RESEARCH ARTICLE

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Impact of Total Hip Replacements on the Incidence of Hip Fractures in Norway During 1999–2019. A Norwegian Epidemiologic Osteoporosis Studies (NOREPOS) Study

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ABSTRACT

The knowledge about why hip fracture rates in Norway have declined is sparse. Concurrent with decreasing hip fracture rates, the rates of total hip replacements (THRs) have increased. We wanted to investigate if hip fracture rates continued to decline, and whether the increase in THRs had any influence on this decline, assuming that living with a hip prosthesis precludes fracture of the operated hip. Information on hip fractures in Norway 1999–2019 was available from the Norwegian Epidemiologic Osteoporosis Studies (NOREPOS) hip fracture database and population size were available in official population tables from Statistics Norway. Primary THRs (for any cause except hip fracture) 1989–2019 were obtained from the Norwegian Arthroplasty Register. We calculated the annual age-standardized incidence rates of hip fracture by sex for the period 1999–2019. The hip fracture rates in a scenario with no hip prostheses were calculated by subtracting 0.5 persons from the population at risk for each prevalent hip prosthesis, considering that each person has two hips at risk of fracture. We estimated how much of the decline could be attributed to the increased prevalence of hip prostheses. From 1999 to 2019, age-standardized incidence rates of hip fracture decreased by 27% in women and 20% in men. The rates remained stable in those under 70 years and decreased in those 70 years and above. Excluding replaced hips from the population at risk led to higher incidence rates, and this impact was considerably larger at higher ages. The increased prevalence of hip prostheses over the period accounted for approximately 18% (20% in women and 11% in men) of the observed decline in hip fracture rates. In conclusion, the incidence of hip fractures continued to decline, and the increasing number of people living with hip prostheses contributed significantly to the observed declining time trends. © 2022 The Authors. *Journal of Bone and Mineral Research* published by Wiley Periodicals LLC on behalf of American Society for Bone and Mineral Research (ASBMR).

KEY WORDS: OSTEOPOROSIS; EPIDEMIOLOGY; GENERAL POPULATION STUDIES; ORTHOPEDICS; IMPLANTS

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Introduction

Hip fractures among older adults are associated with a high burden of morbidity and mortality.[1] There is a large variation in hip fracture incidence rates between countries, with the highest rates in Scandinavia.[2] Decreasing age-adjusted incidence rates have been observed in most Western countries in recent decades,[3] including Norway.[4] However, the continuing increasing life expectancy and population growth will substantially increase the proportion of people aged 60 years and older over the next few decades,[5] forecasting an increasing societal burden of hip fractures that likely cannot be offset by the declining hip fracture rates.[6] The causes for the decrease in hip fracture rates are not clear, although several contributing factors have been suggested.[4] Concurrent with decreasing hip fracture rates, the rates of total hip replacements (THRs) have increased.[7] The dominating indication for a THR is osteoarthritis of the hip, a chronic and progressive condition with loss of cartilage that increases with age.[8] With increasing life expectancy and a growing elderly population, the THR rates are expected to increase further.[9]

In Norway, the lifetime risk of primary THR for osteoarthritis was estimated to be 16% for women and 8.3% for men in 2013,[10] and the annual number of primary THRs has constantly increased.[11] Further, the average age when receiving hip replacement has decreased over time from an average of 69.3 years in 1999 to 68,8 in 2021.[11,12]

Assuming that a hip replacement practically eliminates the risk of fracturing the operated hip, we hypothesized that the increasing population prevalence of persons living with hip prostheses may have contributed to the observed declining trends in risk of hip fracture in Norway during recent decades.[4]

The aims of the present study were to (i) investigate trends in hip fracture incidence rates in Norway from 1999 to 2019 in Norwegians 50 years and older, and (ii) explore the degree to which an increase in the prevalence of people living with hip prosthesis has affected the incidence of hip fracture.

Subjects and Methods

Study population and data sources

The study covered the population of Norway aged 50 years and older in the period 1999 through 2019. Population size as of January 1 for each calendar year 1999 to 2020 according to sex and 1-year age groups was available in official population tables published by Statistics Norway (https://www.ssb.no/en). Within each sex and 1-year age group, the midyear population in each calendar year was defined as the arithmetic mean of the number with index age on January 1 of the respective year and the number with index age+1 on January 1 of the subsequent year.

Information on all inpatient contacts with a hip fracture diagnosis in specialist healthcare in Norway 1994–2019 was available in the Norwegian Epidemiologic Osteoporosis Studies (NOREPOS) hip fracture database (NORHip),[13] including cervical, trochanteric, or subtrochanteric fractures (International Classification of Diseases, Ninth Revision [ICD-9]: 820 with all subgroups; International Classification of Diseases and Related Health Problems, 10th Revision [ICD-10]: S72.0– S72.2). Data from 1994 to 2007 were obtained from the patient administrative systems in the treating hospitals, and the corresponding data for 2008 through 2019 was obtained from the Norwegian Patient Registry. Using information about co-occurrence of other diagnosis codes, surgical procedure codes, and whether the hip fracture was registered as a primary or secondary diagnosis, a comprehensive algorithm was applied to identify the hospitalizations that represented a newly occurred (incident) hip fracture. This algorithm has been validated and has shown high agreement with quality-checked data (http://www.norepos.no/documentation). Up to two hip fractures per person were included, as was done previously.[4,14] Age at discharge was calculated. We included fractures from 1999 onwards in correspondence with previous analyses, allowing a 5-year washout period.

Information on primary total hip replacements in Norway during 1989–2019 were obtained from the Norwegian Arthroplasty Register (NAR). NAR is based on individual reporting from each operation conducted by the orthopedic surgeons and registration in NAR is based on informed consent from the patients. NAR was established in 1987 and covered all Norwegian hospitals from 1989 onward.[15] Registration completeness for primary total hip replacements in NAR has been reported to be 97%.[11,16]

Statistical analyses

We calculated the incidence rates of hip fracture according to sex and 5-year age groups from 50 to 90+ years in three 7-year periods; 1999–2005, 2006–2012, and 2013–2019. Age-standardization of hip fracture rates was done by the direct method using the population distribution of January 1, 2019, separately for women and men. These rates were used to examine trends in hip fracture incidence from 1999 to 2019.

The number of prevalent hip prostheses in living individuals in 2019 was based on data from NAR in the period 1989–2019. Assuming that a limited number of persons receiving THR before 1989 would be alive by 2019, the 2019 prevalence was estimated by calculating the number of primary THRs for any indication other than hip fracture (acute or sequelae) performed between 1989 and 2019 in individuals who were alive and 50 years or older by January 1, 2019. Although the number of prevalent hip prostheses in 2019 was based on 30 years of reporting to NAR (1989–2018), THR data were available for only one decade before 1999. In order to estimate the total number of prevalent hip prostheses per January 1, 1999, we used information from the NAR in the period 1989–1998, a report on THRs in Norway in 1980,[17] and discussions with a former Principal Investigator of NAR. The number of THRs performed in 1980 (2435 primary operations) was approximately one-half of the mean yearly number of primary operations performed in 1989–1991. We assumed that primary operations had also doubled from 1969 to 1978. Based on this we assumed a linear increase of the number of primary operations (a doubling from 1969 to 1979 and another doubling from 1979 to 1989).

To explore the possible impact of changing population prevalence of hip prostheses on the hip fracture incidence, we estimated the hip fracture incidence in a scenario with no prevalent hip prostheses in the population at risk. In this scenario, 0.5 persons were subtracted from the population at risk for each prevalent hip prosthesis, considering that each person has two hips at risk of fracture and that a person with one hip has a relative risk (RR) of 0.5 for a new hip fracture compared to a person with two hips. We verified this assumption in an additional analysis in individual-level data on all inhabitants aged 50–80 years in 2002 in the Norwegian Population and Housing Census 2001 linked with data from NAR and NORHip to identify primary THR and hip fractures during 2002–2018. We excluded patients with THR before 2002 (15 years of washout).

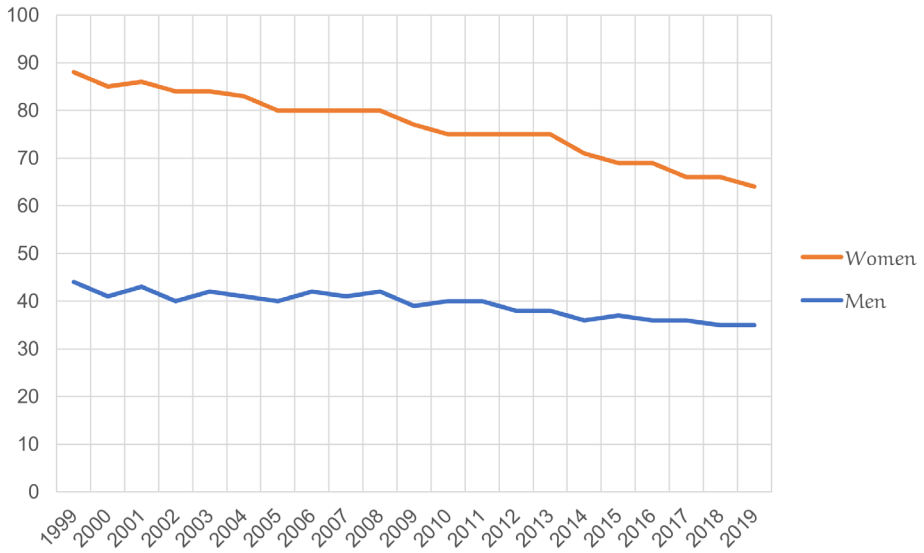

Fig. 1. Age-standardized hip fracture incidence rates per 10,000 person-years in women and men from 1999 to 2019.

The association between THR and risk of hip fracture was estimated using Cox proportional hazards regression with attained age as timescale, with THR as time-dependent exposure. All inhabitants aged 50–80 years without previous THR were followed until hip fracture (event) or censoring due to a second hip replacement, emigration, death, or December 31, 2018, whichever occurred first.

In addition, we estimated how much of the decline in hip fracture incidence rate could be attributed to increase in the prevalence of hip prostheses in the population. First, we calculated the expected number of hip fractures in 2019 given unchanged age- and sex-specific hip fracture rates since 1999. We then calculated the difference between the observed and expected number of hip fractures in 2019. The difference that could be attributed to increased prevalence of hip prostheses in the population was estimated as the difference between the population attributable fractions (PAF) in 1999 and 2019, multiplied by the expected number of hip fractures in 2019, where PAF = [prevalence of hip prostheses*(RR−1)]/[prevalence of hip prostheses*(RR−1) +1] and the RR of hip fractures was set to 0.5.

Using Monte Carlo simulation, we calculated 95% uncertainty intervals for the difference in expected and observed number of hip fractures that was attributed to hip prostheses.[18] This was done by replacing the input parameters by appropriate probability distributions and repeatedly recalculating the output with values randomly sampled from the defined input distributions. We used the Excel (Microsoft Corp., Redmond, WA, USA) add-in Ersatz software (version 1.35; https://www.epigear.com/index_files/ersatz.html) to perform 1000 runs to determine the 95% uncertainty intervals of the hip fractures prevented (2.5th and 97.5th percentile values corresponding to the lower and upper limits, see Table S1).

Ethics

The study and the linkages of data were approved by the Regional Committee for Medical and Health Research Ethics (REK South-East A, ref 15538), the Norwegian Directorate of Health (The Norwegian Patient Registry), the Norwegian Institute of Public Health and Statistics Norway. The data were handled in accordance with the General Data Protection Regulation, and a Data Protection Impact Assessment has been conducted.

Results

From 1999 to 2019 the annual number of hip fractures in women decreased 11% (from 6749 to 6037), while it increased 20% in men (from 2560 to 3084). However, the age-standardized hip fracture rate decreased in both women and men over the period. Women's age-standardized hip fracture rate decreased from 88 per 10,000 in 1999 to 64 per 10,000 in 2019. For men, the hip fracture rate per 10,000 decreased from 44 in 1999 to 35 in 2019 (Fig. 1, Table 1). These rates correspond to a 27% decline in women and a 20% decline in men. The female to male hip fracture rate ratio also declined from 2.0 in 1999 to 1.8 in 2019.

For both women and men under 70 years, the incidence rate remained stable over the three time periods. For women and men aged 70 years and above, the hip fracture rates decreased over the three time periods, with the only exception being men aged 90 years and above who had the highest incidence in 2006–2012 (Table 2).

Concurrent with the declining hip fracture trend, the number of people living with hip prostheses increased. As shown in Table 3, the number of people living with at total hip prosthesis roughly doubled in all age groups in both women and men from 1999 to 2019. In 2019, 2756 fewer hip fractures were observed ($n = 9121$) than expected ($n = 11{,}877$) if the hip fracture rates had remained constant since 1999.

We estimated that 18% (20% in women and 11% in men) of the difference between the observed and expected number of hip fractures in 2019 could be attributed to the increased

Table 1. Total Annual Number of Hip Fractures and Age-Standardized Hip Fracture Incidence Rates per 10,000 Person-Years in Norwegian Women and Men Aged ≥50 Years From 1999 to 2019

	Women					Men				
Year	Number of fractures[a]	Population[b]	Crude rate[c]	Standardized rate[d]	95% CI	Number of fractures[a]	Population[b]	Crude rate[c]	Standardized rate[d]	95% CI
1999	6749	739,638	91	88	86–90	2560	626,707	41	44	42–45
2000	6596	747,521	88	85	83–87	2465	637,261	39	41	40–43
2001	6779	755,060	90	86	84–88	2595	647,577	40	43	41–45
2002	6671	761,613	88	84	82–86	2490	657,223	38	40	39–42
2003	6767	769,694	88	84	82–86	2594	668,232	39	42	40–43
2004	6786	779,128	87	83	81–85	2599	680,070	38	41	40–43
2005	6588	789,171	83	80	78–82	2584	692,451	37	40	39–42
2006	6651	799,555	83	80	78–82	2770	705,926	39	42	41–44
2007	6750	810,503	83	80	79–82	2748	720,209	38	41	39–43
2008	6725	821,206	82	80	78–82	2865	734,266	39	42	41–44
2009	6567	832,638	79	77	75–78	2746	749,047	37	39	38–41
2010	6480	844,164	77	75	73–77	2835	764,520	37	40	39–42
2011	6556	855,632	77	75	74–77	2932	779,973	38	40	39–42
2012	6555	867,259	76	75	73–76	2832	795,838	36	38	37–40
2013	6575	879,306	75	75	73–76	2910	811,920	36	38	37–40
2014	6389	893,025	72	71	70–73	2773	828,527	33	36	34–37
2015	6208	907,892	68	69	67–71	2946	846,920	35	37	35–38
2016	6306	923,106	68	69	68–71	2921	865,400	34	36	34–37
2017	6095	938,734	65	66	65–68	3056	884,296	35	36	35–38
2018	6114	954,851	64	66	64–67	3038	903,065	34	35	34–36
2019	6037	972,093	62	64	62–66	3084	923,145	33	35	33–36

CI = confidence interval.

[a]Total number of hip fractures in people ≥50 years in the NORHip database.

[b]Calculated mid-year population.

[c]Crude hip fracture rate per 10,000 person-years.

[d]Age-standardized hip fracture rate per 10,000 person-years. The standard population was the population distribution of January 1, 2019, separately for women and men.

prevalence of persons living with a total hip prosthesis (Fig. 2). As shown in the Table S2, the 95% uncertainty intervals were narrow. In a sensitivity analysis allowing the prevalence estimate in 1999 to vary by 20% in each direction only increased the uncertainty interval marginally (from 17%–18% to 16%–19%).

In these calculations we assumed that a total hip replacement is associated with a RR of 0.5 for a subsequent hip fracture. This was confirmed in our additional analysis on 1,268,110 individuals aged 50–80 years with 65,772 primary total hip replacements and 93,882 hip fractures during up to 17 years of follow-up. The RR of hip fracture after having a THR was 0.50 (95% confidence interval [CI], 0.48–0.52) compared to not having a THR.

Discussion

It has previously been reported that the incidence of hip fracture in Norway declined from 1999 to 2013,[4] and the current report shows that this decline in age-adjusted rates continued in the period 2014–2019. Hip fracture rates declined significantly in almost all 5-year age groups among those 70 years and older. The decrease in incidence rates was larger in women compared to men and the female/male hip fracture rate ratio was slightly reduced. However, due to demographic changes, the number of hip fractures in the population has been fairly stable with 9309 fractures in 1999 and 9121 fractures in 2019.

In recent decades, decreasing age-adjusted hip fracture incidence rates have been reported in most Western countries.[3] Several factors can have contributed to this decline, including osteoporosis medication and changes in modifiable lifestyle factors[19] and use of fall-risk increasing drugs[20] that have been associated with hip fracture risk. A Danish study suggested that an increase in osteoporosis medication in a best-case scenario could explain up to 20% of the decline in hip fracture rates. An American study showed that the decrease in hip fracture incidence was coincident with a large decrease in smoking.[21] In Norway, the proportion of daily smokers decreased significantly from 18% in 1998 to 11% in 2019 among those aged 67 years or older.[22] Over the study period, an increase in body mass index (BMI; kg/m^2)[23] and leisure time physical activity[24] was also seen and may have contributed to the declining hip fracture trend. However, other risk factors may have increased in prevalence over the study period, such as diabetes.[25]

Using a novel approach, we explored whether the increased use of total hip replacements could explain part of the declining hip fracture rates. Creating a scenario with no hip prostheses in the population at risk, we found that hip fracture incidence rates were overall higher compared to the observed incidence rates, notably in those over 80 years. The results indicated that about 18% of the decline in hip fractures rates from 1999 to 2019 could be attributed to the increased prevalence of people living with hip prostheses. The proportion of the decline that could be attributed to THR was higher in women compared to men,

Table 2. Number and Incidence Rates per 10,000 Person-Years of Hip Fractures in 5-year Age Groups (≥ 50 years) in the Norwegian Population

	1999–2005			2006–2012			2013–2019		
Age	Number of hip fractures[a]	Population[b]	Incidence per 10,000	Number of hip fractures[a]	Population[b]	Incidence per 10,000	Number of hip fractures[a]	Population[b]	Incidence per 10,000
Women									
50–54 years	505	1,034,860	5	478	1,079,847	4	423	1,173,529	4
55–59 years	819	914,195	9	962	1,022,575	9	907	1,089,860	8
60–64 years	1167	692,201	17	1500	957,696	16	1625	1,015,633	16
65–69 years	1910	608,017	31	2162	727,210	30	2827	954,999	30
70–74 years	3756	607,455	62	3262	575,826	57	4010	766,869	52
75–79 years	7571	599,553	126	5832	520,751	112	5737	544,293	105
80–84 years	11,685	483,931	241	9884	459,320	215	8258	420,558	196
85–89 years	11,431	274,994	416	12,099	323,039	375	10,215	304,242	336
90+	8092	126,541	639	10,105	164,591	614	9722	198,916	489
Men									
50–54 years	482	1,078,226	4	510	1,118,437	5	539	123,8091	4
55–59 years	653	935,146	7	761	1,053,518	7	781	1,126,384	7
60–64 years	827	671,731	12	1206	970,076	12	1254	1,026,559	12
65–69 years	1067	551,512	19	1381	696,033	20	1842	947,543	19
70–74 years	1850	504,742	37	1789	501,529	36	2439	719,372	34
75–79 years	3281	428,670	77	2747	404,548	68	2995	456,795	66
80–84 years	4198	277,454	151	4129	295,660	140	3757	301,504	125
85–89 years	3492	121,637	287	4361	156,392	279	3991	172,396	232
90+ years	2037	40,310	505	2844	53,492	532	3130	74,529	420

Data from women and men in the three 7-year time periods 1999–2005, 2006–2012, and 2013–2019.
[a]Total number of hip fractures in people ≥50 years in the NORHip database.
[b]Calculated mid-year population.

Table 3. Hip Fracture Incidence Rates in Three Age Groups for Norwegian Women and Men ≥50 years Observed in 1999 and 2019 and Calculated in a Scenario with No Hip Prostheses in the Population at Risk

Age	Number of hip fractures[a]	Number of hip prostheses[b]	Population[c]	Observed hip fracture incidence[d]	Fracture incidence in scenario[e]
Women 1999					
50–64 years	334	4251	347,463	10	10
65–79 years	2121	18,909	273,054	78	80
80+ years	4294	14,957	119,113	361	385
Women 2019					
50–64 years	413	8984	488,159	8	9
65–79 years	1923	32,551	352,006	55	57
80+ years	3701	31,086	131,919	281	318
Men 1999					
50–64 years	254	2440	349,772	7	7
65–79 years	943	8098	218,917	43	44
80+ years	1363	4611	58,006	235	245
Men 2019					
50–64 years	347	6700	505,563	7	7
65–79 years	1164	17,851	334,738	35	36
80+ years	1073	10,671	82,833	130	138

[a]Number of hip fractures in the NORHip database.
[b]Number of prevalent hip prostheses in living individuals based on information from the Norwegian Arthroplasty Register.
[c]Calculated midyear population.
[d]Observed hip fracture incidence per 10,000.
[e]The hip fracture incidence rates per 10,000 in a scenario with no hip prostheses were calculated by subtracting 0.5 persons from the population at risk for each prevalent hip prostheses.

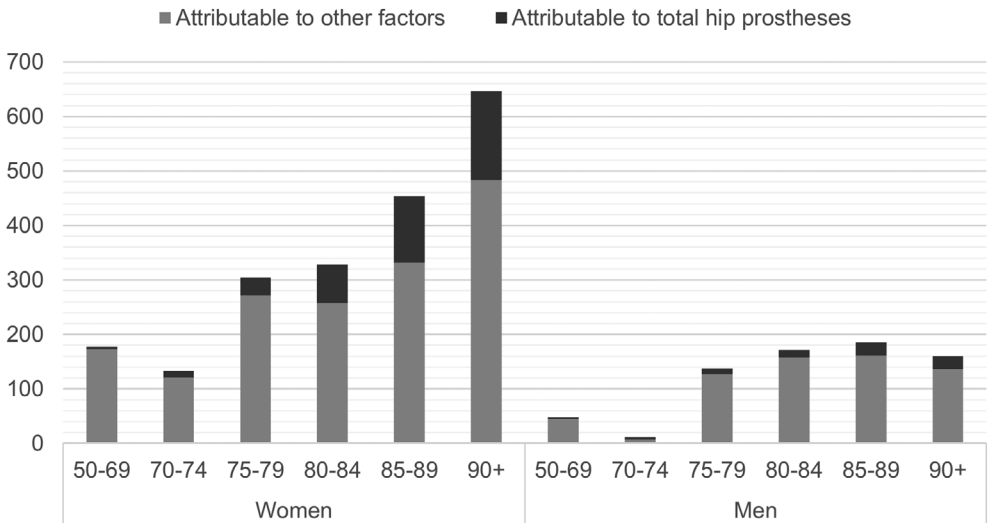

Fig. 2. The total column heights represent the difference between the observed and expected number of hip fractures in six age groups in women and men in 2019 given unchanged hip fracture rates since 1999. The dark parts of the columns represent the differences attributable to the increased prevalence of hip prostheses from 1999–2019.

because a larger proportion of women undergo a total hip replacement and live longer.[10]

In Norway, the primary indication of total hip replacements is osteoarthritis. The age and sex standardized rates of primary total hip replacements has increased over time.[26] It is unclear how osteoarthritis influences the hip fracture risk.[27] A high BMI is a strong risk factor for osteoarthritis of the hip,[28] while reducing hip fracture risk.[29] On the other hand, osteoarthritis may be associated with a greater risk of falling.[30] How undergoing a THR affects the fracture risk of the unoperated hip is unclear. In the present study we found that a THR was associated with a RR of 0.5 for a subsequent hip fracture, confirming our assumption that a person with one unoperated hip has a RR of 0.5 for a new hip fracture compared to a person with two intact hips. In other words, this suggests that overall risk of hip fracture after a THR is similar to the general population.

Despite that hip fracture rates continued to decline through 2019, further actions are most probably needed to counteract a rise in the annual number of hip fractures as the number of older adults is increasing. According to projections by Statistics Norway, the number of people aged 70 years and over will nearly double from 2020 to 2050 (https://www.ssb.no/en). The average annual decline of hip fractures in women between 1999–2019 was 1.3%; however, earlier projections of the burden of hip fractures in Norwegian postmenopausal women suggest that an annual decrease of this magnitude until 2040 would not be sufficient to counteract the effects of the aging population.[6] An increasing number of immigrants from populations with lower hip fracture rates may affect future hip fracture trends in Norway. However, from 1999–2019 this immigrant group was relatively young and is unlikely to explain the reduction in hip fracture rates.[31]

A strength of this study was the inclusion of national data on hip fractures by retrieving information on all cervical, trochanteric, or subtrochanteric hip fractures treated in Norwegian hospitals in the period 1999–2019 available in the NORHip database. Norway has a universal health coverage, and the completeness and validity of this database has been documented (http://www.norepos.no/documentation).

NAR has complete national coverage and the registration completeness of primary total hip replacements has been found to be 97%. This completeness has been stable over the years.[11,16] A limitation was lacking individual information on THR before NAR gained complete national coverage in 1989, which could impact on our calculation of how much of the decline could be attributed to THRs. In addition, the risk of hip fracture in the subgroup of patients in need of THR before and after the THR is not known and we were unable to adjust for a variety of covariates in our own analysis of the RR after THR. However, sensitivity analyses suggest that our calculations are robust.

In conclusion, the age-standardized incidence of hip fractures declined by 27% in women and 20% in men from 1999 to 2019. The increasing number of people living with hip prostheses explained nearly one-fifth of this decline.

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Author Contributions

Helena Kames Kjeldgaard: Conceptualization; data curation; formal analysis; investigation; methodology; writing – original draft; writing – review and editing. **Haakon E. Meyer:** Conceptualization; formal analysis; funding acquisition; methodology; writing – review and editing. **Martin O'Flaherty:** Methodology; writing – review and editing. **Ellen M. Apalset:** Writing – review and editing. **Cecilie Dahl:** Writing – review and editing. **Nina Emaus:** Writing – review and editing. **Anne Marie Fenstad:** Data curation; writing – review and editing. **Ove Furnes:** Data curation; writing – review and editing. **Jan-Erik Gjertsen:** Data curation; writing – review and editing. **Mari Hoff:** Writing – review and editing. **Berit Schei:** Writing – review and editing. **Anne Johanne Søgaard:** Data curation; writing – review and editing. **Grethe S. Tell:** Funding acquisition; writing – review and editing. **Kristin Holvik:** Conceptualization; data curation; funding acquisition; methodology; writing – review and editing.

Conflicts of interest

All authors state no conflict of interest.

Peer Review

The peer review history for this article is available at https://publons.com/publon/10.1002/jbmr.4660.

Data Availability Statement

The current study is part of a research project at the Norwegian Institute of Public Health. The datasets generated and analyzed during this study are not publicly available due to data protection regulations but are made available to project members on a remote access platform. Alternatively, these data can be reconstructed anew by applying to each registry.

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