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Reduced Incidence of Hip Fracture in the Old Order Amish

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ABSTRACT: The incidence of hip fracture was estimated in a community of Old Order Amish and compared with available data from non-Amish whites. Hip fracture rates were 40% lower in the Amish, and the Amish also experienced higher BMD.

Introduction: Understanding the patterns of fracture risk across populations could reveal insights about bone health and lead to the earlier detection and prevention of osteoporosis. Toward this aim, we compared hip fracture incidence and bone mineral density (BMD) between an Old Order Amish (OOA) community, characterized by a rural and relatively active lifestyle, and non-Amish U.S. whites.
Materials and Methods: All hospital admissions for hip fracture among OOA individuals in Lancaster County, PA, were identified between 1995 and 1998 from four area hospitals. Hip fracture incidence was calculated by cross-referencing an available Anabaptist genealogy database with communities located within these hospital service areas and compared with non-Amish whites obtained from National Hospital Discharge data. Additionally, BMD at the hip was compared between 287 Amish subjects and non-Amish whites from the National Health and Nutrition Examination Survey III survey.
Results and Conclusions: OOA experienced 42% fewer hip fractures than would be expected had they experienced the same rate of hip fracture as observed in non-Amish whites ($p < 0.01$) and a higher mean BMD that was significant in women ($p < 0.05$) but not men. Further evaluation of lifestyle and/or genetic differences between Amish and non-Amish populations may shed insights into etiologic factors influencing hip fracture risk.
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Key words: osteoporosis, Amish, bone mineral density, hip fracture, geographic information systems

INTRODUCTION

THE ETIOLOGY OF osteoporosis is complex. Multiple factors contribute to the acquisition of peak bone mass, subsequent bone loss, and ultimate bone strength.[1] These factors, which include genes, hormones, lifestyle, and environmental exposures,[2] determine the risk of fracture as well as susceptibility to falls.[3] At least some of the risk factors for fracture seem to have increased over time because the age- and gender-specific incidence of hip fracture has increased over the past two decades.[4,5] Understanding the myriad of risk factors for fracture could lead to their modification and ultimately to the reduction of fractures and their associated morbidity and mortality. The study of diverse populations, with variability in fracture rates and risk factors, may provide important insights into the pathogenesis of osteoporosis because a 10-fold difference in hip fracture incidence has been observed worldwide.[2] In addition, studying osteoporosis in large families could help to differentiate the respective roles of genetic and lifestyle risk factors in this disease.

The Old Order Amish (OOA) are an interesting population for the study of osteoporosis and its determinants from several perspectives. First, the OOA do not share many of the risk factors for osteoporosis that characterize other populations; for example, they have very low levels of alcohol consumption and smoking[6] and typically do not use prescription drugs. Thus, the effects of many extrinsic factors that may accelerate (or slow) bone loss are generally absent in the OOA. Second, although they have a relatively high standard of living, the OOA also have a uniformly high level of physical activity. Most OOA are farmers, and performing tasks of daily living generally requires relatively high levels of physical activity because OOA neither drive cars nor use electricity in their homes. Because physical exercise has an overall favorable effect on bone health, it

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might be hypothesized that the Amish lifestyle would be associated with low osteoporosis risk.

To assess the bone health of the OOA relative to other white populations, we first estimated the rate of hip fracture in the OOA community from Lancaster County, PA, using hospital billing records and available census data and compared this rate to that observed in the overall non-Amish white population. We next compared mean bone mineral density (BMD) levels between the OOA and a representative non-Amish white population.

Our results suggest that the incidence of hip fracture and the prevalence of osteoporosis are lower in the OOA than in the U.S. non-Amish white population.

MATERIALS AND METHODS

Comparison of hip fracture incidence in the OOA and non-Amish

Comparing hip fracture rates between the OOA and non-Amish entailed four major steps: (1) identifying incident hip fracture cases in the Amish; (2) enumerating the appropriate "at risk" population of Amish residing in the hospital service areas from which cases were identified; (3) updating the mortality experience of the "at risk" population to ensure removal of deceased persons; and (4) estimating the number of fractures in the "at risk" OAA population that would be expected if they experienced the same fracture rates as non-Amish U.S. whites.

We identified all incident hip fractures in the OOA community of Lancaster County by examining the billing records of the four area hospitals that serve the Amish and non-Amish living in the area (Lancaster General Hospital, Ephrata Hospital, St. Joseph's Hospital, and Community General Hospital). For each hospital, we searched the billing records to identify patients who had a hip fracture that was treated surgically in the 3-year period from June 1995 through May 1998. Care was taken to use the appropriate ICD9 and CPT codes to exclude hip surgeries done for other reasons besides fracture (e.g., arthritis). The patient's age, sex, and religious affiliation were retrieved, the latter used to identify patients who were OOA. Amish affiliation was confirmed by cross-referencing individuals having Amish names with individuals identified in the Amish church directory[7] or *Fisher Family History*, one of the largest Amish genealogies available, comprised of approximately 50,000 descendants of a founder who arrived in the United States in the 18th century.[8] The medical records of each OOA patient identified as having a hip fracture were reviewed to confirm the diagnosis of hip fracture and to assess how the fracture occurred (e.g., degree of trauma). Fractures presumed to result from traumatic causes were excluded.

After obtaining the number of hip fractures occurring in the OOA during this 3-year time period, we next set out to define the population at risk. Specifically, we sought to define the population of Amish residing within the areas serviced by our surveyed hospitals (the Hospital Service Areas [HSAs]). To accomplish this, we determined that the four area hospitals we surveyed encompassed two distinct HSAs, Lancaster HSA (which includes three hospitals) and Ephrata HSA. We then obtained a geographic information system (GIS) description of the area corresponding to these two HSAs produced by the Dartmouth Atlas of Health Care (www.dartmouthatlas.org). Using this GIS description, we identified 447 community names located within these two HSAs and matched these community names against those represented in Anabaptist Genealogy Database (AGDB) 3.0[9] using a combination of the software PedHunter[10] and some new in-house software. AGDB 3.0 includes all the data in a 1996 digitized update of Beiler[8] and two other sources, with a total of approximately 295,000 Anabaptist individuals, although not all of them are Amish, and many of them live(d) outside Lancaster County, PA. This procedure resulted in a match of 93 communities containing one or more Amish households and falling within the two HSAs of interest (Fig. 1).

We considered the population at risk to include all OOA individuals identified in AGDB as having an address in one of these 93 communities, as well as the immediate family members of these individuals (i.e., their spouses and children), provided that no alternative address was provided in AGDB for these relatives. Thus, any immediate family member with a missing address would have been included in the population at risk. Identification of these relatives was facilitated by the fact that *Fisher Family History*[8] is organized by nuclear families. Construction and maintenance of AGDB and its usage for this study were done under an Institutional Review Board–approved protocol at the National Institutes of Health.

Having obtained an initial estimate of the likely population at risk for hip fracture, we next considered one additional issue relating to the completeness of the mortality ascertainment in AGDB. Unpublished data that were collected while validating AGDB suggest that *Fisher Family History* starts to deteriorate in completeness of births, marriages, and deaths a few years before its publication in 1988. This concern raises the possibility that the population at risk might be mildly elevated, which would lead to our underestimating true fracture incidence. To address this issue, we again pursued a conservative strategy, by extracting from AGDB the population of individuals believed to be alive as of January 1, 1981 and born between the years of 1890 and 1948. These criteria produced a cohort of individuals who would have been 50 years of age and older during the years 1996–1998. To determine the number of these individuals expected to be alive in 1996, the midpoint of the interval during which we ascertained fractures, we performed a life table analysis by applying the age- and sex-specific mortality rates for U.S. whites using published mortality rates available from 1997.[11]

As the final step of the process, we estimated the age- and sex-specific incidence rates for hip fracture by dividing the number of cases by the total population of the Amish. Hip fracture rates in the Amish were compared with corresponding rates from the general U.S. white population, as estimated from the National Hospital Discharge Data 1988–1989.[12] Because of the small number of events in the Amish, we compared rates from the two studies using the indirect method for age-adjustment[13]; that is, we estimated the number of fractures that would have occurred in the Amish had this group experienced the same rates of fracture

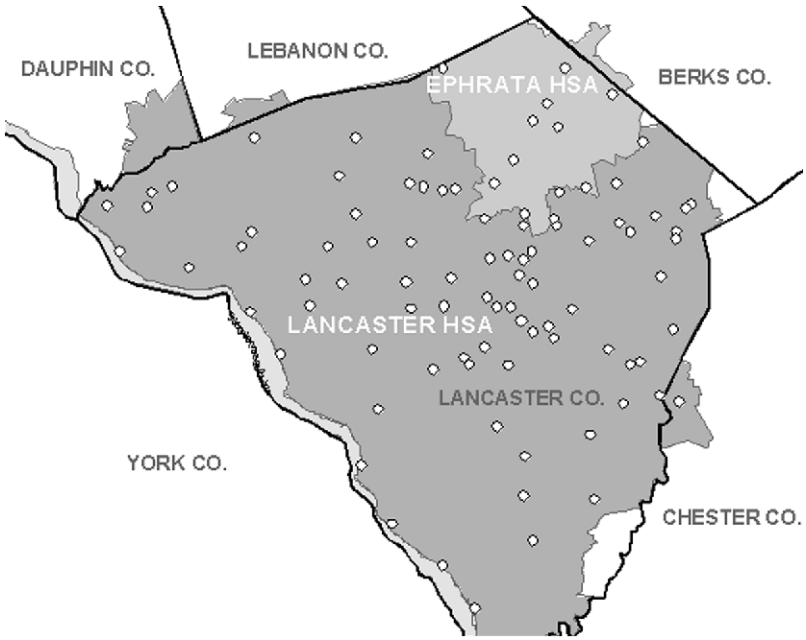

FIG. 1. Communities within the Lancaster and Ephrata Hospital Service Areas with Amish residents.

as observed in the overall U.S. population. The variance of the observed (O) versus expected (E) ratio was computed as O/E^2.

Comparison of BMD between Amish and non-Amish

In addition to estimating the incidence of hip fractures in the Amish community, we also measured BMD in a sample of OOA individuals for comparison with values reported in the U.S. non-Amish white population.[14] The OOA sample consisted of 287 Amish subjects selected from among 990 participants of the Amish Family Osteoporosis Study (AFOS), a genetic study designed with the ultimate goal of mapping genes for osteoporosis. Because the AFOS consisted of families recruited around probands with osteoporosis, we selected for this analysis only those individuals ($n = 287$) who were either spouses of the probands or a spouse of a relative of the proband. The rationale for including only the married-in members of the AFOS families for this analysis was that, because the recruitment of these subjects was independent of their bone health, their BMD would be more representative of values in the overall Amish community. The 287 subjects included in this analysis were recruited into the AFOS between March 1997 and May 2002. The protocol for the AFOS was approved by the Institutional Review Board of the University of Maryland. Informed consent, including permission to contact relatives, was obtained before participation.

Study participants were evaluated at the Amish Research Clinic in Strasburg, PA. A medical history and physical examination were performed. Information relevant to this study included history of fractures (including how the fracture occurred and how it was treated), past and present use of prescription medications, and menstrual and reproductive history in women. BMD was measured by DXA using a Hologic 4500W (Bedford, MA, USA) by a registered nurse certified in bone densitometry. The CV, determined annually by three sequential measures on 1 day for each of 15 individuals, was 0.90% for total hip. The participant's weight was measured in standard Amish clothing but without shoes, and height was measured using a stadiometer.

For comparison, BMD values from the OOA were compared with values using comparable methods (Hologic QDR 1000) in the National Health and Nutrition Examination Survey (NHANES) III survey.[14] Osteoporosis and osteopenia were defined using World Health Organization (WHO) criteria as T-scores less than -2.5 and between -1.0 and -2.5, respectively.[15,16] For the region of the total femur, these definitions correspond to BMD values less than 0.64 g/cm^2 (for osteoporosis) and between 0.64 and 0.82 g/cm^2 (for osteopenia). In addition, we compared mean levels of BMD at the hip between Amish and non-Amish whites across 10-year age groups using mean BMDs for non-Amish whites provided by Looker et al.[17] from NHANES III. Statistical significance of the Amish versus non-Amish comparisons was assessed by estimating the variance of the pooled difference in BMD across age groups.

RESULTS

Hip fracture rates in the Amish

Over the 3-year period of review of hospital records from 1995 to 1998, we identified 22 individuals (5 men and 17 women) hospitalized and billed for surgery after hip fracture among OOA individuals (Table 1). However, if the OOA experienced the same age- and sex-specific fracture rates observed in the reference U.S. white population,[12] a total of 38.0 fractures (9.5 in men and 28.5 in women) would have been expected among the OOA. Fracture rates in the OOA were thus 40–47% less than those in the overall

TABLE 1. OBSERVED AND EXPECTED NUMBER OF HIP FRACTURES IN THE OLD ORDER AMISH

	Amish population				*Fracture rate in U.S. whites (per year)*		*Expected no. of fractures in Amish using U.S. rate (per 3 years)*	
	Estimated no. at risk		*Observed no. of fractures*		*Males (Incidence rate per 100,000)*	*Females (Incidence rate per 100,000)*		
Age groups	*Males*	*Females*	*Males*	*Females*			*Males*	*Females*
50–59	925	1042	1	2	33	60	0.92	1.88
60–64	296	368	0	0	81	117	0.72	1.29
65–69	290	302	1	0	123	252	1.07	2.28
70–74	203	253	2	0	119	437	0.72	3.32
75–79	135	198	0	5	338	850	1.37	5.05
80–84	72	121	0	4	851	1679	1.84	6.09
85+	50	92	1	6	1894	3099	2.84	8.55
Total	1973	2368	5	17			9.48	28.46
Observed/expected ± SE[†]							0.53 ± 0.24	0.60 ± 0.14*

* $p < 0.05$.
[†] O/E for both sexes combined: 0.58 ± 0.12; $p < 0.01$.

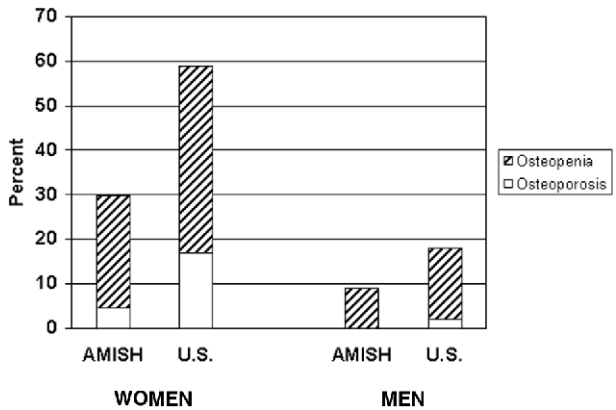

FIG. 2. Prevalence of osteoporosis and osteopenia in the OOA and U.S. non-Amish white population 50 years of age and older.

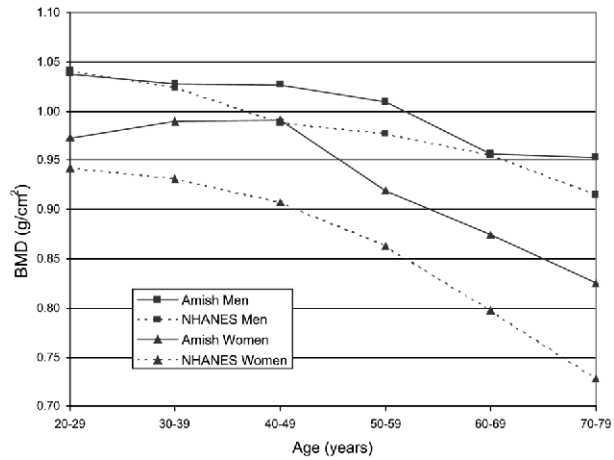

FIG. 3. Mean BMD at the hip (total) in the OOA and non-Amish whites.

non-Amish U.S. white population (observed/expected = 0.53 for men and 0.60 for women; $p < 0.05$ in women and $p < 0.01$ for both sexes combined).

BMD in the OOA

The 287 "marry-in" OOA subjects identified from the AFOS included 137 men and 150 women. Mean ± SD ages were 51.4 ± 14.4 years in men and 49.9 ± 16.8 years in women. The body mass index (BMI) was lower in men (26.3 ± 4.0 kg/m^2) than in women (27.6 ± 6.2 kg/m^2). Calcium intake was estimated from the Block Health Habit and History questionnaire, with additional questions to document calcium supplementation from a subset of 100 randomly chosen subjects, and was found to be 930 mg/day.

Figure 2 shows the prevalence of osteoporosis and osteopenia in the OOA subjects. Compared with non-Amish U.S. whites from NHANES III, OOA men and women, 50 years of age and above, were considerably less likely to have either osteoporosis or osteopenia. Osteoporosis of the hip (total femur) was present in 4.7% (95% CI: 1.2–14.0%) of OOA women compared with 17% (15–19%) of non-Amish white women ($p < 0.05$). Osteopenia was present in 25.0% (15.4–37.6%) of OOA women compared with 42% (40–45%) of non-Amish white women ($p < 0.05$). Thus, 30% of OOA women age 50 and above had either osteoporosis or osteopenia compared with 59% of non-Amish white women. The prevalence of WHO-defined osteoporosis was very low in Amish and non-Amish men (0% and 2%, respectively). The prevalence of osteopenia was also lower in Amish compared with non-Amish white men (8.9% versus 16%), although these differences did not achieve statistical significance.

Figure 3 shows BMD values at the total hip from our spouse group of men and women compared with whites in NHANES III. There is little difference in BMD between OOA and NHANES III men across all ages ($p > 0.20$). In contrast, OOA women had moderately higher BMD than non-Amish white women across all age groups (on average 0.051 g/cm^2 higher; $p < 0.01$).

DISCUSSION

Our results suggest that the OOA have a lower risk of hip fracture and osteoporosis than the non-Amish U.S. white population. These conclusions are based on two separate findings: first, a lower incidence of hip fracture in the OOA; and second, a lower prevalence of WHO-defined osteoporosis and osteopenia at the hip in OOA women compared with the non-Amish U.S. white population. The trend toward decreased risk of fracture observed in OOA women is seen in conjunction with a moderately higher level of BMD. Interestingly, however, there is little difference in mean BMD between Amish and non-Amish men, despite a significantly lower fracture rate in OOA men, possibly suggesting that factors other than BMD may protect OOA men from fracture.

The lower rates of hip fracture and osteoporosis prevalence observed in the OOA are unlikely to be caused by artifact. Our ascertainment of hip fractures in the OOA is likely to be nearly complete because hip fracture essentially always requires hospitalization, and we examined records from all four of the local hospitals in which OOA patients with a hip fracture would be hospitalized. Furthermore, we considered that our approach for estimating the population of OOA at risk was conservative in the sense that we were more likely to have undercounted, rather than overcounted, the total number of OOA in the two HSAs. This is an important distinction, because undercounting the population at risk would lead to our overestimating the fracture rate in the OOA, whereas overcounting the population at risk would lead to our underestimating the fracture rate in the OOA. One way that the population at risk may have been undercounted would be if all residents in a particular household had a missing address in AGDB. On the other hand, if the address was known for head of household, but unknown for his offspring, we assumed the offspring remained living in the area, and an overcount in the population at risk could have occurred if the offspring had, in fact, moved away. An overcount could also have occurred if OOA experienced higher death rates than non-Amish, resulting in fewer OOA being alive and at risk for hip fracture. Although we have no reason to think this is the case, we re-estimated the expected number of hip fracture rates in the OOA assuming that OOA mortality rates were 20% higher than in the non-Amish. Even with this higher mortality rate, we found that the OOA still experienced 35% fewer hip fractures than would be expected ($O/E = 0.65 \pm 0.14$; $p < 0.05$).

Our estimates of the prevalence of osteoporosis and osteopenia in the OOA were based on DXA scans of subjects who married into the probands' families and thus were not themselves ascertained for being at risk for osteoporosis. Although it is possible that this group includes individuals with healthier bones because subjects with poor bone health may have declined to participate, this is unlikely to be an important source of bias because differential nonparticipation would also have been an issue in the NHANES comparison group. Moreover, the refusal rate for participation of spouses in the AFOS was exceedingly low.

Several previous studies have reported reduced rates of hip fracture in rural dwelling compared with urban dwelling populations.[18,19] This protection may be mediated at least in part by relatively higher levels of physical activity. Although we do not have quantitative measurements of energy expenditure in the OOA, it is our observation that their lifestyle is physically more demanding than that of the general U.S. population. We have previously reported that the prevalence of type 2 diabetes is lower in the OOA than in non-Amish whites, despite their having similar BMI levels,[6] an observation that we also speculated that could be attributed to an increased level of high physical activity level in the OOA.[20] It is also possible that genetic factors contribute to the relative protection against hip fracture enjoyed by the OOA.

Exercise seems to induce changes in bone geometry that confer an improvement in bone strength independent of BMD[21–24] and has been correlated with a reduced risk of hip fracture in epidemiological studies.[25–27] Another lifestyle factor that could be playing a protective role from osteoporosis in the OOA is their low incidence of cigarette smoking (<5%).[6] The intake of calcium in the OOA, however, seems to be similar to that in the general U.S. population. In addition, different patterns of obesity are unlikely to be playing a role in the reduced prevalence of osteoporosis in the OOA because mean levels of BMI are similar in OOA compared with non-Amish whites.[28]

In summary, we describe a reduced risk of osteoporosis and hip fracture in the OOA compared with non-Amish whites in the NHANES III database. The unusual attributes of this genetically homogeneous founder population make them ideal for the identification of osteoporosis susceptibility loci and genes and for distinguishing between genetic and environmental factors relating to bone health.

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