1.0 [95% CI 0.94–1.03] per 1,000 population), there was a sharper increase in incidence for patients residing in outer regional/remote locations (from 1.1 [95% CI 1.04–1.31] per 1,000 population to 1.8 [95% CI 1.72–2.02] per 1,000 population) (Figure 5).

DISCUSSION

Estimating lifetime risk of TKR is a relatively new approach, with only 2 other recent studies using this technique (3). Incorporating comprehensive data from both public and private hospital settings in Australia, our study has shown a clear increase in mortality-adjusted lifetime risk of TKR surgery over a 9-year period, most notably for women. We have also provided age- and sex-specific estimates. These data, considered in combination with estimates of the OA burden over time, can be helpful in policy settings to inform population health strategies and motivate uptake of primary and secondary prevention strate-

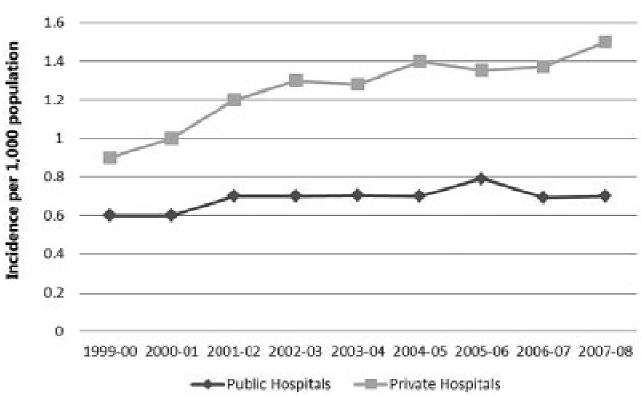

Figure 3. Temporal changes in the incidence of total knee replacement by health care setting.

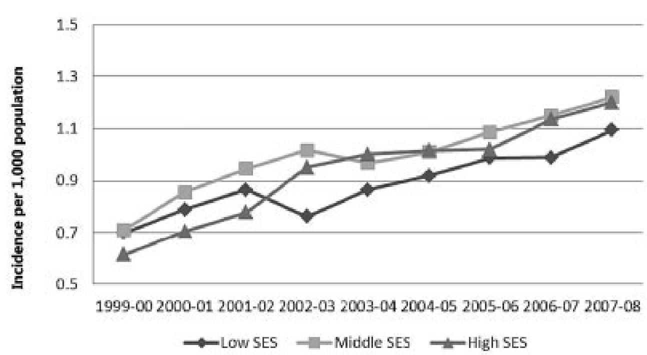

Figure 4. Temporal changes in the incidence of total knee replacement by tertile of socioeconomic status (SES) using the Index of Economic Resources.

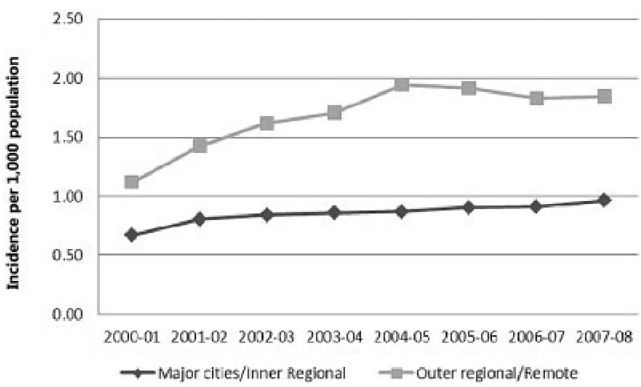

Figure 5. Temporal changes in the incidence of total knee replacement by geographic location. Data on the Victorian metropolitan and regional population were not available from the Australian Bureau of Statistics for 1999/2000.

gies. For example, increases in the lifetime risk of TKR without concomitant increases in the burden of severe OA can signal changes in patient preferences, surgical decision making, or the effects of health care policies. Gaining insight into these population-wide fluctuations, which are independent of disease burden, can be useful for budget priority setting and assessing the impact of policy changes on health care utilization. These data may also support advocacy activities for policy and funding changes. International comparisons of TKR lifetime risk could provide insight into the extent of unmet need within a country or region.

Our lifetime risk estimates for TKR were significantly higher than estimates reported for the UK (3) and the US (4). This is unlikely to relate to differences in risk factors for OA or OA prevalence between countries, but rather to differences in health care provider characteristics (for example, variation in thresholds at which surgery is offered [22,23]) and international variation in health systems (such as the availability of TKR surgery and the proportion of the population covered by health insurance). Of the 3 countries, Australia and the UK have the most in common with regard to the structure of their health care systems. Both Australia and the UK offer universal health care, where interventions such as TKR can be accessed through taxpayer-funded systems (public hospitals in Australia and the NHS in the UK). Both countries also have parallel private health systems that can be accessed by those who hold private health insurance or by those who can afford to pay for the costs associated with treatment. However, the proportion of people with private health insurance in Australia is considerably higher than in the UK (40–45% versus 10%) (24). In Australia, the private health system offers 2 main advantages for patients considering TKR: choice of surgeon and avoidance of lengthy waiting times for consultation and surgery. In the US, publicly funded health care is only provided for specific groups (for example, people ages ≥65 years, those with very low income, and people who are severely disabled). Health care in the US is provided by a range of private, public, and nonprofit organizations and treatment can be associated with significant expenses (25). There was also a sharper temporal increase in lifetime risk for men in Australia when compared to the UK. It is unknown if this is related to sex differences in the uptake of TKR between countries (22). Although limited data are currently available, similar analyses from other countries will be useful for exploring international patterns of lifetime TKR risk and differences in unmet need.

The observed increase in lifetime risk of TKR over the study period could be partly attributed to the aging population, with more people ages >80 years receiving TKRs, increased rates of sporting injuries (26), and rising rates of obesity (all risk factors for knee OA incidence [27–30]), and an increasing prevalence of severe joint disease (28–30). As we identified increased utilization of TKR in the private hospital setting, other potential drivers of growth could include financial incentives to having private health insurance, timelier access to TKR surgery in private hospital settings, and greater awareness of effective surgical interventions as these become increasingly common. An increase in knee arthroscopies for OA within the Australian private health system over this time period also has been demonstrated (31). According to recent data from the AOANJRR, 69.4% of knee replacements in Australia are now performed in the private health system (17). Since significant health insurance reforms were introduced in Australia more than a decade ago, these initiatives may have contributed to the observed rise in incidence of TKR in private hospitals. In 1999–2000, initiatives introduced by the Australian government to boost the number of people with private health insurance (including substantial rebates and incremental loadings on insurance premiums according to age) saw the proportion of Australians with private health insurance increase from 38% in 1998 to 51% in 2001 (32). In our data, rates of TKR increased in the private system over the time period, whereas the rates of TKR in the public system remained constant. The shifting of patients into the private system may have improved access to the public system for individuals who previously would not have received care. However, in 1999/2000, 12.4% of patients in public hospitals waited more than 365 days for a TKR (33), while 14.9% waited 365 days or more in 2008/2009 (34). This suggests there still may be considerable unmet need that may be related to the increasing growth in the aging population over this time period. Improved access and utilization of care have been demonstrated in other countries after health care systems encouraged the uptake of private health insurance; however, inequities in care may become more pronounced (24).

Lower SES was associated with a reduced incidence of TKR during the study period. In Australia, people with low SES generally have reduced access to the private hospital system. Our finding is consistent with studies from the UK and Canada that have reported reduced utilization of TKR by lower SES groups (7,35,36). In contrast to these studies, a cross-sectional Australian study reported higher rates of TKR for Australians living in the most disadvantaged areas compared with those living in the least disadvantaged areas (37). However, this study assessed TKR in 1 year (2006–2007) and used the socioeconomic index for measuring disadvantage (i.e., low income and unskilled occupations). We used the Index of Economic Resources, a measure of income, because we considered this measure would more closely reflect ability to afford health insurance. However, we also found that the lower SES group in our study had higher rates of comorbidities (such as chronic heart failure and diabetes mellitus), which may contraindicate surgery. Other studies have shown that comorbidities are a major barrier to accessing joint replacement for the poorest individuals (38).

On a positive note, we found an increasing incidence of TKR over time for people residing in outer regional and remote areas, suggesting improved access to TKR surgery for these individuals. However, it should be noted that the incidence of TKR in regional areas was already greater than in metropolitan areas at the beginning of the study period. This builds on the findings from an earlier Australian cross-sectional study that demonstrated higher rates of knee replacements in regional areas of Australia compared to major cities over a 2-year period from 2005–2007 (37). The increased incidence of TKRs in outer regional and remote areas could reflect a greater need for TKR surgery due to an older population in these regions, supported by median age data for regional Victoria compared with metropolitan Melbourne (the capital of Victoria) (39). People living in outer regional and remote areas also may be at greater risk for knee OA due to occupational risk factors such as manual labor. The larger increase in incidence for these individuals could also relate to greater previously unmet need and the increased provision of orthopedic services in regional areas over the past decade.

A major strength of our study design was the inclusion of public and private hospital data to improve the accuracy of our estimates and the external validity of the study. We acknowledge that this study utilized administrative data collected primarily for hospital reimbursement purposes, and although all procedures were primary TKRs, we do not have information on whether patients had previously received a primary TKR for the contralateral knee. This could overestimate the age at first TKR. Although the majority of the cohort had a diagnosis of OA (96%), we also utilized data from people who had other diagnoses (such as RA), and this may conflate the risk estimates due to the different course of each disease. However, our sensitivity analysis (limited to people with OA) produced similar findings for lifetime risk. We relied on area-based measures of socioeconomic status and rurality, which are known to have limitations (40). These indices were based on patients' residential locations rather than where they received treatment. There were 15.6% of cases with missing SLA data due to missing address information within the hospital admission records, where we imputed economic resource scores and rurality codes. We conducted a sensitivity analysis where we excluded cases with missing data, and this did not alter the trends we identified. We also acknowledge that changes in population factors (for example, age, injury rates, and SES distribution) may have contributed to temporal changes in lifetime risk and TKR incidence, but population data on these factors were not available for our analyses. Comorbidity data were obtained from the hospital episode records for the TKR admission and any admission within the year prior to the TKR. However, comorbidities have been shown to be underreported within hospital administrative data (41). Only 2.2% of the cohort was found to be obese, which is well below the population estimates of obesity for Australia (20.5%) (42); therefore, these data were not included in our analyses. Since comorbidities were not included in the analysis of lifetime risk, this is unlikely to change our estimates. Finally, although we did not have access to national hospital data, as Australia's second most populous state, it is reasonable to expect the Victorian data to be representative of other large Australian states. However, there may have been state-based policy initiatives to improve access to TKR (for example, in regional areas) during the study period of which we are not aware.

Increases in lifetime risk of TKR were evident over a 9-year period, although our understanding of contributing factors remains limited. While growth in risk factors for OA and greater disease severity may have partly driven this increase, government incentives to encourage the uptake of private health insurance also may have improved access to care for some people. Although the rising incidence of TKR for those living in more remote areas is encouraging, the observed disparities relating to health care setting and SES are concerning and warrant further investigation.

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AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be published. Dr. Bohensky had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
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REFERENCES

1. Murphy L, Schwartz TA, Helmick CG, Renner JB, Tudor G, Koch G, et al. Lifetime risk of symptomatic knee osteoarthritis. Arthritis Rheum 2008;59:1207–13.
2. Murphy LB, Helmick CG, Schwartz TA, Renner JB, Tudor G, Koch GG, et al. One in four people may develop symptomatic hip osteoarthritis in his or her lifetime. Osteoarthritis Cartilage 2010;18:1372–9.
3. Culliford DJ, Maskell J, Kiran A, Judge A, Javaid MK, Cooper C, et al. The lifetime risk of total hip and knee arthroplasty: results from the UK general practice research database. Osteoarthritis Cartilage 2012;20:519–24.
4. Weinstein AM, Rome BN, Reichmann WM, Collins JE, Burbine SA, Thornhill TS, et al. Estimating the burden of total knee replacement in the United States. J Bone Joint Surg 2013;95:385–92.
5. Ackerman IN, Busija L. Access to self-management education, conservative treatment and surgery for arthritis according to socioeconomic status. Best Pract Res Clin Rheumatol 2012;26: 561–83.
6. Hawker GA, Wright JG, Glazier RH, Coyte PC, Harvey B, Williams JI, et al. The effect of education and income on need

and willingness to undergo total joint arthroplasty. Arthritis Rheum 2002;46:3331–9.
7. Dixon T, Shaw M, Ebrahim S, Dieppe P. Trends in hip and knee joint replacement: socioeconomic inequalities and projections of need. Ann Rheum Dis 2004;63:825–30.
8. Dixon T, Shaw ME, Dieppe PA. Analysis of regional variation in hip and knee joint replacement rates in England using Hospital Episodes Statistics. Public Health 2006;120:83–90.
9. Skinner J, Weinstein JN, Sporer SM, Wennberg JE. Racial, ethnic, and geographic disparities in rates of knee arthroplasty among Medicare patients. N Engl J Med 2003;349: 1350–9.
10. Australian Bureau of Statistics. 3101.0 Australian demographic statistics. Canberra: ACT; 2012.
11. Australian Bureau of Statistics. 3235.0: population by age and sex, regions of Australia, 2010. Canberra: Australian Bureau of Statistics; 2011.
12. Australian Bureau of Statistics. Technical paper census of population and housing: Socio-Economic Index for Areas (SEIFA). Canberra: Australian Bureau of Statistics; 2004.
13. Australian Bureau of Statistics. Population estimates by remoteness area, 2001 to 2010: report 3218.0. Canberra: Australian Bureau of Statistics; 2011.
14. Australian Bureau of Statistics. 3302.2.55.001 life tables, Victoria, 2007-2009. Canberra: Australian Bureau of Statistics; 2010.
15. Roberts RF, Innes KC, Walker SM. Introducing ICD-10-AM in Australian hospitals. Med J Aust 1998;169 Suppl:S32–5.
16. Preen DB, Holman CD, Spilsbury K, Semmens JB, Brameld KJ. Length of comorbidity lookback period affected regression model performance of administrative health data. J Clin Epidemiol 2006;59:940–6.
17. Australian Orthopaedic Association National Joint Replacement Registry. Annual report. Adelaide: Australian Orthopaedic Association; 2012.
18. DoctorConnect. District of workforce shortage. 2013. URL: http://www.doctorconnect.gov.au/internet/otd/Publishing.nsf/Content/dwsFactsheet.
19. Blagojevic M, Jinks C, Jeffery A, Jordan KP. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. Osteoarthritis Cartilage 2010;18: 24–33.
20. Gardner W, Mulvey EP, Shaw EC. Regression analyses of counts and rates: Poisson, overdispersed Poisson, and negative binomial models. Psychol Bull 1995;118:392–404.
21. Greenland S, Rothman D. Introduction to categorical statistics. In: Rothman KJ, Greenland S, Lash TL, editors. Modern epidemiology. 3rd ed. Philadelphia: Lippincott, Williams and Wilkins; 1998. p. 238–57.
22. Ackerman IN, Dieppe PA, March LM, Roos EM, Nilsdotter AK, Brown GC, et al. Variation in age and physical status prior to total knee and hip replacement surgery: a comparison of centers in Australia and Europe. Arthritis Rheum 2009;61: 166–73.
23. Dieppe P, Judge A, Williams S, Ikwueke I, Guenther KP, Floeren M, et al. Variations in the pre-operative status of patients coming to primary hip replacement for osteoarthritis in European orthopaedic centres. BMC Musculoskelet Disord 2009;10:19.
24. Colombo F, Tapay N. Private health insurance in OECD countries: the benefits and costs for individuals and health systems. Paris: Organisation for Economic Co-operation and Development; 2004.
25. Blumenthal D, Dixon J. Health-care reforms in the USA and England: areas for useful learning. Lancet 2012;380:1352–7.
26. Andrew NE, Gabbe BJ, Wolfe R, Cameron PA. Trends in sport and active recreation injuries resulting in major trauma or death in adults in Victoria, Australia, 2001-2007. Injury 2012; 43:1527–33.
27. Tjoumakaris FP, Van Kleunen J, Weidner Z, Huffman GR. Knee sports injury is associated with an increased prevalence of unilateral knee replacement: a case-controlled study. J Knee Surg 2012;25:403–6.
28. Hart DJ, Doyle DV, Spector TD. Incidence and risk factors for radiographic knee osteoarthritis in middle-aged women: the Chingford Study. Arthritis Rheum 1999;42:17–24.
29. Grotle M, Hagen KB, Natvig B, Dahl FA, Kvien TK. Obesity and osteoarthritis in knee, hip and/or hand: an epidemiological study in the general population with 10 years follow-up. BMC Musculoskelet Disord 2008;9:132.
30. Wang Y, Wluka AE, Simpson JA, Giles GG, Graves SE, de Steiger RN, et al. Body weight at early and middle adulthood, weight gain and persistent overweight from early adulthood are predictors of the risk of total knee and hip replacement for osteoarthritis. Rheumatology (Oxford) 2013;52:1033–41.
31. Bohensky MA, Sundararajan V, Andrianopoulos N, de Steiger RN, Bucknill A, Kondogiannis CM, et al. Trends in elective knee arthroscopies in a population-based cohort, 2000-2009. Med J Aust 2012;197:399–403.
32. Australian Bureau of Statistics. Private health insurance: a snapshot, 2004-05. Report no.: 4815.0.55.001. Canberra: Australian Bureau of Statistics; 2006.
33. Australian Institute of Health and Welfare (AIHW). Waiting times for elective surgery in Australia 1999-00: AIHW cat. no. HSE 18. Canberra: AIHW (Health Services Series no. 18); 2001.
34. Australian Institute of Health and Welfare (AIHW). Australian hospital statistics 2008-09. Health services series no. 17. Cat. no. HSE 84. Canberra: AIHW; 2010.
35. Judge A, Welton NJ, Sandhu J, Ben-Shlomo Y. Equity in access to total joint replacement of the hip and knee in England: cross sectional study. BMJ 2010;341:c4092.
36. Rahman MM, Kopec JA, Sayre EC, Greidanus NV, Aghajanian J, Anis AH, et al. Effect of sociodemographic factors on surgical consultations and hip or knee replacements among patients with osteoarthritis in British Columbia, Canada. J Rheumatol 2011;38:503–9.
37. Dixon T, Urquhart DM, Berry P, Bhatia K, Wang Y, Graves S, et al. Variation in rates of hip and knee joint replacement in Australia based on socio-economic status, geographical locality, birthplace and indigenous status. ANZ J Surg 2011;81:26–31.
38. Steel N, Melzer D, Gardener E, McWilliams B. Need for and receipt of hip and knee replacement: a national population survey. Rheumatology (Oxford) 2006;45:1437–41.
39. Australian Bureau of Statistics. 3235.0: population by age and sex, regions of Australia, 2008. Canberra: ACT; 2009.
40. McCracken K. Into a SEIFA SES cul-de-sac? Aust N Z J Public Health 2001;25:305–6.
41. Quan H, Parsons GA, Ghali WA. Validity of information on comorbidity derived from ICD-9-CCM administrative data. Med Care 2002;40:675–85.
42. Walls HL, Magliano DJ, Stevenson CE, Backholer K, Mannan HR, Shaw JE, et al. Projected progression of the prevalence of obesity in Australia. Obesity (Silver Spring) 2012;20:872–8.