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The purpose of this study was to: (a) identify bone mineral density (BMD) at the femoral neck (FBMD) and of the whole body (WBMD) in samples of premenopausal adult women with and without mental retardation (MR and NMR groups, respectively); and (b) determine relationships between BMD and both body composition and muscle strength variables. Thirty-two subjects (MR = 16; NMR = 16), matched by age, body mass index (BMI), and use or non-use of birth control medication, were measured on the Hologic QDR 1000W dual energy x-ray absorptiometer to determine FBMD, WBMD, lean muscle mass (LMM), and percent body fat (BF). Peak force generated (kg) during isokinetic strength testing at the biceps (BS) and quadriceps (QS) muscle groups was determined at 30 degrees per second using the KinCom 500H. Analysis of variance techniques revealed that the MR group had significantly lower LMM, BS, and QS, but higher BF. Significant differences were not found ($p > .05$) between groups for FBMD and WBMD. Refer to the following table:

	FBMD	WBMD	LMM**	BF*	BS***	QS***
MR	.845 ± .13	1.068 ± .09	39.87 ± 5.85	31.88 ± 8.74	8.33 ± 2.30	25.65 ± 9.49
NMR	.910 ± .13	1.108 ± .07	47.18 ± 4.00	26.03 ± 4.01	15.13 ± 3.92	55.78 ± 11.90

*p < .05, **p < .001, ***p < .0001; FBMD & WBMD = g/cm^2; LMM, BS, & QS = kg; BF = %

Multiple linear regression detected a significant positive correlation between LMM and both FBMD ($r = .74$; $p < .01$) and WBMD ($r = .81$; $p < .001$) in the MR group. In the NMR group, QS was significantly correlated with WBMD ($r = .74$; $p < .05$). Major conclusions were: (a) there are no differences between MR and NMR subjects despite differences among LMM, BF, BS, and QS; and (b) LMM is the most robust predictor of BMD in the MR sample while muscle strength seems to be the best predictor of BMD in the NMR sample.

Bone Mineral Density in Adult Women with Mental Retardation

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BONE MINERAL DENSITY IN ADULT WOMEN WITH MENTAL RETARDATION

INTRODUCTION

Bone mineral loss is commonplace among aging women from many different societies and cultures. In Western societies today, approximately 1 of every 3 women over 65 years of age will exhibit a clinical manifestation of bone mineral loss (Barth & Lane, 1988). This statistic translates into an estimated annual medical cost between 7 and 10 billion dollars (Aloia, 1989).

The most likely outcome as a result of excessive bone mineral loss is osteoporosis, which has been described as a critical reduction in bone mass to the point that fracture occurs (Snow-Harter & Marcus, 1991). With only minimal amounts of force applied to bone associated with critically low bone mass, a fracture may result. These osteoporotic fractures are often recurrent, very painful, debilitating, and ultimately leading to permanent disability and dependency (Stevenson, 1990).

Due to both the marked economic impact and the consequent personal trauma suffered by individuals with osteoporosis, bone mineral loss with aging is currently a major health care issue. Considerable concern exists regarding bone loss among adult women, particularly since older females are most likely to suffer from osteoporotic fractures relative to males of the same age. In general, not only do women possess lower peak bone mass values than men, but they also typically

experience dramatic bone loss due to menopause (Garn, 1975; Smith, 1982).

Bone mass is interactively influenced by a wide array of internal biological and external environmental factors. Some biological influences on bone mass include heredity, disease status (e.g. osteoporosis and hyperthyroidism), bone remodelling capabilities, and menopausal status. Environmental influences on bone mass include nutritional intake (e.g. calcium and alcohol), cigarette smoking, medications, and physical activity. (For a detailed analysis of these factors, see Literature Review, Appendix A.) Among these many important factors, physical activity and menopausal status are two of the most crucial determinants of peak bone mass in women.

Researchers have measured the level of bone mineral to depict the degree of bone loss in women. Bone mineral is the absolute amount of hydroxyapatite (calcium phosphate crystal) in bone, usually measured in gram units. Bone mineral density (BMD) is defined as the relative value of bone mineral per bone area, usually measured in grams per squared centimeters (Snow-Harter & Marcus, 1991).

Physical Activity

It is now widely recognized that level of physical activity is positively related to BMD (Aloia, Vaswani, Yeh, & Cohn, 1988; Brewer, Meyer, Keele, Upton, & Hagan, 1983; Dalen & Olsson, 1974; McCulloch, Bailey, Houston, & Dodd, 1990). Women who are more physically active tend to have higher BMD values. Conversely, women who

are less physically active tend to have lower values of BMD, and, consequently, are at a greater risk of bone fracture.

A growing body of evidence has supported that muscle strength and muscle mass are major determinants of BMD in women independent of age (Bevier et al., 1989; Peterson et al., 1991; Pocock et al., 1989; Sinaki & Offord, 1988; Snow-Harter & Marcus, 1991; Snow-Harter et al., 1990). These investigations support the animal and theoretical models developed by Rubin and Lanyon (1984) and Whalen, Carter, & Steele (1987), respectively. Their theories predict that the magnitude of a load is a far greater osteogenic stimulus than the number of repetitions of a load. If this assumption holds true, then physical activities that promote muscular strength, such as weightlifting, would be more beneficial to increase BMD than activities such as walking or jogging which are not specific to muscular strength.

It appears that bone mass is maintained at an appropriate level which coincides to the forces that are regularly acting on the bone. This notion stems from Wolff's law which states that bone will modify its structure in response to the level of mechanical loading on the bone (Wolff, cited in Lane, Cornell, & Healey, 1987). According to Wolff, the mechanical loading derived from physical activity, then initiates the stimulation of osteoblastic activity resulting in skeletal adaptation.

Menopausal Status

Estrogen function plays a key role in maintaining adequate BMD levels in females. There is strong evidence that estrogen deficiency, and not aging, is the primary cause of bone loss after menopause (Richelson, Wahner, Melton, & Riggs, 1984). Multiple physiological mechanisms whereby estrogen exerts its effect on BMD have been postulated. First, estrogen promotes the synthesis of calcitonin, which inhibits bone resorption. Secondly, estrogen also enhances the active metabolite of vitamin D, 1,25-dihydroxyvitamin D_3, which increases absorption of calcium at the intestine (Marks & Popoff, 1988). Calcium blood levels need to be maintained; otherwise, bone resorption may take place to alleviate low calcium levels since 99% of all calcium in the body is stored in bone tissue (Aloia, 1989). Thirdly, estrogen deficiency permits osteoclasts to resorb bone with greater efficiency (Snow-Harter & Marcus, 1991).

Prior to menopause, ovarian failure is demonstrated by irregular menstrual cycles and nonovulation starting as early as the age of 35 years. This parallels the age-related, gradual decrease in bone loss after peak bone mass is attained during the third decade of life (Sinaki, 1989). With menopause and the consequent decrease in ovarian estrogen, BMD has been noted to decline rapidly, particularly during the first five years following menopause (Snow-Harter & Marcus, 1991). In light of the rapid decline in BMD shortly after menopause coupled with the slight decline in BMD in the mid-thirties, it is paramount to stress the importance of obtaining a maximal peak bone density.

Mental Retardation and BMD

Virtually all of the research pertaining to BMD has been addressed in populations without mental retardation. To date, no studies have examined BMD levels in women with mental retardation.

Generalizing some of the results of BMD research in adult female nonmentally retarded (NMR) populations, one would expect that adult females with mental retardation would have relatively lower BMD. Previous research on individuals with mental retardation, both males and females, have shown that they have lower physical activity levels, lower physical fitness levels, and reduced muscular strength and endurance performance compared to their NMR counterparts (Fernhall, Tymeson, & Webster, 1988; Pitetti, 1990; Reid, Montgomery, & Seidl, 1985). If the positive association between muscular strength and physical activity with BMD holds true, then individuals with mental retardation should have lower BMD levels based on their physical activity and strength characteristics. In addition, it has been recently discovered that lean muscle mass is more of a predictor of BMD than fat mass (Shaw, Snow-Harter, Robinson, Wegner, & Shelley, 1993; Snow-Harter, Shaw, Wegner, Robinson, & Shelley, 1993; Sowers, Kshirsagar, Crutchfield, & Updike, 1992; Wegner, Snow-Harter, Robinson, Shaw, & Shelley, 1993). Assuming that females with MR have relatively lower lean muscle mass would suggest that they have lower BMD levels than females without MR.

In contrast, slight evidence relating to obesity based on BMD research in adult females without MR may

suggest that MR adult females would indeed have relatively similar BMD values. In several studies, obesity was prevalent in a large number of adult females with mental retardation. For example, Kelly, Rimmer, & Ness (1986) found that 50.5% of adult females with mental retardation had a percent body fat level greater than 30%. One study measuring percent body fat in adults with mental retardation found that as many as 83.7% of females were obese (Felix, Rimmer, Tymeson, & Looney, 1992). The significance of these facts as it relates to BMD lies with the effect of fatty tissue on estrogen production as well as the extra loading due to excessive weight.

When ovarian estrogen decreases, particularly at menopause, the major source of circulating estrogen is derived from the adrenal glands. The adrenal glands produce androgens which are converted to estrogen in the fatty tissues. This conversion rate increases with age and with weight (Hemsell, Grodin, Brenner, Siiteri, & MacDonald, 1974). Because of the obesity characteristics of MR adult females, there may be a protective effect of obesity against low BMD levels as a result of this metabolic conversion.

Another protective effect of obesity on BMD may be attributed to the weight-bearing effect on bone tissue. Typically, women who are thin and slender are at a greater risk for osteoporotic fracture than women who are more obese. It is reasonable to assume that adult females with mental retardation may have normal BMD levels based on their general endomorphic body type characterized by high levels of percent body fat.

Significance

There is a need to determine BMD levels in adult women with MR. Research regarding BMD levels in this population has been nonexistent. Adult females with MR are associated with characteristics which suggest that they may be at risk for osteoporosis. In fact, one investigation found that as many as 10% of people with MR in an intermediate care facility (55 of 553 residents) have experienced bone fractures (Tannenbaum, Lipworth, & Baker, 1989). Interestingly, elderly women (45-64 years) who demonstrated the greatest mobility (i.e. ambulatory independence) were most likely to fall and suffer a fracture. According to this study, the fracture rate for a population with MR was 3.5 times higher than the average population.

Currently, there is a rapid increase of older adults with MR. Previous generations of persons with developmental disabilities frequently did not survive into old age. Now, over 500,000 persons with developmental disabilities are over 65 years of age (Seltzer, 1989). Due to a rapidly rising population and increased life expectancy among individuals with MR, quality of life and health care are major concerns. As such, health concerns of older adult females with mental retardation should include issues related to BMD and osteoporosis. Combined with the rising health care costs paid by Medicare and Medicaid for older adults, the rationale for research in this area is paramount to determine if interventions such as exercise programs are needed for optimal skeletal health. The outcomes

documented in this research may identify important long term health implications for persons with MR.

Purpose

The primary purpose of this investigation is to identify BMD levels in a sample of pre-menopausal adult females with MR. These values will be compared to BMD values in control group of NMR females who will be matched according to age and body mass index (BMI). A secondary purpose of this study is to determine the relationships between BMD, lean muscle mass (LMM), and muscle strength of the hand, biceps (elbow flexion), and quadriceps (knee extension) in the females with MR.

Hypotheses

The specific null and alternative hypotheses to be tested in this investigation are as follows:

H_{o1}: No significant differences exist among BMD and muscle strength between MR and NMR pre-menopausal adult females.

H_{a2}: Significant differences do exist among BMD, and muscle strength between MR and NMR pre-menopausal adult females.

H_{o2}: No significant relationships exist between BMD, LMM, and muscle strength in pre-menopausal females with MR.

H_{a2}: Significant relationships do exist between BMD, LMM, and muscle strength in pre-menopausal females with MR.

METHODS

This investigation employed a single ex post facto design with mental retardation status as the independent variable. A total of 32 pre-menopausal female subjects, 16 with MR and 16 without MR volunteered to participate in the study. The age range of the subjects was from 19.50 to 44.83 years of age.

Subject Characteristics

Based on the American Association of Mental Retardation, the definition of mental retardation refers to substantial limitations in certain personal capabilities. It is manifested as significantly subaverage intellectual functioning, existing concurrently with related disabilities in two or more of the following applicable adaptive skill areas: communication, self-care, home living, social skills, community use, self-direction, health and safety, functional academics, leisure, and work. Mental retardation begins before age 18 (Luckasson et al., 1992). All subjects with MR consisted of volunteers who live in the community of Corvallis, OR, or its surrounding areas.

In order to be included into the study (both MR & NMR subjects), the following inclusion criteria were met: (a) subjects were female older than 18 years of age; (b) subjects were independently ambulatory; (c) subjects did not take any medications known to

affect bone metabolism (except for oral contraceptives); (d) subjects were in good health and free from any life-threatening diseases such as cancer; and (e) subjects were able to lie quietly on the bone densitometer for 15 minutes. Anyone who did not meet all of these criteria was excluded from the study. No exclusion criterion based on ethnicity was enforced.

Although requirements for inclusion into the study were considered stringent, these criteria were needed to maximize the accuracy of the obtained results, particularly for the MR subjects. For example, individuals with MR who could not maintain a motionless horizontal position on the bone densitometer were excluded from the study because this would have greatly reduced the accuracy of the BMD measurement. Efforts were made to orient the subject and encourage subjects to remain quiet. Music or other similar reinforcers were used to help keep the subjects still during BMD testing. Subject heterogeneity may have been compromised by having such criteria, however, accuracy of data was not.

Sampling Procedures

All subjects were recruited from the Corvallis, OR, area. Females with MR were identified in cooperation with program directors of persons served by mental health/developmental disabilities agencies in the surrounding counties. Possible subjects and/or their parent(s)/guardian(s) were mailed a letter requesting participation in the study (see Appendix B) and a

description of the proposed study, including its benefits and risks (see Appendix C).

Interested subjects mailed a completed "interest in participation form" back to the primary investigator (see Appendix D). Upon receipt of this form, the possible subject was contacted to arrange the initial health screening and interview.

All the inclusion requirements were met for subject selection. After selection, each subject: (a) was verbally informed of the all the possible risks, benefits, and rights as a volunteer participant in the study; (b) gave her consent to participate in this study by signing an informed consent form (see Appendix E); (c) underwent a familiarization process with the procedures for BMD and strength measurements; and (d) was scheduled to come to the bone laboratory a second time for strength testing and bone scan measurements.

Subjects in the nonmentally retarded group (NMR) were selected and matched to the MR group according to age, menopausal status, body mass index (BMI), and use or non-use of oral contraceptives. These subjects met the same inclusion requirements as the MR subjects, but were measured on the bone densitometer in previous research from the OSU Bone Research Laboratory. Thus, the data for the NMR group were obtained from existing records.

Informed Consent

The Oregon State University Institutional Review Board approved this project prior to data collection (see Appendix F). It should be noted that many

individuals with MR over the age of 21 years gave their consent without any parent/guardian approval. As determined by the OSU Institutional Review Board, the selected NMR subject did not have to provide additional consent for this study.

Data Collection

All participants were subjected to evaluation in the following areas: (a) physical activity and osteoporosis risk assessment; (b) bone mineral density assessment; (c) muscle strength; and (d) body composition. All testing, except for the physical activity and osteoporosis risk assessment, took place at the Department of Exercise and Sport Science of Oregon State University (Corvallis, Oregon). Transportation assistance to the facility was arranged by the primary investigator.

Physical Activity and Osteoporosis Risk Assessment

For the subjects with MR, a physical activity and osteoporosis risk assessment based on medical history was given in order to verify pre-menopausal status and to determine eligibility into the study. This assessment (Appendix G) was an abridged version of the Oregon State University Bone Research Laboratory Health and Physical Activity Questionnaire. The questionnaire was completed with the assistance of parents and/or group home supervisors who were familiar with the subject. Sources of medical information came directly

from medical records from the subjects' local county mental health office, private physician, or indirectly from guardian knowledge of the subject. Consent to access this information was given by the subject and/or the parent/guardian. Information gathered from this questionnaire included menopausal status, physical activity levels, dietary habits, and medications taken. Upon completion of this form, subjects were screened for eligibility and inclusion into the study.

Bone Mineral Assessment

Bone mineral density (BMD = grams of calcium hydroxyapatite/cm^2) of the proximal femur and whole body was measured at the Oregon State University Bone Research Laboratory using the Hologic QDR 1000W dual energy x-ray absorptiometer. A qualified technician operated this apparatus for all bone scans. The order of which the bone scans were performed was first, the proximal femur, and second, the whole body. The proximal femur was analyzed specifically at the femoral neck. The coefficient of variation for replicate measures was less than 1% at the site of the femur and less than 1.5% for the whole body.

The use of this technique to measure BMD requires the subject to lie in a supine position on the scanning table. A scanning arm located above the table is carefully positioned over the area of interest with the help of a laser. An x-ray source and detector, controlled by a computer interface, is scanned back and

forth across the area of interest (i.e. femoral neck or whole body).

The method of assessment utilized a noninvasive dual energy x-ray technique (Hologic, Waltham, MA), which allows both cortical and trabecular bone to be measured more quickly, accurately, and consistently than single and dual photon absorptiometry techniques. Because single photon absorptiometry does not account for soft tissue, this technique would be inappropriate since the femur is surrounded by both muscle and fat tissue (Snow-Harter & Marcus, 1991). Quantitative computed tomography (QCT) is another method that has been used to detect trabecular bone. Although the coefficient of variation for repeated measurements has been as low as 1.6% for QCT, radiation exposure is considerably higher (500-1,000 millirem) than DEXA (2-5 millirem). The radiation dosage for DEXA is only about 1/10 of the exposure for a standard chest x-ray. These very low levels emitted by the bone densitometer are highly unlikely to be hazardous to the subjects.

Muscle Strength

Several indices of muscular strength were measured in this investiagtion. A hand-held grip dynamometer was used to measure grip strength and an isokinetic device was used to measure strength in both the biceps brachii and hip flexor muscles.

Overall muscle strength was assessed using a grip strength dynamometer. Isometric grip strength has been accepted as an indicator of overall muscle strength in normal populations and has also been determined to be a

reliable method of assessing grip strength in children with MR (Kasch & Zasueta, 1971).

The Jamar Dynamometer (Asimow Engineering Co., Santa Monica, CA) consists of an adjustable handle and hydraulic mechanism attached to a meter that measures peak force (kg) applied. A modified Jamar version was used in this study. A force transducer which is capable of producing an output voltage that is proportional to the applied force was attached in replace of the meter. The voltage was sampled at a frequency of 200 Hz using a DAS-8 (Metrabyte) analog-to-digital board in an MS-DOS Compaq Portable II computer. The use of this device has provided a force measurement accuracy of better than ± 0.09 kg (Smith, Nelson, Sadoff, & Sadoff, 1989).

The subject used the dominant hand to squeeze the handle and was tested in an upright position. One trial consisted of squeezing the dynamometer as hard as possible for a period of 5 seconds. A demonstration and practice trial preceded 6 actual trials interspersed with rest periods of greater than than 1 minute. Peak force values (kg) were stored on a computer disk and used in the statistical analysis.

The KinCom 500H (Chattecx Corp., Hixson, TN) was used to assess elbow flexion and knee extension isokinetic muscular strength. All movements were performed at a speed of 30 degrees per second. Each subject was tested 5 times on each movement with a minimum of 1 minute of rest in between trials. A gravity correction procedure was used in determining peak force generated during the strength maneuver. Of all 5 trials for each movement, the highest peak force generated was recorded.

With elbow flexion, the subject was stabilized in a seated position with the right arm extended (resting on a pad) and the palmar side of the hand facing upward. A lever arm was attached at the wrist with the axis positioned at the elbow. Upon verbal request, the subject flexed the arm as hard and as quickly as possible from 0 degrees (extension) to approximately 110 degrees (flexion).

With knee extension, the subject was stabilized in a seated position with the lever arm attached just above the lateral malleolus of the left tibia and the axis positioned at the knee joint. Upon verbal request, the subject extended the lower leg from 90 degrees (flexion) to approximately 180 degrees (extension).

Body Composition

Lean muscle mass data were generated from the whole body scan procedure on bone densitometer. Using this technique allowed lean mass to be determined using a three-compartment model (i.e. bone, muscle, and fat tissue) rather than the traditional two-compartment model (i.e. lean and fat tissue). Thus, the lean mass value reflected tissue independent of bone.

Percent body fat data were also generated from the whole body scan on the bone densitometer. This method had been found to highly correlate ($r = .95$) with hydrostatic weighing in a small group of persons without mental retardation in studies done at the Human Performance Laboratories at Oregon State University. The potential for problems in test administration with hydrostatic weighing and validity concerns with skinfold

measurements in individuals with MR prompted the use of this method. The accuracy and simplicity of testing procedures was considered the most feasible and valid method of determining percent body fat.

Data Analysis

Means, standard deviations, and other descriptive statistics were calculated for BMD, strength, and body composition profiles for each group. Multivariate analyses of variance (MANOVA) were used to determine if differences exist between groups (MR and NMR) among BMD and isokinetic strength of the bicep and quadricep muscle groups. Grip strength was not entered into the MANOVA analysis since the NMR group was not measured on this variable. The significance level was set at an alpha level of .05.

Multiple linear regression techniques were used to obtain correlation coefficients between BMD, body composition, and strength for each group (Neter, Wasserman, & Kutner, 1989). Stepwise regression analysis (with and without an indicator variable) was also used to determine which variables best predicted BMD in both groups. These regression techniques were tested for significance at an alpha level of 0.05. In addition, simple linear regressions were employed to determine correlation coefficients between subject characteristics and femoral neck and whole body BMD. An alpha level of 0.01 was chosen as the criterion for significance since multiple comparisons were used to help control for Type I error.

Multivariate analyses were computed using the SuperANOVA (Abacus Concepts, Inc., Berkeley, CA) statistical software program while regression analyses were computed using the StatView II (Abacus Concepts, Inc., Berkeley, CA) personal computer statistical software program. The Oregon State University Department of Statistics Consulting Service was also consulted for assistance with data analysis.

Power Analysis

No power analysis techniques have been developed for multivariate statistics (without repeated measures). In light of this, it has been suggested that univariate power tables be used for reference. In doing so, adequate statistical power for between groups analysis has been achieved as determined by Cohen (1988).

In addition, statistical sources recommend that there be more cases than two times the number of dependent measures (Tabachnick & Fidell, 1989). This particular criterion has been met in this investigation.

Assumptions

1. The KinCom 500H muscle testing device provided valid isokinetic measurements in premenopausal adult females with MR.
2. The MR group understood all directions and was motivated to perform all strength maneuvers with maximal effort.

Delimitations

1. Only subjects with MR with certain characteristics were included in the study (e.g. inclusion and exclusion criteria). There was considerable sampling bias in recruiting subjects who were able to meet the requirements of the study.
2. Only 16 subjects with MR, 2 with Down syndrome, participated in the study.
3. Subjects came from Corvallis, OR, and its surrounding areas.

Limitations

1. Calcium nutrition, dietary intake, and lifestyle factors were not measured directly.

RESULTS

A total of 32 pre-menopausal subjects were used in all data analyses. Sixteen subjects in the MR group were matched by age, BMI, and the type of birth control with 16 control subjects (NMR). Two of the subjects in the MR group had Down syndrome (DS). Two subjects in each group were currently on oral contraceptives at the time of testing. There were no missing values for any measure.

General Characteristics

Table 1A depicts means and standard deviations of age, height, weight, and BMI characteristics for each group. See Appendix H, Description of Variables, for frequency distributions and standard scores for these variables.

A one-way MANOVA was computed to detect any differences between MR and NMR groups on the matching variables of age and BMI. Wilks' Lambda criterion revealed no significant differences between groups among age and BMI ($F_{2,29} = .695$, $p = .51$). Mean age was 28.14 $\pm$ 8.43 years and 29.64 $\pm$ 10.86 years for the MR and NMR groups, respectively. Although BMI was slightly higher in the MR group than the NMR group (26.07 $\pm$ 4.38 and 24.58 $\pm$ 2.97, respectively), no significant difference was obtained. In addition, it was revealed that no significant difference existed between MR and NMR

TABLE 1A

Mean Age, Height, Weight,
and Body Mass Index of MR and NMR Subjects

	MR (n = 16)		NMR (n = 16)
Age (yrs)	28.14 ± 8.43	NS	29.64 ± 10.86
Height (m)	1.56 ± 0.06	**	1.65 ± 0.06
Weight (kg)	63.19 ± 12.08	NS	67.22 ± 7.19
BMI (kg/m2)	26.07 ± 4.38	NS	24.58 ± 2.98

** $p < .001$; NS $p \geq .05$

subjects for weight (63.19 kg and 67.22 kg, respectively; $F_{1,30} = 1.316$, $p > .05$). However, a significant difference existed between the groups for height ($F_{1,30} = 18.173$, $p < .001$) with the NMR group being taller than the MR group (1.56 m vs. 1.65 m). Table 1B gives the range of values and standard error for each characteristic for both MR and NMR groups.

TABLE 1B

Range of Scores and Standard Errors of
Age, Height, Weight, and BMI for MR and NMR groups

	MR		NMR	
	Range	SE	Range	SE
Age (yrs)	19.50 - 44.83	2.11	18.50 - 47.00	2.72
Height (m)	1.45 - 1.65	1.58	1.55 - 1.78	1.62
Weight (kg)	44.24 - 93.29	3.02	53.51 - 78.00	1.80
BMI (kg/m2)	18.43 - 34.76	1.10	18.48 - 29.51	0.74

BMD, Body Composition, and Strength

Mean values and standard deviations are depicted in Table 2A. Table 2B reports the range and standard error for each quantity. All measures were considered normally distributed based on sigmoidal-shaped cumulative frequency curves generated on each variable for each group. Additionally, excessive skewness and kurtosis values ($> \pm 3.00$) were also evaluated in determining normality. The presence of outliers was determined using a criterion of standard Z-scores for each data point greater than ± 3.00. No outliers were detected. See Appendix H for cumulative frequency

TABLE 2A

Bone Density, Body Composition, and Strength Measurements

	MR (n = 16)		NMR (n = 16)
Bone Density (g/cm^2)			
FBMD	.845 ± 0.13	NS	.910 ± 0.13
WBMD	1.068 ± 0.09	NS	1.108 ± 0.07
Body Composition			
LMM (kg)	39.87 ± 5.85	**	47.18 ± 4.00
BF (%)	31.88 ± 8.74	*	26.03 ± 4.01
Strength (kg)			
biceps	8.33 ± 2.30	***	15.13 ± 3.92
quadriceps	25.65 ± 9.49	***	55.78 ± 11.90
grip	19.20 ± 7.06	#	

Grip strength measurements were taken only on the MR group.

* $p < .05$; ** $p < .001$; *** $p < .0001$; NS $p > .05$

distributions, skewness and kurtosis values, and standard scores for each variable.

The multivariate analysis of variance for FBMD, WBMD, LMM, BF, biceps strength (BS), and quadriceps strength (QS) was found to be significant ($F_{5,26} = 23.08$,

$p < .0001$) using the Wilks' Lambda Criterion. (See Appendix I for all MANOVA output and Appendix J for evidence of meeting MANOVA assumptions.) Subsequent analyses of variance ($F_{1,30}$) revealed that LMM ($F = 17.06$, $p < .001$), BF ($F = 5.92$; $p < .03$), BS ($F = 35.81$; $p < .0001$), and QS ($F = 62.70$; $p < .0001$) were all significantly different between the MR and NMR groups.

With body composition variables, subjects in the MR group had, on average, less LMM (39.87 ± 5.85 kg vs. 47.18 ± 4.00 kg), but more percent BF ($31.88 \pm 8.74\%$ vs. $26.03 \pm 4.01\%$) than subjects in the NMR group. Interestingly, 50% of the subjects in the MR group (8 of 16) had body fat in excess of 30% (therefore considered obese), while only 25% of the subjects in the NMR group (4 of 16) had body fat in excess of 30%.

In view of the strength variables, the MR group yielded lower values than the NMR group in both BS (8.33 ± 2.30 kg vs. 15.13 ± 3.92 kg) and QS (25.65 ± 9.49 kg vs. 55.78 ± 11.90 kg). No comparisons were made between groups on GS since the NMR group was not measured on this variable.

Although the average FBMD value was lower for MR subjects ($.845 \pm .13$) than NMR subjects ($.910 \pm .13$), this difference did not reach significance ($p = .1665$). Similarly, the average WBMD value was also lower for MR subjects ($1.068 \pm .09$) than NMR subjects ($1.108 \pm .07$), but this difference was not significant as well ($p = .1802$).

TABLE 2B

Range of Scores and Standard Errors of Bone Density, Body Composition, and Strength Variables for MR and NMR Groups

	MR		NMR	
	Range	SE	Range	SE
Bone Density (g/cm2)				
FBMD	.673 - 1.149	.03	.717 - 1.179	.03
WBMD	.923 - 1.306	.02	.977 - 1.205	.02
Body Composition				
LMM (kg)	29.84 - 55.45	1.46	39.88 - 52.14	.99
BF (%)	19.90 - 53.60	2.19	20.00 - 32.00	1.00
Strength (kg)				
Biceps	5.62 - 13.47	.58	9.48 - 22.86	.98
Quadriceps	9.39 - 41.59	2.37	25.71 - 75.96	.98
Grip	8.17 - 38.60	2.04		

Relationships With Bone Mineral Density

Multiple linear regression was used to determine correlation coefficients between BMD and LMM, BF, BS, and QS. For multiple linear regression analysis output, see Appendix K. Correlates with FBMD are given in Table 3 for both MR and NMR groups. With LMM, BF, BS, and QS entered into the regression model, only LMM was

TABLE 3

Correlations with FBMD in MR and NMR Groups and their Associated p-values

	FBMD			
	MR	p	NMR	p
Body Composition				
LMM (kg)	.74**	.0040	.45	.8573
BF (%)	.01	.9474	-.31	.9534
Strength (kg)				
BS	.43	.4026	.68	.0992
QS	.30	.3694	.57	.1338

**p < .01

significantly correlated ($p < .01$) with FBMD in the MR group ($r = .74$; $r^2 = .552$; refer to Figure 1). Neither of the body composition or strength variables were significantly correlated with FBMD in the NMR group.

FIGURE 1

Relationship Between Femoral Neck BMD and Lean Muscle Mass in MR Group

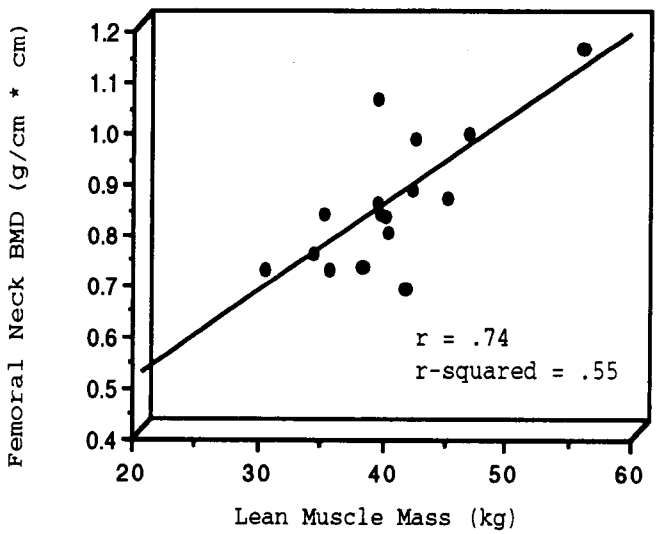


Table 4 presents correlation coefficients of WBMD with LMM, BF, BS, and QS derived from multiple linear regression. As was the case with FBMD, only LMM was significantly ($p < .001$) correlated with WBMD for

TABLE 4

Correlations with WBMD in MR and NMR Groups and their Associated p-values

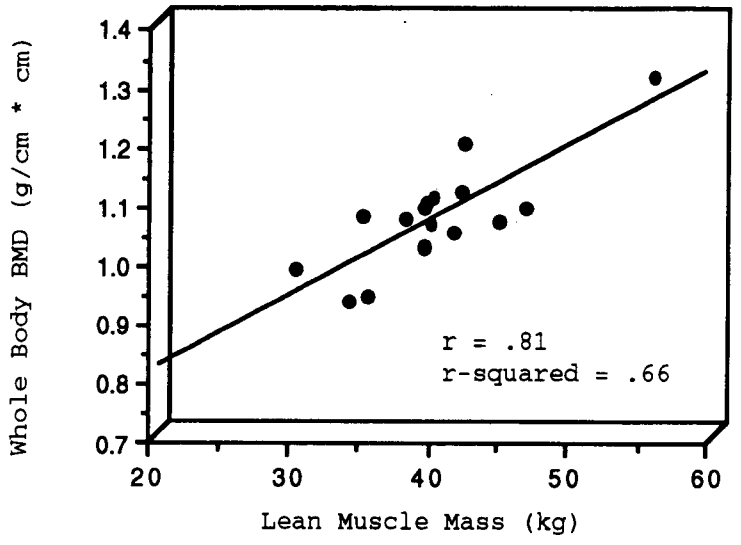
	WBMD			
	MR	p	NMR	p
Body Composition				
LMM	.81**	.0006	.62	.1037
BF	.22	.0691	-.18	.7818
Strength				
BS	.39	.0515	.52	.8704
QS	.09	.4649	.67*	.0349

*p < .05; **p < .001

subjects in the MR group (r = .81; r^2 = .66; refer to Figure 2). Interestingly, although not statistically significant, both BF and BS approached significance (p = .0691 and p = .0515, respectively).

FIGURE 2

Relationship Between Whole Body BMD and Lean Muscle Mass in MR Group

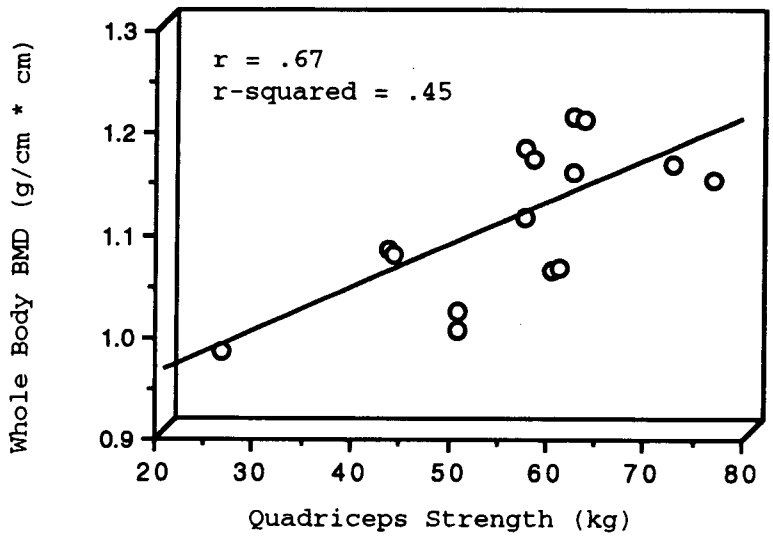


In the NMR group, QS was the only measure that was significantly ($p < .05$) correlated with WBMD ($r = .67$; $r^2 = .45$; refer to Figure 3). However, it is noteworthy that LMM did have a fairly low p-value ($p = .1037$).

Other relationships between BMD were determined through simple regression. Multiple comparisons were accommodated by using a significance level of alpha = .01 to control for Type I errors. Table 5 depicts the relationships between BMD and age, height, weight, BMI, and GS.

FIGURE 3

Relationship Between Whole Body BMD and Quadriceps Strength in NMR Group



The only significant correlation was between body weight and WBMD in the MR group ($r = .67$; $r^2 = .45$). The regression between body weight and FBMD also seemed to approach significance ($p = .0435$; alpha = .01) in the MR group.

TABLE 5

Simple Regressions for Age, Height, Weight, BMI, and Grip Strength on BMD

	FBMD				WBMD			
	MR	p	NMR	p	MR	p	NMR	p
Age	-.22	.4063	-.50	.0485	-.20	.4610	-.09	.7461
Height	.29	.2756	.08	.7811	.26	.3249	.16	.5540
Weight	.51	.0435	.21	.4363	.67*	.0046	.43	.0983
BMI	.38	.1423	.26	.3307	.58	.0172	.29	.2749
GS#	.21	.4656	-	-	.07	.8100	-	-

#No measures of GS were taken for NMR group.
*$p < .01$

Stepwise Regression Analysis

Forward stepwise regression analysis was used to determine which variables best predicted FBMD and WBMD. First, an indicator variable for group status was used in the following model:

$$Y_i = B_{oi} + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5,$$

where, Y_i = BMD (FBMD or WBMD),
B_{oi} = intercept,
B_1 = beta(X1),
X_1 = indicator {0 = MR, 1 = NMR},
B_2 = beta(X2),
X_2 = LMM,
B_3 = beta(X3),
X_3 = %BF,
B_4 = beta(X4),
X_4 = BS,
B_5 = beta(X5), and
X_5 = QS.

Stepwise regression analysis revealed that LMM was the best predictor for both FBMD ($F_{1,30} = 19.66$, $p < .01$) and WBMD ($F_{1,30} = 32.39$; $p < .01$). None of the other variables was significant to enter into the model equation.

For FBMD, the resultant prediction equation was:

FBMD = .285 + [.014 * LMM].

The correlation between the fitted FBMD, predicted from LMM, and the observed FBMD was R = .63. R^2 was .39 and the adjusted R^2 was.38.

For WBMD, the resultant prediction equation was:

$$\mathbf{WBMD = .659 + [.010 * LMM]}.$$

The correlation between the fitted WBMD, predicted from LMM, and the observed WBMD was R = .72 . R^2 was .52 and the adjusted R^2 was .50. See Appendix L for all stepwise regression analysis output.

Since the indicator variable in the above analysis was not significant, stepwise regression analysis was also used to determine which variables best predicted FBMD and WBMD for each MR and NMR group separately.

In the MR group, LMM was the best predictor for both FBMD ($F_{1,14} = 17.24$; $p < .01$) and WBMD ($F_{1,14} = 27.30$; $p < .01$). Correlations between fitted BMD and observed BMD, predicted by LMM, for the femoral neck and whole body were .74 and .81, respectively. The resultant R^2's were .55 and .66, respectively. The prediction equations that best determined BMD in the MR group are as follows:

$$\mathbf{FBMD_{MR} = .168 + [.017 * LMM]}, \text{ and}$$

$$\mathbf{WBMD_{MR} = .561 + [.013 * LMM]}.$$

In the NMR group, BS was the best predictor of FBMD ($F_{1,14} = 12.24$; $p < .05$). The correlation between fitted FBMD and observed FBMD, predicted by BS, was .68. The

resultant R^2 and adjusted R^2 were .47 and .43, respectively. The following equation best predicts FBMD in the NMR group:

$$\mathbf{FBMD_{NMR} = .570 + [.023 * BS].}$$

The best predictors of WBMD in the NMR group were both QS and LMM ($F_{2,13} = 11.98$; $p < .05$). When these two variables were used to predict WBMD, the correlation between fitted and observed WBMD was .805. The resultant R^2 and adjusted R^2 were .65 and .59, respectively. The following equation best predicted WBMD in the NMR group:

$$\mathbf{WBMD_{NMR} = .514 + [3.347E\text{-}3 * QS] + [8.641E\text{-}3 * LMM].}$$

DISCUSSION

The need for identifying BMD levels in special populations is an important health consideration. People with MR have reduced physical activity levels, possess low muscle strength and muscle mass, and have frequently been found to be obese (Fernhall, Tymeson, & Webster, 1988; Kelly et al., 1986; Pitetti, 1990). These characteristics can be changed through structured exercise programs and are important factors in skeletal health, an important health issue particularly among women.

Further concern for skeletal health in individuals with MR has been demonstrated in a study regarding the number and rate of bone fractures in adult persons with mental retardation. Tannenbaum and colleagues (1989) observed that about 10% of people with MR residing in intermediate health care facilities (55 of 553) had experienced bone fractures. Additionally, the fracture rate among their sample of subjects was approximately 3.5 times higher than the relative population. This study contributes to the concern of aging and its consequences in individuals with developmental disabilities (Ansello & Rose, 1989; Janicki & MacEachron, 1984).

In light of the information mentioned above, two major research questions were addressed in this investigation. First, do pre-menopausal women with MR have lower bone density values than similar pre-menopausal women without MR? Secondly, what are the

specific relationships between bone density, strength, and body composition in pre-menopausal women with MR? With respect to these questions, BMD (FBMD and WBMD), body composition (LMM and %BF), and strength (BS and QS) were measured in 16 pre-menopausal adult subjects with MR and compared to 16 control NMR subjects. Relationships between BMD and the body composition and strength variables were determined.

Bone Mineral Density

Results revealed no statistical differences existed between the MR and NMR groups for both FBMD and WBMD. Mean FBMD values were .845 $\pm$ .13 g/cm^2 and .910 $\pm$ .13 g/cm^2 for the MR and NMR groups, respectively. Mean WBMD values were 1.068 $\pm$ .09 g/cm^2 and 1.108 $\pm$ .07 g/cm^2 for the MR and NMR groups, respectively. Although not statistically different, values seemed to approach significance for both of these variables (FBMD: $p = .1665$; WBMD: $p = .1802$).

To conclude that there are no true differences between populations with and without MR is not warranted. It is possible that significant differences may have been reached had their been more subjects in this investigation. Thus, the degree of Type II error may have been great enough to reduce the statistical power needed to find significant differences between our samples of MR and NMR subjects for FBMD and WBMD. Another possible reason for not finding statistical significance could be attributed to large variances

among the variables in the MR group relative to the NMR group (refer to Appendix H).

The average percent differences between groups for FBMD and WBMD were 7.14% and 3.61%, respectively. Although actual BMD values were not statistically significant, these percent differences may indeed reflect a practical difference between the groups. It may be that these differences, although statistically minute, are large enough to warrant caution in risk for osteoporosis.

Accuracy of Measured BMD Values

The validity of the resultant bone density values was a concern throughout the investigation. The MR subjects' ability to lie motionless in a supine position on the bone densitometer was initially questioned, though not confirmed following the study.

Despite concerns of measurement inaccuracies in subjects with MR, it became apparent that there was no reason to doubt the validity of these measurements. Standard errors in the MR group was .033 for FBMD and .023 for WBMD while in the NMR group, standard errors were .032 and .019, respectively. Possible sources of measurement error either came from inherent random error of the bone densitometer or from the subject's ability to participate accordingly in the measurement process. Significant error stemming from the bone densitometer is highly unlikely given that precision is less than 1% and 1.5% for the FBMD and WBMD scans, respectively.

Error stemming from the MR subjects' ability to lie still during the bone scans was also considered

unlikely. None of the 16 subjects with MR had any difficulty with completing the bone scanning process. This may have been attributed to the equipment and procedural familiarization process that several subjects underwent in order to maximize accuracy of results. On the other hand, there may have been a sampling bias toward MR subjects with certain characteristics i.e. inclusion requirements.

Table 6 provides a summary of BMD values measured in subjects from this study and other studies with non-MR groups. Most of the subjects from the other studies were considered as sedentary controls or from the general population. Although direct conclusions should not be made since many other variables were not taken into account (e.g. method of determining bone density and physical activity levels), it does provide a general frame of reference of how the data in this study compare with other studies.

Comparisons show that FBMD is lower than the other studies. Even when the subjects were older (Peterson et al., 1991), FBMD is still relatively lower in our subjects with and without MR. Mean WBMD values from Howat et al. (1989) were also higher than the subjects in this study. Matching factors could account for the lower BMD values in our subjects with MR. Again, direct inferences cannot be made; however, these comparisons help to show that bone density values measured in this investigation are plausible.

TABLE 6

Comparison of BMD Values with Other Studies with Subjects of Similar Characteristics

Study		FBMD	WBMD	N	age	method
Felix '93	MR	.845 ± .13	1.068 ± .09	16	28.14 ± 8.43	DEXA
	NMR	.910 ± .13	1.108 ± .07	16	29.64 ± 10.86	DEXA
Mazess et al.,'91		1.02 ± .69	---	46	20 - 24	DPA
		.98 ± .10	---	50	25 - 29	DPA
		1.00 ± .13	---	69	30 - 34	DPA
		.96 ± .12	---	75	35 - 39	DPA
		.99 ± .12	---	218	20 - 39	DPA
Snow-Harter et al.,'90		.93 ± .02	---	59	23.40 ± .58	DEXA
Peterson et al.,'91		.892 ± .09	---	19	51.60 ± 6.1	DPA
Howat et al.,'89		---	1.20 ± .08	10	21.50 ± .88	hydrost weigh

DEXA = Dual Energy X-ray Absorptiometry; DPA = Dual Photon Aborptiometry; hydrost weigh = hydrostatic weighing

Differences Through Regression

Another attempt to find statistically significant differences between groups for FBMD and WBMD was employed through forward stepwise progression procedures with an indicator variable. However, the results of the

stepwise regression analysis did not find significant beta coefficients for the indicator variable when trying to predict either FBMD or WBMD (see Appendix L). Using this analysis, LMM was the best predictor of bone density in our sample of subjects (see stepwise regression analysis discussed below).

To this point, this discussion has emphasized the possibility of existing significant differences between MR and NMR groups for FBMD and WBMD. Yet, another alternative possibiltiy exists. Simply, that there are no differences between groups with MR and NMR for FBMD and WBMD. From an ethical standpoint, this finding should be viewed in a positive manner.

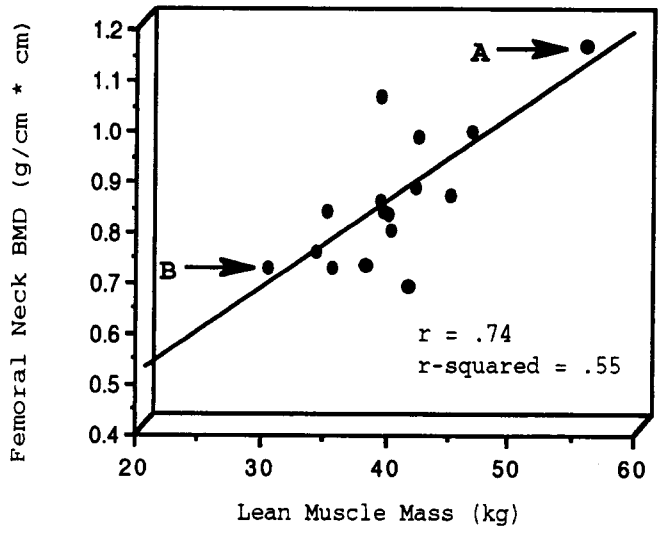
Physical Activity and BMD

A summary report of physical activity and osteporosis risk in subjects with MR can be found in Appendix N. Although not quantified, physical activity of several case subjects with MR may provide valuable insight regarding the influence of physical activity on bone density.

Subject A had the highest FBMD and WBMD among the MR subjects (refer to Figures 4 and 5). Moreover, she was very physically active relative to other subjects with MR. She was actively participating in Special Olympics sports programs for 2 times per week nearly year-round. Her involvement in these sports programs included track and field, bowling, basketball, softball, and downhill skiing. She reportedly liked to walk downtown and throughout a local shopping mall for approximately 1 mile 1 to 2 times per week. Her present

FIGURE 4

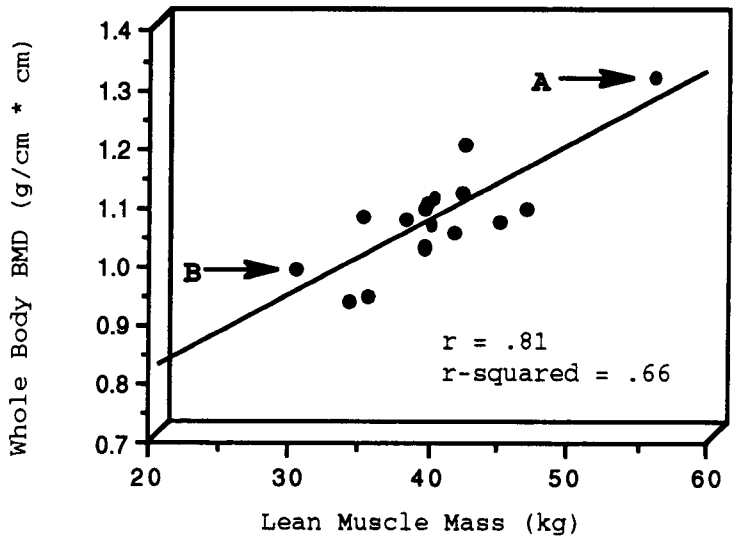
Relationship Between Femoral Neck BMD and Lean Muscle Mass in MR Group: Comparison of Subjects A and B



work duties consisted of sorting, labelling, and stacking boxes at a vocational workshop for individuals with developmental disabilities. She has maintained her work schedule of 6 hours per day 5 days per week for the last 2 years. Hours of TV watched was estimated at 1 hour per day. Although anecdotal, subject A's physical activity habits may have positively enhanced BMD of both the whole body and femoral neck.

FIGURE 5

Relationship Between Whole Body BMD and Lean Muscle Mass in MR Group: Comparison of Subjects A and B



Subject B had one of the lowest FBMD values and the third lowest WBMD value relative to other subjects with MR (refer to Figures 4 and 5). Her physical activity levels were clearly not as rigorous relative to those of subject A. Subject B participated only in Track and Field Special Olympics. Her involvement included a walking event and a throwing event. She was employed at a local credit union and worked 4 hours per day, 4 days per week for the last 2 years. Her work duties consisted primarily of copying receipts onto microfiche,

but she also performed light cleaning duties such as dusting and arranging papers. She mentioned that she did not like to exercise, but does take an occasional walk. Hours of TV watched was estimated at 3.5 hours per day. After testing, subject B fractured her ankle at a recent Special Olympics track and field event.

Although subjective, the physical activity habits of subjects A and B seem to reflect their level of bone density. In these case scenarios, the notion that physical activity levels contribute to bone density does hold true. Caution must be taken in this implication, since other factors are not considered e.g. lean muscle mass, diet, and genetics. In general, most of the physical activity levels among the other subjects with MR were higher than that of subject B, but lower than subject A.

Body Composition and Muscle Strength

Body Composition

Statistical differences among both LMM ($p < .001$) and %BF ($p < .03$) between the MR and NMR groups were expected. The MR group had significantly more body fat and less muscle mass than the NMR group.

Mean body fat percentage was 31.88 $\pm$ 5.85% for the MR group while the NMR group had a mean value of only 26.03 $\pm$ 4.01%. Using the 30% body fat criterion (McArdle, Katch, & Katch, 1993), 50% (8 of 16) of the subjects in the MR group were considered obese while only 25% (4 of 16) of the subjects in the NMR group were considered obese.

Similar to the results of this study, other research has shown that obesity is prevalent in the MR population. In a study by Kelly, Rimmer, & Ness (1986), multiple skinfold and girth measurements were taken to determine percent body fat in 553 subjects with MR, ages 18 to 40 years (mean age = 27 years). The results revealed that 50.5% of the females were obese. In addition, it was also observed that individuals with more mild levels of MR had the highest body fat percentage and prevalence of obesity relative to the more profound levels of MR. In this investigation, all of the MR subjects had mild mental retardation.

Since two subjects in the MR group had Down syndrome, there is a concern that these data may have skewed the body fat mean value. Research on individuals with both MR and Down syndrome have shown that they may exhibit more fat mass and percent body fat than individuals with MR alone (Ovalle, Cole, Climstein, & Dunn, 1991). However, this was not the case in this study. In fact, their body fat data points were below the mean value (19.90% and 26.40%).

Mean lean mass, independent of bone tissue, was significantly ($p < .001$) lower for the MR group (39.87 ± 5.85 kg) than the NMR group (47.18 ± 4.00 kg). To date, no studies have been conducted to directly determine muscle mass in individuals with MR. Given the generalization of lower fitness levels in individuals with MR, it is not surprising that muscle mass was significantly lower in the MR group than the NMR group. The lower lean muscle mass values in the MR group parallel their lower strength values relative to the NMR group.

Muscle Strength

Consistent with other literature, the MR group yielded significantly ($p < .0001$) lower values of BS and QS compared to the NMR subjects. Isokinetic strength at the biceps was 8.33 ± 2.30 kg and 15.13 ± 3.92 kg for the MR and NMR groups. Isokinetic strength at the quadriceps was 25.65 ± 9.49 kg and 55.78 ± 11.90 kg for the MR and NMR groups.

These values show that the MR group had lower isokinetic strength levels by approximately 45% at the biceps and 54% at the quadriceps than the NMR group. Some studies indicate that adults with MR may have lower strength values with a range from 30% to 78% compared to other adults with MR (Fernhall, 1993; Nordgren, 1970).

Mean grip strength was 19.20 ± 7.06 kg for the MR adults. Although no comparisons could be made for this measure, the mean value for GS in this study is lower than other mean values reported elsewhere in other subjects without MR (Snow-Harter et al., 1990).

Body Composition and Strength Relationships with Bone Mineral Density

Correlations derived through multiple linear regression among LMM, %BF, BS, and QS with FBMD and WBMD can be found in Tables 4 and 5 (pages 28 and 31) of the Results section. Computer output from this analysis can be found in Appendix K and evidence for meeting multiple regression assumptions can be found in Appendix M.

Body Composition

In the MR group, a significant positive relationship existed between LMM and both FBMD ($r = .74$; $p < .001$) and WBMD ($r = .81$; $p < .05$). As expected in this sample, as the amount of muscle mass increased, bone mineral density at the femoral neck and of the whole body increased. Refer to Figures 1 and 2 (pages 27 and 29) in Results section. Coefficients of determination indicate that 55% of the variance in FBMD can be attributed to LMM. With WBMD, 66% of its variation can be attributed to LMM.

These findings are in support of the hypothesis that bone density is influenced by loading on the skeleton induced by the amount of muscles mass (Nilsson & Westlin, 1971; Rutherford & Jones, 1992). Consequently, a person with large muscle mass will be able to generate relatively high levels of skeletal loading compared to someone with small muscle mass thereby having higher bone density values. Doyle and colleagues (1970) found a significant correlation ($r = .52$; $p < .001$) between the ash weight of the third lumbar vertebral body from 46 necropsies even when body weight, age, and height were taken into account. The authors concluded that the weight of a muscle reflects the forces that it exerts on the bones to which it is attached and, moreover, that muscle weight is an important determinant of bone mass.

In the NMR group, however, a significant relationship was not found between LMM and both FBMD ($p = .8573$) and WBMD ($p = .1037$). It is not clear why the NMR group did not demonstrate a similar association

found in the MR group. Upon inspection of the data, however, it was noticed that the variance for the NMR group was approximately 50% of the variance for the MR group. The homogeneity of LMM data points for the NMR group may have contributed to a nonsignificant relationship between LMM and the BMD values.

Neither group yielded significant relationships between body fat and FBMD or WBMD. Correlations ranged from $r = .01$ to $r = -.31$ in both groups. These results were consistent with the literature. It has been found that fat mass is not a robust predictor of bone density (Shaw et al., 1993; Snow-Harter et al., 1993; Sowers et al., 1992; Wegner et al., 1993). Rather, these investigations have found that LMM is a robust predictor of bone density in both pre- and post-menopausal women at the whole body, lumbar, and femoral neck sites.

Muscle Strength

Only one significant relationship existed between the strength variables and BMD. In the NMR group, isokinetic strength of the quadriceps had a positive relationship with WBMD ($r = .67$; $p < .05$). As quadriceps strength increased, WBMD increased. This relationship is consistent with the hypothesis that bone will remodel (adapt) in response to muscular forces exerted upon it. Although not significant, the relationship between BS and WBMD in the MR group approached significance ($p = .0515$)

Many other studies have found that muscular strength, in general, is significantly related to BMD (Bevier et al., 1989; Peterson et al., 1991; Pocock et

al., 1989; Rutherford & Jones, 1992; Snow-Harter et al., 1990; Sinaki, McPhee, & Hodgson, 1986; Zimmermann, Smidt, Brooks, Kinsey, & Eekhoff, 1990). However, of these studies, only Zimmermann et al., (1990) and Pocock et al., (1989) have found significant relationships between quadriceps strength and femoral neck BMD ($r = .33$; $p < .05$ and $r = .39$; $p < .001$, respectively).

The relationships between muscular strength and BMD are unclear and remain speculative. While some studies have shown that muscle strength affects BMD locally at sites where muscular attachments are located, other studies have shown that these relationships are more complicated. For example, back extensor strength has been found to significantly correlate with lumbar spine mineral density in middle-aged women (Sinaki et al., 1986) and elderly men (Bevier et al., 1989). However, other studies provide evidence that muscle groups with attachments that are distant to the bone site of interest may influence BMD (Pocock et al., 1989; Snow-Harter, 1990).

In this investigation, it was anticipated that BS would have a significant relationship with FBMD as determined by preveious studies (Pocock et al., 1989; Snow-Harter, 1990). This was not found in this study.

In the MR group, grip strength was not correlated with either FBMD or WBMD (using simple regressions; refer to Table 5, page 31). Grip strength has been found to predict bone density at the lumbar spine, radius, and forearm (Bevier et al., 1989; Pocock et al., 1989; Snow-Harter et al., 1990). It was expected that grip strength would be significantly correlated with

WBMD since this measurement reflects a general index of muscular strength.

Stepwise Regression Analysis

Using stepwise analysis, the best predictors of BMD were determined. When an indicator variable for group status was entered into the model, LMM was the best predictor of both FBMD ($p < .01$) and WBMD ($p < .01$). With respect to the resultant equation, LMM would have accounted for 38% and 50% of the variation in FBMD and WBMD, respectively.

When stepwise regression was used without an indicator variable (i.e. groups analyzed separately), LMM, again, was the most robust predictor for both FBMD and WBMD in the MR group, accounting for 55% and 66% (adjusted R^2) of the variance, respectively.

In the NMR group, however, BS strength was the best predictor of FBMD, accounting for 43% (adjusted R^2) of the variance. It must be noted that when determining correlations with FBMD (through multiple linear regression), the strength variables did approach significance (BS, $r = .68$; $p = .0992$; QS, $r = .57$; $p = .1338$). With WBMD, both LMM and QS were significant predictors, accounting for 59% (adjusted R^2) of the variance.

Summary

This is the first study to: (a) identify bone density values in adult women with MR, and (b) determine

bone density relationships with body composition and muscle strength (factors that have been found to influence bone density in persons without MR) in adult women with MR. Multivariate analyses indicated that BMD of the femoral neck and whole body were not significantly different between the MR and NMR groups despite the fact that significant differences existed among muscle mass, percent body fat, biceps strength, and quadriceps strength.

It was no surprise that the MR group would yield lower values of LMM, BS, and QS and higher values of %BF than the NMR group. These findings are consistent with the other studies comparing these variables between subjects with and without MR.

Because muscle mass and muscle strength have been found to have a positive association with BMD, it was expected that the MR group would yield lower BMD values since they have less muscle mass as well as biceps and quadriceps strength. This hypothesis was not confirmed in this study.

In the MR group, significant relationships were found between LMM and both FBMD and WBMD. In the NMR group, a significant relationship was found between QS and WBMD.

Stepwise analysis revealed that LMM was the best predictor for both FBMD and WBMD when both groups were analyzed together (i.e. with an indicator variable). When analyzed separately, LMM was still the best predictor for both FBMD and WBMD in the MR group. However, in the NMR group, BS was the best predictor of FBMD and both LMM and QS were the best predictors for WBMD.

Recommendations for Future Study

In light of the findings of this study, several recommendations can be made to improve any similar investigations. First, the number of subjects needs to be increased. Any true differences in bone density between individuals with and without MR may be more evident with a larger sample. This would increase the power and may detect these differences. Secondly, stringent control of associated factors of the MR subjects must be employed. Associated factors such as physical activity, smoking, and diet may influence BMD, but these were not taken into account in the analysis in this study (see Appendix N). Any variation in these factors may have confounded the results. Thirdly, variation within some factors should be minimized. For example, although age was matched between groups, age ranged from 19.5 years to 44.8 years. This is not acceptable since some change in BMD may be age-related (e.g. BMD generally peaks in mid-thirties in women). Lastly, indices of strength should be evaluated at different sites other than the hand, biceps and quadriceps muscle groups, and more skeletal sites should be measured for BMD (e.g. lumbar, radius, and calcaneus) as well. This may help to specifically explain some of the relationships, if any, between muscle strength and bone density.

Although some comparisons (e.g. FBMD and WBMD in MR and NMR groups) and associations (e.g. BS and WBMD in MR group) in this study approached statistical significance, the practical significance of these differences or relationships must be considered. Do

adult women with MR have a higher fracture threshold thereby making osteoporotic fractures more prevalent in this population? Studies are needed to look at the association between BMD and incidence of fracture rate in this population.

Other recommendations for future research addressing bone mineral density concerns in adults with MR are numerous. Studies that have been done among persons without MR should also be done among persons with MR. Some of the research questions of interest may include: (a) Does trabecular BMD peak at the approximate ages in women with MR as they do other women without MR?; (b) Is physical activity related to BMD in the MR population?; (c) What effect does exercise training have upon bone density among individuals with MR and which type is the best?; (d) What are the parameters of exercise that best enhance BMD in individuals with MR?; (e) Does BMD vary in individuals ranging from mild to severe MR?; and, (f) Do individuals with both DS and MR have different bone density values than individuals with MR alone?.

These questions may be investigated in both cross-sectional and longitudinal (intervention) studies. Other researchers who partake in these research investigations involving subjects with MR must realize the difficulty in garnering large sample sizes, maximizing accuracy of measurements, and controlling for confounding variables in this heterogeneous population. These issues, no doubt, will continue to challenge researchers.

Conclusions

In this investigation, lean muscle mass, and biceps and quadriceps strength are significantly lower while body fat is significantly higher in the MR group than the NMR group. Despite these differences, it is concluded that bone mineral density of the femoral neck and the whole body is not different between MR and NMR groups in this sample of subjects. It must be pointed out, however, that unaccounted factors and a small sample size may have contributed to nonsignificance between these groups. A replication of this study with stringent controls and a larger sample size is recommended.

It was also concluded that muscle mass is positively correlated with both FBMD and WBMD in this sample of MR subjects. Furthermore, muscle mass is the most robust predictor of FBMD and WBMD, accounting for approximately 50% and 65% of the variance, respectively. Moreover, percent body fat is not significantly correlated or a predictor of bone denisty in either the MR or NMR group.

In the NMR group, quadriceps strength is positively correlated with WBMD. Additionally, both quadriceps strength and muscle mass are the best predictors for WBMD. Moreover, FBMD is best predicted by biceps strength in this sample.

Whether or not bone density is truly different between individuals with and without MR has not been answered in this investigation. If bone density is not different, then why do some of the positive relationships between muscle mass and muscle strength

with bone density found in this investigation and others hold true yet muscle mass and muscle strength are lower in individuals with MR? If bone density is genuinely different, then what contributes to this difference (i.e. lifestyle-related or genetic factors) and what can be done to enhance it? These questions need to be answered through future controlled research investigations. This task is not easily undertaken when working with subjects with mental retardation. However, until then, these inquiries remain speculative.

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APPENDICES

APPENDIX A

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Bone loss in women is one of the major health concerns today. This is exemplified partly by the establishment of the National Osteoporosis Foundation in 1985 and increased research activity demonstrated by the National Institutes of Health (NIH) large allotment of federal research monies funding investigations involving skeletal health. In 1987, the NIH co-sponsored a meeting with the National Osteoporosis Foundation called "Research Directions in Osteoporosis" (Aloia, 1989). Since then, there has been an aggressive effort to gain much needed knowledge through research on bone mass, warrant society on the consequences of osteoporosis, and encourage individuals to exercise as a mode of prevention against osteoporosis. In general, current research has found that bone loss in women is both preventable and treatable in both men and women to a great extent at younger and older ages.

This review of literature will address the following areas: (a) general osteology; (b) bone remodeling; (c) age-related bone changes in females; (d) bone mass and osteoporosis; (e) biological and environmental influences on bone mass; (f) physical activity and bone mass; and lastly, (g) physical activity and anthropometric profiles in individuals with mental retardation.

General Osteology

Skeletal bones have multiple functions within the human body. The chief function is that of giving support for the soft tissues of the body. It gives direct attachment to most of the skeletal muscles and together they give the body its basic form (Crouch, 1985). The bones provide a basis for movement, serving as levers which muscles act upon. Another function of bones is to protect many of the vital organs such as the brain (skull), heart and lungs (rib cage), and the urinary bladder and uterus (pelvis). Bones also act as the major storage site for 99% of all calcium. To maintain adequate blood calcium levels, calcium stores in the bone may be sacrificed. Lastly, several bone structures have the capability of generating innate blood cells.

The 206 bones of the skeletal system can be classified into two skeletal systems, the axial skeleton and the appendicular skeleton. The axial skeletal system consists of bones of the skull, vertebral column, ribs, and sternum. The remainder of the bones comprise the appendicular skeletal system which includes the bones of the pelvic girdle, pectoral girdle, lower limbs, and upper limbs.

Bones can further be categorized according to its particular microstructure, either cortical bone or trabecular bone. The relative amounts of these substances vary in different bones of the body and within parts of the same bone, depending upon their particular requirements for strength or lightness (Crouch, 1985). Cortical bone structure is primarily

made of dense compact plates known as lamallae, and contributes to 80 percent of skeletal mass. The shafts of the long bones such as the femur and humerus are entirely made up of cortical bone which enclose the medullary cavity.

Trabecular bone, or cancellous bone, is light and spongy-like relative to cortical bone. Its microstructure consists of a horizontal and vertical network of trabeculae intermixed with varying fractions of marrow and fat (Snow-Harter & Marcus, 1991). In the long bones, trabecular bone is found primarily in the metaphyseal ends such as the head of the femur. However, vertebral bodies have a greater amount of trabecular bone relative to the appendicular bones. Vertebral bodies consist of about 35% trabecular bone by weight (Nottestad, Baumel, Kimmel, Recker, & Heany, 1987) and about 70% by surface area. Because the number of remodeling units is fairly equal in both trabecular and cortical bone, changes in bone mass are much more significant in trabecular bone due to its greater surface area (Snow-Harter & Marcus, 1991) and greater metabolic activity (Sinaki, 1989).

Bone Remodeling

The exact physiological mechanism(s) whereby bone responds to activity are not well understood. However, it has been well established that a bone adapts accordingly depending on the forces exerted upon it. Wolff's law states that bone will modify its structure in response to the level of mechanical loading on the bone (Wolff, cited in Lane, Cornell, & Healey, 1987).

With this in mind, bone hypertrophy will occur when force is applied in excess of normal levels. Conversely, bone loss will occur when less than normal magnitudes of force are applied. These skeletal adaptations are the basis for bone remodeling.

Bone remodeling is a continuous and coupled process performed by bone forming cells called osteoblasts and bone resorbing cells called osteoclasts. Alteration in remodeling activity is the final common pathway to modifications in bone mineral density (Snow-Harter & Marcus, 1991). In one remodeling cycle, multi-nucleated osteoclasts initially resorb a certain volume of bone leaving a cavity in the bone. Thereafter, osteoblasts lay down osteoid (bone mineral), thereby refilling the cavity. After the osteoid is mineralized, the cycle is complete (Sinaki, 1989). When osteoblastic activity exceeds osteoclastic activity, bone formation occurs. Conversely, when osteoclastic activity exceeds osteoblastic activity, bone resorption (bone loss) occurs.

In an ideal homeostatic condition, the amount of bone at the beginning of a single remodeling cycle is equal to the amount of bone at the completion of the same cycle. However, this maintenance model may be unbalanced, since a minute deficit in bone mass still occurs persistently with each remodeling cycle. These deficits may account for the age-related bone loss found in many individuals (Snow-Harter & Marcus, 1991).

Age-Related Bone Changes In Females

With cortical bone, bone growth is present during adolescence and then reaches a plateau level during the middle of the third decade of life until approximately age 50. Thereafter, a progressive and gradual loss is noted (Garn, Rohman, & Nolan, 1966). In women, the initial cortical bone loss after age 50 may be more rapid, possibly due to the effects of menopause (Hui, Wiske, Norton, & Johnston, 1982; Mazess, 1982; Smith, Khairi, Norton, & Johnston, 1976).

With trabecular bone, bone loss begins prior to age 50, possibly beginning as early as the third decade of life (Birkenhager-Frenkel, Courpron, & Hupscher, 1988; Marcus, Kosek, Pfefferbaum, & Horning, 1983). Marcus and colleagues (1983) found that trabecular bone volume measured from iliac crest biopsies taken from 62 women between 18 and 50 years of age was negatively correlated with age. It was predicted that trabecular bone loss could be as high as 0.7% annually of original bone volume. This additive effect over a span of 30 years could translate into possible trabecular bone loss of 25% of original bone volume prior to menopause. Birkenhager-Frenkel and colleagues (1988) found similar patterns of bone loss prior to menopause also from iliac crest biopsies taken from 94 subjects aged 20 to 80 years (in addition, they also found an accelerated trabecular loss beginning at 50 years of age). Likewise, vertebral trabecular bone loss has been found to begin during or even prior to the third decade of life (Buchanan, Myers, Lloyd, & Greer, 1988).

Although current theory suggests a significant loss of trabecular bone exists prior to 50 years of age, some studies fail to support this view (Gallagher, Goldgar, & Moy, 1987; Nilas, Gotfredsen, Hadberg, & Christiansen, 1988). It has been speculated that the reasons for these discrepencies may be attributed to the research design of the majority of the studies being cross-sectional as well as geographical, ethnic, dietary, and physical activity differences unaccounted for within and between investigations (Snow-Harter & Marcus, 1991).

After menopause, trabecular bone loss has been found to accelerate initially within the first five years and then slowly decline thereafter (Aloia, Vaswani, Ellis, Yuen, & Cohn, 1985; Cann, Genant, Kolb, Ettinger, 1985; Gallagher, Goldgar, & Moy, 1987). This pattern of bone loss is clearly related to estrogen production. Given the bone loss patterns mentioned above, the 90 year-old female will have lost about 47% of their maximal young adult bone mass in trabecular bone and about 30% in cortical bone (Sinaki, 1989).

The age at which peak bone density (grams of hydroxyapatite per measured area) occurs has now become a controversial issue. Traditionally, it has been assumed that peak bone density is reached during the third decade of life; however, recent evidence suggests that maximal bone mass may occur in late adolescence (Gilsanz, Gibbons, & Carolson, 1988; Gilsanz, Roe, & Carolson, 1988; Snow-Harter & Marcus, 1991). Gilsanz and associates (1988) found that peak vertebral bone density occurred shortly after puberty. Similarly, based on 82 normal women aged 12 to 30 years measured at the Stanford Bone Research Laboratory (Palo Alto, CA),

it was found that spine density increased significantly until the age of 17, after which no significant changes occurred (Snow-Harter & Marcus, 1991). Further research is needed to clarify the issue of the age at which peak bone density occurs.

Bone Mass and Osteoporosis

Osteoporosis, caused by many conditions, is a disease in which there is a reduced bone mass per unit volume of bone which results in porous bone and an increased likelihood of fracture (Sinaki, 1988). It is currently defined as a critical reduction in bone mass to the point that fracture vulnerability increases (Snow-Harter & Marcus, 1991).

Osteoporosis can be classified either as primary or secondary osteoporosis (Aloia, 1989; see Appendix O). Primary osteoporosis occurs when low bone mass is not related to any illness. It also comprises Type I (postmenopausal) and Type II (age associated) conditions. Secondary osteoporosis occurs when it is linked to another disease such as osteogenesis imperfecta or to prolonged medical treatment involving the use of certain medications.

It is noteworthy that primary osteoporosis is a disease process characterized by critically low bone density. Bone fracture is the end point of osteoporosis and is the result of a long-standing disease process (Stevenson, 1990).

Influences on Bone Mass

Biological Factors

The causes of the decline in bone mineral density with age are multifactorial. The most commonly cited contributing biological factors are genetics, disease status, menopausal status, and calciotropic hormone status.

The peak bone mass that any individual can attain is most likely to be genetically determined (Aloia, 1989). ***Genetic factors*** determine the basic structure and mass of the skeleton. For instance, males have higher bone mass than women throughout life. If a female mother has a small bone frame and is a slender, fair-skinned woman with low peak bone mass, then her daughter is more likely to have a low peak bone mass as well. The characteristics mentioned in the mother are nonmodifiable risk factors for osteoporosis and are likely to be inherited.

It has been found that bone mass differs among people with different ethnic backgrounds. People who are black Americans, both men and women, are more likely to have higher bone mass than people who are caucasian (Mazess, 1982). Consequently, the incidence of osteoporosis is relatively lower in black populations than white populations. Low bone mass is also prevalent in many Asian populations (Aloia, 1989).

Critically low bone mass can be attributed to or linked to a heterogeneous group of ***disease conditions*** (see Appendix P). As mentioned above, when this occurs, it is referred to as secondary osteoporosis. These

disease conditions may be inherited congenitally such as osteogenesis imperfecta, Werdnig-Hoffman disease, or gonadal dysgenesis, or they may be acquired later in life. Those disease conditions that are acquired later in life may include liver disease, chronic obstructive pulmonary disease, and endocrine disorders such as acromegaly, diabetes mellitus, and hypogonadism (Sinaki, 1989).

Menopause is highly associated with osteoporosis due to its direct linkage with the estrogen hormone. At the onset of menopause, decreased ovarian function results in a loss of estrogen which is an anti-bone resorptive agent (Nordin, Aaron, Speed, & Crilly, 1981). There are several physiological mechanisms whereby estrogen exerts its effect on bone mineral density. First, estrogen promotes the synthesis of calcitonin, which inhibits bone resorption. Secondly, estrogen also enhances the active metabolite of vitamin D, 1,25-dihydroxyvitamin D_3, which increases absorption of calcium at the intestine (Marks & Popoff, 1988). Thirdly, estrogen deficiency permits permits greater osteoclastic activity (Snow-Harter & Marcus, 1991). As a result of decreased estrogen production at menopause, bone mineral density declines rapidly, particularly during the first five years following menopause.

The importance of estrogen function can be demonstrated when a young woman has had her ovaries surgically removed. Following an oophorectomy, a rapid phase of bone loss occurs similarly as when a woman undergoes menopause (Fogelman, Poser, Smith, Hart, & Bevan, 1984). This pattern of bone loss, attributed to

loss of estrogen, also occurs when a woman simply undergoes menopause at early ages as well.

Although the hormone estrogen plays the primary role in the development of postmenopausal osteoporosis, other hormonal changes related to calcium homeostasis can be associated with increased incidence of osteoporosis. Imbalances in parathyroid hormone, 1,25-dihydroxyvitamin D_3 (calcitriol), and calcitonin can collectively contribute to bone loss (Eastell, Heath, Kumar, & Riggs, 1988; Wallach, 1979). These hormones are known as ***calciotropic hormones***.

With aging, decreases in renal function decreases plasma 1,25-dihydroxyvitamin D_3, the agent which stimulates calcium absorption in the intestines and calcium reabsorption in the kidneys. If blood calcium levels are not sufficient, then parathyroid hormone will increase in response. It's action increases bone resorption by stimulating osteoclastic activity resulting in loss of bone and restoration of adequate blood calcium levels (Marks & Popoff, 1988). Parathyroid hormone levels in women are two times higher than men at younger ages, and increases in production are noted beginning at about 40 years of age.

Calcitonin, produced in the thyroid gland, counteracts the effect of parathyroid hormone. In response to high blood calcium levels (hypercalcemia), calcitonin acts to inhibit bone resorption. Comparatively, blood levels of calcitonin are lower in women than in men and decline with aging (Aloia, 1989).

Environmental Factors

Many environmental influences on bone mass exist but can be broadly categorized as dietary/nutritional influences, cigarette smoking, medications, and physical activity. All these influences may be modified thereby reducing risk of developing osteoporosis.

Several ***dietary factors*** may contribute to bone loss. Excess consumption of protein, caffeine, alcohol, and phosphorous have been implicated to the development of osteoporosis (Aloia, 1989). Diets high in protein increase urinary excretion of calcium resulting in physiological responses (bone breakdown) to maintain blood calcium levels (Heaney, et al., 1982). The recommended dietary protein intake is 20% of total calories. When high amounts of phosphorous are ingested, bone loss may occur (Aloia, et al., 1985). For instance indivduals who drink large amounts of carbonated soft drinks e.g. 6 cans per day (approximately 20 milligrams per 100 millilters) could experience some bone loss. Caffeine and alcohol intake may also lower bone mass. Excess ingestion of these substances should be limited for adequate skeletal health.

Adequate calcium intake (1200 milligrams/day) has been suggested to have its most significant contribution to bone integrity during the adolescent years since bone growth is pronounced during this time (Snow-Harter & Marcus, 1991). With this in mind, it has been speculated that calcium intake is not as beneficial during the third through fifth decades of life since bone growth has stopped. After 60 years of age,

however, dietary calcium should be increased due to a rise in parathyroid hormone associated with menopause.

Cigarette smoking has been associated with low bone mass. Aloia et al. (1985) found that osteoporotic patients had a higher incidence of cigarette smoking than age-matched controls. Women who smoked increased their risk of hip fracture by 1.7 times. Smoking has been implicated for 10% to 20% of hip fractures. The mechanism of action caused by cigarette smoking is unknown, but it has been suggested that women who smoke undergo an early menopause by affecting estrogen metabolism or calcium absorption (Jensen, Christiansen, & Rodbro, 1985).

A variety of ***drugs and medications*** are known to cause bone loss (Aloia et al., 1985). Cortisol, used to treat patients with asthma or rheumatic disorders, is associated with osteoporosis. Diuretics e.g. furosemide causes calcium excretion which may lead to bone breakdown. Regular use of aluminum-containing antacids such as Maalox and Mylanta may need to be supplemented with 500 milligrams of calcium per day to prevent bone loss. Lastly, anticonvulsant medication interferes with vitamin D metabolism consequently leading to bone loss. These drugs, and many others (see Appendix Q) should be avoided for maximizing skeletal health. However, if it is necessary to take these drugs, then other steps to increase bone mass should be taken.

One of the most influential determinants of bone mass in pre-menopausal adults is ***physical activity***. This factor will be highlighted in the section below.

Physical Activity and Bone Mass

Most cross-sectional studies have shown a positive relationship between level of physical activity and bone mineral density in pre-menopausal adult females (Aloia, Vaswani, Yeh, & Cohn, 1988; Brewer, Meyer, Keele, Upton, & Hagan, 1983; Dalen & Olsson, 1974; Fehily, Coles, Evans, & Elwood, 1992; Halioua & Anderson, 1989; McCulloch, Bailey, Houston, & Dodd, 1990). Aloia et al., (1988) found that total activity, measured by a motion sensor, was significantly correlated ($r = .41$; $p < .05$) with spinal BMD, measured by dual photon absorptiometry, in 24 pre-menopausal adult females. Similarly, Halioua and Anderson (1989) showed that high physical activity ($\geq$ 45 minutes of moderate to strenuous activity 4 times per week) was significantly associated with BMD at both the distal and mid sites of the radius.

Several studies demonstrate the influence of childhood physical activity on bone density later on as young adults. In a study involving 101 healthy female subjects aged 20 to 35 years, those subjects who reported greater physical activity as a child had greater calcaneal bone density as young adult (McCulloch et al., 1990). Furthermore, Fehily et al., (1992) found that sports activity during adolescence was a stronger determinant of female BMD of the nondominant forearm than were dietary influences.

Athletes have been shown to have higher BMD than nonathletes. Dalen and Olsson (1974) found that cross country runners yielded greater BMD than sedentary persons at many different skeletal sites. Brewer et al. (1983) found significantly higher BMD's at the radial

midshaft and hand for 42 female marathon runners compared to 38 sedentary control women; however, the sedentary group yielded higher BMD at the calcaneal site. This difference was attributed to the greater body weight in the sedentary control group. In a study comparing professional tennis players to sedentary college students, it was observed that the tennis players had 34% and 15% higher bone mineral content in the dominant and nondominant arm, respectively (Pirnay, Bodeux, & Crielaard, 1987). In another study, elite water polo players and weightlifters were found to have higher spinal trabecular BMD than a nonexercising comparison group (Block et al., 1989). Interestingly, no differences were noted between the water polo players and the weightlifters.

The relationship between physical activity and BMD is less clear with athletes who have menstrual dysfunctions. Howat, Carbo, Mills, & Wozniak (1989) suggest that prolonged menstrual dysfunction, as in the case of amenorrheic athletes, may lower bone density, in spite of physical activity. This conflicts with research currently ongoing at the Oregon State University Bone Research Laboratory (Robinson, Snow-Harter, Gillis, & Shaw, 1993). Preliminary results suggest that in a group of elite gymnasts and runners who have similar percent body fat and amenorrheic menstrual dysfunction, the gymnasts display higher BMD at the femoral neck, lumbar spine, and whole body. These differences suggest the importance of bone loading to increase BMD. Although not a focus of this review, the effects of menstrual dysfunction on BMD in athletes need to be more closely addressed.

The positive relationship between physical activity level and bone mineral density also holds true for post-menopausal females (Jacobson, Beaver, Grubb, Taft, & Talmage, 1984; Nelson, Meredith, Dawson-Hughes, & Evans, 1988). In a group of endurance-trained post-menopausal women (mean age = 62 years), BMD of the spine and radius was significantly higher than sedentary controls when normalized for body weight (Nelson et al., 1988). Jacobson et al. (1984) demonstrated that older athletic women had higher BMD values than inactive older women and similar values relative to younger athletic women. These authors further implied that habitual lifetime activity is associated with a lower rate of age-related bone loss. It was observed that the older athletic women did not display a 0.7% annual decrease in spine BMD displayed by the nonactive older women.

Type of Physical Activity

Perhaps one of the most important important inquiries in BMD research concerns the type of physical activity that best enhances BMD. Most cross-sectional research has found a positive relationship between physical activity and BMD, but this relationship is not quite as clear in longitudinal studies. In those study designs where physical activity programs have been relatively more intense, longer in duration, and have included more activities that overload the muscular system, however, increases in BMD have been more significant (Marcus et al., 1992).

Rubin and Lanyon (1984) found that cyclic loading was essential to maintain bone mass. For a given

strain, bone adapts accordingly to meet the needs of that particular load. Repetitive cyclic loading to the bone, however, does not result in an additional increase in bone mass. Whalen, Carter, and Steele (1987) further suggested that the magnitude of a load was a more important determinant of bone mass than the number of cycles of a load. In exercise training, then, physical activity that sufficiently overload bone tissue will elicit a greater osteogenic stimulus than those exercises that do not adequately overload the bone. For example, a sedentary female who underwent a rigorous weightlifting program would produce greater bone changes had she undergone a non-weightbearing flexibility program.

With this in mind, researchers have realized the importance between muscle strength and BMD. In general, those individuals that are stronger at a particular muscle group are likely to have greater bone mass at that same site. For instance, back strength would predict vertebral BMD and hip strength would predict hip BMD, and forearm strength would predict radial BMD. This site specific hypothesis has been supported by a number of researchers (Ayalon, Simkin, Leichter, & Raifmann, 1987; Bevier et al., 1989, Sinaki & Offord, 1988).

Sinaki & Offord (1988) found that back extensor strength was positively correlated with lumbar spine BMD in healthy postmenoapausal women. Also, Bevier and colleagues (1989) found significant correlations between grip strength and forearm BMD in elderly men and women. In an exercise training program designed to load the

forearm, radial BMD increased by 3.8% in a group of 14 postmenopausal osteoporotic women (Ayalon et al., 1987).

Several recent investigations have shown that site-specific relationships between BMD and strength is more complicated than once thought. Pocock et al., (1989) found that biceps strength was the most robust predictor of BMD at the spine and proximal femur (femoral neck, Ward's triangle, and trochanteric region) and explained more of the variance in BMD than age. In support of the site-specific hypothesis, however, grip strength was found to be an independent predictor of bone mass in the distal forearm.

Snow-Harter et al., (1990) found that biceps strength was the best predictor of hip density and dominant grip strength the best predictor of spine density. These researchers suggest that these relationships exist because arm activity is linked to the simultaneous contraction of trunk stabilizing muscles that directly exert forces on the hip and spine.

These studies mentioned above suggest that exercise programs that provide mechanical loads to enhance muscle strength are most likely to enhance BMD. Muscular tension or weightbearing can serve as an osteogenic stimulus. However, the physiological mechanisms by which bone adapts to mechanical load stresses are unclear (Rubin & Lanyon, 1984). There is evidence that exercise programs that focus on increasing cardiorespiratory fitness may enhance BMD (Chow et al., 1986; Pocock et al., 1989), however, its relationship with BMD is most likely manifested through weightbearing stimulation inherent in the fitness activity. Thus, the

general consensus on physical activity as a mode to increase or maintain current BMD levels, is that it should be resistive, weightbearing, and sufficient enough to overload the bone.

APPENDIX B

LETTER REQUESTING PARTICIPATION

(DATE)

Dear Parent/Guardian,

Hello! I am a graduate student attending Oregon State University. My interests are enhancing the health status of individuals with mental retardation. Currently, I am undergoing a research project regarding the health of adult women with mental retardation. This research involves measuring bone strength and muscle strength in adult females with mental retardation. The relevence of this study is significant since more and more adult females with mental retardation are living longer and are also susceptible to bone disease.

I am writing you to receive your support in getting _____ to participate in the study. To participate in this study, she will need to spend approximately three hours at OSU. Transportation will be provided.

Enclosed is a description of the study. If interested, please sign the enclosed form and mail it back to me in the self-addressed, stamped envelope. If she participates in the study, you will receive valuable information regarding her muscles and bones at no expense -- this information normally costs about $400.00 if performed in a clinical setting.

If you have any questions regarding this study, you may call me at 737-3402. If I am not there, please leave a message on the answering machine.

Thank you for your cooperation! I hope to hear from you soon!

Sincerely,

Manny Felix

enclosure

APPENDIX C

DESCRIPTION OF STUDY

DESCRIPTION OF STUDY

TITLE: Bone Mineral Density in Adult Women with Mental Retardation

INVESTIGATORS: Manny Felix, Dr. Jeff McCubbin, and Dr. Christine Snow-Harter, Oregon State University

PURPOSE: This study will measure bone strength and muscle strength in adult females with mental retardation who are 18 years or older.

WHY: Bone strength, and muscle strength are important factors in bone disease (osteoporosis) and overall health. More research in this area needs to be done in adults with mental retardation since this information is nonexistent compared to nontretarded females.

WHAT THE SUBJECT NEEDS TO DO IN THE STUDY:

1. She simply needs to lie down quietly without moving on a bone scanning machine.

2. She needs to squeeze a grip device as hard as possible for 5 seconds.

3. She needs to tighten her arm and leg muscles as hard as possible for 3 seconds.

4. She needs to go to Oregon State University (Corvallis, OR) 2 times. The 1st time will be to discuss her health, thoroughly inform her of the study, and then familiarize herself with the procedures. The 2nd time she will undergo the test procedures. All transportation will be provided by the investigators.

POSSIBLE RISKS: The bone machine emits a very small amount of radiation which is no more than a normal x-ray. She may feel some soreness in the hand or arm from squeezing the grip device. She may also feel some soreness in her leg or arm from tightening her muscles. These risks, however, are very small.

BENEFITS: This study can give her and her caretaker important information about the health of her muscles and bones. She will receive this information at no cost and will be given advice on how to improve her health habits.

CONFIDENTIALITY: Nobody but the investigators will know what her results are.

VOLUNTEERING: She will be invited to be a subject in this study. This is purely voluntary. She may withdraw from the study at any time with no penalty at all.

APPENDIX D

INTEREST IN PARTICIPATION FORM

INTEREST IN PARTICIPATION

If interested in being in this study, the "Interest in Participation Form" must be filled out below. This form allows us to look at your medical records for health purposes (this will be strictly confidential).

Please complete the form and mail it back in the enclosed self-addressed, stamped envelope. Thank you for your cooperation. When we receive this form, we will call you and set up a time for your first visit to Corvallis.

****

INTEREST IN PARTICIPATION FORM

I am interested in being in this study. I realize this study is voluntary and I may withdraw at any time. If I sign this form, it does not mean I will be included in the study. By signing this form it only means I am willing to be a part of the study. I give you permission to look at my medical records for the purpose of gathering health information.

Date_____ Phone_____

Name_____

Signature_____

Address_____

Parent/Guardian Name_____

Parent/Guardian Signature_____

APPENDIX E

INFORMED CONSENT

CONSENT TO PARTICIPATE IN BONE DENSITY STUDY

TITLE OF STUDY

Bone Mineral Density, Muscle Strength, and Body Composition in Female Adults With Mental Retardation

PURPOSE OF STUDY

This study will see how healthy my bones are, to see how strong my muscles are, and to see how much fat I have. These things will be measured because it is important to my health.

EXCLUSION CRITERIA

I will do these tests only if I want to. If I am not able to walk without using anything else, then I cannot be in the study. If I am taking any medicine that affects my bones, except estrogen, then I cannot be in the study. If I cannot lie on the bone machine quietly, then I cannot be in the study.

POSSIBLE RISKS

My hand, arm, and leg might be sore from squeezing the grip handle and tightening my arm and leg muscles as hard as I can. The bone scanning machine takes a picture of my bones and is less harmful than an x-ray.

BENEFITS FROM THE STUDY

I will know how strong my muscles and bones are, and I will know how fat I am. I will know these things for free if I am in the study.

CONFIDENTIALITY OF RECORDS

The researchers who test me will know how strong my muscles and bones are. They will also know how much fat I have on my body and know things about my health. They will not tell anyone about these things.

DECISION NOT TO PARTICIPATE IN THE STUDY

I don't have to be in the study if I don't want to. If I am in the study but change my mind, I can quit anytime. If I am in the study, I will go to Oregon State University two times. Each time, I will be there for one and a half hours.

(go to next page)

CONSENT STATEMENTS

I have read these papers or the researchers have told me everything about it. They answered all my questions. I understand it and want to be in the study.

Oregon State University is not responsible for any injury that might happen to me while I am at Oregon State University.

If I have any questions, I can talk to Manny Felix by calling 737-3402 or Jeff McCubbin by calling 737-5921.

Subject or Guardian's Signature	Witness Signature
Subjects Name Printed	Witness Name Printe
Date	Date
Subject's Address	Subjects Phone Number

INTERVIEWER'S/INVESTIGATOR'S STATEMENT

I have explained the purpose, procedures, and possible risks and discomforts of this study to the recipient, and have satisfied her questions. I have given the recipient a copy of this consent form.

Interviewer's/Investigator's Signature	Witness Signature
Interviewer's/Investigator's Name Printed	Witness Name Printed
Date	Date

APPENDIX F

OREGON STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD APPLICATION AND APPROVAL FORM

OREGON STATE UNIVERSITY

Committee for the Protection of Human Subjects

Chairman's Summary of Review

Title: Bone mineral density in women with mental retardation

Program Director: Jeff McCubbin

Recommendation:

X Approval*	*The informed consent forms obtained from each subject need to be retained for the long term. Archives Division of the OSU Department of Budgets and Personnel Service is willing to receive and archive these on microfilm. At present at least, this can be done without charge to the research project. Please have the forms retained in archives as well as in your files.
_____ Provisional Approval	
_____ Disapproval	
_____ No action	

Remarks: All concerns of the IRB have been appropriately addressed and necessary changes made.

Date: 22 February, 1993 Signature [signature]

If the recommendation of the committee is for provisional approval or disapproval, the program director should resubmit the application with the necessary corrections within one month.

1. Description

The incidence of osteoporosis has resulted in both an economic and health crisis in our society. It is widely recognized through previous research that level of physical activity is positively related to bone mineral density (BMD). Furthermore, a growing body of evidence has supported that muscle strength and muscle mass is a major determinant of BMD in women independent of age. Virtually all of the research pertaining to BMD, however, has been addressed in target populations without mental retardation. The results of this proposed study will provide descriptive data of adult females with mental retardation (MR) on BMD, body composition, and muscle strength; all of which have been shown to influence osteoporosis in populations that are not mentally retarded (NMR). This study is unique in that: (a) it is the first attempt to identify BMD in females with MR; (b) it will utilize a control group of age- and weight-matched control subjects for comparison; and (c) it will examine and compare the relationships between BMD, body composition, and muscle strength in both the MR and NMR subjects according to menopause. Generalizing results of BMD research in NMR adult females and the physcial fitness data available on MR adult females, one would expect that MR adult females would have lower BMD, strength, and higher percent body fat relative to their normal age-and weight-matched counterparts.

2. Methods & Procedures

A 2 x 2 factorial design (mental retardation status x menopausal status) will be employed in this study. Female subjects will be categorized as MR or NMR. Within each category, subjects will be divided into either a premenopausal (PRE) or postmenopausal (POST) group. Each group will contain 15 subjects for a total of 60 subjects participating in the study.

Data will be collected in the following areas: (a) menopausal status; (b) bone mineral density; (c) muscle strength; and (d) body composition. Menopausal status will be determined through an interview and/or medical records. At the interview, a nonretarded adult (either a parent or group home supervisor) will be present at this time for assistance. Bone mineral assessment will

be determined using the Hologic QDR 1000W Bone Densitometer at the Oregon State University Bone Research Laboratory. This method requires the subject to simply lie quietly in a supine position on a scanning table while an x-ray source and detector, controlled by a computer interface, is scanned back and forth across the area of interest. Muscle strength will be measured using a Jamar Dynamometer (grip strength) and Nicholas Manual Muscle Tester (elbow and hip flexion). Grip strength requires the subject to simply squeeze a hand grip device as hard as possible for a duration of 5 seconds. Use of the Nicholas Manual Muscle Tester requires the subject to hold an isometric contraction while an external force (from the investigator) is applied over a period of 3 seconds to break the contraction. Body composition data will be generated from the whole body scan on the bone densitometer.

3. Benefits & Risks

Benefits: The potential benefits to the subjects far outweigh the risks. As a result of participating in this study, subjects and their care providers will receive valuable information regarding factors affecting long term health. Suggestions of maintaining or enhancing bone status and controlling obesity will be provided after data assessment for each subject. In addition, they will receive a copy of the bone mineral assessment, which typically costs an average of $400 in a clinical setting.

Risks: The potential risks to the subjects are minimal in this investigation. Grip strength measurements may result in slight forearm, wrist, or finger pain; however, no lasting effects should occur and any discomfort as a result of this test should subside. Strength measurements determined at the hip and elbow may also result in slight pain at these sites, but should subside as well. Values obtained through the use of the bone densitometer will require the use of an x-ray technique. The method used (dual energy x-ray absorptiometry), however, emits minimal amounts of radiation (1/10 of a normal chest x-ray).

4. Subjects

Thirty MR and 30 NMR subjects (controls) are expected to participate in this investigation. In order to be included into the study (both MR and NMR subjects), the following inclusion criteria will be as follows: (a) subjects will be female who are older than 18 years of age; (b) subjects will be ambulatory; (c) subjects should not be taking any medications known to affect bone metabolism (except for estrogen); (d) subjects will be in good health and be free from any diseases such as cancer; and (e) subjects will be able to lie quietly on the bone densitometer for 15 minutes. Anyone who does not meet all of these criteria will be excluded from the study.

Although this investigation is limited to only females, selection of subjects will be open to include individuals of all races an ethnic populations. Individuals with mental retardation should be considered a special population that is under-represented in aging related research.

Subjects in the NMR group will be selected as age, menopausal status, and weight-matched controls. For each MR subject, an NMR subject will be chosen based on their similarity of age and weight. These NMR subjects will have met the same inclusion requirements as the MR subjects, but will have been measured on the bone densitometer previously in other studies performed at the OSU Bone Research Laboratory.

5. Informed Consent

See attached copy of Consent To Participate in Bone Density Study. All females with MR identified in cooperation with program directors of persons employed by mental health/developmental disabilities agencies in the surrounding counties will be considered. All females with MR will either live with their parents or in a group home. Possible subjects and/or their parent(s)/guardian(s) will be mailed a letter requesting particpation in the study and a description of the proposed study, including its benefits and risks (see attached letter and description of study).

Interested subjects will be instructed to mail the "Interest in Participation form" to the primary

investigator (see attached Interest in Participation form). Upon receipt of this form, the possible subject will be contacted to arrange the initial health screening and interview.

All the inclusion requirements must be met for the subject to be selected. After being selected for the study, each subject will further: (a) be verbally informed, in a language he/she can understand, of all the possible risks, benefits, and rights as a volunteer participant in the study; and (b) give their consent to participate in this study by signing two informed consent forms. A nonretarded adult (parent or group home supervisor) will be present when the study is explained and when the informed consent forms will be signed. One copy will be given to the subject and the other will be filed in the Department of Exercise and Sport Science.

6. Confidentiality

Anonymity will be preserved at all times. A system of code numbers will be used to match each subject with individual data from computer-generated output. Only the researchers will have access to a list of names of subjects and their coded numbers. Upon completion of the study, the master list of the names of the subjects and their respective data points will be destroyed. A list of code numbers and respective data points will be kept for future data inspection and possible research use.

7. Additional Materials.

See attached pages. [Note: These pages are found throughout the Appendixes.]

8. Funding Proposal.

A funding proposal, through the Minority Dissertation Research Grants in Aging (National Institute on Aging) was written and sent, but not funded. This proposal is not attached.

APPENDIX G

HEALTH AND PHYSICAL ACTIVITY HISTORY FORM

HEALTH AND PHYSICAL ACTIVITY HISTORY

Code # _____ Date of birth _____

Smoking

Do you smoke now? Y N
If no, did you smoke in the past? Y N
How many times do you smoke per day?____
How long have you been smoking?____

Calcium

Do you drink milk? Y N
How many glasses of milk do you drink per day?____
per week?____

Do you eat cheese? Y N
How many times a day do you eat cheese per day?____
per week?____

Do you eat yogurt? Y N
How many times a day do you eat yogurt per day?____
per week?____

Physical Activity

How many hours a day do you watch TV?

How often do you walk outside the house?

Where do you walk?

How long or how far do you walk?

Do you run or jog?

How many times per week do you run or jog?

Are you involved in any sports?

Which sports are you involved with?

How often do you play sports?

Where do you work?

How many hours/day do you work?

What do you do when you work?

OSTEOPOROSIS RISK FACTORS

Code # _____ Date of birth _____

Data to be gathered from health records, parent/guardian, or group home supervisor.

T F DN Has been treated with cortisone or similar drugs.
T F DN Has close relative with osteoporosis.
T F DN Has history of overactive thyroid gland.
T F DN Has history of overactive parathyroid gland.
T F DN Has history of alcoholism.
T F DN Has lactase deficiency (inability to digest milk).
T F DN Avoids milk and dairy products.
T F DN Drinks more than 2 cups of coffee or tea daily.
T F DN Drinks 3 or more alcoholic beverages daily.
T F DN Has taken thyroid hormone pills.
T F DN Has taken phenobarbitol or dilantin for over one year.
T F DN Has taken furosamide (Lasix) for over one year.
T F DN Has been treated with lithium for over one year.

T F DN Lost period for a year or more before it came back.
T F DN Has had irregular menstrual periods.
T F DN Menstrual period did not begin until after age 16.
T F DN Has medical history of endometriosis.
T F DN Has had both ovaries surgically removed.
T F DN Has breast fed a baby for one month or more.
T F DN Takes tamoxifin as treatment for breast cancer.
T F DN Went through menopause before age 50.
T F DN Has gone through menopause.
T F DN Has received estrogen treatment after menopause.
T F DN Is taking birth control pills.

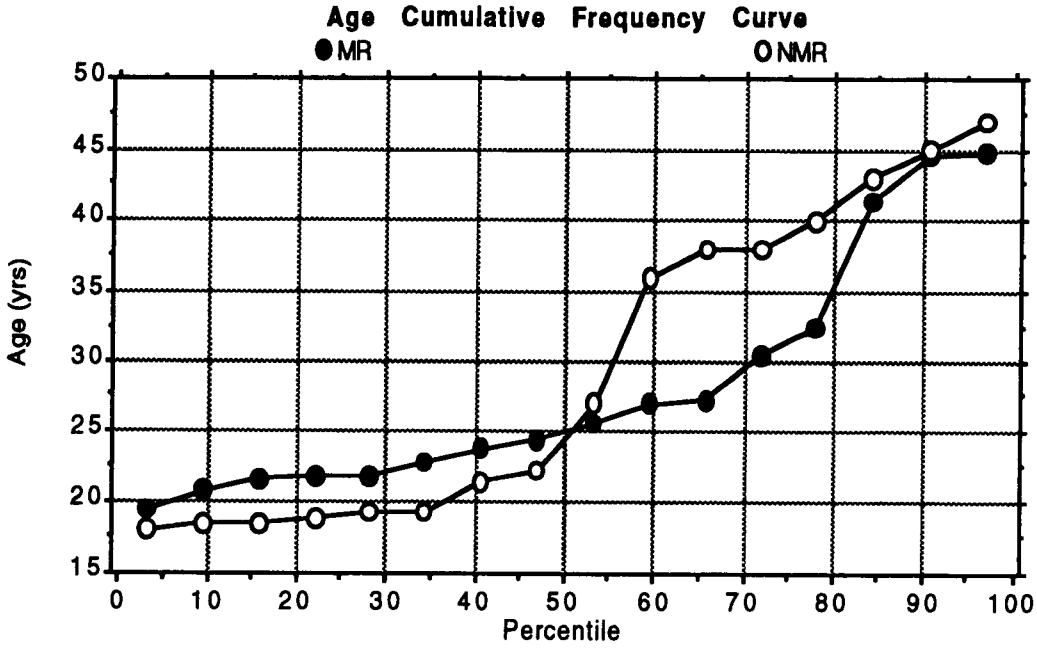
If taking estrogen, for how many years?_____
If have children, how many?_____
Date of last menstrual period?_____

Additional Information:

APPENDIX H

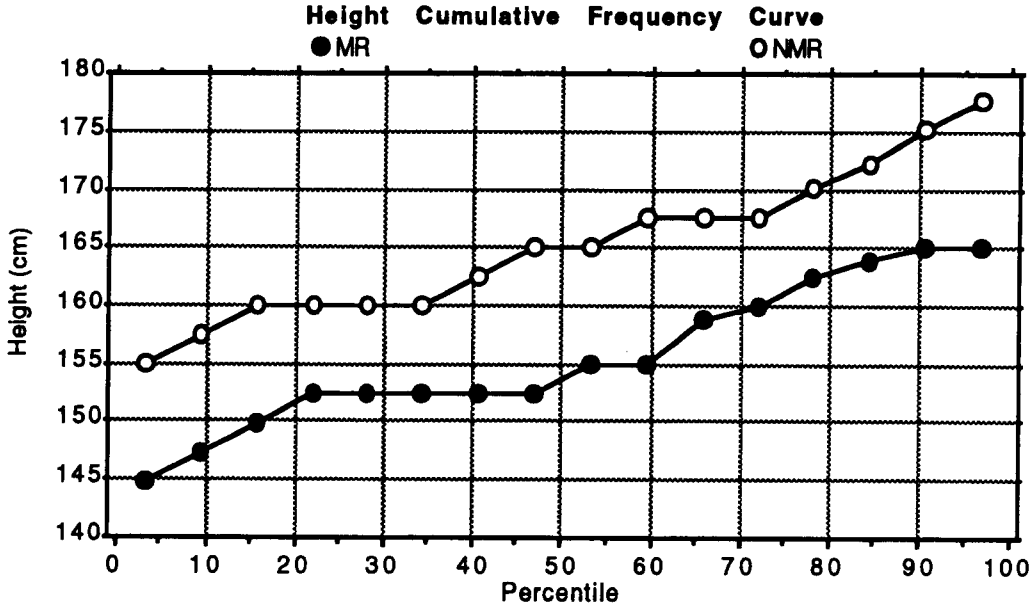
DESCRIPTION OF VARIABLES

Variable: AGE



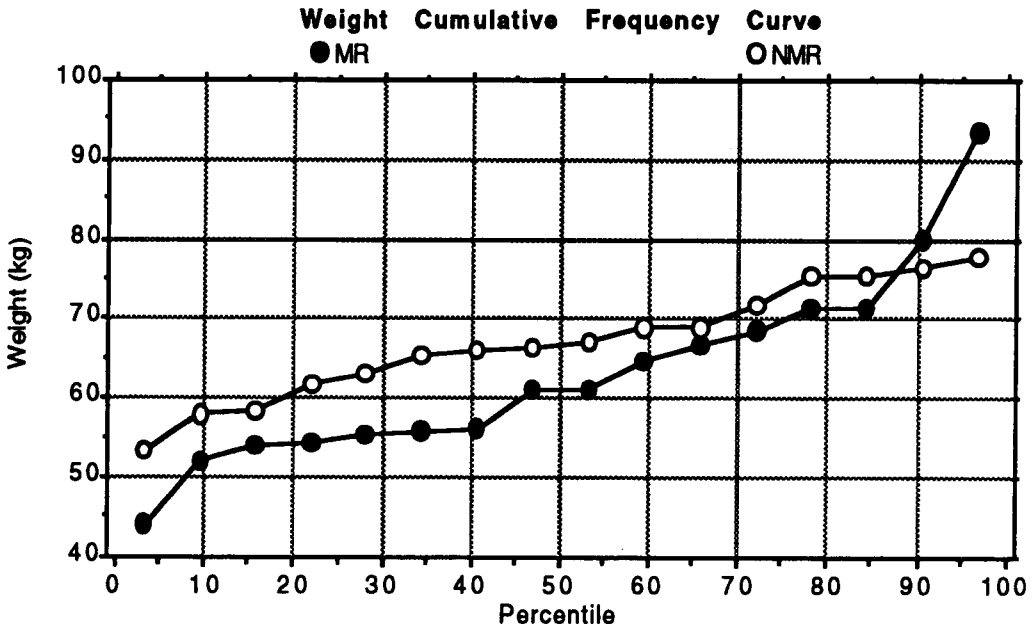
	MR	NMR
Count	16	16
# missing	0	0
Maximum	44.830	47.000
Minimum	19.500	18.100
Range	25.330	28.900
Variance	71.115	123.143
Standard Deviation	8.433	11.097
Coefficient of Variation	29.968	37.777
Maximum Z-Score	1.979	1.588
Minimum Z-Score	-1.025	-1.016
95% Confidence		
Lower	23.646	23.461
Upper	32.634	35.289
Mean	28.140	29.375
Standard Error	2.108	2.774
Skewness	1.072	.325
Kurtosis	-.250	-1.590

Variable: Height



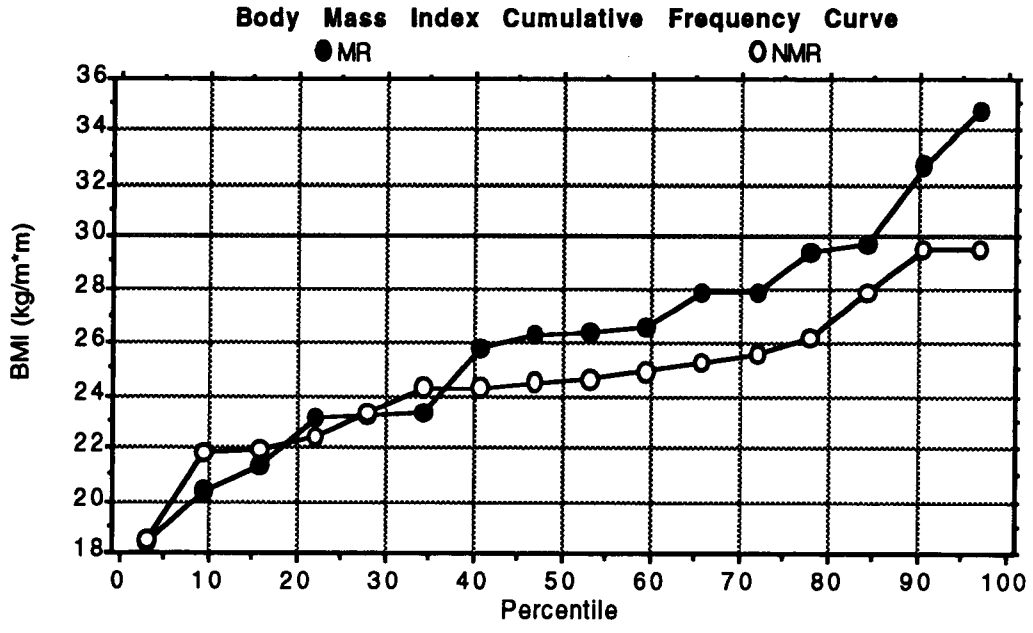
	MR	NMR
Count	16	16
# missing	0	0
Maximum	165.100	177.800
Minimum	144.780	154.940
Range	20.320	22.860
Variance	39.785	42.119
Standard Deviation	6.308	6.490
Coefficient of Variation	4.054	3.928
Maximum Z-Score	1.510	1.937
Minimum Z-Score	-1.711	-1.586
95% Confidence		
Lower	152.214	161.772
Upper	158.936	168.689
Mean	155.575	165.231
Standard Error	1.577	1.622
Skewness	.160	.344
Kurtosis	-1.033	-.753

Variable: WEIGHT



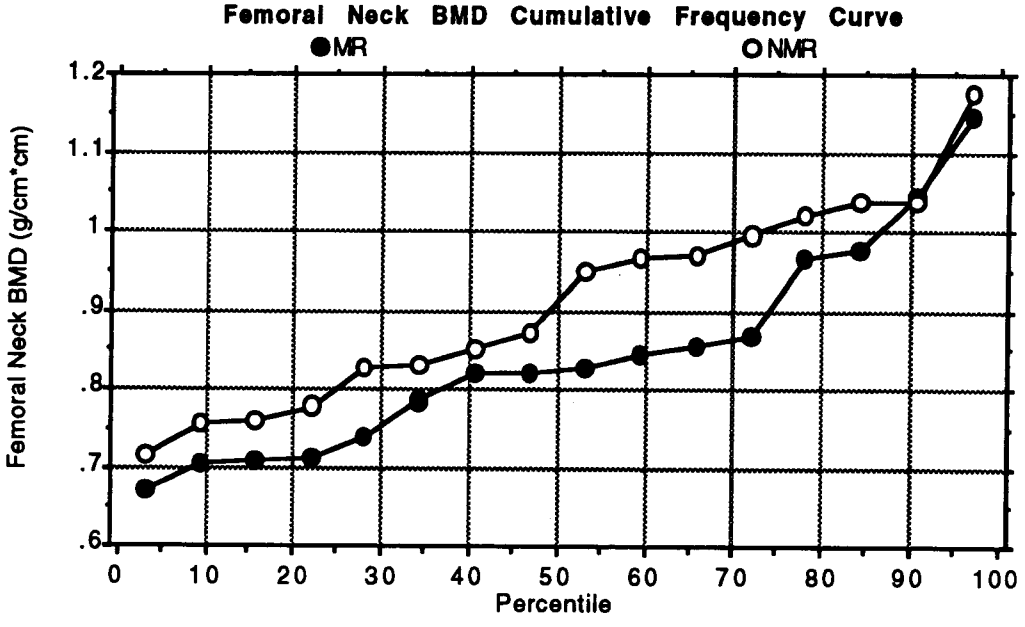
	MR	NMR
Count	16	16
# missing	0	0
Maximum	93.290	78.000
Minimum	44.240	53.510
Range	49.050	24.490
Variance	145.796	51.642
Standard Deviation	12.075	7.186
Coefficient of Variation	19.109	10.691
Maximum Z-Score	2.493	1.501
Minimum Z-Score	-1.569	-1.907
95% Confidence		
Lower	56.752	63.387
Upper	69.622	71.046
Mean	63.187	67.216
Standard Error	3.019	1.797
Skewness	.884	-.176
Kurtosis	.613	-.827

Variable: BMI



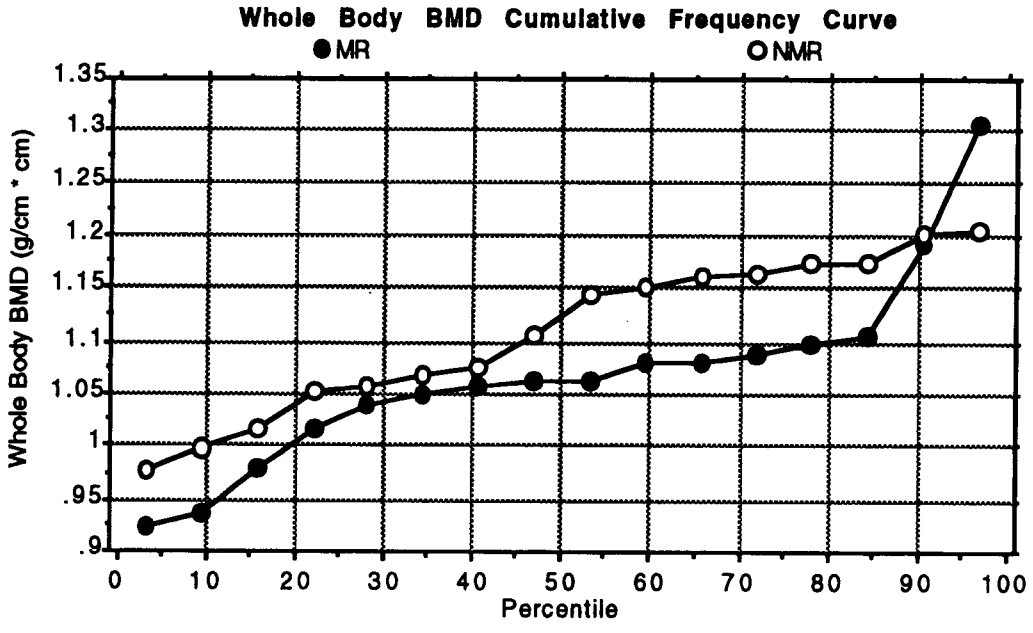
	MR	NMR
Count	16	16
# missing	0	0
Maximum	34.760	29.510
Minimum	18.430	18.480
Range	16.330	11.030
Variance	19.177	8.134
Standard Deviation	4.379	2.852
Coefficient of Variation	16.796	11.561
Maximum Z-Score	1.984	1.697
Minimum Z-Score	-1.745	-2.170
95% Confidence		
Lower	23.739	23.150
Upper	28.407	26.190
Mean	26.073	24.670
Standard Error	1.095	.713
Skewness	.188	-.079
Kurtosis	-.470	.052

Variable: FBMD



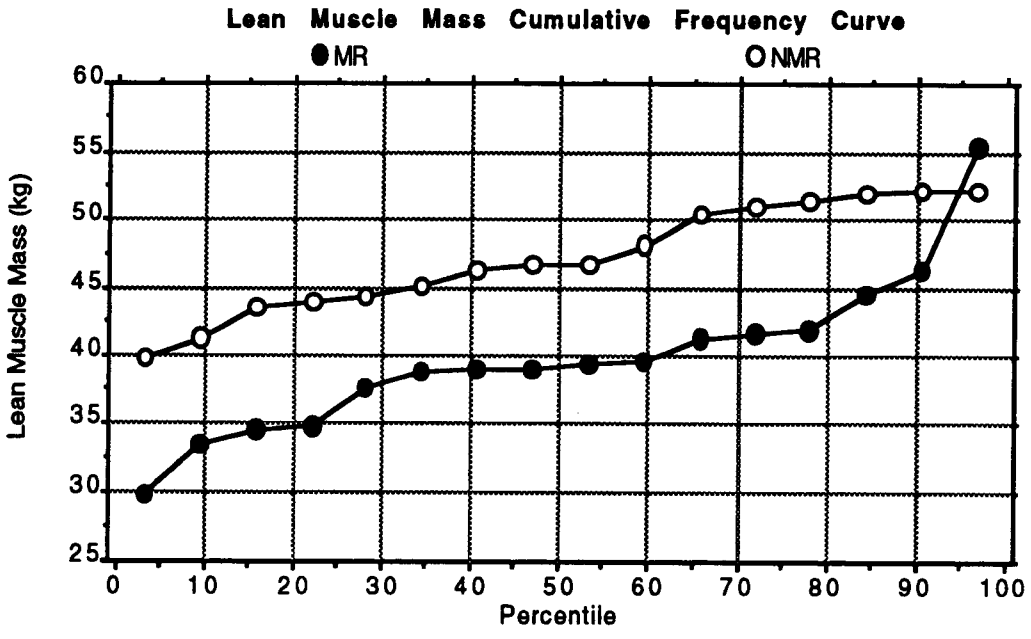
	MR	NMR
Count	16	16
# missing	0	0
Maximum	1.149	1.179
Minimum	.673	.717
Range	.476	.462
Variance	.018	.017
Standard Deviation	.134	.129
Coefficient of Variation	15.809	14.199
Maximum Z-Score	2.280	2.077
Minimum Z-Score	-1.285	-1.496
95% Confidence		
Lower	.773	.842
Upper	.916	.979
Mean	.845	.910
Standard Error	.033	.032
Skewness	.789	.273
Kurtosis	-.136	-.770

Variable: WBMD



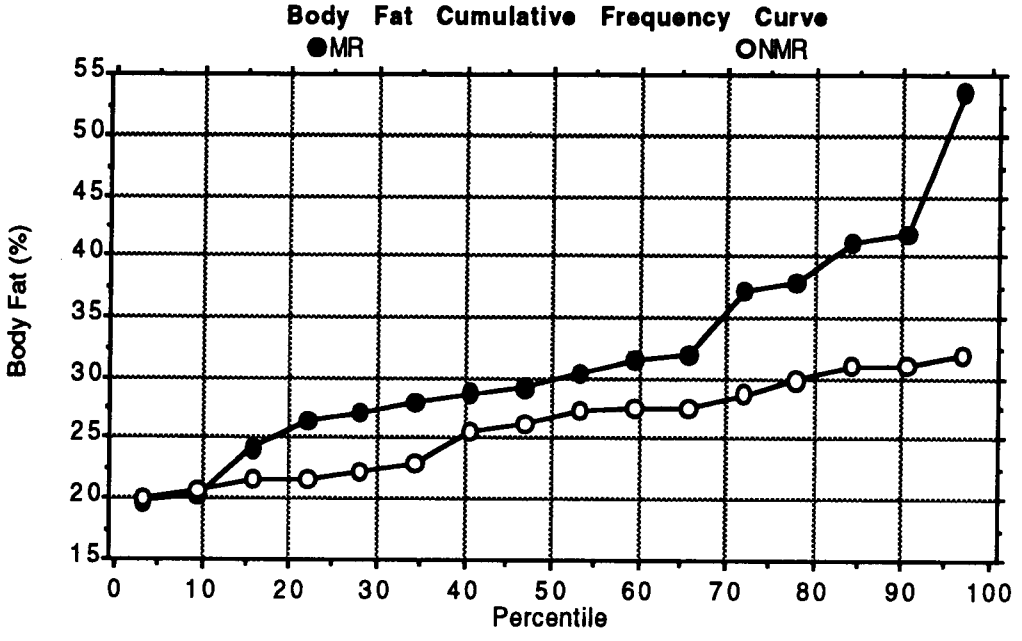
	MR	NMR
Count	16	16
# missing	0	0
Maximum	1.306	1.205
Minimum	.923	.977
Range	.383	.228
Variance	.008	.005
Standard Deviation	.091	.074
Coefficient of Variation	8.559	6.694
Maximum Z-Score	2.607	1.306
Minimum Z-Score	-1.584	-1.768
95% Confidence		
Lower	1.019	1.069
Upper	1.116	1.148
Mean	1.068	1.108
Standard Error	.023	.019
Skewness	.840	-.335
Kurtosis	1.354	-1.189

Variable: LMM



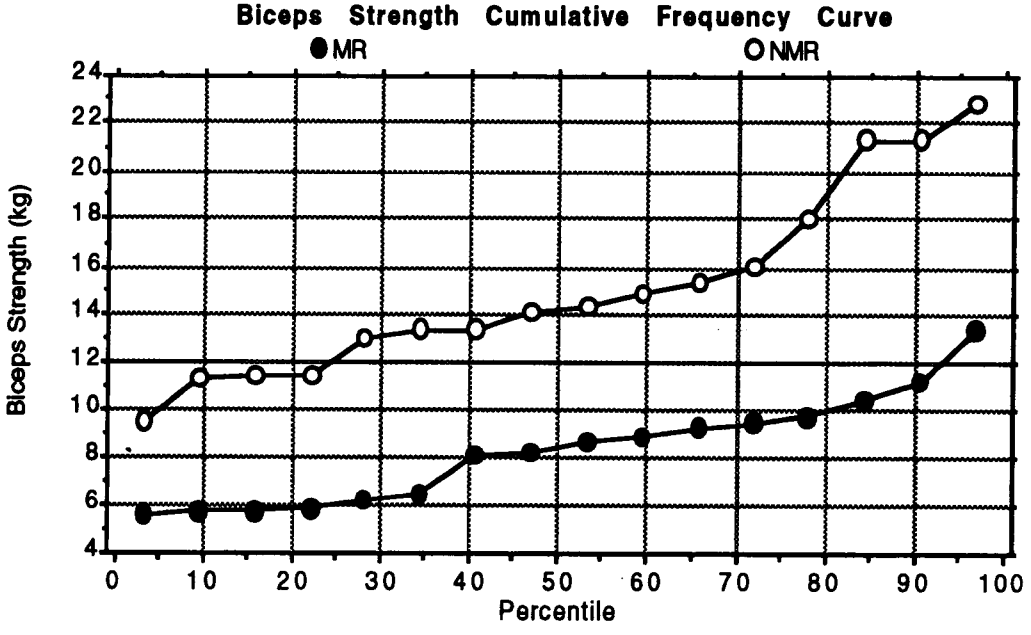
	MR	NMR
Count	16	16
# missing	0	0
Maximum	55.450	52.140
Minimum	29.840	39.882
Range	25.610	12.258
Variance	34.183	15.962
Standard Deviation	5.847	3.995
Coefficient of Variation	14.665	8.468
Maximum Z-Score	2.665	1.242
Minimum Z-Score	-1.715	-1.827
95% Confidence		
Lower	36.752	45.050
Upper	42.983	49.309
Mean	39.867	47.180
Standard Error	1.462	.999
Skewness	.904	-.207
Kurtosis	1.511	-1.137

Variable: %BF



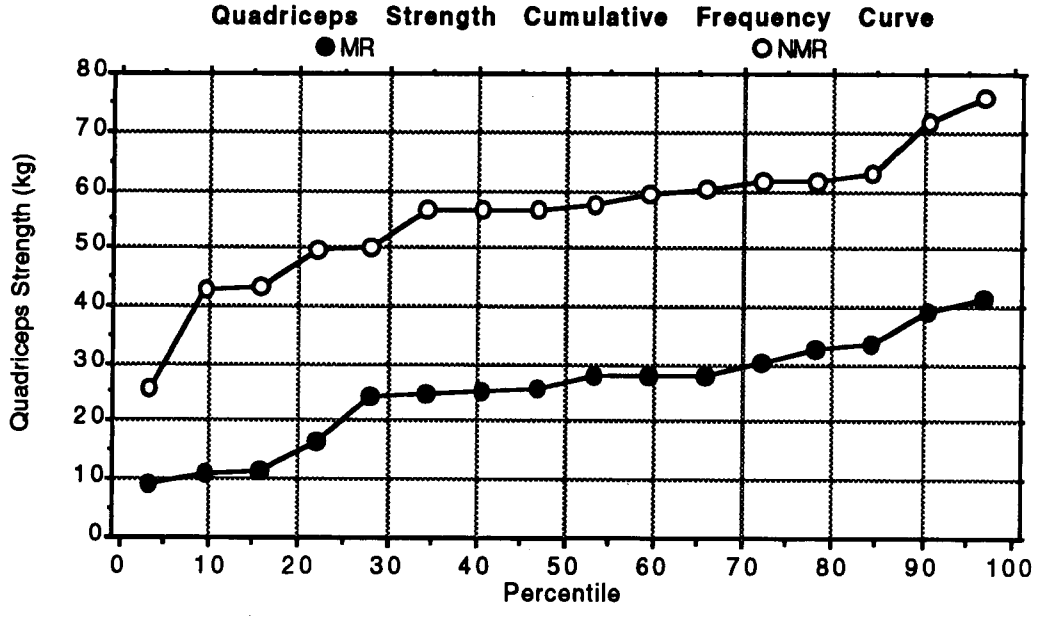
	MR	NMR
Count	16	16
# missing	0	0
Maximum	53.600	32.000
Minimum	19.900	20.000
Range	33.700	12.000
Variance	76.426	16.096
Standard Deviation	8.742	4.012
Coefficient of Variation	27.421	15.412
Maximum Z-Score	2.484	1.488
Minimum Z-Score	-1.371	-1.503
95% Confidence		
Lower	27.222	23.893
Upper	36.540	28.169
Mean	31.881	26.031
Standard Error	2.186	1.003
Skewness	.861	-.070
Kurtosis	.486	-1.374

Variable: BS



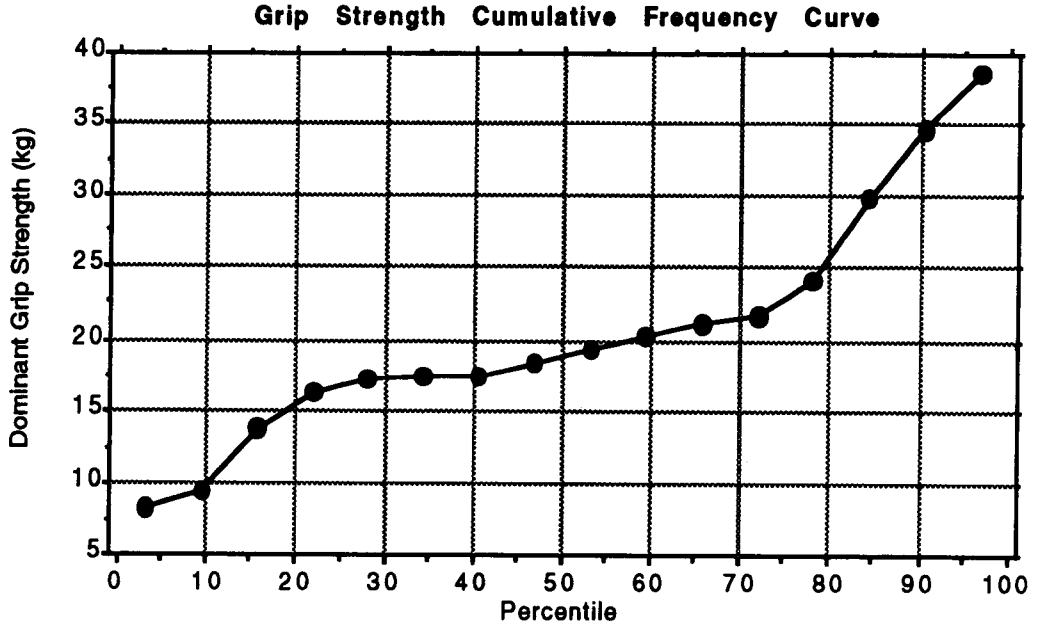
	MR	NMR
Count	16	16
# missing	0	0
Maximum	13.470	22.860
Minimum	5.620	9.480
Range	7.850	13.380
Variance	5.297	15.381
Standard Deviation	2.302	3.922
Coefficient of Variation	27.632	25.918
Maximum Z-Score	2.234	1.971
Minimum Z-Score	-1.177	-1.441
95% Confidence		
Lower	7.103	13.042
Upper	9.556	17.222
Mean	8.329	15.132
Standard Error	.575	.980
Skewness	.484	.694
Kurtosis	-.432	-.537

Variable: QS



	MR	NMR
Count	16	16
# missing	0	0
Maximum	41.590	75.960
Minimum	9.390	25.710
Range	32.200	50.250
Variance	90.123	141.607
Standard Deviation	9.493	11.900
Coefficient of Variation	37.018	21.334
Maximum Z-Score	1.680	1.696
Minimum Z-Score	-1.712	-2.527
95% Confidence		
Lower	20.586	49.437
Upper	30.704	62.120
Mean	25.645	55.779
Standard Error	2.373	2.975
Skewness	-.287	-.755
Kurtosis	-.665	.942

Variable: GS



	MR	NMR
Count	16	0
# missing	0	16
Maximum	38.600	-
Minimum	8.170	-
Range	30.430	-
Variance	49.892	-
Standard Deviation	7.063	-
Coefficient of Variation	36.790	-
Maximum Z-Score	2.175	-
Minimum Z-Score	-1.561	-
95% Confidence		
Lower	15.121	-
Upper	23.278	-
Mean	19.199	-
Standard Error	1.888	-
Skewness	.567	-
Kurtosis	.124	-

APPENDIX I

MULTIVARIATE ANALYSIS OF VARIANCE OUTPUT

Multivariate Analysis of Variance
Computer Generated Output

"DAT.32.MATCHVAR"
Type III MANOVA Table

Effect: GROUP
Dependent Measures: AGE, BMI

S 1
M 0.000
N 13.500

	Value	F-Value	NumDF	DenDF	P-Value
Wilks' Lambda	.954	.695	2.000	29.000	.5072
Roy's Greatest Root	.048	.695	2.000	29.000	.5072
Hotelling-Lawley Trace	.048	.695	2.000	29.000	.5072
Pillai Trace	.046	.695	2.000	29.000	.5072

Type III Sums of Squares: **Dependent = AGE**

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Group	1	17.940	17.940	.190	.6662
Residual	30	2835.704	94.523		

Type III Sums of Squares: **Dependent = BMI**

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Group	1	17.895	17.895	1.278	.2673
Residual	30	420.127	14.004		

Means Table
Effect: Group
Dependent: AGE

	Count	Mean	St Dev	St Err
MR	16	28.140	8.433	2.108
NMR	16	29.637	10.86	2.715

Means Table
Effect: Group
Dependent: BMI

	Count	Mean	St Dev	St Err
MR	16	26.073	4.379	1.095
NMR	16	24.578	2.972	.743

Multivariate Analysis of Variance
Computer Generated Output

"DAT.32.ANAL"
Type III MANOVA Table

Effect: GROUP
Dependent Measures: FBMD, WBMD, LMM, BF, BS, GS

S 1
M 2.000
N 11.500

	Value	F-Value	NumDF	DenDF	P-Value
Wilks' Lambda	.183	18.651	6.000	25.000	.0001
Roy's Greatest Root	4.476	18.651	6.000	25.000	.0001
Hotelling-Lawley Trace	4.476	18.651	6.000	25.000	.0001
Pillai Trace	.816	18.651	6.000	25.000	.0001

Type III Sums of Squares: **Dependent = FBMD**

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Group	1	.035	.035	2.010	.1665
Residual	30	.518	.017		

Type III Sums of Squares: **Dependent = WBMD**

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Group	1	.013	.013	1.888	.1802
Residual	30	.208	.007		

Type III Sums of Squares: **Dependent = LMM**

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Group	1	427.745	427.745	17.061	.0003
Residual	30	752.167	25.072		

Type III Sums of Squares: **Dependent = BF**

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Group	1	273.78	273.78	5.918	.0212
Residual	30	1387.819	46.261		

Type III Sums of Squares: **Dependent = BS**

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Group	1	370.192	370.192	35.805	.0001
Residual	30	310.171	10.339		

Type III Sums of Squares: **Dependent = QS**

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Group	1	7264.343	7264.343	62.697	.0001
Residual	30	3475.952	115.865		

Means Table
Effect: Group
Dependent: FBMD

	Count	Mean	St Dev	St Err
MR	16	.845	.134	.033
NMR	16	.910	.129	.032

Means Table
Effect: Group
Dependent: WBMD

	Count	Mean	St Dev	St Err
MR	16	1.068	.091	.023
NMR	16	1.108	.074	.019

Means Table
Effect: Group
Dependent: LMM

	Count	Mean	St Dev	St Err
MR	16	39.867	5.847	1.462
NMR	16	47.180	3.995	.999

Means Table
Effect: Group
Dependent: BF

	Count	Mean	St Dev	St Err
MR	16	31.881	8.742	2.186
NMR	16	26.031	4.012	1.003

Means Table
Effect: Group
Dependent: BS

	Count	Mean	St Dev	St Err
MR	16	8.329	2.302	.575
NMR	16	15.132	3.922	.980

Means Table
Effect: Group
Dependent: QS

	Count	Mean	St Dev	St Err
MR	16	25.645	9.493	2.373
NMR	16	55.779	11.900	2.975

APPENDIX J

EVIDENCE FOR MEETING MANOVA ASSUMPTIONS

Issues in multivariate analysis

1) Unequal sample sizes and missing data

In this investigation, there were equal sample sizes and no missing data points. Refer to Appendix H.

2) Outliers

No univariate outliers existed using maximum and minimum z-scores (± 3.00) as a criterion. No check on multivariate analysis was done e.g. Mahalanobis Distance check.

3) Normality

Refer to Appendix H. Skewness and kurtosis check was adequate (within ± 3.00). Cumulative frequency curves for each variable resembled sigmoidal curves.

4) Multicollinearity/singularity

Refer to next page.

5) Homogeneity of variance-covariance matrices.

Refer to page 122.

6) Homoscedasticity

Refer to bivariate plots, page 123-132.

Multicollinearity and Singularity Check: Correlation Matrix for Variables with Undifferentiated Data

	FBMD	WBMD	LMM	%BF	BS	QS
FBMD	1.00					
WBMD	.780	1.00				
LMM	.629	.721	1.00			
%BF	-.177	.001	-.171	1.00 →		
BS	.554	.464	.652	-.479	1.00	
QS	.452	.405	.565	-.374	.747	1.00

FBMD = femoral neck bone mineral density (g/cm^2)
WBMD = whole body bone mineral density (g/cm^2)
LMM = lean muscle mass (kg)
%BF = percent body fat
BS = biceps strength (kg)
QS = quadriceps strength (kg)

The correlations among the variables used in the multivariate analysis suggest that problematic issues of multicollinearity or singularity were not present. In this instance, the strongest correlation between any two variables was among FBMD and WBMD with a correlation of .78. Variables would have been considered multicollinear had they been correlated .90 and above or singular had they been perfectly correlated.

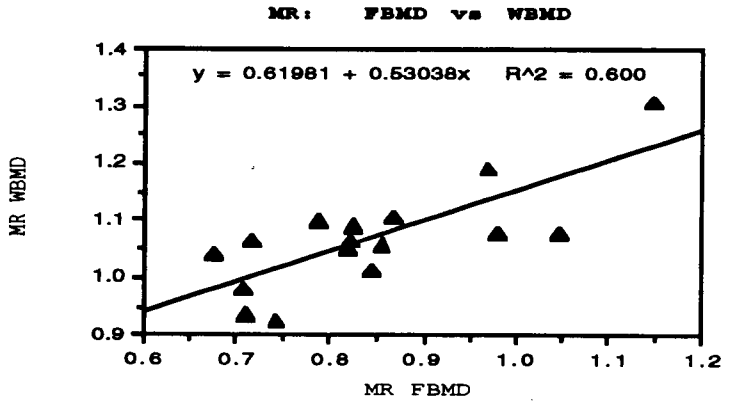
*Note: Statistical source: Tabachnik, B., & Fidell, L. (1989). Using multivariate statistics (2nd ed.). New York: Harper and Row.

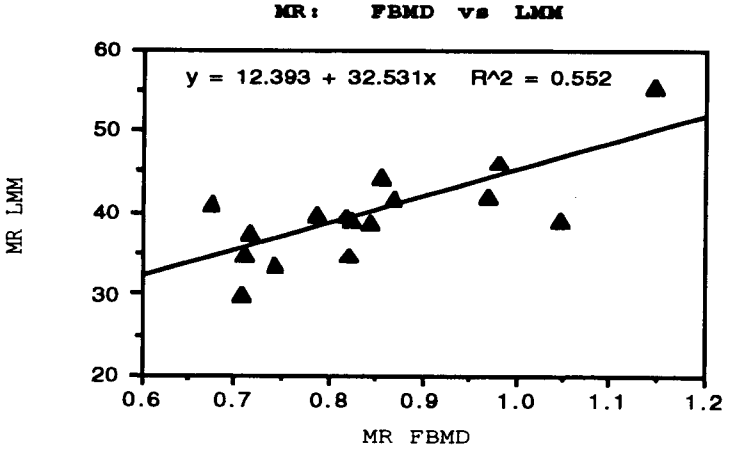
Homogeneity of Variance-Covariance Matrices Check

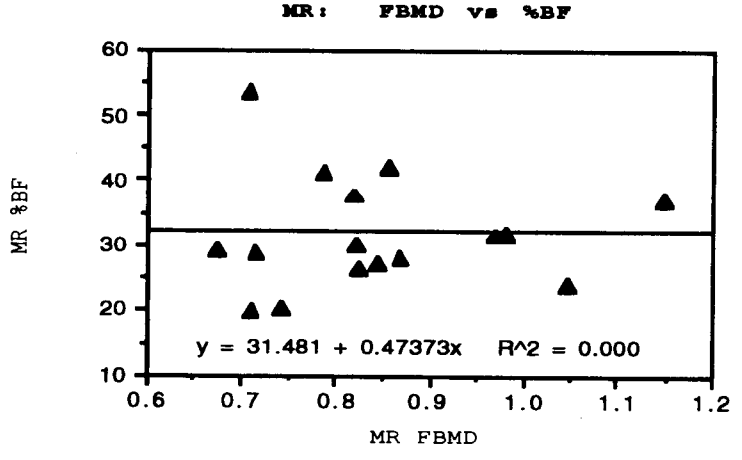
Variable	MR s^2	NMR s^2	ratio
Age	71.115	123.143	1.732:1
Height	39.795	42.119	1.058:1
Weight	145.796	51.642	2.823:1
BMI	19.177	8.134	2.358:1
FBMD	.018	.017	1.059:1
WBMD	.008	.005	1.600:1
LMM	34.183	15.962	2.142:1
%BF	76.426	16.096	4.748:1
BS	5.297	15.381	2.904:1
QS	90.123	141.607	1.571:1

As a preliminary check for robustness, sample variances for each dependent variable are compared across groups (MR and NMR). If the ratio of the largest to smallest variance for each dependent variable does not approach 20:1, then the assumption of homogeneity of variance-covariance matrices is satisfied (Tabachnik & Fidell, 1989, Pg. 411).

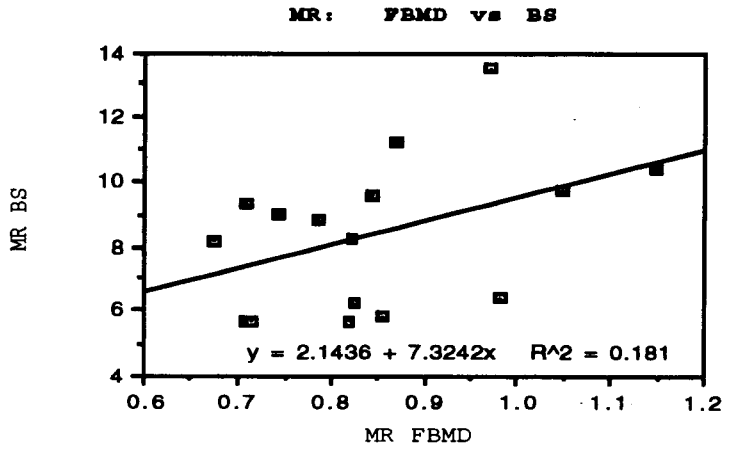
Homoscedasticity Check -- Bivariate Plots: MR Group

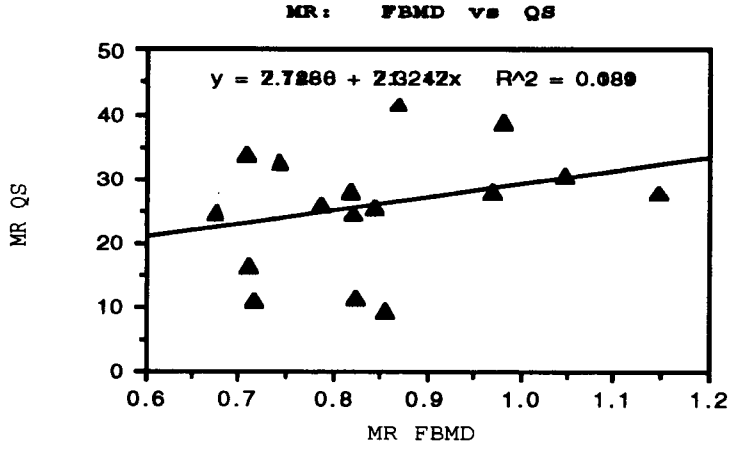


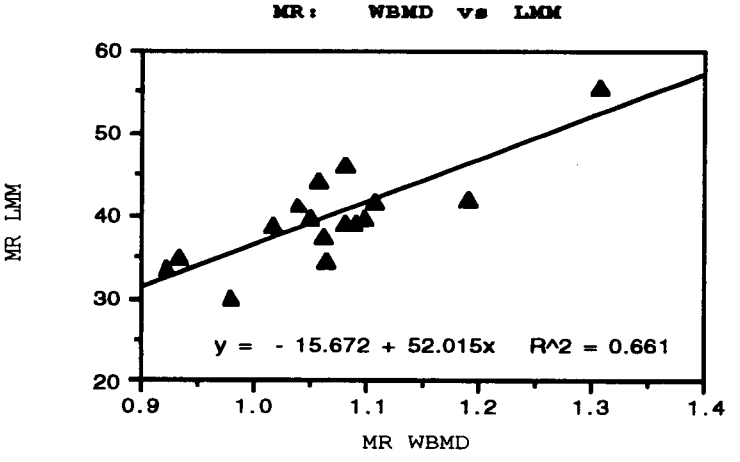




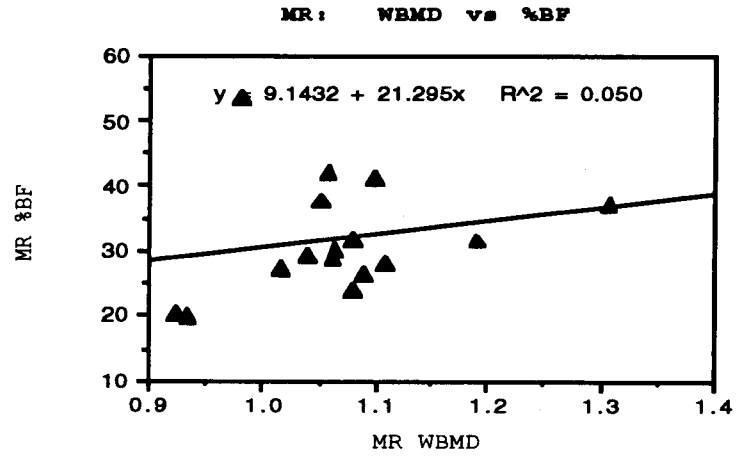
Homoscedasticity Check -- Bivariate Plots: MR group (cont'd)

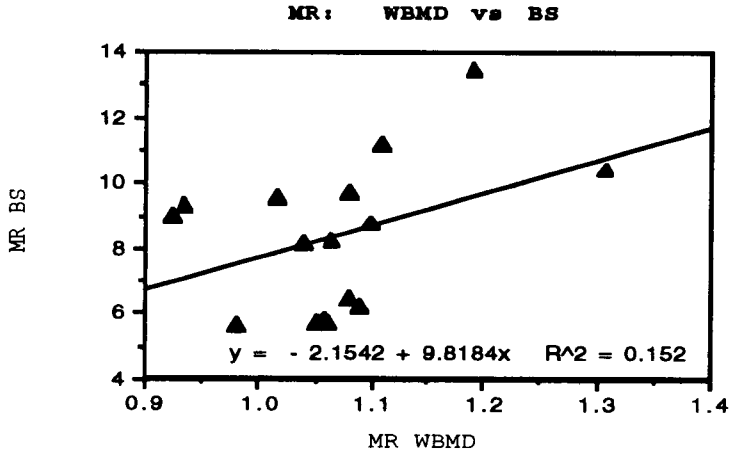


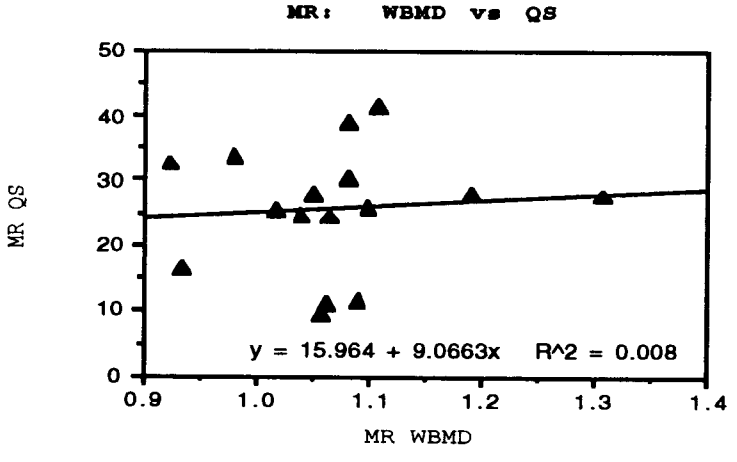




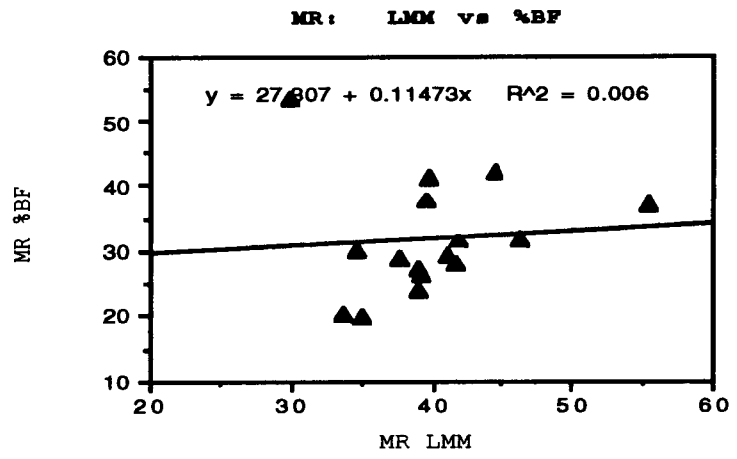
Homoscedasticity Check -- Bivariate Plots: MR group (cont'd)

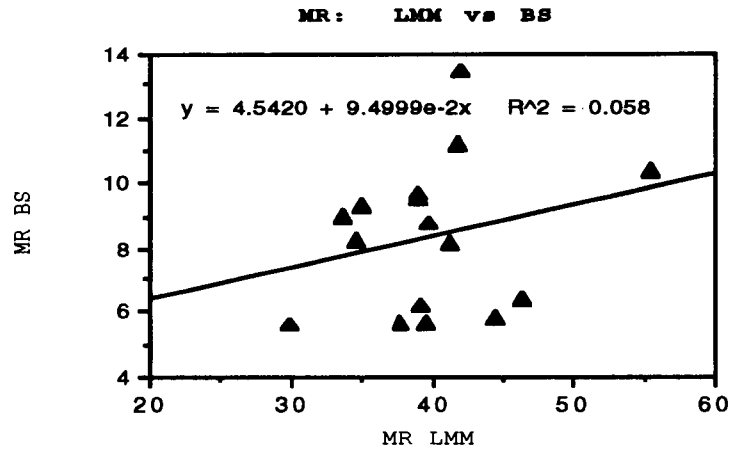


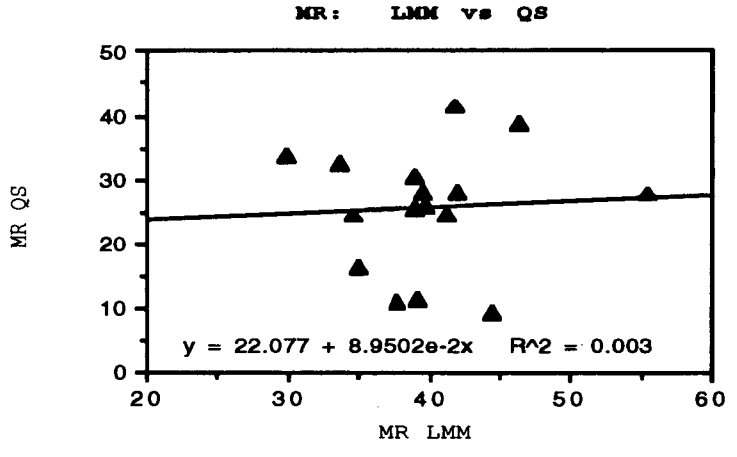




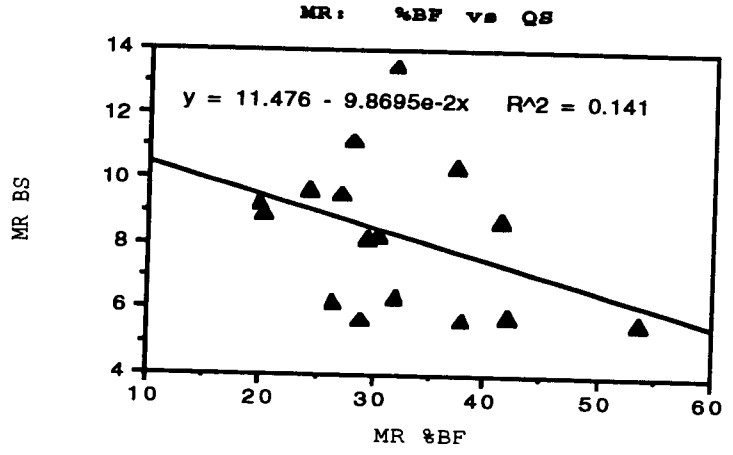
Homoscedasticity Check -- Bivariate Plots: MR Group (cont'd)

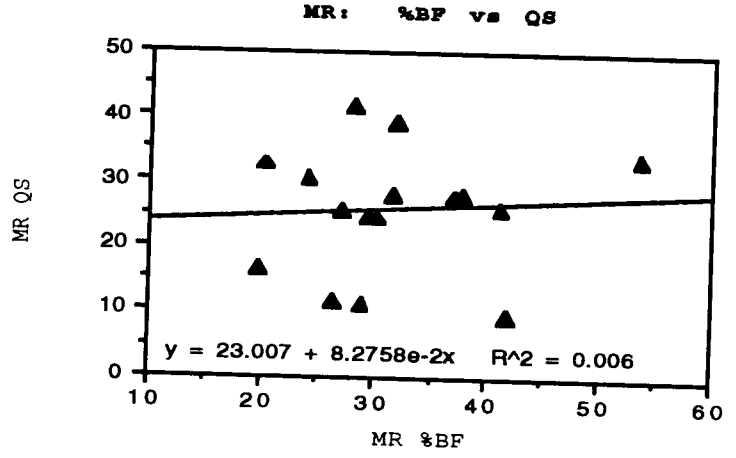


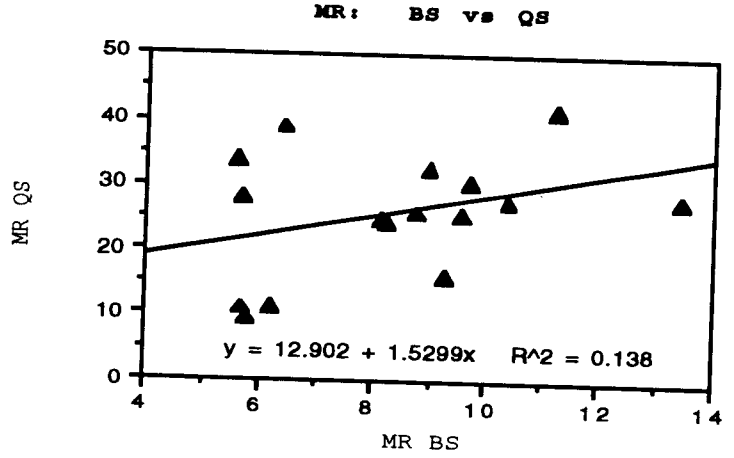




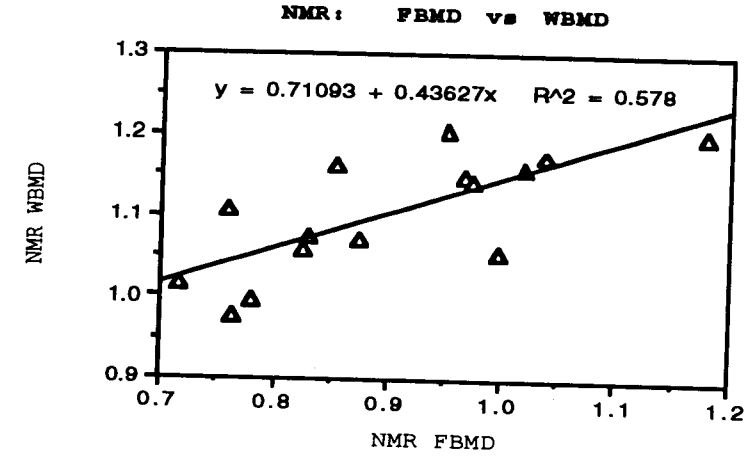
Homoscedasticity Check -- Bivariate Plots: MR Group (cont'd)

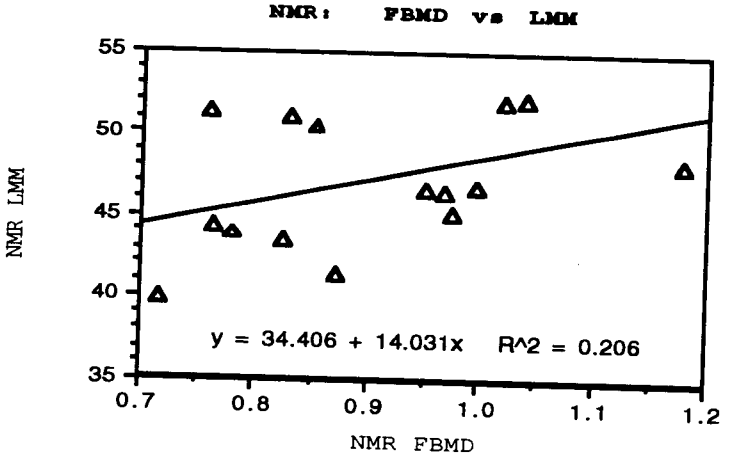


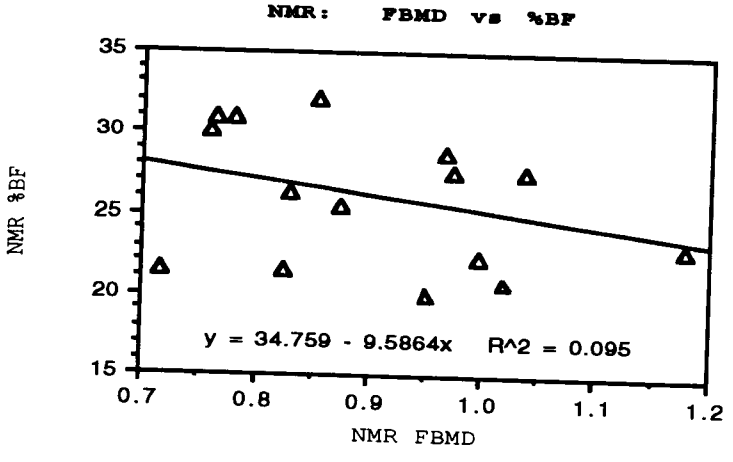




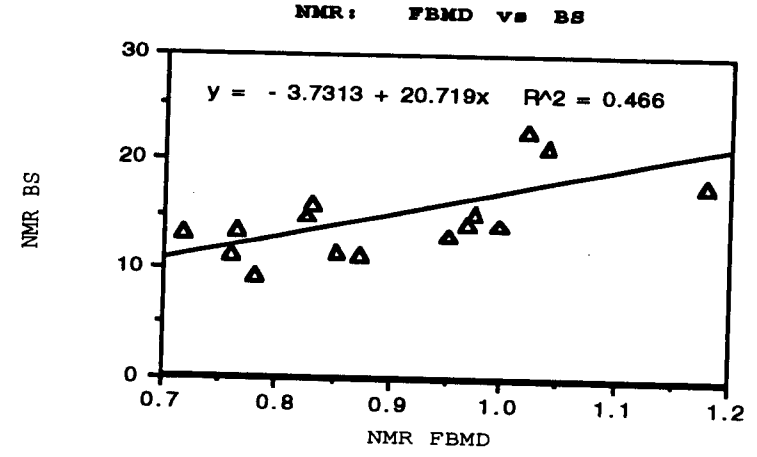
Homoscedasticity Check -- Bivariate Plots: NMR Group

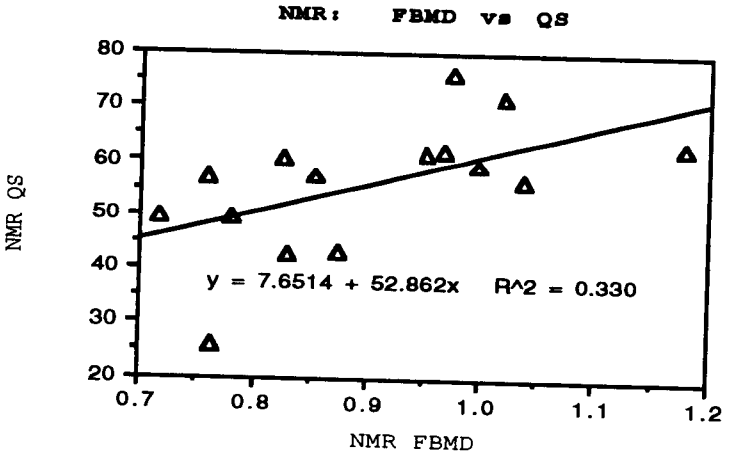


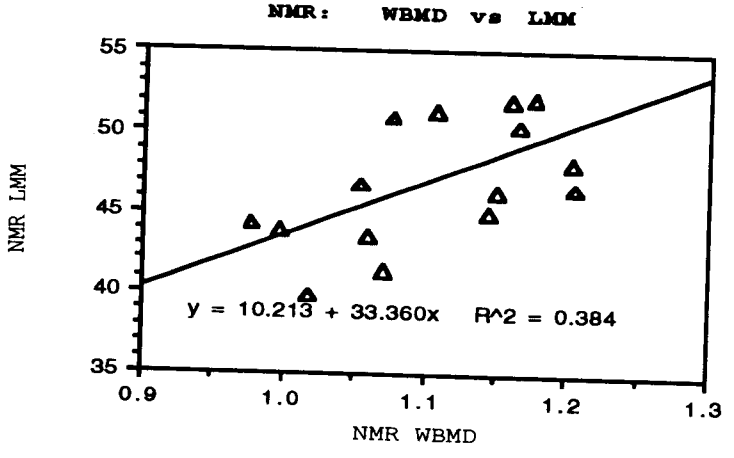




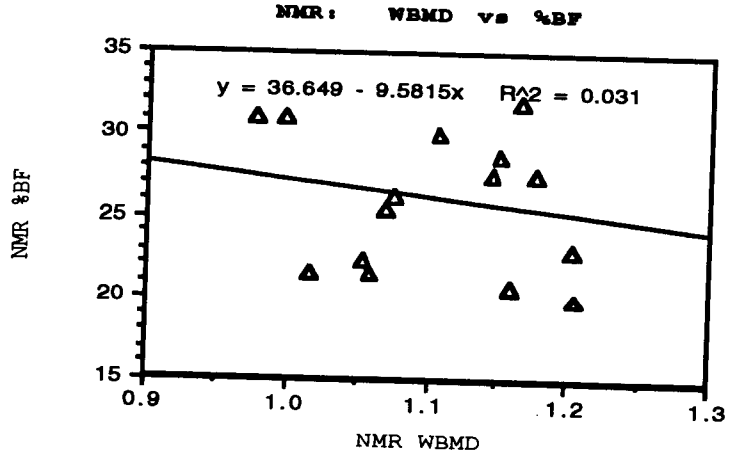
Homoscedasticity Check -- Bivariate Plots: NMR Group (cont'd)

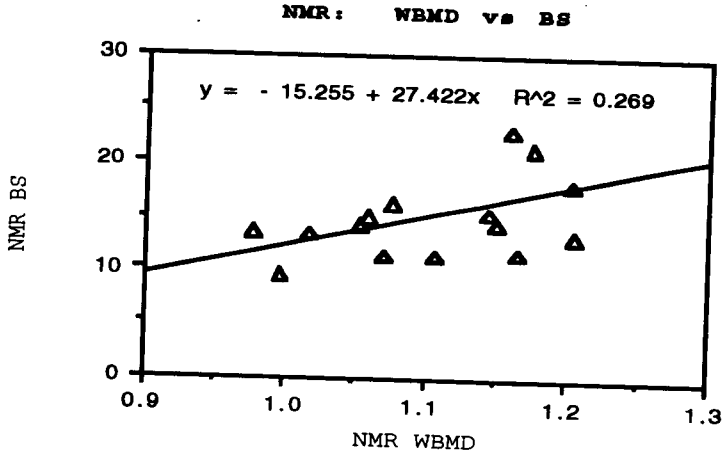


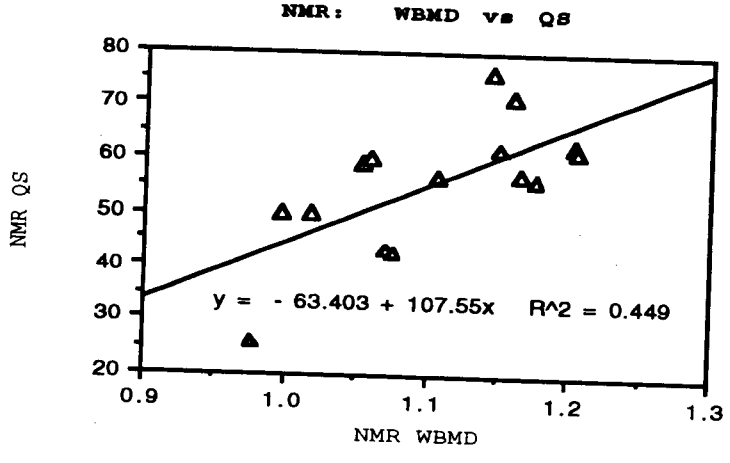




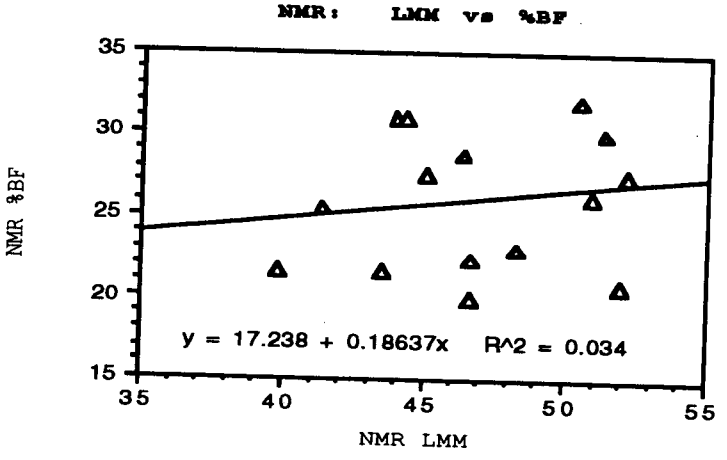
Homoscedasticity Check -- Bivariate Plots: NMR Group (cont'd)

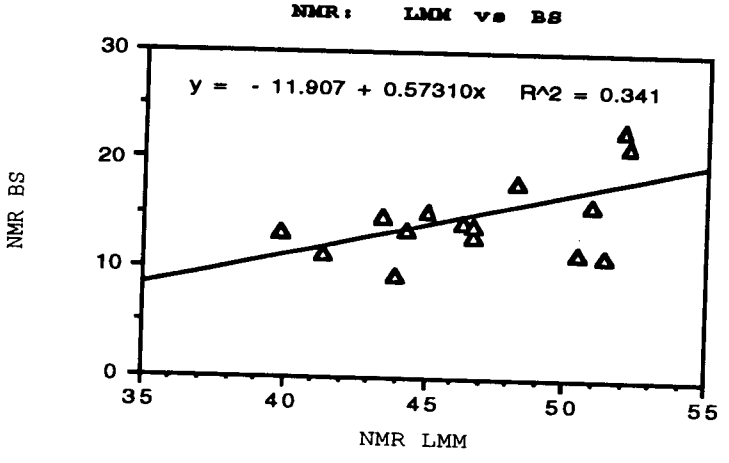


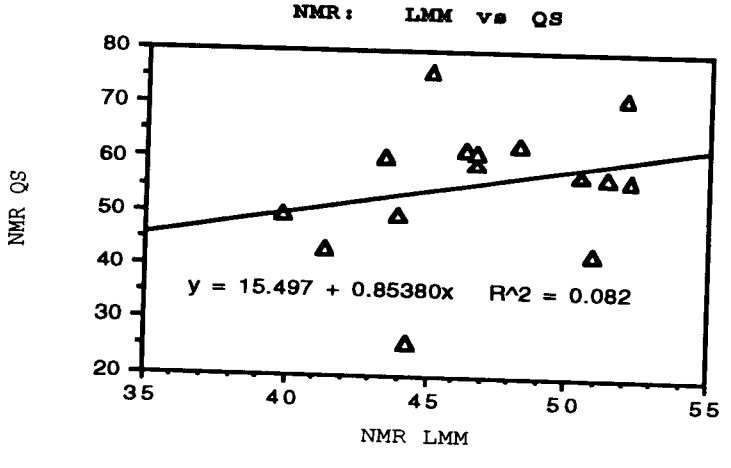




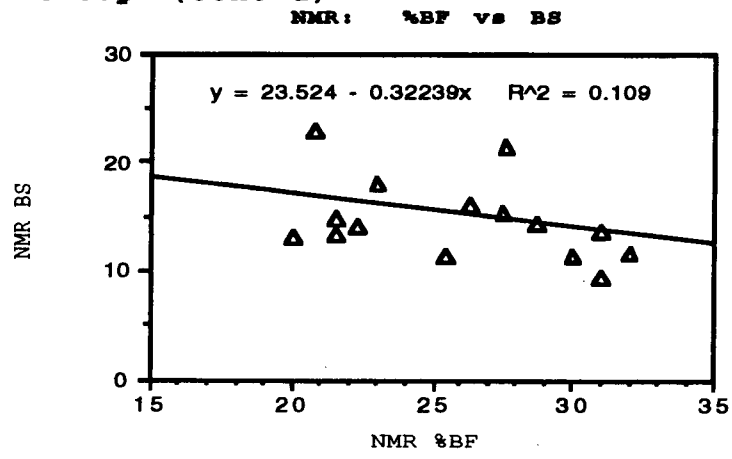
Homoscedasticity Check -- Bivariate Plots: NMR Group (cont'd)

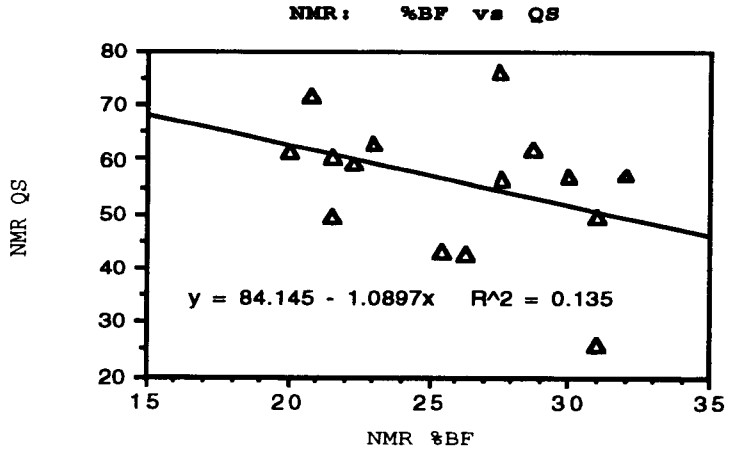


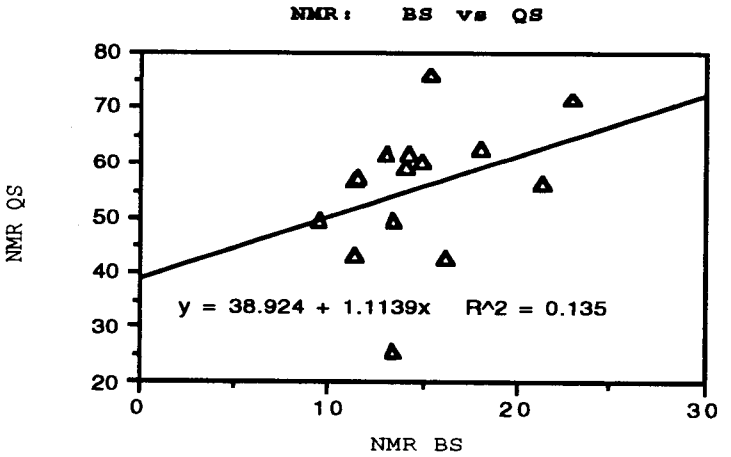




Homoscedasticity Check -- Bivariate Plots: NMR Group (cont'd)







APPENDIX K

MULTIPLE LINEAR REGRESSION OUTPUT

Multiple Linear Regression
Computer Generated Output

MR Group "Whole Body Bone Mineral Density"

Y	WBMD
X	LMM, %BF, BS, QS

DF	R	R^2	Adj R^2	Std Err
15	.884	.782	.703	.050

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	4	.098	.024	9.879
Residual	11	.027	2.480E-3	p = .0012
Total	15	.125		

Residual Information Table

SS[e(i)-(i-1)]	e>0	e<0	DW test
.088	9	7	3.211

Beta Coefficient Table

Parameter	Value	Std Err	Std Vlue	t-value	Probability
INTERCEPT	.425				
LMM	.011	2.316E-3	.702	4.738	6.0000E-4
%BF	3.369E-3	1.673E-3	.322	2.014	.0691
BS	.015	7.006E-3	.385	2.184	.0515
QS	-1.145E-3	1.512E-3	-.119	.757	.4649

Confidence Intervals and Partial F Table

Parameter	95% lower	95% upper	90% lower	90% upper	Partial F
LMM	5.873E-3	.016	6.812E-3	.015	22.447
%BF	-3.1336E-3	7.052E-3	3.6447E-4	6.374E-3	4.056
BS	-1.1901E-4	.031	2.720E-3	.028	4.771
QS	-4.474E-3	2.184E-3	-3.861E-3	1.571E-3	.573

Correlation Matrix for Variables

	LMM	%BF	BS	QS
LMM	1			
%BF	.077	1		
BS	.241	-.375	1	
QS	.055	.076	.371	1

Corr Coeff X1: LMM Y1: WBMD

Count	Covariance	Correlation	R-squared
16	.434	.813	.661

Corr Coeff X1: %BF Y1: WBMD

Count	Covariance	Correlation	R-squared
16	.178	.223	.050

Corr Coeff X1: BS Y1: WBMD

Count	Covariance	Correlation	R-squared
16	.082	.390	.152

Corr Coeff X1: QS Y1: WBMD

Count	Covariance	Correlation	R-squared
16	.076	.087	7.617E-3

Multiple Linear Regression
Computer Generated Output

MR Group "Femoral Neck Bone Mineral Density"

Y FBMD
X LMM, %BF, BS, QS

DF	R	R^2	Adj R^2	Std Err
15	.805	.647	.519	.093

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	4	.173	.043	5.048
Residual	11	.094	8.572E-3	p = .0148
Total	15	.267		

Residual Information Table

SS[e(i)-(i-1)]	e>0	e<0	DW test
.215	10	6	2.276

Beta Coefficient Table

Parameter	Value	Std Err	Std Vlue	t-value	Probability
INTERCEPT	.053				
LMM	.016	4.305E-3	.684	3.63	.0040
%BF	2.0997E-4	3.110E-3	.014	.068	.9474
BS	.011	.013	.195	.871	.4026
QS	2.632E-3	2.812kE-3	.187	.936	.3694

Confidence Intervals and Partial F Table

Parameter	95% lower	95% upper	90% lower	90% upper	Partial F
LMM	6.151E-3	.025	7.895E-3	.023	13.177
%BF	-6.637E-3	7.057E-3	-5.377E-3	5.796E-3	4.557E-3
BS	-.017	.04	-.012	.035	.758
QS	-3.557E-3	8.821E-3	-2.418E-3	7.681E-3	.876

Correlation Matrix for Variables

	LMM	%BF	BS	QS
LMM	1			
%BF	.077	1		
BS	.241	-.375	1	
QS	.055	.076	.371	1

Corr Coeff X1: LMM Y1: FBMD

Count	Covariance	Correlation	R-squared
16	.580	.743	.552

Corr Coeff X1: %BF Y1: FBMD

Count	Covariance	Correlation	R-squared
16	.8.445E-3	7.235E-3	5.2344E-5

Corr Coeff X1: BS Y1: FBMD

Count	Covariance	Correlation	R-squared
16	.131	.425	.181

Corr Coeff X1: QS Y1: FBMD

Count	Covariance	Correlation	R-squared
16	.378	.298	.089

Multiple Linear Regression
Computer Generated Output

NMR Group "Whole Body Bone Mineral Density"

Y WBMD
X LMM, %BF, BS, QS

DF	R	R^2	Adj R^2	Std Err
15	.809	.655	.529	.051

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	4	.054	.014	5.217
Residual	11	.028	2.590E-3	p = .0132
Total	15	.083		

Residual Information Table

SS[e(i)-(i-1)]	e>0	e<0	DW test
.047	7	9	1.659

Beta Coefficient Table

Parameter	Value	Std Err	Std Vlue	t-value	Probability
INTERCEPT	.548				
LMM	8.608E-3	4.852E-3	.464	1.774	.1037
%BF	-1.223E-4	4.309E-3	-.066	.284	.7818
BS	8.248E-4	4.939E-3	.044	.167	.8704
QS	3.099E-3	1.288E-3	.497	2.405	.0349

Confidence Intervals and Partial F Table

Parameter	95% lower	95% upper	90% lower	90% upper	Partial F
LMM	-2.072E-3	.019	-1.0573E-4	.017	3.148
%BF	-.011	8.262E-3	-8.963E-3	6.516E-3	.081
BS	-.010	.012	-8.045E-3	.010	.028
QS	2.6296E-4	5.935E-3	7.850E-4	5.413E-3	5.786

Correlation Matrix for Variables

	LMM	%BF	BS	QS
LMM	1			
%BF	.186	1		
BS	.584	-.330	1	
QS	.287	-.367	.367	1

Corr Coeff X1: LMM Y1: WBMD

Count	Covariance	Correlation	R-squared
16	.184	.619	.384

Corr Coeff X1: %BF Y1: WBMD

Count	Covariance	Correlation	R-squared
16	-.053	-.177	.031

Corr Coeff X1: BS Y1: WBMD

Count	Covariance	Correlation	R-squared
16	.151	.519	.269

Corr Coeff X1: QS Y1: WBMD

Count	Covariance	Correlation	R-squared
16	.592	.670	.449

Multiple Linear Regression
Computer Generated Output

NMR Group "Femoral Neck Bone Mineral Density"

Y FBMD
X LMM, %BF, BS, QS

DF	R	R^2	Adj R^2	Std Err
15	.767	.589	.439	.097

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	4	.148	.037	3.938
Residual	11	.103	9.372E-3	p = .032
Total	15	.251		

Residual Information Table

SS[e(i)-(i-1)]	e>0	e<0	DW test
.145	8	8	1.404

Beta Coefficient Table

Parameter	Value	Std Err	Std Vlue	t-value	Probability
INTERCEPT	.366				
LMM	1.699E-3	9.230E-3	.053	.184	.8573
%BF	-4.9027E-4	8.197E-3	-.015	.060	.9534
BS	.017	9.395E-3	.513	1.801	.0992
QS	3.968E-3	2.451E-3	.365	1.619	.1338

Confidence Intervals and Partial F Table

Parameter	95% lower	95% upper	90% lower	90% upper	Partial F
LMM	-.019	.022	-.015	.018	.034
%BF	-.019	.018	-.015	.014	3.577E-3
BS	-3.763E-3	.038	4.3447E-5	.034	3.243
QS	-1.427E-3	9.363E-3	-4.3424E-4	8.370E-3	2.621

Correlation Matrix for Variables

	LMM	%BF	BS	QS
LMM	1			
%BF	.186	1		
BS	.584	-.330	1	
QS	.287	-.367	.367	1

Corr Coeff X1: LMM Y1: FBMD

Count	Covariance	Correlation	R-squared
16	.234	.454	.206

Corr Coeff X1: %BF Y1: FBMD

Count	Covariance	Correlation	R-squared
16	-.160	-.309	.095

Corr Coeff X1: BS Y1: FBMD

Count	Covariance	Correlation	R-squared
16	.346	.683	.466

Corr Coeff X1: QS Y1: FBMD

Count	Covariance	Correlation	R-squared
16	.883	.574	.330

APPENDIX L

STEPWISE REGRESSION ANALYSIS OUTPUT

Stepwise Regression
Computer Generated Output

FBMD: "With Indicator Variable"

Y = FBMD
X = Indicator, LMM, %BF, BS, QS

F to enter: 4.21
F to remove: 4.21

(Last Step) Step No. 1
Variable Entered: LMM

R	R2	Adj R2	Std Err
.629	.396	.376	.106

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	1	.219	.219	19.66
Residual	30	.334	.011	
Total	31	.553		

STEP 1

Variables in Equation

Parameter	Value	Std Err	Std Value	F remove
Intercept	.285			
LMM	.014	3.072E-3	.629	19.66

Variables Not in Equation

Parameter	Par Corr	F enter
Indicator	.207	1.294
%BF	-.091	.241
BS	.244	1.83
QS	.15	.664

Stepwise Regression
Computer Generated Output

WBMD: "With Indicator Variable"

Y = WBMD
X = Indicator, LMM, %BF, BS, QS

F to enter: 4.21
F to remove: 4.21

(Last Step) Step No. 1
Variable Entered: LMM

R	R^2	Adj R^2	Std Err
.721	.519	.503	.059

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	1	.115	.115	32.392
Residual	30	.106	3.54E-3	
Total	31	.221		

STEP 1

Variables in Equation

Parameter	Value	Std Err	Std Value	F remove
Intercept	.659			
LMM	.01	1.732E-3	.721	32.392

Variables Not in Equation

Parameter	Par Corr	F enter
Indicator	.345	3.91
%BF	.179	.958
BS	-.01	2.956E-3
QS	-3.543E-3	3.641E-3

Stepwise Regression
Computer Generated Output

MR Group: "Femoral Neck BMD"

Y = FBMD
X = LMM, %BF, BS, QS

F to enter: 4.60
F to remove: 4.60

(Last Step) Step No. 1
Variable Entered: LMM

R	R^2	Adj R^2	Std Err
.743	.552	.520	.093

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	1	.148	.148	17.24
Residual	14	.12	8.559E-3	
total	15	.267		

STEP 1

Variables in Equation

Parameter	Value	Std Err	Std Value	F remove
Intercept	.168			
LMM	.017	4.086E-3	.743	17.24

Variables Not in Equation

Parameter	Par Corr	F enter
%BF	-.075	.073
BS	.378	2.168
QS	.385	2.264

Stepwise Regression
Computer Generated Output

MR Group: "Whole Body BMD"

Y = WBMD
X = LMM, %BF, BS, QS

F to enter: 4.60
F to remove: 4.60

(Last Step) Step No. 1
Variable Entered: LMM

R	R^2	Adj R^2	Std Err
.813	.661	.637	.055

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	1	.083	.083	27.301
Residual	14	.042	3.033E-3	
Total	15	.125		

STEP 1

Variables in Equation

Parameter	Value	Std Err	Std Value	F remove
Intercept	.561			
LMM	.013	2.432E-3	.813	27.301

Variables Not in Equation

Parameter	Par Corr	F enter
%BF	.276	1.072
BS	.343	1.73
QS	.073	.070

Stepwise Regression
Computer Generated Output

NMR Group: "Femoral Neck BMD"

Y = FBMD
X = LMM, %BF, BS, QS

F to enter: 4.60
F to remove: 4.60

(Last Step) Step No. 1
Variable Entered: BS

R	R^2	Adj R^2	Std Err
.683	.466	.428	.098

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	1	.117	.117	12.239
Residual	14	.134	.01	
Total	15	.251		

STEP 1

Variables in Equation

Parameter	Value	Std Err	Std Value	F remove
Intercept	.57			
BS	.023	6.435E-3	.683	12.239

Variables Not in Equation

Parameter	Par Corr	F enter
LMM	.093	.114
%BF	-.121	.194
QS	.476	3.813

Stepwise Regression
Computer Generated Output

NMR Group: "Whole Body BMD"

Y = WBMD
X = LMM, %BF, BS, QS

F to enter: 4.60
F to remove: 4.60

Step No. 1
Variable Entered: QS

R	R^2	Adj R^2	Std Err
.67	.449	.41	.057

Analysis of Variance Table

Source	DF	Sum Squares	Mean Square	F-test
Regression	1	.037	.037	11.429
Residual	14	.045	3.246E-3	
Total	15	.083		

STEP 1

Variables in Equation

Parameter	Value	Std Err	Std Value	F remove
Intercept	.875			
QS	4.179E-3	1.236E-3	.67	11.429

Variables Not in Equation

Parameter	Par Corr	F enter
LMM	.601	7.349
%BF	.100	.132
BS	.395	2.401

STEP 2

Variables in Equation

Parameter	Value	Std Err	Std Value	F remove
Intercept	.514			
LMM	8.641E-3	3.188E-3	.465	7.349
QS	3.347E-3	1.070E-3	.537	9.782

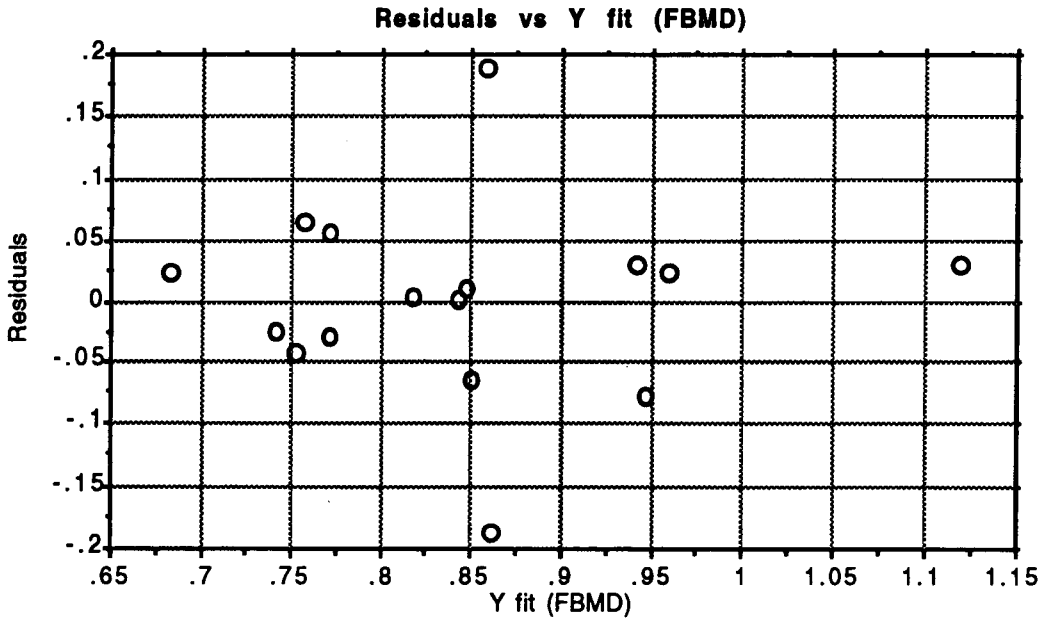
Variables Not in Equation

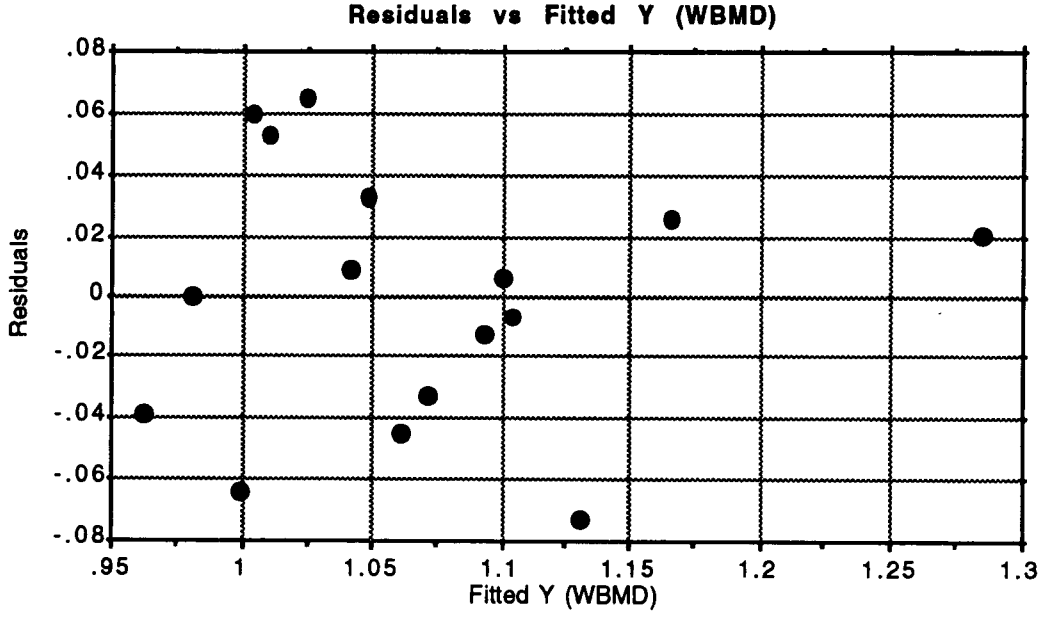
Parameter	Par Corr	F enter
%BF	-.127	.197
BS	.107	.139

APPENDIX M

EVIDENCE FOR MEETING REGRESSION ASSUMPTIONS

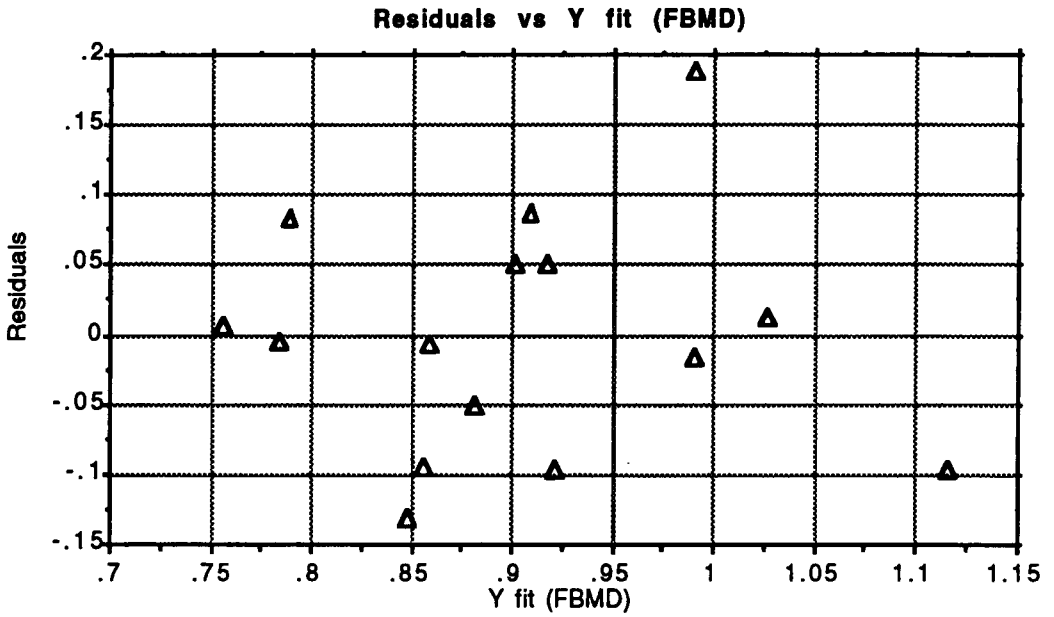
MLR Assumption of Homoscedasticity: MR Group

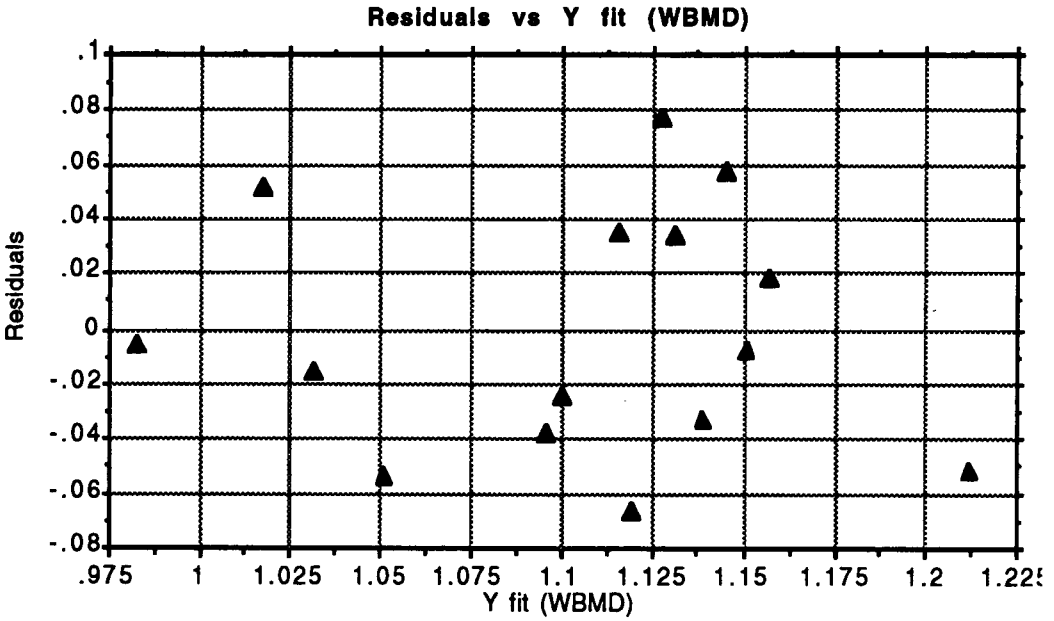




Fitted Y (WBMD)

MLR Assumption of Homoscedasticity: NMR Group





APPENDIX N

SUMMARY REPORT OF PHYSICAL ACTIVITY AND OSTEOPOROSIS RISK IN MR GROUP

SUMMARY REPORT OF PHYSICAL ACTIVITY AND OSTEOPOROSIS RISK IN SUBJECTS WITH MR

Smoking

All 16 of the subjects were non-smokers. None of them had smoked in the past.

Calcium

Of the 16 subjects, 14 were milk drinkers, and 2 currently did not drink any milk at all. Of the milk drinkers, the average amount of milk consumed each day was 1.76 glasses or 10.25 glasses per week.

Of the 16 subjects, 15 ate cheese, and 1 did not eat cheese. Of those who ate cheese, the average number of times they ate cheese was .40 times per day or 4.4 times per week.

Of the 16 subjects, 13 ate yogurt, and 3 did not eat yogurt. Of those who did eat yogurt, the average number of times they ate yogurt was .01 times per day or 1.62 times per week.

Note: One subject reported that she did not consume any milk, cheese, or yogurt. This person has a lactate deficiency.

Physical Activity

The average reported number of hours watching TV was 2.38 hours. The range of reported values was 1.00 to 5.00 hours.

Fifteen subjects were exposed to some degree of walking exercise. Walking ranged from an "occasional walk" to walking 3 miles/day for 5 days/week. Most of the individuals reported walking while going to and from work or during work hours. One subject did not walk for exercise at all (nor was she involved in any physical activity programs).

Only 1 person reported that she was a jogger, but only during good weather during the summer time (2 times per week).

One person reported that she was not involved in any sports. The remaining 15 subjects were involved with Special Olympics sports programs. Sporting events included swimming, track and field, downhill skiing, volleyball, bowling, softball, and basketball. These sport programs were seasonal, and most reported being actively involved 1-2 times per week during the season.

Specified sites of occuptions included: Grand Manor Inn, Pizza Hut, Open Door, Fred Meyer, Payless, and OSU Federal Credit Union. Unspecified sites of occupations included: a greenhouse, secretaries office, janitors station, clothing store, and a child day care center.

Duties performed at work included: maid work (cleaning rooms), cleaning tables, gardening, clerical work, stacking/sorting/arranging, assisting day care workers, janitorial work, and lawn maintenance.

The average number of hours worked per day was approximately 5.25 hours per day. The average number of days per week worked was approximately 4.00 days per week.

OSTEOPOROSIS RISK FACTORS

T	F	DN	
1	14	1	Has been treated with cortisone or similar drugs.
2	13	1	Has close relative with osteoporosis.
0	12	4	Has history of overactive thyroid gland.
0	10	6	Has history of overactive parathyroid gland.
2	14	6	Has history of alcoholism.
2	12	2	Has lactase deficiency.
1	15	0	Avoids milk and dairy products.
2	14	0	Drinks more than 2 cups of coffee or tea daily.
0	16	0	Drinks 3 or more alcoholic beverages daily.
0	13	3	Has taken thyroid hormone pills.
0	15	1	Has taken phenobarbitol or dilantin for over one year.
0	16	0	Has taken furosamide (Lasix) for over one year.
0	16	0	Has been treated with lithium for over one year.
0	16	0	Lost period for a year or more before it came back.
5	10	1	Has had irregular menstrual periods.
1	12	4	Menstrual period did not begin until after age sixteen.
0	13	3	Has medical history of endometriosis.
0	16	0	Has had both ovaries surgically removed.
0	16	0	Has breast fed a baby for one month or more.
0	16	0	Takes tamoxifin as treatment for breast cancer.
0	16	0	Went through menopause before age 50.
0	15	1	Has gone through menopause.
0	16	0	Has received estrogen treatment after menopause.
2	14	0	Is taking birth control pills. (T = ~3 yrs and 4 yrs)

T = True
F = False
DN = Don't Know

APPENDIX O

FACTORS IN OSTEOPOROSIS CLASSIFICATIONS

Factors Contributing to Secondary Osteoporosis (Taken from Aloia, 1989).

Drugs:

- Glucocorticoids
- Heparin
- Anticonvulsants
- Alcohol
- Methotrexate

Congenital Conditions:

- Osteogenesis imperfecta
- Hypophosphatasia
- Homocystinuria
- Hemolytic anemia

Diet:

- Malabsorption syndromes
- Calcium dificiency
- Starvation
- Scurvy

Endocrine:

- Hypogonadism
- Cushing's syndrome
- Hyperparathyroidism
- Hyperthyroidism
- Growth hormone deficiency

Others:

- Renal tubular acidosis
- Rheumatoid arthritis
- Immobilization
- Mastocytosis
- Liver disease
- Multiple myeloma, lymphoma
- Leukemia

Factors Influencing Postmenopausal (Type I) and Involutional (Type II) Osteoporosis (Taken from Aloia, 1989).

Factors	**Type I**	**Type II**
Age	55 to 75	> 70
Sex (F:M)	6:1	2:1
Fracture types	Wrist/vertebrae	Hip/vertebrae, long bones
Hormonal Deficiency	Estrogen	Calcitriol
Calcium absorption	Decreased	Decreased
Increased PTH	No	Yes
Importance of dietary calcium	Moderate	High

APPENDIX P

MEDICAL CONDITIONS INFLUENCING LOW BONE MASS

Common Medical Causes of Osteoporosis (Taken from Sinaki, 1989).

Hereditary:
- Osteogenesis imperfecta
- Neurologic disturbances
  - Myotonia congenita
  - Werdnig-Hoffman disease
- Gonadal dysgenesis

Acquired (primary and secondary):
- Generalized:
  - Idiopathic (premenopausal/juvenile)
  - Postmenopause
  - Senility
  - Nutrition
    - Malnutrition, anorexia nervosa
    - Vitamin deficiency (C or D)
    - Vitamin overuse (D or A)
    - Calcium deficiency
    - High sodium intake
    - High caffeine intake
    - High protein intake
    - High phosphate intake
    - Chronic alcoholism
  - Liver disease
  - Nephropathies
  - Chronic obstructive pulmonary disease
  - Malignancy (multiple myeloma, disseminated carcinoma)
  - Immobility
  - Drugs
    - Phenytoin
    - Barbiturate,
    - Cholestyramine
    - Heparin
  - Endocrine disorders
    - Acromegaly
    - Hyperthroidism
    - Cushing's syndrome (iatrogenic or endogenous)
  - Hyperparathyroidism
  - Diabetes mellitus
  - Hypogonadism
- Localized
  - Inflammatory arthritis
  - Fractures and immobilization in cast
  - Limb dystrophies
  - Muscular paralysis

APPENDIX Q

DRUGS AFFECTING BONE MASS

Drugs that may produce bone loss (Derived from Aloia, 1989).

Glucocorticoids

Thyroid hormone in excess

Antiestrogens

Gonadotropin-releasing hormone agonists

Antacids containing aluminum

Loop diuretics

Tetracycline

Isoniazide

Anticonvulsants

APPENDIX R

RAW DATA

ID#	Group	Age	Height	Weight	BMI	FBMD	WBMD	LMM	BF	QS	BS	GS
01	MR	44.83	149.86	51.94	23.13	.821	1.064	34.56	30.30	24.49	8.25	21.04
02	MR	21.83	152.40	61.15	26.33	.673	1.039	41.21	29.30	24.76	8.16	8.17
03	MR	27.08	165.10	55.51	20.36	.715	1.063	37.63	28.90	11.02	5.71	9.48
04	MR	44.50	165.10	80.13	29.40	.856	1.058	44.42	41.90	9.39	5.80	17.32
05	MR	20.83	152.40	64.77	27.89	.970	1.191	41.93	31.60	28.03	13.47	13.74
06	MR	25.67	162.56	56.23	21.28	.845	1.016	38.95	27.20	25.49	9.57	34.56
07	MR	23.83	160.02	71.40	27.88	.981	1.081	46.26	32.00	39.05	6.44	17.41
08	MR	21.58	144.78	68.54	32.66	.706	.981	29.84	53.60	33.56	5.62	16.24
09	MR	19.50	152.40	54.08	23.28	1.046	1.081	39.00	24.20	30.48	9.71	17.37
10	MR	21.75	154.94	44.24	18.43	.742	.923	33.63	20.30	32.74	8.98	24.17
11	MR	24.50	163.83	93.29	34.76	1.149	1.306	55.45	37.20	27.94	10.39	21.63
12	MR	30.42	158.75	67.01	26.59	.820	1.051	39.53	37.90	28.03	5.71	18.41
13	MR	27.17	154.94	71.33	29.71	.785	1.098	39.75	41.30	25.81	8.75	19.41
14	MR	22.83	152.40	61.02	26.27	.868	1.107	41.65	28.10	41.59	11.20	29.84
15	MR	41.42	152.40	54.42	23.43	.710	.935	34.95	19.90	16.42	9.30	38.60
16	MR	32.50	147.32	55.93	25.77	.826	1.090	39.12	26.40	11.52	6.21	20.36
17	NMR	43.00	167.40	61.68	21.95	.952	1.205	46.69	20.00	61.59	13.06	
18	NMR	18.50	160.02	65.53	25.59	.974	1.144	45.05	27.50	75.96	15.37	
19	NMR	27.00	170.18	53.51	18.48	.717	1.016	39.88	21.60	49.98	13.38	
20	NMR	47.00	172.27	78.00	26.15	.852	1.165	50.39	32.00	57.41	11.52	
21	NMR	18.50	165.10	66.20	24.29	1.179	1.203	48.22	23.00	62.81	18.05	
22	NMR	22.20	154.94	58.26	24.27	.873	1.069	41.39	25.50	43.31	11.43	
23	NMR	19.20	160.02	75.57	29.51	1.039	1.175	52.14	27.60	56.60	21.32	
24	NMR	36.00	165.10	67.12	24.62	.763	.977	44.29	31.00	25.71	13.47	
25	NMR	18.90	167.64	62.99	22.41	.996	1.053	46.73	22.30	59.32	14.15	
26	NMR	22.30	177.80	69.02	20.35	1.019	1.160	51.95	20.80	71.88	22.86	
27	NMR	40.00	160.02	71.66	27.98	.831	1.076	50.90	26.30	42.72	16.10	
28	NMR	38.00	162.56	66.67	25.23	.779	.997	43.93	31.00	49.75	9.48	
29	NMR	19.20	160.02	75.57	29.51	1.039	1.175	52.14	27.60	56.60	21.32	
30	NMR	21.40	157.48	58.09	23.42	.826	1.058	43.49	21.60	60.36	14.97	
31	NMR	38.00	175.26	76.64	24.95	.760	1.106	51.33	30.00	56.69	11.34	
32	NMR	45.00	167.64	68.93	24.53	.968	1.151	46.35	28.70	61.77	14.29	

Age = yrs; Height = cm; BMI = kg/m^2; FBMD & WBMD = g/cm^2; Weight, LMM, QS, BS, & GS = kg; BF = %