

More than 2,000 women classified by relative vertebral density were observed for subsequent fractures for more than 3 years.

Osteoporosis in Women 45 Years and Over Related to Subsequent Fractures

ALBERT P. ISKRANT and RICHMOND W. SMITH, Jr., M.D.

SKELETAL WASTING of the aged has received increasing epidemiologic attention recently because of its possible relationship to fractures of the hip or spine. Because this form of osteoporosis develops asymptotically, for the most part, its considerable morbid and socioeconomic consequences remain hidden until fractures occur.

Results of epidemiologic studies have shown that osteoporosis is most prevalent in white women, especially of northwestern European stock (1-4). To the extent that deaths from falls reflect the incidence of fractured hips, the national mortality statistics support the association of falls with osteoporosis, as rates for mortality from falls become higher in women and white persons in the older years (5). Epidemiologic investigations by the Public Health Service of injuries the elderly incur in falls, although failing to identify causes which might be amenable to control measures, reemphasized the high probability that physical characteristics, such as bone fragility, underlay the hip fractures of elderly women (6, 7). The great interest of the Public Health Service in the growing consequences of fractured hips and in

the development of measures which might reduce the toll of death and disability led to an agreement with the Henry Ford Hospital in Detroit, Mich., to determine the degree of positive association between osteoporosis and fractures in women 45 years and over.

The study was conducted in the general medical clinics of the hospital among ambulatory outpatients who came to the clinics for periodic health appraisals. A limited number of ambulatory short term inpatients and hospital employees were included to facilitate the survey of a large number of subjects in a short time. All women 45 years of age and over were considered eligible for selection except for patients with a previously established diagnosis of osteoporosis and those with organic diseases which may result in osteoporosis, such as hyperthyroidism, rheumatoid arthritis, multiple myeloma, uncontrolled diabetes, or any condition requiring prolonged corticosteroid therapy or that may result in significant skeletal wastage.

Based on data from the National Health Survey and studies carried out by the Injury Control Program, Public Health Service, we estimated a probable fracture rate of about 3.0 per 100 per annum (2.0 in nonosteoporotics and 5.0 in osteoporotics) for women in this age group. We also estimated that the prevalence of radiologically significant osteoporosis in the group would be about 30 percent. Approximately 3,000 women were evaluated in the Henry Ford Hospital (essentially women from south-

Mr. Iskrant, who is now with the National Center for Health Services Research and Development, Public Health Service, at the time of the study was with the Service's Injury Control Program. Dr. Smith is chairman of the department of medicine, Henry Ford Hospital, Detroit, Mich.

eastern Michigan) and about 200 in Puerto Rico. The radiologic findings, diet patterns, and other observations relevant to the issue of possible causality in osteoporosis have been reported (4, 8-10).

About 10 patients per day were selected by the clinic nurse or other survey personnel. Potential subjects were then evaluated by an attending internist as to their medical qualifications. He then described the study and explained its purposes to the qualified subjects from whom he had received an agreement to participate. Through a questionnaire, data were obtained regarding areas lived in, job history, reproductive history, menstruation, physical activity, sun exposure, previous fractures, dietary patterns, and grandparents' country of origin. Much of this is reported elsewhere (4, 8, 10, 11). The patient received a roentgenographic examination of skull, dorsolumbar spine, pelvis and upper femur, and right hand.

Diagnosis of Osteoporosis

All lateral roentgenograms of the dorsolumbar spine were evaluated by one observer, who estimated an overall density difference between the bodies of the dorsolumbar vertebra and the adjoining soft tissues (4). Readings were made without knowledge of the subject's age. Subjects were classified into four categories. Grade 3 was considered maximal relative density (normal) and grade 0 minimal. Grades 2 and 1 were intermediate between those of 3 and 0. From previously accumulated observations in roentgenograms taken of young women who had had trauma, it was concluded that grade 2 could be considered "normal," even though of less than maximal relative density.

In roentgenograms of spines classed as grade 3, end plates were minimally evident or not seen; for grade 0 relative density, the vertebral body was distinguished from adjacent soft tissues only by the periosteal outline or prominence of the end plates. For replicate readings made more than a year apart, an intraobserver correlation coefficient of 0.78 was obtained for the four grades. Spines of grades 2 and 3 relative density were considered as nonosteoporotic and those of grades 0 and 1 as osteoporotic. The observations in this report are based on the relation between the extent of

osteoporosis in the Michigan women, as determined by lateral roentgenograms of the dorsolumbar spine, and their subsequent fracture experience.

When the initial phase was completed, some 2,100 women had entered the survey and were accepted for the followup study. This number was considered sufficient because the prevalence of significant osteoporosis was found to be higher than expected, and the followup period was extended from 2 to 3 years.

The distribution of the 2,088 women by age and relative vertebral density is shown in table 1. As was expected, but previously not characterized in a large population group, vertebral density declined progressively with age. Vertebral density was found to be less in white than in nonwhite women and least in those whose ancestral origin was Great Britain or Ireland. The percentage of women with relative densities of grades 0 and 1 (osteoporosis) varied from less than 20 percent in the age group 45-49 to about 90 percent in ages 80 and over. For all white women in Michigan the prevalence of grades 0 and 1 was 57 percent, for Negro Michigan residents it was 44 percent, and for those with family origins in Great Britain or Ireland, 61 percent (4).

Followup

In the followup phase of the study information on injuries, especially fractures, was accumulated. Initial information about injuries and fractures was obtained from answers to a

Table 1. Number of women in study by grade of vertebral density and age at X-ray

Age group (years)	All women	Grade of relative vertebral density				Percent with 1 and 0
		3	2	1	0	
45-49-----	290	102	136	49	3	17.9
50-54-----	309	47	141	116	5	39.2
55-59-----	514	26	191	281	16	57.7
60-64-----	426	10	137	252	27	65.5
65-69-----	299	6	73	174	46	73.5
70-74-----	177	2	26	98	51	84.2
75 and over..	73	0	8	35	30	89.0
Total...	2,088	193	712	1,005	178	56.7

Table 2. Number of fractures and rates per 100 man-years of exposure by grade of vertebral density and age of women observed for 3 years or more

Age group ¹ (years) and item	All women	Grade of vertebral density					
		3	2	1	0	3 and 2	1 and 0
45-54:							
Man-years	2, 678	690	1, 241	713	33	1, 931	746
Occurrences	78	14	28	33	3	42	36
Rate	2. 9	2. 0	2. 3	4. 6	(²)	2. 2	4. 8
55-64:							
Man-years	4, 004	160	1, 396	2, 269	179	1, 556	2, 448
Occurrences	142	3	41	87	11	44	98
Rate	3. 5	(²)	2. 9	3. 8	6. 2	2. 8	4. 0
65-74:							
Man-years	1, 871	27	383	1, 093	367	410	1, 460
Occurrences	90	1	11	51	27	12	78
Rate	4. 8	(²)	2. 9	4. 7	7. 4	2. 9	5. 3
75 and over:							
Man-years	279	0	34	135	111	34	246
Occurrences	15	0	0	8	7	0	15
Rate	5. 4	(²)	(²)	5. 9	6. 3	(²)	6. 1
Total:							
Man-years	8, 831	877	3, 055	4, 211	689	3, 932	4, 900
Occurrences	325	18	80	179	48	98	227
Rate	3. 7	2. 0	2. 6	4. 2	7. 0	2. 5	4. 6

¹ Age at time of X-ray.

² Less than 5 fractures and less than 250 man-years of observation in the group.

brief questionnaire mailed to each participant twice a year. These were sent in staggered fashion (averaging 80 per week) to permit proper processing of replies which came in daily. Delinquent respondents were pursued by a second and, if necessary, a third letter of inquiry during each mailing cycle. If no answer was received to a third letter, contact by telephone or personal visit was attempted. The overall reply rate from mailed questionnaires, telephone calls, and personal visits was about 95 percent.

All injuries resulting in a bone fracture were investigated as soon as possible. If a participant living in the Detroit metropolitan area received a fracture, she was interviewed to obtain details, especially the etiology of the accident. These interviews were usually conducted at home, but a number were carried out at the hospital since many participants were continuing outpatients. If a participant living outside the Detroit Metropolitan area but in the State of Michigan experienced a fracture, the director of the local health department was contacted, and arrangements made for a public health nurse to conduct the interview. The fullest cooperation was obtained. In addition to these followup procedures, the medical records of the participants at

the Henry Ford Hospital were periodically reviewed for nonreported injuries or fractures. Of those originally screened and evaluated for osteoporosis, only 10 refused to participate beyond the initial study.

When a participant died, a copy of her death certificate was obtained from the vital records section, Michigan Department of Public Health, to verify the death and to obtain the primary and secondary causes. Usually a participant's death was reported by a relative or friend. In addition the obituary columns of the local newspapers were routinely checked, and a few deaths were discovered in that manner.

The derived data are based on 2,088 women, 135 of whom were Negro. Fracture rates for Michigan participants were computed on the basis of man-years in the study, as of the last recorded observations, including notice of death (more than 100 deaths are recorded to date). As of March 20, 1967, approximately 9,000 man-years were recorded for the group based on the age of subjects at the time of the initial X-ray. The calculations of fracture rate were also based on age at the time of the initial X-ray. More than 500 of the man-years of observation are for the Negro participants. Their fractures, when

bone density is considered, were of the same pattern as that of white participants and these data are included in all tables and analyses.

Incidence of Fractures

The overall annual fracture rate was 3.7 percent, varying from 2.0 in those with a density grade of 3 (nonosteoporotics) to 7.0 in the osteoporotics with a density grade of 0 (table 2). Altogether, our prestudy estimates of 2 percent for nonosteoporotics and 5 percent for osteoporotics were remarkably close to these findings. Within each age group the fracture rate declines as the degree of vertebral density increases. The rate increases with age, but not consistently, when adjusted for vertebral density. The consistent decrease in fracture rate by grade of vertebral density clearly supports the hypothesis of a positive association between osteoporosis, based on roentgenograms of the spine, and subsequent fractures in women 45 years and over.

In addition to the 325 persons suffering fractures, 859 persons incurred injuries which were not fractures. The percentages of persons receiving fractures among all those injured were calculated in the two broad categories of vertebral density (table 3). In each age group, fractures constitute a higher percentage of injuries for the subjects with density grades of 0 and 1. Except for grades 2 and 3 in the age group 45-54, the proportion with fractures is higher for women injured in falls; the proportion with fractures also increases up to age 75.

Table 3. Percentage of women receiving fractures of all women injured and of those injured in falls, by grade of vertebral density and age group

Age group (years)	Percent of all women injured with fractures		Percent of women injured in falls with fractures	
	Grades 2 and 3	Grades 0 and 1	Grades 2 and 3	Grades 0 and 1
45-54	17	26	10	27
55-64	21	30	31	42
65-74	31	43	55	59
75 and over	(¹)	32	(¹)	50
Total	20	33	26	46

¹ No injuries.

In table 4 is shown the anatomic site of fracture by grade of vertebral density and by age group. Also shown is the percentage of fractures of persons who were classified in grades 0 and 1. The proportion for upper femur is given, even though there were only 16 such fractures. Only two of these 16 occurred to women with density grades 2 and 3, depicting the strong association of this injury with osteoporosis. For the radius, only two of 20 subjects were in grades 2 and 3, whereas for ribs, fingers, and toes, more than 40 percent were so classified. This approach was used rather than calculating specific fracture rates by degree of vertebral density, since the numbers in most cells were small.

We did, however, calculate the fracture rate for the combined four sites of wrist, ankle, radius, and upper femur. In the age group 45-54 years the fracture rate per 100 was 5.2 for grades 2 and 3 and 21.4 for grades 0 and 1. This ratio is about 4 to 1 compared to a ratio about 2 to 1 for all fractures. In the age group 55-64, the combined rate was 7.7 for grades 2 and 3 and 16.3 for grades 0 and 1. The ratio again was greater than that for all fractures. Thus the excess of these fractures for densities 0 and 1 is greater than for all fractures.

The proportions of subjects with spine density grades 0 and 1 in various categories are summarized in the following list.

Category	Percent in grades 0 and 1
All women examined	56
All women injured	58
All fracture incidents	70
Falls	74
Falls, same level	81
Nonfalls	60
Moving motor vehicle accidents	46
Site of fracture:	
Radius	90
Upper femur	88
Wrist	78
Ankle	74
Spine	70
Ribs	68
Metatarsal	68
Fingers	58
Toes	33

Less than half of those receiving a fracture in an accident while in a moving motor vehicle were in grades 0 and 1. Osteoporosis appears to

Table 4. Number of fractures incurred by anatomic site, vertebral density, and age at time of X-ray

Anatomic site	Total	Density grade					Age group (years)			
		0	1	2	3	Percent 0 and 1 ¹	45-54	55-64	65-74	75 and over
Fingers.....	31	3	15	11	2	58	5	18	7	1
Wrist and carpal.....	45	4	31	9	1	78	6	26	12	1
Humerus.....	16	3	9	2	2	-----	1	4	7	4
Radius.....	20	2	16	2	0	90	5	6	9	0
Metacarpal.....	5	0	2	3	0	-----	2	2	1	0
Elbow.....	5	1	3	1	0	-----	0	5	0	0
Ulna.....	3	0	2	1	0	-----	1	0	2	0
Lower femur.....	2	0	1	0	1	-----	1	1	0	0
Upper femur.....	16	4	10	1	1	88	3	6	4	3
Tibia.....	3	1	2	0	0	-----	0	2	1	0
Fibula.....	8	0	6	1	1	-----	2	4	1	1
Ankle and tarsal.....	42	7	26	5	4	79	10	21	11	0
Metatarsal.....	28	5	14	6	3	68	10	8	10	0
Toes.....	² 42	4	19	14	3	58	18	12	11	1
Patella.....	13	0	8	5	0	-----	2	7	4	0
Clavicle.....	5	0	1	4	0	-----	2	2	1	0
Neck.....	1	1	0	0	0	-----	0	1	0	0
Jaw and cheek.....	4	0	2	2	0	-----	1	1	1	1
Nose.....	8	1	4	2	1	-----	3	2	2	1
Skull.....	3	0	2	1	0	-----	1	0	2	0
Shoulder.....	9	2	4	3	0	-----	1	5	3	0
Ribs.....	103	20	50	26	7	68	27	33	38	5
Pelvis.....	2	1	1	0	0	-----	0	1	0	1
Spine.....	20	4	10	6	0	70	1	5	13	1
Coccyx.....	3	0	1	1	1	-----	1	1	1	0
Sternum.....	2	0	1	1	0	-----	1	0	1	0
Total.....	² 439	63	240	107	27	69	104	173	142	20

¹ Percentages calculated where 20 cases or more (16 for upper femur).

² Includes 2 cases with no vertebral density evaluation.

be associated with fractures received in falls (74 percent), especially those occurring on a level (81 percent), and particularly when the fracture involved the radius (90 percent), femur (88 percent), wrist (78 percent), or ankle (74 percent).

Discussion

Of the women in this study about 70 percent of those incurring a fracture were in vertebral density grades 0 and 1 (osteoporosis). If this were true of the nation as a whole, it would mean that of the approximately 1 million women age 45 and older who sustain fractures each year, about 700,000 have osteoporosis. As the fracture rate is about twice as high as that of "nonosteoporotic" women, it would appear that the elimination of osteoporosis would result in a reduction of about 350,000 fractures

each year in this group of women. The relative reduction in fractures of the femur would be even greater.

Summary

The relationship of a diagnosis of osteoporosis to the incidence of fractures was studied among 2,100 Michigan women age 45 and older. Relative vertebral density was determined by examination of lateral roentgenograms of the dorsolumbral spine. The women's subsequent fracture experience was recorded for 3 years.

A total of 325 women suffered fractures; 859 others were injured but did not receive fractures. The annual fracture rate was 3.6 percent, varying from 2 percent among nonosteoporotics to 7 percent in those with osteoporosis. The fracture rate was about twice as high in each age group in women with osteoporosis as in women

with greater relative vertebral density. In each 10-year age group the fracture rate increased with a decrease in vertebral density.

The closest association of fractures with decreased density was of fractures of the radius, femur, wrist, and ankle, especially when the injury was caused by a fall on the same level.

Based on these findings, it is estimated that, of the approximately 1 million fractures experienced each year by women 45 years or older in the United States, about 700,000 are incurred by women with osteoporosis. Elimination of osteoporosis would prevent an estimated 350,000 fractures. The relative reduction in fractures of the upper femur would be even greater.

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DHEW Staff Appointment

Dr. James H. Cavanaugh has been named Director of a newly established Office of Planning and Program Coordination. The Office provides support to the Assistant Secretary in the review and coordination of health activities and programs within the Department. This includes policy guidance in the management of the Department's extramural health grants program; the coordination of Department concerns in comprehensive health planning; activities related to the development and review of health legislation and budget and program planning; liaison with health-involved organizations; and provision of staff support to the National Advisory Health Council.

Dr. Cavanaugh was formerly Director of the Office of Comprehensive Health Planning, Public Health Service. In this position, he

directed the organization and implementation of a new national program to redirect Public Health Service grant support toward a more flexible and efficient system for bringing comprehensive health planning and services more directly within reach of the States and their people.

From 1962 to 1966, Dr. Cavanaugh was a faculty member of the program in hospital and health administration in the College of Medicine at the University of Iowa. Prior to that he was a member of the administrative staff of the Princeton (N.J.) Hospital.

A native of Madison, N.J., Dr. Cavanaugh received his B.S. degree from Fairleigh Dickinson University, Rutherford, N.J., in 1959. In 1964 he was awarded his doctorate by the University of Iowa.