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Substantial rise in the lifetime risk of primary total knee replacement surgery for osteoarthritis from 2003 to 2013: an international, population-level analysis

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SUMMARY

Objective: To estimate and compare the lifetime risk of total knee replacement surgery (TKR) for osteoarthritis (OA) between countries, and over time.
Method: Data on primary TKR procedures performed for OA in 2003 and 2013 were extracted from national arthroplasty registries in Australia, Denmark, Finland, Norway and Sweden. Life tables and population data were also obtained for each country. Lifetime risk of TKR was calculated for 2003 and 2013 using registry, life table and population data.
Results: Marked international variation in lifetime risk of TKR was evident, with females consistently demonstrating the greatest risk. In 2013, Finland had the highest lifetime risk for females (22.8%, 95%CI 22.5–23.1%) and Australia had the highest risk for males (15.4%, 95%CI 15.1–15.6%). Norway had the lowest lifetime risk for females (9.7%, 95%CI 9.5–9.9%) and males (5.8%, 95%CI 5.6–5.9%) in 2013. All countries showed a significant rise in lifetime risk of TKR for both sexes over the 10-year study period, with the largest increases observed in Australia (females: from 13.6% to 21.1%; males: from 9.8% to 15.4%).
Conclusions: Using population-based data, this study identified significant increases in the lifetime risk of TKR in all five countries from 2003 to 2013. Lifetime risk of TKR was as high as 1 in 5 women in

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Finland, and 1 in 7 males in Australia. These risk estimates quantify the healthcare resource burden of knee OA at the population level, providing an important resource for public health policy development and healthcare planning.

Introduction

Knee osteoarthritis (OA) represents a significant public health challenge internationally. The increasing burden of knee OA worldwide is evident from the results of the Global Burden of Disease Study[1]. This landmark study highlighted a major shift in the global burden of disease over the past 20 years from infectious diseases to non-communicable diseases including musculoskeletal conditions that are associated with significant disability[2]. This is supported by data from a range of developed countries that show steady growth in the rate of knee replacement surgeries performed predominantly for severe knee OA over the past two decades[3–5]. Total knee replacements (TKRs) represent the majority of procedures performed, with only a small proportion of patients receiving unicompartmental knee replacement (UKR)[5,6]. While joint replacement surgery is cost-effective[7], planning for future healthcare demand is critical and requires robust population-level data on disease burden and healthcare utilisation.

Estimating the lifetime risk of joint replacement surgery is an evolving area within musculoskeletal epidemiology. This statistical approach is commonly used in the cardiovascular and cancer fields[8,9]. The lifetime risk of TKR refers to the probability of having this surgical procedure over an individual's lifetime. Lifetime risk estimates provide a complementary approach to quantifying population-level disease burden and related use of healthcare services, and can be easily interpreted by health policymakers, clinicians and patients (as they are expressed as percentages). A key advantage of the lifetime risk statistic is that it provides a cumulative measure of risk that incorporates population life expectancy and all-cause mortality.

Data on the lifetime risk of TKR surgery are limited. Research from the United Kingdom found that the lifetime risk of TKR had increased markedly over a 15-year period from 1991 to 2006, particularly for women[10]. In the United States, Weinstein *et al.*[11] used national health survey data to estimate the cumulative lifetime risk of TKR, although changes in risk over time were not evaluated. Most recently, Bohensky and colleagues used hospital administrative data to estimate the lifetime risk of TKR in the state of Victoria, Australia[12]. A clear increase in the lifetime risk of TKR was evident over a nine-year period (1999–2008), most notably for females. Previous studies investigating the lifetime risk of TKR have all obtained data on joint replacement utilisation from observational studies or health system administrative datasets, which have known limitations around generalisability, completeness and accuracy. The use of population-based procedure data from national arthroplasty registries with almost complete coverage would enable more precise estimates of the lifetime risk of TKR.

While a number of earlier studies have compared TKR incidence rates or utilisation rates between countries[4,6,13–15], an international comparison of the lifetime risk of TKR has not been undertaken. The present study aimed to:

- estimate and compare the lifetime risk of primary TKR for OA in five countries;
- describe change in lifetime risk over a ten-year period (2003–2013); and
- examine changes in utilisation rates of primary TKR and UKR performed for OA over time.

Methods

Study design

A multi-national, population-level retrospective analysis was undertaken.

Data sources

We obtained data on all primary TKR and UKR procedures performed for OA from 1 January 2003 to 31 December 2003 and 1 January 2013 to 31 December 2013 in Australia, Denmark, Finland, Norway and Sweden. These countries were selected for their longstanding and comprehensive national arthroplasty registries. The years 2003 and 2013 were chosen to align with the most recent life table data available across all five countries. De-identified, aggregate data on the number of surgical procedures and the number of patients receiving TKR and UKR in each year were obtained from the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), the Danish Knee Arthroplasty Register, the Finnish Arthroplasty Register (Finnish UKR data were obtained from the Finnish Hospital Discharge Register), the Norwegian Arthroplasty Register, and the Swedish Knee Arthroplasty Register. These registries collect data from public and private hospitals and all report over 95% registration completeness for primary joint replacement procedures. Approval for accessing AOANJRR data was obtained from The University of Melbourne Human Research Ethics Committee and the AOANJRR Data Review Committee. The study was also approved by the Nordic Arthroplasty Register Association. Ethics approval was not required for Denmark, Finland, Norway or Sweden, in line with local legislation.

Extracted registry data for each country included:

- sex;
- age; and
- operation type: TKR and UKR.

Life table data for 2003 and 2013 (stratified by gender) were obtained online from the Australian Bureau of Statistics, Statistics Denmark, Statistics Norway, and Statistics Sweden. Life table data for Finland were obtained online from Eurostat, the statistical office of the European Union. Life tables use all-cause mortality rates to estimate the number of people alive at each year of age (age range 0–100 years) for a hypothetical cohort of 100,000 people. Data on the population of each country (by age and sex) and life expectancy for 2003 and 2013 were obtained from the above sources and OECD.Stat[16], respectively.

Data analysis

Data were categorised into pre-specified age groups for analysis: <40 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years and ≥80 years. A 'standardised lifetime risk' calculation incorporating age-specific rates[17] was used to calculate the lifetime risk of primary TKR, accounting for potential differences in population size and life expectancy between countries (Supplementary material). Simultaneous bilateral TKR was counted as one TKR procedure to avoid potential over-estimation of lifetime risk. Where staged (non-

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simultaneous) bilateral TKR procedures were performed within the same year, only the first procedure was included in the dataset.

The lifetime risk of TKR was calculated for each age group by dividing the total number of people having TKR procedures in that year (obtained from registry data) by the age group-specific and sex-specific population, and then multiplying these rates by the total number of people expected to be alive at the beginning of the interval (obtained from life table data). Lifetime risk of TKR was calculated for 2003 and 2013, with separate calculations undertaken for males and females due to known gender differences in knee OA prevalence and surgery rates[3,14,18]. Confidence intervals (95%CI) were estimated using Poisson models[17]. Changes in lifetime risk of TKR over time and comparison of lifetime risk estimates between countries were analysed descriptively, using calculated confidence intervals. Lifetime risk of UKR was not calculated due to the small number of procedures performed. Instead, a sensitivity analysis (Supplementary material) was undertaken to estimate the combined lifetime risk of TKR and UKR in 2003 and 2013 in each country (using the same methods as for the TKR-only analyses).

Similar to previous methods[15,19], overall and age-based utilisation rates for TKR were calculated for each country in 2003 and 2013 by summing the count of procedures from each registry and dividing by the relevant population (with regard to gender and age group) for that year. These are reported as TKR utilisation rates per 100,000 population, with separate calculations for males and females. Where bilateral TKRs were performed, these were counted as two procedures to avoid underestimating the true utilisation of TKR. For UKR, only overall utilisation rates were calculated due to the relatively small numbers of procedures performed.

Results

Population characteristics and demographics of TKR

Table I summarises the population characteristics for each country. While population size varied substantially across the five countries, the gender distribution was similar. Life expectancy was comparable across the countries and all countries experienced an increase in life expectancy from 2003 to 2013. Demographic data relating to primary TKR use are also presented in Table I. In 2003 and 2013, the majority of TKR procedures in each country were undertaken for females. The proportion of TKRs performed for people aged ≤60 years increased over time for all countries, from 15.8% to 17.1% in Australia, from 17.2% to 17.7% in Denmark, from 12.7% to 17.4% in Finland, from 11.3% to 16.4% in Norway, and from 13.1% to 16.1% in Sweden. The proportion of TKRs performed for the oldest individuals (those aged ≥80 years) decreased over the 10-year period in all countries except Finland (Table I). In 2003, the majority of TKR procedures in each country were performed for the 70–79 age group (Table I). In 2013, this was still evident for Denmark, Finland and Sweden, although TKR was most frequently performed for the 60–69 age group in Australia and Norway at this time point.

Comparison of lifetime risk of TKR between countries

Table II presents the lifetime risk of TKR for males and females in each country in 2003 and 2013. Overall, lifetime risk varied considerably across the countries. In 2003, the lifetime risk of TKR for females ranged from 5.84% (in Denmark) to 19.21% (in Finland), and the lifetime risk for males ranged from 2.76% (in Norway) to 9.77% (in Australia). Across all five countries, females had a consistently higher lifetime risk of surgery. This was most evident in Finland, where lifetime risk of TKR for females was more than double the risk for males in 2003 (19.21% vs 7.91%; $P < 0.05$).

In 2013, the lowest lifetime risk for females was seen in Norway and the greatest lifetime risk for females was in Finland, closely followed by Australia (Table II). For males, the lowest lifetime risk of TKR was in Norway and the highest lifetime risk was in Australia. Similar to the 2003 data, females consistently demonstrated a higher lifetime risk of TKR across all countries in 2013. The difference in lifetime risk between sexes was greatest in Finland, where the risk for females in 2013 was almost double the risk for males (22.79% vs 11.68%; $P < 0.05$).

Changes in lifetime risk of TKR over time

Each country demonstrated a significant increase in the lifetime risk of TKR from 2003 to 2013 for both females and males. For females, the greatest absolute increases in lifetime risk over time were evident for Australia and Denmark (Fig. 1), while Finland and Norway had the smallest absolute change. All five countries also

Table I
Population characteristics and TKR demographics

Country	Population data			TKR data from registries							
	Population size	% Female	Life expectancy*	Number of primary TKR†	% Female‡	% Aged <40 years‡	% Aged 40–49 years‡	% Aged 50–59 years‡	% Aged 60–69 years‡	% Aged 70–79 years‡	% Aged ≥80 years‡
Australia											
2003	19,720,737	50.4	80.3 years	20,986	57.2	0.2	1.9	13.7	30.8	40.1	13.3
2013	23,125,868	50.2	82.2 years	42,919	56.6	0.1	1.8	15.2	38.3	32.8	11.8
Denmark											
2003	5,387,174	50.5	77.4 years	2,908	65.7	0.3	2.2	14.8	31.7	36.8	14.4
2013	5,605,836	50.4	80.4 years	6,107	61.2	0.2	2.7	14.8	36.0	36.5	9.8
Finland											
2003	5,219,732	51.1	78.5 years	6,090	69.8	0.1	1.1	11.5	29.1	47.0	11.3
2013§	5,451,270	50.8	81.1 years	9,569	64.3	0.2	1.7	15.5	33.8	35.9	13.0
Norway											
2003	4,552,252	50.4	79.6 years	2,168	71.7	0.0	1.3	10.0	26.2	44.4	18.0
2013	5,051,275	49.8	81.8 years	4,010	62.3	0.1	2.4	13.9	37.4	34.6	11.5
Sweden											
2003	8,975,670	50.5	80.3 years	6,656	61.4	0.1	1.0	12.0	29.5	42.9	14.5
2013	9,644,864	50.1	82.0 years	12,124	56.8	0.1	2.2	13.8	36.2	37.0	10.7

* Data on population life expectancy at birth were obtained from OECD.Stat[13].
† Bilateral procedures performed within the same year were counted as two TKRs.
‡ Proportion of those who received primary TKR at each time point.
§ Three TKR patients ($n = 4$ TKR procedures) from Finland were excluded from these analyses due to missing data on gender.

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Table II
Between-country variation in lifetime risk of TKR

Country	Lifetime risk (95%CI)	
	Females	Males
Australia		
2003	13.63 (13.40–13.86)	9.77 (9.58–9.97)
2013	21.13 (20.85–21.42)	15.37 (15.13–15.61)
Denmark		
2003	5.84 (5.69–5.99)	3.10 (2.99–3.21)
2013	10.85 (10.65–11.06)	6.76 (6.60–6.93)
Finland		
2003	19.21 (18.94–19.49)	7.91 (7.74–8.09)
2013*	22.79 (22.49–23.08)	11.68 (11.47–11.89)
Norway		
2003	6.59 (6.43–6.75)	2.76 (2.66–2.87)
2013	9.70 (9.50–9.89)	5.78 (5.63–5.93)
Sweden		
2003	7.70 (7.53–7.87)	4.93 (4.79–5.07)
2013	11.81 (11.59–12.02)	8.87 (8.69–9.06)

Data are presented as percentages.
Simultaneous bilateral TKR was counted as one TKR procedure to avoid potential over-estimation of lifetime risk. Where staged bilateral TKR procedures were performed within the same year, only the first procedure was included in the dataset.
* Three TKR patients from Finland were excluded from the 2013 analyses due to missing data on gender.

demonstrated significant increases in the lifetime risk of TKR for males over time (Fig. 2). Australia had the greatest absolute increase, while the other countries showed smaller absolute increases.

Sensitivity analyses incorporating both TKR and UKR data produced similar results (Supplementary material), with marked between-country variation and significant increases over time in the combined lifetime risk of TKR and UKR observed for both sexes in all countries.

Age-specific utilisation rates for primary TKR

For all countries, the greatest TKR utilisation rates were observed for people aged between 70 and 79 years and this was evident for both sexes and at both time points (Table III). Across the countries, females aged 70–79 years in Finland experienced the highest rate of TKR (1770 procedures per 100,000 population in 2013). This rate was over 1.5 times higher than the utilisation rate for similarly-aged females in Australia and approximately three times higher than the rate for 70–79 year old females in Norway,

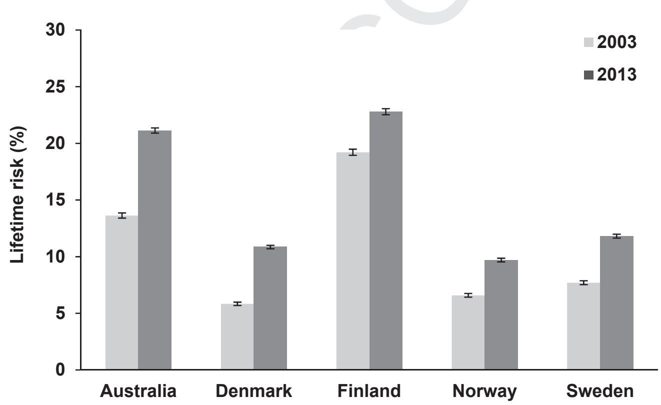

Fig. 1. Changes in lifetime risk of TKR over time for females. Whiskers indicate 95% CI; $P < 0.05$ for all 2003–2013 comparisons. For these estimates, simultaneous bilateral TKR was counted as one TKR procedure to avoid potential over-estimation of lifetime risk. Where staged bilateral TKR procedures were performed within the same year, only the first procedure was included in the dataset.

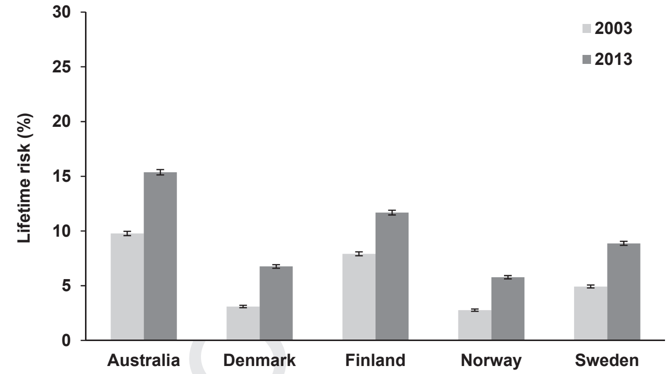

Fig. 2. Changes in lifetime risk of TKR over time for males. Whiskers indicate 95%CI; $P < 0.05$ for all 2003–2013 comparisons. For these estimates, simultaneous bilateral TKR was counted as one TKR procedure to avoid potential over-estimation of lifetime risk. Where staged bilateral TKR procedures were performed within the same year, only the first procedure was included in the dataset.

Denmark, and Sweden. While utilisation rates for people aged ≤50 years were low, each country demonstrated an increase in TKR rates over time for females and males aged 40–49 years, 50–59 years, 60–69 years, 70–79 years and ≥80 years (Table III).

Overall utilisation of UKR surgery

Compared to the number of TKR procedures performed, utilisation of UKR in each country was relatively low. In 2003, the number of UKR procedures ranged from 426 (in Norway) to 4070 (in Australia). In 2013, the number of procedures ranged from 276 (in Finland) to 2056 (in Australia). As a proportion of all knee replacement procedures, UKR utilisation decreased substantially in all countries from 2003 to 2013; from 16.2% to 4.6% in Australia, from 15.6% to 5.5% in Denmark, from 7.0% to 2.8% in Finland, from 16.0% to 9.7% in Norway, and from 12.5% to 3.7% in Sweden.

When population size was taken into account, a reduction in UKR utilisation rate over time was also evident for all countries. The greatest reductions were observed for Australia (from 20.6 UKR procedures per 100,000 population in 2003 to 8.9 procedures per 100,000 in 2013) and Sweden (from 10.6 to 4.9 UKR procedures per 100,000). Smaller reductions in utilisation rates were seen for Denmark (from 9.9 to 6.4 UKR procedures per 100,000), Finland (from 8.8 to 5.1 UKR procedures per 100,000) and Norway (from 9.4 to 8.5 UKR procedures per 100,000).

Discussion

This study is the first to use population-based arthroplasty registry data to estimate the lifetime risk of TKR at the national level, and to compare lifetime risk between countries and over time. We used data from five well-validated registries to obtain the most accurate information on TKR utilisation. We found a marked increase in the lifetime risk of primary TKR for OA in all countries over the ten-year study period, and substantial variation between countries in the utilisation of TKR. These lifetime risk estimates advance our understanding of population-level knee OA disease burden and healthcare utilisation, beyond data from the Global Burden of Disease Study that were modelled using systematic reviews of OA prevalence and incidence[1], and beyond published TKR incidence or utilisation rates that do not consider life expectancy, age-specific mortality, or whether individuals have multiple surgical procedures[13,15].

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Table III
Comparison of age-specific utilisation rates for TKR

Country	Utilisation rate* per 100,000 people						
	Overall	<40 years	40–49 years	50–59 years	60–69 years	70–79 years	≥80 years
Australia							
Females 2003	121	0	15	128	450	789	427
Females 2013	209	0	27	251	766	1135	575
Males 2003	92	0	12	108	371	656	447
Males 2013	162	0	21	193	650	907	565
Denmark							
Females 2003	70	0	10	74	204	381	206
Females 2013	132	0	24	153	369	612	279
Males 2003	37	0	6	40	146	208	164
Males 2013	85	1	17	95	261	439	222
Finland†							
Females 2003	159	0	9	118	441	1720	218
Females 2013	222	1	25	238	533	1770	301
Males 2003	72	0	7	59	249	917	121
Males 2013	127	0	23	157	339	1081	210
Norway							
Females 2003	68	0	5	49	209	414	222
Females 2013	99	0	19	108	323	537	235
Males 2003	27	0	4	25	102	189	129
Males 2013	60	0	7	69	224	361	164
Sweden							
Females 2003	90	0	8	74	241	491	216
Females 2013	143	0	23	172	398	633	265
Males 2003	58	0	3	54	193	347	180
Males 2013	109	0	17	114	348	525	256

* The overall utilisation rate was calculated using the total number of procedures for females (or males) as the numerator and the number of females (or males) in the population as the denominator. Age-specific utilisation rates were calculated using the number of procedures for each age group as the numerator and the age-specific population as the denominator. Bilateral procedures performed within the same year were counted as two TKRs for calculating utilisation rates to avoid underestimating the true utilisation of TKR.

† Four TKR procedures from Finland were excluded from the 2013 analyses due to missing data on gender.

The observed international variation in lifetime risk is unlikely to be explained purely by differences in knee OA prevalence, given the overlap in prevalence data for the five included countries[20–25]. It is possible that differences in OA severity distributions may have contributed to our findings, although country-level severity data are not available to confirm this hypothesis. Variation in obesity rates between countries[15,26] and changes over time may also influence the knee OA burden in individual countries. According to national health survey data collated by the Organisation for Economic Co-operation and Development (OECD)[26], the prevalence of self-reported obesity in Finland increased from 12.8% in 2003 to 15.7% in 2013, and from 9.8% in Sweden in 2003 to 11.7% in 2013. Only single year obesity prevalence estimates are available for Denmark and Norway during the period 2003–2013 (14.2% in Denmark in 2013, and 10.0% in Norway in 2012). For Australia, the national prevalence of obesity increased from 24.6% in 2007 to 28.3% in 2011 but these estimates are based on measured height and weight data rather than self-reported data (the latter tend to under-report obesity). As high-income countries, life expectancy in Australia and the Nordic countries was similar and unlikely to have contributed to the international variation in lifetime risk. Longer life expectancy for females is likely, however, to have contributed to the higher lifetime risk of TKR seen for females in all countries.

The most plausible explanation for the between-country differences in lifetime risk of TKR is international variation in health system factors. These include (but are not limited to) differences in local indications for surgery, access to surgery, healthcare funding and health workforce issues. Earlier research has shown significant international variation in the pre-operative status of people undergoing joint replacement for OA[27,28], suggesting differing clinical thresholds for performing surgery. The higher lifetime risk in Australia could also relate to increased access to surgery within the private healthcare system. In contrast, orthopaedic surgeons in the Nordic countries might be more likely to consider non-surgical management, given the availability of region-based OA prevention and management programs that actively encourage people to trial physiotherapy, disease education and exercise prior to considering surgery. These include the ‘Better management of patients with OsteoArthritis’ (BOA) program in Sweden[29], the ‘Good Life with osteoarthritis in Denmark’ (GLA:D) program in Denmark[30], and ‘AktivA’ in Norway[31]. However, while conservative management programs might improve OA symptoms and delay the need for TKR surgery[32], whether they can ultimately reduce an individual's lifetime risk is not known. Personal factors could also play a role in promoting the uptake of TKR in individual countries and increasing lifetime risk; for example, greater acceptance of joint replacement surgery in the community, cultural factors, more exposure to successful outcomes among peers, and access to paid leave or injury compensation schemes. The high lifetime risk in Finland might relate to local patient preferences for surgery, with registry research suggesting that Finnish baby-boomers elect to undergo TKR when their OA symptoms are relatively mild[33]. It is not clear why Norway had the lowest lifetime risk of TKR for both sexes in 2013 but this could relate to their relatively high utilisation of UKR and the comparatively good patient-reported outcomes for UKR in that country[34], although a recent systematic review reported higher revision rates than for TKR[35].

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The significant increases in lifetime risk over time for each country are also unlikely to relate simply to growth in OA prevalence. In contrast, Global Burden of Disease data showed that worldwide, the age-standardised prevalence of knee OA did not change significantly from 1990 to 2010[1] while in Finland, national health surveys have shown that the prevalence of knee OA among women has actually decreased over a 20-year period[20]. Our data showed that Australia experienced the greatest absolute change in lifetime risk over time (for both sexes), and this probably reflects 'catch up' of previous unmet need following the introduction of government financial incentives in 1999–2000 to promote the uptake of private health insurance cover. Finland also experienced considerable unmet need for TKR prior to 2005, with patients experiencing long delays in accessing surgery. New Finnish legislation introduced in 2005 specified maximum waiting times for orthopaedic consultation and TKR, and hospitals received additional resources to meet these requirements. Although this cannot be quantified, these macro-level initiatives would undoubtedly have contributed to the rise in lifetime risk of TKR in both Australia and Finland. While detailed information on policy changes in each country was not available, it is possible that changes to government healthcare policies in the other countries over the study period may have contributed to the growth observed.

Our calculated utilisation rates showed the greatest burden of TKR was borne by the 70–79 age group in 2003 and 2013. Younger patients (those aged 40–59 years) demonstrated only a small absolute increase in utilisation rates over the ten-year period, and perhaps this reflects awareness of the relatively high TKR revision rates for younger individuals[36,37]. These utilisation rates cannot be directly compared to other studies examining TKR incidence or utilisation rates between countries, predominantly due to differences in data sources and methods. The study by Kurtz *et al.*[13] used a combination of inpatient hospital administrative data and arthroplasty registry data. Their reported incidence rates were not stratified by age or sex and were calculated at different time points (2007–2010) than those used for our study. The authors also acknowledged hospital coding limitations, where it was not possible to consistently determine primary TKR from revision TKR, or TKR from UKR. Most recently, Pabinger *et al.*[15] compared TKR utilisation rates in OECD countries but separate analyses for males and females were not reported.

Our research design has uniquely generated burden of knee OA estimates using national data from five countries. Combined, the five countries had a population of almost 49 million people and performed over 74,000 primary TKRs in 2013. A major strength of this study is our use of robust arthroplasty registry data to ensure accurate estimations of lifetime risk and enable fair international comparisons. The Nordic countries have led the world with regard to implementing and maintaining high-quality national arthroplasty registries and the five included registries have near-complete TKR capture at the population level. We counted all TKR procedures when calculating utilisation rates but were careful to avoid erroneously inflating our lifetime risk estimates by only counting bilateral TKR procedures at the patient-level for these analyses. Given that provision of TKR is highly age-related, the standardised lifetime risk approach was important for dealing with changes to a country's age structure over time (for example, growth in older age groups due to population ageing). In this way, standardised lifetime risk calculations are likely to more accurate for monitoring changes in lifetime risk and undertaking between-country comparisons than non-standardised methods. We also acknowledge the limitations of this research. We included all patients who received a primary TKR for OA in 2003 or 2013 (regardless of whether they had previously received a contralateral primary TKR), as from a clinical perspective these patients are still 'at risk' of having surgery in the years of interest. This method also accounts for the different establishment years for each registry, and reflects the challenges of estimating lifetime risk for conditions that can have multiple occurrences over time[38] or conditions that can affect more than one joint, in the case of knee OA. Annual lifetime risk was not calculated as annual life tables were not consistently available for all countries, and it is possible that fluctuations may have occurred over the ten-year study period. Finally, we acknowledge that there may be some variation in the coding of diagnoses and classification of knee replacement procedures between the national registries that cannot be accounted for in our analyses.

In conclusion, this study has identified significant increases in the lifetime risk of primary TKR performed for OA in Australia, Denmark, Finland, Norway and Sweden over a ten-year period. There was substantial variation in lifetime risk across all countries, with females consistently demonstrating the highest risk. These data augment our understanding of the population burden of knee OA, and can be used by individual countries to inform public health policy and resource planning.

Author contributions

Study conception and design: INA, MAB, RDS, CAB and GG; data acquisition: all other authors; data analysis: MAB and INA; manuscript drafting: INA with input from all authors. All authors have approved the final version of the manuscript.

Competing interests

All authors have completed the ICMJE disclosure form and declare: no support from any organisation for the submitted work; AE has received payment for lectures from DePuy and Stryker and research and travel grants from DePuy outside the submitted work; no other relationships or activities that could appear to have influenced the submitted work.

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Supplementary data

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