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LIFE SCIENCES RESEARCH OFFICE
FEDERATION OF AMERICAN SOCIETIES FOR EXPERIMENTAL BIOLOGY
9650 Rockville Pike
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FDA Contract No. 223-84-2059

Task II: QR-#1: $8,000

Competitively Awarded
September 28, 1984

Project Officers:

M. McDowell and E. Yetley
Clinical Nutrition Assessment Section
Division of Nutrition HFF-265
Center for Food Safety and Applied Nutrition
Food and Drug Administration
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Washington, D.C. 20204

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DATA AVAILABLE FOR ESTIMATION OF THE RISK
AND PREVALENCE OF OSTEOPOROSIS

October 1985

Quick Response Report #1

Prepared for

CENTER FOR FOOD SAFETY AND APPLIED NUTRITION
FOOD AND DRUG ADMINISTRATION
DEPARTMENT OF HEALTH AND HUMAN SERVICES
WASHINGTON, D.C. 20204

under

Contract No. FDA 223-84-2059

prepared by

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FOREWORD

The Federation of American Societies for Experimental Biology (FASEB) recognizes that its resources are particularly suited to marshalling scientific expertise for review and assessment of topics in the biological and medical sciences. The Life Sciences Research Office (LSRO) was established by FASEB in 1962 as an operational arm of the Executive Director's staff to provide a means for conducting such scientific reviews and analyses. Reports of LSRO studies are based upon comprehensive literature reviews and the scientific opinions of knowledgeable investigators in specific areas of biology and medicine.

This technical report was prepared by Sue Ann Anderson, Ph.D., Senior Staff Scientist, LSRO, FASEB. It was prepared as Quick Response #1 for the Center for Food Safety and Applied Nutrition, Food and Drug Administration, in accordance with the provisions of FDA Contract No. 223-84-2059, Task II: "Quick Response Actions on Request". This report has been reviewed by the consultants listed in Section VI and their viewpoints and opinions were incorporated; however, the listing of their names does not imply endorsement of the conclusions of this report.

In accordance with the policies and guidelines developed by the LSRO Advisory Committee, this report has been reviewed and approved for submission by the Chairman of the LSRO Advisory Committee. Reports prepared by LSRO do not necessarily reflect the opinion of the individual members of the FASEB constituent societies. The author and LSRO are solely responsible for the contents of this report.

Date

Kenneth D. Fisher, Ph.D.
Director
Life Sciences Research Office

November 8, 1985
EXECUTIVE SUMMARY

Decreases in bone mass occur asymptotically over a varying time continuum and are often not recognized and diagnosed until a fracture occurs in an older person. As stated by Parfitt (1984), "... osteoporosis is not a disease like tuberculosis that the patient either has or does not have, but corresponds to a [necessarily arbitrary] dividing line chosen by the physician on a continuous scale ...". For this reason it is particularly difficult to estimate the prevalence of osteoporosis.

Estimates of the prevalence of osteoporosis have been approached in two ways. First, because of the paucity of data concerning the incidence of osteoporosis itself, the incidence of hip fracture, an epidemiologically recognizable consequence of osteoporosis, has been used as a substitute measure. This approach was used recently to estimate the prevalence of osteoporosis for the NIH Consensus Development Conference on Osteoporosis.

The most extensive compilations of the incidence of hip fracture in national population groups are the data of the National Health Interview Survey and the National Hospital Discharge Survey. Data from both studies are specific for age, sex, and race of participants, but the diagnostic information of the latter survey may be more reliable because it is based on medical records rather than on household interviews. Data from either of these surveys, neither of which includes the elderly institutionalized population, could be supplemented by data currently being collected in the National Nursing Home Survey if the data bases are compatible.

A potential source of information on fracture incidence in the civilian noninstitutionalized population is the National Medical Care Utilization and Expenditure Survey. This survey will be conducted in 1987 and specific questions relating to fracture and/or osteoporosis could be incorporated into the questionnaire. Two other potential sources of information on the incidence of hip fracture are the follow-up study for NHANES I participants which includes about 5,600 persons who were 55 to 74 years of age at the time of NHANES I and the EPESE (Established Population for Epidemiologic Studies in the Elderly) which has between 12,000 and 16,000 participants at four locations in the United States. One limitation of the latter population is that it includes only persons over age 65 years.

The most comprehensive study of the epidemiology of fracture of the white population is that of the Rochester/Olmsted County Epidemiology Project. Medical records of residents of the Rochester, Minnesota area were analyzed to determine the incidence of fractures including fractures of the hip, pelvis, proximal humerus, and Colles' fractures. Data on
the prevalence of osteoporosis based on the incidence of hip fracture in the nonwhite population of the United States are less extensive.

Data from the 1978 Survey of Disability and Work of the Social Security Administration are considered less appropriate for estimating the incidence of hip fractures to derive a basis for subsequent estimation of the prevalence of osteoporosis. First, the data were collected in 1978 and are, therefore, relatively old; and, more importantly, the survey excludes persons older than age 64 years who constitute a large portion of the population considered at risk for the development of osteoporosis.

Data from the National Ambulatory Medical Care Survey probably are not presently supplementary to the hip fracture data of the National Hospital Discharge Survey. Persons requiring treatment for hip fractures would not be expected to seek office-based treatment. However, if the scope of this study was expanded to include emergency room treatment, then data from this survey might supplement data of the National Hospital Discharge Survey for fractures at the hip and other sites.

Incidence of fractures at sites other than the hip has been analyzed less frequently. Data of the National Hospital Discharge Survey include categories for fractures of the vertebrae and proximal humerus. However, the data bases for these fractures are probably less complete than those for hip fractures. Vertebral crush fractures may not require immediate medical treatment and may go undiagnosed for varying periods. Fractures of the proximal humerus may not require hospitalization and therefore only a portion of these fractures would be included in surveys based on hospital discharge records.

No estimates of the national prevalence of osteoporosis and one estimate of the national prevalence of bone demineralization were found which were based on assessment of bone mineral content. Of the national surveys, only NHANES I and NHANES II collected data that might be used to estimate bone density status. These data were collected using x-ray methods that may be adequate for assessment of bone density of large population groups even though the methods lack the specificity and sensitivity necessary for clinical diagnosis of individuals. However, bone changes at sites measured in the survey may not be representative of bone changes at sites where fracture is likely to be associated with osteoporosis.

Data on bone mineral content measured by single and dual photon absorptiometry techniques are available for several relatively large populations within the United States, but not for a national probability sample. It is not yet possible to determine that osteoporosis is present based on a defined value for bone mineral content; however, efforts are presently underway to develop models to predict current and future risk of fracture.
of the vertebrae and proximal femur from bone mineral content of these sites determined by dual photon absorptiometry. Validation of the model will be necessary before such information can be used for interpretation of data on bone mineral status.

In summary, the most often used surrogate for estimation of the prevalence of osteoporosis in populations is the incidence of hip fracture. Most hip fractures in the elderly are thought to be attributable to osteoporosis; however, incidence of hip fractures probably underestimates the prevalence of osteoporosis. Fracture at this site is only one manifestation of a complex disorder occurring in the elderly and only a fraction of the population having low bone mass will have a fracture or history of fracture at any given time.

Measurement of the mineral content provides a means of estimating bone status to assess risk of osteoporosis in individuals prior to the occurrence of fracture. Bone mineral content can decrease asymptotically over time and varying amounts of bone loss can occur prior to fracture. Models predictive of fracture based upon bone mineral content are being developed for several fracture sites associated with age-related bone loss. It is expected that these or similar models will become widely used for estimating the risk and prevalence of osteoporosis as the validity of such models is established.
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I. INTRODUCTION

Osteoporosis is generally regarded as a significant health problem in the older population of the United States, particularly in postmenopausal women. In 1984, osteoporosis was considered a public health problem sufficiently serious to warrant a National Institutes of Health Consensus Development Conference to address issues pertinent to the etiology, progression, and treatment of the disease (Consensus Development Panel, 1984).

Because the Food and Drug Administration has responsibility for assessing public health needs in terms of safety and nutritional adequacy of the food supply, a request was made by the Center for Food Safety and Applied Nutrition to the Life Sciences Research Office to review and summarize data available on United States population groups that might be used to assess the risk or prevalence of osteoporosis. The objectives specified for this study were:

- To identify sources of data for assessing the risk or prevalence of osteoporosis in the U.S. population and for identifying sub-groups at greatest risk. These data sources shall include, but not necessarily be limited to, nationally representative surveys, major clinical studies, and to government health monitoring or surveillance systems; and,

- To review the data and summarize results of selected studies or data bases; the criteria for selection shall be based on scientific merit and appropriateness for estimating risk or prevalence of osteoporosis in U.S. population groups.

This study presents relevant information regarding the stated objectives. Names of reviewing consultants for this report are listed in Section VI.
II. OVERVIEW OF OSTEOPOROSIS

Osteoporosis can be described as an age-related condition in which bone mass decreases, resulting in greater susceptibility to fracture, particularly to atraumatic fracture (Parfitt, 1984). Beyond this point, further definition of osteoporosis becomes difficult in part because of differences in means of recognition of the condition. Clinically, osteoporosis is recognized most often by the presence of vertebral crush fractures. Epidemiologically and as a public health concern, the incidence of hip fracture is used most frequently as a surrogate for the prevalence of osteoporosis. Investigatively, osteoporosis is described in terms of low bone mass. However, it is widely recognized that the complex etiology of fractures encompasses more than loss of bone mass and may involve abnormalities in the microstructure of bone or possibly abnormalities extrinsic to the skeleton as well (Johnston et al., 1981; Kleerekoper et al., 1985).

Horsman et al. (1981) defined osteoporosis in terms of cortical and trabecular bone volume deficits determined from bone biopsy samples with further subcategories based on degree of severity, rate of loss, and presence or absence of identifiable cause. However, osteoporosis is associated with widely heterogeneous characteristics of etiology, histology, and biochemistry; thus, diagnosis of primary osteoporosis can be made only after biochemical and histologic screening to rule out other osteopenic conditions or diseases primarily responsible for bone loss (Melsen and Mosekilde, 1981; Meunier, 1984).

Typically, bone loss occurs over a time continuum of unpredictable length. Skeletal content of both trabecular and cortical bone decreases; these losses may vary significantly at different skeletal sites (Parfitt, 1984). Measures of bone mineral content of appendicular bone have not correlated well with measures of bone mineral content of the axial skeleton (Mazess, 1985). Noninvasive methods, e.g., single and dual photon absorptiometry and quantitative computed tomography, can be used to identify bone that has low mineral content. In addition, roentgenographs can indicate the presence of fracture. As yet, such measures of bone mineral content early in life cannot determine bone that will become osteoporotic later in life. However, efforts are currently underway to develop a model to estimate the current and future risk of proximal femur fractures and vertebral fractures from measures of bone density of the proximal femur and vertebrae, respectively (Melton, 1985; Melton et al., 1985).

Bone mass at skeletal maturity is considered an important determinant of bone mass later in life (Heaney, 1983; Kleerekoper et al., 1981). The amount of bone present at any age after skeletal maturity is reached depends upon the peak adult
bone mass attained and subsequent rates of loss (Johnston et al., 1981). Peak bone mass is reached between the ages of 30 and 40 years; is primarily determined by genetic factors; but, also reflects nutritional and other environmental factors (Heaney, 1983; Parfitt, 1984). Peak bone mass is about 30% higher in men than women and about 5 to 10% higher in blacks than whites (Garn, 1981). Individual differences vary among age groups; the coefficient of variation is less than 10% in young normal subjects and about 15% in elderly groups (Garn, 1981; Runge et al., 1980).

Rate of bone loss has been measured extensively in women. Such studies have led to considerable disagreement among investigators concerning rates of bone loss of postmenopausal women. For example, investigations of Cann et al. (1985) have shown an accelerated loss of spinal trabecular bone mineral over a relatively short period of time. Results of Riggs et al. (1982) suggest a smaller increase in loss of spinal trabecular bone mineral over a longer time period.

Riggs et al. (1982, 1983) have attempted to distinguish between Type I (postmenopausal) and Type II (senile) osteoporosis on the basis of patterns of bone mineral density of the proximal femur and/or lumbar spine determined by dual photon absorptiometry. Type I osteoporosis was characterized by a disproportionately large loss of trabecular bone in the lumbar spine and proximal femur, occurrence primarily in women (female: male ratio 6:1) during the early postmenopausal period, and higher frequency of vertebral fractures. Type II osteoporosis was characterized by similar losses of both cortical and trabecular bone, occurrence in almost all elderly women and a substantial proportion of elderly men 70 years of age and older (female: male ratio 2:1), and occurrence of hip and/or vertebral fractures. Endocrine influences on bone loss for both types of osteoporosis were discussed by Riggs et al. (1983).

In addition to intrinsic factors affecting rates of bone loss, several lifestyle factors are associated with risk of development of osteoporosis. Lack of weight-bearing exercise, lower body weight, smoking, and use of alcohol have been suggested as risk factors for decreased bone mineral content in men (Nilsson and Westlin, 1971; Seeman et al., 1983). In women, menopause (primarily decreased estrogen production), smoking, use of alcohol, and low body weight have been associated with development of osteoporosis (Anderson and Tylavsky, 1984; Kleerekoper et al., 1981; Krølner et al., 1983). Physical activity has been suggested as a protective factor for women (Jacobson et al., 1984; Smith et al., 1981). Cummings et al. (1985) have discussed these and other risk factors possibly associated with osteoporosis.

Because bone density can decrease asymptptomatically for long periods before fractures occur, the incidence of osteoporosis has been estimated from the clinical problems it causes,
i.e., skeletal fractures. In the absence of measurements indicative of development of osteoporosis, bone fracture rates have been generally accepted as a useful indicator of osteoporosis for interpopulation comparisons (Matkovic et al., 1979; Nordin, 1971). Although agreement is not universal on fracture sites associated with the occurrence of osteoporosis, fractures of the proximal femur and proximal humerus and crush fractures of the vertebrae have been associated with osteoporosis in older individuals. Fractures of the pelvis and Colles' (wrist) fractures are associated with aging; however, their relation to continued loss of bone mass (i.e., osteoporosis) is less certain (Jensen et al., 1982).

Thus, data for estimating the prevalence of osteoporosis may be derived from two sources: incidence of fractures and measures of bone mineral content. The following section summarizes the available data from these sources that are potentially useful for determining the prevalence of osteoporosis in the U.S. population.
III. DATA AVAILABLE FOR ESTIMATING THE RISK AND PREVALENCE OF OSTEOPOROSIS

A. FRACTURE INCIDENCE ESTIMATED FROM NATIONAL SURVEYS

Data useful for estimation of the incidence of fractures are collected in several national surveys. Organizational aspects of these surveys and publications estimating incidence of fracture based on data collected in these surveys are summarized below.

1. National Hospital Discharge Survey

Description of survey. The National Hospital Discharge Survey (NHDS) has been conducted annually since 1964 by the National Center for Health Statistics (NCHS). The 1983 survey data are the most recent information available from the NHDS (Kozak and Moien, 1985). This publication provides a tabulation of first-listed and all-listed diagnoses according to International Classification of Diseases, 9th Revision, Clinical Modifications (ICD-9-CM) codes for patients discharged from a nationally representative sample (418) of nonfederal hospitals in the United States. Data for the 1983 survey were obtained from the face sheets of a sample of about 206,000 medical records of patients discharged from these hospitals. Estimates are subject to sampling and nonsampling errors. Simmons and Schnack (1970) has presented a detailed description of the survey design.

The survey includes a specific category listing for osteoporosis as a clinical entity. In addition, two types of fractures specifically associated with osteoporosis in older persons are also included in the categories of diagnoses: vertebral fractures (without spinal cord injury), and neck of femur fractures.

The methods used in the NHDS count each hospital discharge rather than each patient. Therefore, each discharge is counted for any patient readmitted for revisional surgery. With the increasing per capita utilization of total hip arthroplasty (Melton et al., 1982a), the apparent incidence of proximal femur fracture will be inflated. However, because few persons are hospitalized for vertebral crush fractures, incidence of these fractures will be seriously underestimated. The estimates for numbers of fractures reported for each of these categories are listed in tables of data, along with cautions concerning reliability of estimates of incidence less than 10,000 and estimates for which the standard error is greater than 30% of the estimate itself (Kozak and Moien, 1985). Data tapes are available from NCHS.
Studies utilizing NHDS data. Data collected for the NHDS between 1972 and 1978 were used to estimate the average annual number of hospital discharges for patients having a first-listed diagnosis of osteoporosis (Holbrook et al., 1984). These investigators estimated 5,000 annual discharges for patients ages 45 to 64 years and 21,000 for patients over age 65 years. Because of the small number of hospital discharges, estimates were not made according to race and sex.

Cummings et al. (1985) cited estimates of the risk and incidence of hip fracture, Colles' fracture, and vertebral fracture based on data from the NHDS of 1977 as utilized by Lewinnek et al. (1980) and on the Rochester/Olmsted County data.

The 1974-1979 NHDS data on incidence of hip fractures categorized by race and sex for persons ages 30 to 84 years were analyzed by Farmer et al. (1984). These investigators also analyzed data from a 1980 District of Columbia Council of Governments survey of hospital discharges from nonfederal hospitals in the Washington, D.C. metropolitan area because the information available on race for the latter survey was considered more reliable. Age-specific incidence rates and relative risk estimates for men and women were presented based on analyses of data from both surveys. These data cannot be compared directly with the overall estimate of hip fracture rate of Lewinnek et al. (1980) who presented an estimate of incidence of both sexes and all races and ages combined. Similarly, the estimates of hip fracture incidence of Kelsey (1984) and Lewinnek et al. (1980) were not age-, race-, and sex-specific. (See pages 9-10 for a summary of these studies). Because osteoporosis is related to these three factors, estimates of its prevalence should take these factors into account.

Table 1 presents the findings of averaged hip fracture incidence for men and women by racial category calculated from data by Farmer et al. (1984). No data were presented by Farmer et al. (1984) for persons age 85 years and older. Investigators consulted during the preparation of this quick response report suggested that this study appears to be adequate for comparing incidence of hip fracture between white and nonwhite groups. However, it is not adequate for an estimate of the incidence of hip fracture in the entire population.

Farmer et al. (1984) discussed three possible sources of bias for both of the surveys analyzed. The first involved underestimation of true incidence rates resulting from incomplete ascertainment of cases and under- or overestimation of relative risks between racial groups resulting from differential ascertainment of cases by races. The second involved overestimation of true incidence rates resulting from counting prevalent hip fractures as incident events and the third addressed missing data on race.
TABLE 1. Age-Specific Hip Fracture Incidence by Sex and Racial Category, National Hospital Discharge Survey, 1974-79*

<table>
<thead>
<tr>
<th>AGE (yr)</th>
<th>WOMEN†</th>
<th></th>
<th>MEN†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White</td>
<td>Nonwhite</td>
<td>White</td>
</tr>
<tr>
<td>45-49</td>
<td>33.9</td>
<td>10.6</td>
<td>23.4</td>
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<tr>
<td>50-54</td>
<td>50.1</td>
<td>18.4</td>
<td>25.3</td>
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<td>55-59</td>
<td>88.9</td>
<td>31.4</td>
<td>40.7</td>
</tr>
<tr>
<td>60-64</td>
<td>152.8</td>
<td>38.2</td>
<td>67.1</td>
</tr>
<tr>
<td>65-69</td>
<td>237.2</td>
<td>101.5</td>
<td>116.6</td>
</tr>
<tr>
<td>70-74</td>
<td>530.5</td>
<td>167.4</td>
<td>222.4</td>
</tr>
<tr>
<td>75-79</td>
<td>1018.4</td>
<td>409.1</td>
<td>434.2</td>
</tr>
<tr>
<td>80-84</td>
<td>1731.5</td>
<td>880.6</td>
<td>734.8</td>
</tr>
</tbody>
</table>

* Data from Farmer et al. (1984).
† Incidence per 100,000 person-years.
2. **National Ambulatory Medical Care Survey**

The National Ambulatory Medical Care Survey (NAMCS) has provided statistical data about ambulatory medical care provided by office-based physicians since 1973. The target population of the survey is all office visits within the United States excluding Alaska and Hawaii by ambulatory patients to nonfederal physicians who are in office-based practice and provide office-based care. It is estimated that this design provides data on a majority of ambulatory care services because approximately 70% of all direct ambulatory medical care visits occur in physicians' offices (Pearce, 1981). Emergency room services are not included in this survey nor in the NHDS unless hospital admission occurs. Planners for this survey indicate that, at the earliest, emergency room services may be incorporated into the design for the 1988 National Ambulatory Medical Care Survey. If this survey is expanded to include emergency room services, data from this survey could supplement data on fractures of the NHDS.

Lists of licensed physicians providing office-based patient care maintained by the American Medical Association and the American Osteopathic Association are used as the sampling frame. Physicians are selected for participation in the survey by a modified probability proportional-to-size sampling procedure using separate sampling frames for standard metropolitan sampling areas and for nonmetropolitan counties. These physicians report on a fraction of the patient visits to their offices for 1 week. Data are collected continuously throughout the year in order to detect any seasonal variations. At the present time approximately 3,000 physicians are selected each year, 75% of whom participate in the survey. Information is thereby obtained on about 50,000 patient visits per year. Data tapes are available from NCHS (Pearce, 1981).

3. **National Health Interview Survey**

**Description of survey.** The National Health Interview Survey (NHIS) has been conducted annually since 1957 by the NCHS. It provides cross-sectional national data on the incidence of acute illness and accidental injuries, the prevalence of chronic conditions and impairments, and the extent of disability in the civilian noninstitutionalized population of the United States. The data are collected through personal household interviews. Therefore, information on patients in long-term care facilities, persons on active military duty (although dependents are included in the survey), and United States nationals living in foreign countries is excluded (Pearce, 1981). Thus, the survey procedure removes from the sampling frame groups that would be expected to contribute significantly to the incidence of hip fractures: institutionalized patients, persons admitted to nursing homes subsequent to a hip fracture, and persons who died following occurrence of a hip fracture.
Sampling for the NHIS is done by a multistage probability plan designed to yield national estimates. Data are collected continuously throughout the year from approximately 40,000 households, representing about 110,000 individuals. Each year the questionnaire for NHIS consists of two parts: a standard core of health, socioeconomic and demographic questions comprising about 70% of the questionnaire and one or more sets of rotating and single-time supplementary health questions reflecting specific topics of interest (Pearce, 1981). A lead time of at least 1 year is required to develop and pretest questions for inclusion as special supplements. According to planners for NHIS, specific questions have not been asked concerning osteoporosis because the expected number of reports of osteoporosis is too small for use of the question in a national survey sample. In addition, many persons are not aware that they have osteoporosis. However, data on fracture occurrence are available from three parts of the survey: 1) fractures occurring within the past 2 weeks; 2) disability from fractures occurring over the past few months; and, 3) chronic disabilities resulting from fractures. NCHS has not analyzed these data for the purpose of assessing incidence of fractures. Data tapes are available from NCHS.

Studies utilizing NHIS data. Lewinnek et al. (1980) utilized information from the NHIS, the NHDS, and an unpublished study described only as a survey of Medicare beneficiaries in 1976 of the Social Security Administration to estimate the incidence of hip fractures in the United States population. Data collected in the NHIS were obtained in household interviews in 1975 and 1976 and included noninstitutionalized persons of all ages. The estimate derived from data in this survey was 210,617 hip fractures per year (98/100,000 population). Data from the NHDS of 1977 provided a similar estimate of 213,000 hip fractures per year (99/100,000 population). The Social Security Administration survey was based on a sample of 20% of the aged and disabled Medicare beneficiaries over age 65 years in 1976. The estimate derived from these data was 131,460 hip fractures and was considered low in part because of the restricted age range of the population sampled.

Kelsey (1984) utilized a similar approach for estimation of the incidence and prevalence of osteoporosis for the NIH Consensus Development Conference on osteoporosis. She estimated the number of fractures (1.3 million/year) that might be attributed to osteoporosis rather than an estimate of the prevalence of osteoporosis. This estimate was based on the report that 70% of fractures in women age 45 years and older are attributable to osteoporosis (Iskrant and Smith, 1969). Determination of osteoporosis in that study was based on relative vertebral density as determined by dorsolumbar roentgenographs. The total number of hip fractures was determined from data of the NHIS, 1970-77 (Kelsey, 1984). Data from the 1980 study of Gallagher et al. on
the incidence rates of hip fracture in Rochester/Olmstead County, Minnesota were utilized as the basis for comparison of fracture rates in the United States with rates in other countries.

Using data obtained in the NHIS between 1970 and 1977, Holbrook et al. (1984) estimated the average annual incidence of fractures at all sites and at several sites associated with osteoporosis (Table 2). Estimates of hip fracture incidence rates derived from the NHIS data base by Holbrook et al. (1984) are much lower than the estimates derived by Farmer et al. (1984) from the NHDS data base (see Table 1).

4. National Medical Care Utilization and Expenditure Survey

A potential source of information on fracture incidence in the civilian noninstitutionalized population is the National Medical Care Utilization and Expenditure Survey (NMCUES) conducted by NCHS. The first cycle of the survey was conducted in 1980; the second cycle is planned for 1987. The purpose of this survey is to collect information on the health care expenditures associated with health services utilization for the entire U.S. population and to produce estimates over time for evaluation of the impact of legislation and programs on health status, costs, utilization, and illness-related behavior in the medical care delivery system. The questionnaire for the household component of the first cycle included questions on episodes of illness and the nature of health conditions.

The household portion of Cycle I consisted of 1) a national multistage probability sample of the civilian noninstitutionalized population (about 6,000 households) and 2) a survey of the Medicaid populations of New York, California, Texas, and Michigan (about 1,000 households in each state) (Pearce, 1981). Data tapes are available from NCHS for Cycle I of the survey.

Plans for the 1987 survey are currently being formulated; specific questions on osteoporosis could be incorporated into the questionnaire. However, because much of the disability of hip fracture in older persons is associated with institutionalization, exclusion of institutionalized persons from the data set will greatly underestimate the incidence and economic impact of hip fractures.

5. National Nursing Home Survey

The National Nursing Home Survey conducted by the NCHS is a potential source of information about the health status of patients in long-term care facilities excluded from the NHIS
Table 2: Estimated Average Annual Incidence Rate By Age Category, National Health Interview Survey, 1970-1977*

<table>
<thead>
<tr>
<th>SITE</th>
<th>45-64</th>
<th>65+</th>
</tr>
</thead>
<tbody>
<tr>
<td>All sites</td>
<td>2450</td>
<td>2880</td>
</tr>
<tr>
<td>Radius and ulna</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Humerus</td>
<td>130</td>
<td>110</td>
</tr>
<tr>
<td>Vertebral column</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>Hip</td>
<td>20§</td>
<td>430</td>
</tr>
<tr>
<td>Femur</td>
<td>--</td>
<td>30§</td>
</tr>
</tbody>
</table>

* Data from Holbrook et al. (1984).
† Incidence per 100,000 person-years.
§ Standard error of the estimate is greater than 30% of the estimate itself.
and the NHDS. The survey contains a residents' questionnaire which includes questions about residents' demographic characteristics, health status, and functional status. Information on randomly selected residents is obtained through a personal interview with the nurse who provides care to the patient. Information from the patient's medical records may be used to complete the questionnaire. Similarly, information about selected discharged patients is obtained through an interview with the nurse most familiar with the medical records and who refers to information from the medical records.

Data have been collected for two cycles of the survey: 1973-74 and 1977. Sample nursing homes were selected from the National Master Facility Inventory. The 1977 survey had a total sample of 1,700 nursing homes, 7,100 current residents, and 5,300 discharged residents. About 85% of these residents were age 64 years and older (Pearce, 1981). The 1977 survey did not include a specific category for osteoporosis; however, nursing home data imputed from proportional estimates were used by Holbrook et al. (1984) to calculate that about 8% of nursing home residents have hip fractures. This estimate is probably low because of the incomplete nature of the data on osteoporosis from the National Nursing Home Survey.

Data for a new cycle of the survey are currently being collected and will be available in 1987. Two open-ended questions may be useful for the determination of the incidence of hip fractures in this population. The first deals with the diagnosis at the time of initial entry into the nursing home; the second with the current diagnosis of the resident.

6. 1978 Survey of Disability and Work

The most recent Social Security Administration survey utilizing diagnostic data is the 1978 Survey of Disability and Work (Bye and Schechter, 1982). In this survey 12,000 working-age adults aged 18 to 64 years were interviewed. The sample was obtained from various sources: 6,900 persons interviewed for the 1976 NHIS and classified as being disabled to varying degrees; 4,600 were persons allowed Social Security disability benefits; and, 500 individuals who had applied for, but were denied, Social Security disability benefits (Lando et al., 1982). No specific category of "osteoporosis" was included in the survey questionnaire although categories of disability relating to broken bones and to the musculoskeletal system were included. According to statisticians associated with this survey, these data were categorized by ICD-9-CM numbers for cross-referencing with other surveys but have not been analyzed for incidence of conditions or factors that might be related to osteoporosis. Data tapes are not available for this survey; however, specific analyses can be requested from the Division of Disability Studies, Social Security Administration.
7. Studies sponsored by other federal agencies

In addition to the surveys described above, inquiries were made to federal agencies having an interest in epidemiology, aging, and health. The results of these inquiries are summarized below.

The Epidemiology, Demography and Biometry Branch of the National Institute on Aging has not collected specific data on the prevalence of osteoporosis and is not planning any major studies on this subject in the next 2 to 3 years. However, two efforts of the Epidemiology, Demography and Biometry Branch will include gathering and analysis of data related to osteoporosis.

The first is the EPESE (Established Population for Epidemiologic Studies of the Elderly) which is a community-based study at three sites, each having 3,000 to 4,000 noninstitutionalized persons ages 66 years and older. A fourth EPESE site has recently been established in a predominantly black population in North Carolina. Data will be available from the EPESE studies in about 4 years.

The second effort is the 1982-1984 follow-up survey of the first National Health and Nutrition Examination Survey 1971-1974 (NHANES I). In this survey 14,407 of the NHANES I participants, 5,646 of whom were 55 to 74 years of age at the time of the original survey, were contacted for further study (CornoHuntley et al., 1983). Personal interviews were conducted with persons who were traced or with a proxy for those deceased and diagnostic information from hospital records was collected. The frequency of hip fracture during the 10-year period between the NHANES I and the follow-up study will be tabulated and the data will be examined for factors predictive of hip fractures. Results of this study should be available in October 1986.

The Nutrition Epidemiology Branch of the Centers for Disease Control is currently working with data on fracture incidence from the 1983 NHDS, but the analyses have not yet been completed. A CDC telephone interview survey of behavioral risk factors associated with certain diseases is a potential source of information on factors associated with osteoporosis; however, efforts for utilizing this survey to obtain information on behavioral risk factors associated with osteoporosis are not planned currently.
B. FRACTURE INCIDENCE ESTIMATED FROM REGIONAL SURVEYS

1. Rochester/Olmsted County, Minnesota studies

The most extensive regional studies of the epidemiology of fractures in the United States have been made in Rochester/Olmsted County, Minnesota. Incidence of several types of fractures associated with aging have been determined for this population.

Proximal femoral fractures. Gallagher et al. (1980) studied the incidence of fractures of the proximal femur occurring in residents of Rochester/Olmsted County for the 10-year period 1965 to 1974. The total population size was approximately 52,000 (23,456 males and 28,290 females; 4,275 males and 6,647 females over age 50 years) and more than 99% were white. Diagnoses for both inpatients and outpatients were made in health care facilities including nursing homes in the immediate vicinity of Rochester. Master diagnostic indexes for all major diagnoses recorded for patients since the early 1900s were available for these facilities. Original medical records were obtained for each patient. Information on fractures of the vertebrae was derived from medical charts along with information about specific illnesses, therapies, or conditions predisposing to the development of osteoporosis. Only patients whose first fracture occurred during the study period were included. Patients whose fractures resulted from severe trauma or metastases were excluded. Fractures of the proximal femur were divided into two principal groups, cervical and trochanteric fractures, based on roentgenographs and clinical and surgical records. Incidence was calculated for each group of fractures and for total fractures of the proximal femur. The rates were adjusted to the United States white population of 1970.

A total of 415 patients (328 females and 87 males) had a first proximal femoral fracture during the study period (Gallagher et al., 1980). All patients having fractures were white. Age-specific incidence of hip fractures for females was lower than for males up to age 50 years (female: male ratio 0.3:1). After age 50 more women than men experienced hip fractures (female: male ratios of 1.6 to 3.2:1). As age increased, the incidence for men increased but never approached the incidence for women (Gallagher et al., 1980). Incidence for women rose from 9/100,000 person-years for ages 35 to 44 years to a maximum of 3,317/100,000 person-years for ages 85+ years. Incidence for men over the same age spans increased from 10/100,000 person-years to 1,833/100,000 person-years (Melton and Riggs, 1983).

The overall incidence age-adjusted to the United States white population was 101.6/100,000 person-years for women and 50.5/100,000 person-years for men (female: male ratio 2.01:1). Gallagher et al. (1980) estimated that each year about 147,000 persons (113,000 women and 34,000 men) over 50 years of age
would incur a hip fracture. Comparison of numbers of cervical and trochanteric fractures indicated similar numbers for each type up to age 80. At older ages, trochanteric fractures were more prevalent for both men and women.

Comparison of the Rochester data with data available from other countries suggested that the age-adjusted incidence of hip fracture in the United States was higher than in other populations for which hip fracture data were available (Gallagher et al., 1980). Higher recent rates have now been reported by investigators in other countries (Boyce and Vessey, 1985; Johnell et al., 1984; Zetterberg and Andersson, 1982), but Rochester rates are still higher than most reported from other countries. Melton et al. (1982b) have analyzed secular trends in hip fracture incidence over the past 50 years in residents of Rochester, Minnesota. Age-adjusted incidence rates for men and women rose during the first 15 years of the study and then stayed relatively constant for the remaining 35 years. During the first 15 years, few cases of hip fracture were found in the medical records. The authors attributed this deficiency to underreporting of cases during that period.

**Proximal humeral fractures.** Incidence of humeral fracture was studied in the Rochester population over the time period 1965-1974 by Rose et al. (1982). Proximal humeral fractures occurred in this population at about 70% of the rate reported for proximal femur fractures. Incidence of fracture of the proximal portion of the humerus associated with minimal trauma increased rapidly with age, particularly after age 40 years. In this age group, minimal trauma accounted for 83% of fractures of the proximal humerus. Incidence increased with age for both sexes but the increase was much more rapid for women. For the age group 70+ years, the incidence rate reached 317/100,000 person-years for women and 51/100,000 person-years for men (Rose et al., 1982).

**Colles' fractures.** Incidence of Colles' fractures occurring over a 30-year period (1945-1974) in residents of Rochester aged 35 years and older was reported by Owen et al. (1982a). In that time span 1,137 residents experienced 1,118 initial and 117 recurrent Colles' fractures. Approximately 92% of the fractures were associated with moderate trauma. Incidence of fractures associated with moderate trauma increased 2.5 times in men and more than 5 times in women between the ages 35 to 44 years and 65 to 74 years. At age 35 to 44 years the female: male ratio for moderate trauma fractures was 3:1; at age 75 years and older this ratio increased to 7:1. The age-adjusted female: male incidence ratio was 4.6:1. The higher age-related incidence of Colles' fractures associated with moderate trauma in women is considered by some investigators as evidence for these fractures being attributable to osteoporosis; however, other investigators
conclude that the association of Colles' fractures with continued bone loss has not been ascertained. Increased incidence over time was not noted for Colles' fractures in this population (Owen et al., 1982a).

**Pelvic fractures.** Analysis of the incidence of pelvic fractures in the Rochester population between 1968 and 1977 was reported by Melton et al. (1981). Incidence of pelvic fractures increased exponentially after age 65 years for both men and women; however, women in this age group had a much higher incidence than men. Minimal trauma was associated with 50% of all pelvic fractures, 67% in persons over age 35 years, and 84% in women over age 35 years. In this group, 40% of the men and 70% of the women had an earlier radiologic diagnosis of osteoporosis or a preceding fracture of the vertebrae, proximal humerus, proximal femur, or distal radius occurring in conjunction with minimal trauma (Melton et al., 1981).

**Fractures at multiple sites.** Incidence of other fractures was examined in patients having hip fractures (Gallagher et al., 1980). Overall, 68% of women and 59% of men had fractures at sites other than the hip. Colles' fractures preceded hip fractures in 17.8% of patients (mean age for Colles' fracture 68.9 years and for hip fracture 79.3 years). Vertebral fractures preceded hip fractures in 25.5% of patients (mean age 73.3 years for vertebral fractures and 78.3 years for hip fractures). Owen et al. (1982b) utilized the population of Rochester residents aged 35 years or older having Colles' fractures between 1945 and 1974 to conduct a retrospective cohort study to evaluate the potential of Colles' fractures for predicting subsequent risk of hip fracture. In order to allow time for follow-up of subsequent hip fractures in this group, the subgroup having Colles' fractures between 1945 and 1959 was studied. For men, the relative risk overall was 6.4 but the number of cases (seven) was too small to permit further analysis. For women the relative risk overall was only 1.3. However, an age effect was observed in women. Although relative risk doubled for women having Colles' fractures at age 70 years or older, it was not increased for women having Colles' fractures at younger ages. Based on these results, the power of Colles' fractures to predict subsequent hip fractures was considered quite low (Owen et al., 1982b).

2. **Michigan studies**

The prevalence of vertebral crush fractures in subjects having low vertebral densities as determined by lateral x-rays of the dorsolumbar spine was examined in a study of women aged 45 years and older (Smith and Rizek, 1966). The subjects of this study were 200 Puerto Rican women and 1890 Michigan women (1753 white and 137 black). Up to age 59 years, prevalence of vertebral crush fractures was about 4% or less in both the Michigan and Puerto Rican women. Analysis by 5-year age increments from age 60 through 74 years showed steady increases in
the percentage of women with vertebral fractures with each 5-year increment in age. In the age group 75 years and older, the percentage with vertebral fractures fell; however, interpretation of the data was constrained because of the small sample size of this group. In this study all vertebral fractures were found in white subjects. Data for vertebral crush fractures were not reported for women with higher vertebral densities (Smith and Rizek, 1966).

A follow-up study of the Michigan women over age 45 years (2,088 women, 1,953 white, and 135 black) related grade of vertebral density as determined by lateral x-ray of the dorsolumbar spine to subsequent fracture incidence over a 3-year period (Iskrant and Smith, 1969). Sites of fracture reported over this period were radius, proximal femur, wrist, ankle, spine, ribs, metatarsal, fingers, and toes. Fracture rates for women having lower grades of vertebral density were higher for four sites (wrist, ankle, radius, and proximal femur) than for overall fracture rates and were more often associated with falls rather than traumatic incidents such as automobile accidents. The annual fracture rate was 3.6%, ranging from about 2% in women with higher vertebral density to 7% for women classified as having osteoporosis.

Fracture rate increased as vertebral density decreased and age increased in 10-year increments. Overall, about 70% of the women in this study in whom a fracture occurred had lower grades of spinal bone density defined as osteoporotic by the authors (Iskrant and Smith, 1969). Less than 20% of women aged 45 to 49 years had relative dorsolumbar bone densities classified as indicative of osteoporosis while approximately 90% of women aged 80 years and over were classified as having dorsolumbar bone density indicative of osteoporosis. Ethnic background also was related to bone density: 61% of women whose ancestry was Great Britain or Ireland and 44% of black women had dorsolumbar bone densities considered indicative of osteoporosis. Overall 57% of women in this study were classified as having osteoporosis on the basis of low vertebral density (Iskrant and Smith, 1969).

3. Estimates of incidence of fractures related to osteoporosis

Iskrant and Smith (1969) estimated that about 70% of fractures occurring in women age 45 years and older resulted from osteoporosis. This estimate was based on their finding that about 70% of Michigan women over age 45 years who experienced a fracture over a 3-year study period had lower grades of spinal bone density determined by lateral x-ray of the dorsolumbar spine. This factor was recently used by Kelsey (1984) in estimating the number of hip fractures resulting from osteoporosis in the U.S. population over age 45 years for the NIH Consensus Development Conference.
Another approach was taken by Melton and Riggs (1983) who compared the number of fractures observed in persons ages 40 years and older with those of persons aged 30 to 39 years and estimated the excess incidence over and above that expected if the 30 to 39 year-old rates continued to apply at subsequent ages. Age and sex-specific fracture rates were based on fracture incidence in the population of Rochester, Minnesota. Overall, the excess fracture rate at all sites for both sexes was about 51%. Excess rates for specific sites of fractures associated with osteoporosis were also presented (Melton and Riggs, 1983).

C. BONE MASS STATUS ESTIMATED FROM NATIONAL SURVEYS

Data collected for the first and second National Health and Nutrition Examination Surveys (NHANES I and II) conducted by the NCHS included several x-ray measurements. For NHANES I (1971-1974), all persons aged 1 to 17 years received hand-wrist roentgenographs for determination of bone age and bone density. A subsample of adults receiving detailed physical examinations also had chest, hip, knee, and hand-wrist roentgenographs. All adult males and females over age 50 years received hip roentgenographs. Females between the ages of 12 and 45 years were carefully screened to avoid x-ray exposures of pregnant subjects (Miller, 1973).

In NHANES II, roentgenographs of chest and of cervical and lumbar spine were made on subjects 25 to 74 years of age. For females, lumbar spine measurements were limited to women age 50 years and older. No x-ray measurements were made for pregnant women (McDowell et al., 1981). These data, although collected, have not been completely analyzed and tabulated by NCHS. Methodology for assessing bone status has advanced rapidly since the NHANES I and NHANES II surveys and the x-ray techniques and sites of measurement used in these surveys are not considered adequate for the determination of bone mass of individuals (Kimmel, 1984) or for the diagnosis of osteoporosis. Experts consulted during preparation of this quick response report have suggested that such data may be adequate for assessment of group data even though the data lack sufficient specificity and sensitivity to be used clinically for individual assessments. These experts also noted that lateral chest roentgenographs made as a part of an NHANES could provide an excellent data set for estimating the prevalence of vertebral fractures.

Data tapes of the bone mass values of the middle phalanx of the little finger (V-2) of 6,030 adults receiving hand-wrist roentgenographs in NHANES I were analyzed recently by Mangaroo et al. (1985). The Goldsmith-Vose technique utilizing an aluminum equivalency standard expressed as millimeters of aluminum on a standard wedge was originally used to calculate the values for bone mass on the data tapes. Mean bone mass at the V-2 site for all subjects was 0.228 mm aluminum equivalence ± 0.042 SD.
Based on results of several previous studies and because the distribution was quite skewed, Manganaro et al. (1985) chose 0.200 mm aluminum equivalents as the lower limit of normal bone mass for the entire population. With this cutoff value, nearly 20% of white females and about 13% of white males had low bone mass at ages 25 to 34 years. The percentage increased to about 44% for white females ages 65 to 74 years and about 34% for white males of this age range. Smaller percentages of black males and females had low bone mass but the same age- and sex-related trends were shown for blacks as for whites. Cautious interpretation of these data was advised by investigators consulted during the preparation of this report. The V-2 site is composed primarily of cortical bone and bone demineralization at this site may not be representative of bone changes associated with development of osteopenia in vertebrae and femur.

D. BONE MINERAL CONTENT DATA AVAILABLE FROM REGIONAL STUDIES

1. Studies in white women

Bone mineral content measured by single photon absorptiometry is available for midshaft and distal radius of 941 white females, 571 of whom were 50 years of age or older (Smith et al., 1975). This population excluded subjects on cortisone therapy or those with chronic liver disease, renal disease, bone diseases other than osteoporosis, or other diseases known to affect bone metabolism. Varying amounts of additional medical information were reported to be available for each subject. Mean values for bone mineral content are presented for age groupings of 10-year intervals. In addition, frequency distributions of bone mineral content of the midshaft radius are presented for subjects 50 years of age and older (Smith et al., 1975).

Bone mineral content of distal radius is also available from single photon absorptiometry measurements in a sample of approximately 700 white women in North Carolina described as normal, healthy, and belonging to a moderate to high socioeconomic group (Awbrey et al., 1984). The subjects ranged in age from 18 to 98 years. Bone density was measured at three different sites along the radius, with evaluation of the distal radius at the site where the radius and ulna were 5 mm apart. For 140 of the 700 subjects, bone density of the lumbar spine (L2-L4) was determined by dual photon absorptiometry. The mean ratio of lumbar spine density/distal radial density was essentially constant for the lifespan examined. The correlation coefficient between the 5 mm radius site across age groupings was 0.52, whereas the correlation coefficient at the midradius was 0.50. Although these relationships between localized bone loss at different sites were examined, the study did not demonstrate the value of use of distal radius measurements in screening for bone loss in osteoporosis.
Correlates of midradial bone mineral content of 324 postmenopausal women 55 to 80 years of age of northern European heritage and living in two northwest Iowa communities with different levels of calcium in the drinking water were studied by Sowers et al. (1985). Mean daily calcium intakes from food and drinking water for subjects in the two communities were 964 and 1,329 mg/day. Because no significant community differences in bone mineral parameters were observed, analyses combined subjects across communities. Midradial bone mineral content adjusted for age and muscle area was slightly lower (2%) in women reporting incidence of proximal femoral, vertebral, or Colles' fractures than in women reporting no fractures or fractures of other bones. Midradial bone mineral content was also slightly lower for women having recent fractures (since 1972) than those having earlier fractures. This finding was based on lifetime physician-documented fracture records available for 27% of women 55 to 64 years of age and 39% of women 65 to 80 years of age. More vertebral fractures (6 vs. 0, p <0.0081) were reported by women living in the community with lower calcium content of drinking water. No differences in incidence of fractures at other sites were reported (Sowers et al., 1985).

A model for age-related bone loss in postmenopausal women was developed from longitudinal data on bone mineral content of the midshaft radius measured by single photon absorptiometry (Hui et al., 1982). Subjects for this study were 268 white women ages 50 to 95 years who were followed prospectively for 1 to 7 years. Statistical techniques used in the study permitted analysis of irregularly collected data from subjects of different ages. Analysis of cross-sectional data of bone mineral content of 583 postmenopausal women age 50 years and older showed good agreement with the model derived from the longitudinal data. Both data sets showed evidence of an increase in variance of bone mineral content with age (Hui et al., 1982).

Bone status of an age-stratified random sample of 300 women age 30 years and older in Rochester, Minnesota is being studied extensively. Measurements include single photon absorptiometry of the mid- and distal radius, dual photon absorptiometry of the spine and hip, and x-rays of the spine. Results of this study are now being analyzed (Melton, 1985).

2. Studies in selected racial or ethnic groups

Bone mineral content of distal and midshaft radius and ulna and midshaft humerus of 1,851 normal white subjects (763 children ages 5 to 19 years; 538 adults ages 20 to 49 years; and, 550 adults ages 50 years and over) was assessed by single photon absorptiometry to provide baseline data for evaluation of abnormalities of bone mineral content (Mazess and Cameron, 1974). Height and weight measurements of these subjects are available. Criteria for selection of these subjects were not specified.
Bone mineral content of normal white children and young adults (ages 6 to 39 years) was measured by Hui et al. (1985). Participants in this study were 692 Indiana and 1,082 Wisconsin residents. Bone mineral content was measured by single photon absorptiometry at the mid- and distal radius in the Indiana subjects and at the distal radius in Wisconsin subjects. Mean bone mass adjusted for age and bone width was higher for the Wisconsin subjects and most other growth measurements differed significantly between the two states. Because of the systematic differences observed in bone mass between the residents of the two states, separate growth curves for bone mass for each state were necessary (Hui et al., 1985).

A study of bone mineral status of distal radius of 3,511 adults (2,695 white, 662 black, and 154 Asian, divided into 10-year age groupings for persons 10 to 89 years of age) representative of an insured working population in California is also available (Goldsmith et al., 1973). This population was described by the authors as a "fair composite" of the working population of the eastern shore of the San Francisco Bay area with some under representation of the Asian population and an under representation of the wealthy and indigent poor. In this study, black subjects had a higher mean bone mineral content than white subjects although white subjects did not have more bone mineral than Asian individuals. Bone mineral content decreased with age in all groups. Male subjects had greater amounts of bone mineral than females for all of the groups examined. Of the 3,511 subjects, 939 were also evaluated for evidence of vertebral osteoporosis by miniature roentgenogram of the abdomen. These data showed an inverse relationship between distal radial bone mineral content and diagnosis of vertebral osteoporosis from roentgenograms. The authors concluded that single photon absorptiometry measurement of bone mineral content of the radius was not a useful screening tool for early detection of vertebral osteoporosis.

The Baltimore Longitudinal Study of Aging includes a component on bone changes with age. This overall study is an on-going, long-term multidisciplinary effort to investigate various aspects of aging. Participants in this study are primarily white volunteers of above average socioeconomic status and education level. Longitudinal data from hand-wrist x-rays have been collected since 1958 on more than 500 men ages 18 years and older. Women have been included in the study since 1978. X-rays were obtained to investigate changes in bone associated with development of osteoarthritis and osteoporosis. Analysis of bilateral hand-wrist x-rays obtained from 176 female and 448 male participants indicated that medullary width of the second metacarpal increased and the percent cortical area and combined cortical thickness decreased with age in both sexes (Plato and Purifoy, 1982). Dietary history data on calcium intake
is available for men for the years 1958 to 1978. These data were obtained by 7-day dietary diaries recorded at varying times throughout the 20-year period. In addition, data relating to physical exercise have been obtained as a part of this study.

Investigators associated with this project indicate that single photon absorptiometry measurements have been made on the distal radius since the mid 1960s. Approximately 500 men have longitudinal assessment of the bone mineral content of the distal radius. Longitudinal data on bone mineral content of the distal radius of women are not yet available. Dual photon absorptiometry measurements of the bone mineral content of the lumbar spine were begun in 1983. Assessments have been made for a limited number of male and postmenopausal female participants. As data are accumulated on greater numbers of participants, this study may become a source of longitudinal data concerning bone loss with aging.

The bone mineral content of the radius of 413 North Alaskan Eskimos (217 children ages 5 to 19 years; 89 adults ages 20 to 49 years; and, 107 adults ages 50 years and older) was measured by single photon absorptiometry (Mazess and Mather, 1974). Bone mineral content of adults over 40 years of age was reported to be 10 to 15% less than that of a U.S. white population used for comparison. The largest deficit was reported for Eskimo women age 70+ years whose bone mineral content was about 30% lower than that of the reference population. Similarly, bone mineral content of the radius of 117 male and 124 female Canadian St. Lawrence Island Eskimos ages 5 through 70+ years was lower than that of an age- and sex-matched reference population of Wisconsin white subjects (Harper et al., 1984).

Bone mineral content of distal radius and ulna, proximal radius and ulna, and os calcis was determined by single photon absorptiometry in a sample of Japanese-American men and women living in Hawaii (1,368 men ages 61 to 81 years and 1,098 women ages 43 to 80 years) (Yano et al., 1984). Decreased bone mineral content was found in the distal and proximal radius of Japanese-American men and women in comparison to that of two U.S. white reference populations developed by Goldsmith et al. (1973) and Mazess and Cameron (1974).

Bone mineral content measured by single photon absorptiometry for a large population (8,000 persons) in Germany by Runge et al. (1980) was similar to bone mineral content reported in several U.S. studies. One of the scientists consulted during preparation of this quick response report suggested that these data could be extrapolated to the U.S. white population.
E. CLINICAL STUDIES

Several clinical studies of skeletal status and osteoporosis and/or susceptibility to fracture should be considered for interpretation of data regarding the relationship of fractures and bone mineral content.

Bone mineral content of the distal third of the radius was measured by single photon absorptiometry in 24 females ages 20 to 49 years, 48 females ages 50 to 80 years, 13 normal males ages 20 to 61 years, 18 females ages 50 to 74 years diagnosed as having osteoporosis by multiple spinal fractures and/or minimal trauma fractures of distal radius and ribs, 11 adult males (ages not specified) with osteoporosis and taking corticosteroids for asthma or arthritis, and 20 adults with renal osteodystrophy (Mazess et al., 1984). These measures were compared to total body bone mineral and bone mineral content of major skeletal regions determined by dual photon absorptiometry. For normal males and females, total or regional skeletal status could be estimated from radius bone mineral content with relatively small error (6-10%). However, bone mineral content of distal radius in men and women with osteoporosis overestimated total body bone mineral content by 6-8% and spinal density by 12-15%. The regression lines for subjects with osteoporosis differed from those of normal subjects and did not predict spinal status in osteoporosis, probably because of preferential bone loss from the spine (Mazess et al., 1984).

Single photon absorptiometry measurements of distal radius bone mineral content were made in 123 women ages 48 to 80 years with primary osteoporosis as determined by vertebral crush fractures and in 89 women ages 45 years and older (Wahner et al., 1977). Radiographic measurement of proximal femoral trabecular (Singh) index was also assessed in women with osteoporosis and compared with normal values for women more than 50 years of age. The measures of bone mineral content of distal and midradius were considered "less than satisfactory" as a discriminator between normal subjects and those with osteoporosis. From the results of this study, the Singh index was judged the more sensitive indicator to distinguish among subjects with vertebral fractures and age-matched normal subjects (Wahner et al., 1977).

These two methods (determination of bone mineral content by single photon absorptiometry and Singh index by radiography) were also compared by Khairi et al. (1976) as a means of determining present and future fracture incidence. The subjects for this study were 106 white women ages 70 to 95 years who did not have organic bone disease other than osteoporosis, chronic liver disease, renal disease, evidence of malignancy or other diseases known to affect bone metabolism. A significant positive correlation (value not stated) was reported between values for bone mineral content of the distal and midshaft radius. Presence
of bone diseases correlated inversely with the presence of a fracture at the time of the study. However, bone mineral content was reported to be a better predictor of subsequent fractures in these subjects over a 3-year follow-up period. Incidence of fracture during the follow-up study was inversely correlated with bone mineral content but was not correlated with the Singh index (Khairi et al., 1976).

Riggs et al. (1981) described patterns of bone loss in the axial and appendicular skeleton based upon bone density measurements of lumbar spine (dual photon absorptiometry) and distal and midradius (single photon absorptiometry). Subjects for this study were 187 normal adults (105 women and 82 men ages 20 to 89 years) and 85 adults (76 women and 9 men ages 50 to 85 years) who had vertebral fractures attributed to primary osteoporosis (Riggs et al., 1981). This research group has further described differences in Type I and Type II osteoporosis based upon bone loss patterns of the proximal femur and lumbar spine (Riggs et al., 1982, 1983). These studies involved 205 normal adult subjects (123 women and 82 men ages 20 to 92 years) and 31 patients with atraumatic hip fractures (26 women and 5 men ages 55 to 91 years). See Section II for a more detailed description of these studies.

The relationship between vertebral fracture and lumbar bone mineral content determined by dual photon absorptiometry was examined by a "gradient of risk" model (Melton et al., 1985). An age-stratified random sample of women residents of Rochester, Minnesota was utilized for the study. Women with bone mineral content at least 1.40 g/cm² had no vertebral fractures. Women whose bone mineral content was between 1.0 and 1.39 g/cm² had a prevalence of vertebral fractures of about 7%. All women whose bone mineral content was less than 0.60 g/cm² had at least one vertebral fracture (Melton et al., 1985).
IV. CONCLUSIONS

A. PREVALENCE OF OSTEOPOROSIS

- Generally accepted, validated data on the national prevalence of osteoporosis were not identified during the preparation of this Quick Response report. Estimation of the prevalence of osteoporosis is particularly difficult because osteoporosis is not a disease with a discrete onset. Typically, osteoporosis is recognized in older persons who obtain medical treatment for fractures.

B. INCIDENCE OF HIP FRACTURES

- Data on occurrence of hip fractures, an epidemiologically recognizable consequence of osteoporotic bone mass losses, has been used as a surrogate for the prevalence of osteoporosis because of the difficulty of defining osteoporosis.

- Most hip fractures in the elderly are thought to be attributable to osteoporosis; however, data on incidence of hip fracture probably underestimate the actual prevalence of osteoporosis. Hip fracture is only one manifestation of a complex disorder occurring in the elderly and only a fraction of the population having low bone mass will have a fracture or history of fracture at any given time.

- Fracture of the proximal humerus and crush fracture of the vertebrae are also associated with osteoporosis. However, incidence of fractures at these sites is difficult to identify by methods used in any single national survey. Vertebral crush fractures may not require immediate medical treatment and may go undiagnosed for varying periods of time. Fractures of the proximal humerus may not require hospitalization and, therefore, only a portion of these fractures would be included in surveys based on hospital discharge records.

- The most extensive compilations of the incidence of hip fracture in national population groups are the data of the National Health Interview Survey and the National Hospital Discharge Survey. Data from both studies are specific for age, sex, and race of participants. The diagnostic information of the National Hospital Discharge Survey may be more reliable because medical records rather than household interviews were used.
Data from either of these surveys, neither of which includes the elderly institutionalized population, could be supplemented by data currently being collected in the National Nursing Home Survey if the data bases are compatible.

Data from the National Health Interview Survey or the National Hospital Discharge Survey probably could not be supplemented by data from the National Ambulatory Medical Care Survey. Persons requiring treatment for hip fractures would not be expected to seek office-based treatment. However, if the scope of this survey were expanded to included emergency room treatment, then data from this survey might complement data for fractures from the National Hospital Discharge Survey.

Potential sources of further information on fracture incidence in the civilian noninstitutionalized population are the follow-up study of NHANES I participants which is currently underway and the National Medical Care Utilization and Expenditure Survey which will be conducted in 1987. The Established Population for Epidemiologic Studies in the Elderly may also supply data on incidence of fracture in 12,000 to 16,000 non-institutionalized persons over the age of 65 years at four geographic locations in the United States.

The most comprehensive study of the epidemiology of fracture is that of the Rochester/Olmsted County Epidemiology Project. This survey is based on data accumulated in extensive medical records for residents of the area for time periods as long as 50 years. Data analyzed thus far include incidence of fracture of the hip, pelvis, proximal humerus, Colles' fractures, and all limb fractures.

C. MEASUREMENTS OF BONE MINERAL CONTENT

A more direct approach to estimating the prevalence of osteoporosis is based upon measurement of bone mineral content. The national prevalence of bone demineralization has been estimated from assessment of bone density gathered during NHANES I. Of the national surveys, only the NHANES I and NHANES II collected data that might be used to estimate bone density status. These data were collected using x-ray methods that may be adequate for assessment of bone density of large population groups. However, bone changes at sites measured in these surveys may not be representative of bone changes at sites where fracture is likely to be associated with osteoporosis.
Bone mineral content determined by single and dual photon absorptiometry techniques is considered the best indicator of bone status applicable to large groups. It is not yet possible to define bone mineral contents indicative of osteoporosis; however, efforts are presently underway to develop models to predict risk of fracture based on bone mineral content of fracture sites associated with age-related bone loss. These techniques have not been used in national surveys, but data are available for several relatively large groups in the U.S. population.
V. LITERATURE CITED


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