CORTICAL BONE QUALITY AMONG PRE-IROQUOIAN AND IROQUOIAN POPULATIONS OF THE LOWER GREAT LAKES REGION

By

REBECCA ANNE SOUTHERN, B.A.

A Thesis

Submitted to the School of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree

Master of Arts

McMaster University

MASTER OF ARTS (1990)
(Anthropology)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: Cortical Bone Quality Among Pre-Iroquoian and Iroquoian Populations of the Lower Great Lakes Region

AUTHOR: Rebecca Anne Southern

SUPERVISOR: Professor Shelley R. Saunders

NUMBER OF PAGES: x, 116

ABSTRACT

This study was designed to distinguish environmental from population-based influences on cortical bone quality among pre-Iroquoian and Iroquoian populations of the lower Great Lakes region. Excavated human bone from a total of seven archaeological sites in southern Ontario and New York State was studied. These skeletal samples span approximately 1500 years of prehistory in this region and represent populations subject to a range of environmental conditions which could have had an impact on cortical bone status. Single photon absorptiometry of the radius and radiography of the second metacarpal and radius were used to obtain values for the bone mineral index (BMI) and percent cortical area (PCA) respectively. The data were compared by age and by sex both within and between skeletal samples. Comparisons were also made to published data on modern populations.

Significant differences were found between the skeletal samples as well as between the skeletal samples and modern populations. These results suggest that a combination of environmental and population-based factors influenced cortical bone quality among the pre-Iroquoian and Iroquoian populations of this geographic region. These findings may have implications for an understanding of cortical bone loss among living Iroquoian populations in this area.

ACKNOWLEDGEMENTS

First, I'd like to thank my supervisor, Dr. Shelley Saunders. Her suggestions and advice as well as her encouragement, support and friendship are greatly appreciated. I'd also like to thank Dr. Emöke Szathmary and Dr. Susan Pfeiffer for their support and interest in this project and for their comments and criticisms on earlier drafts of this thesis. I am especially indebted to Dr. Szathmary for initially sparking my interest in the etiology of bone loss among Canadian Natives.

I am grateful to the Royal Ontario Museum, the Rochester Museum and Science Center, the Canadian Museum of Civilization and the Department of Anthropology at the University of Toronto for allowing me access to the skeletal collections in their care. I'd especially like to thank those individuals at these institutions who so gave generously their time and advice. In particular, I'd like to thank Dr. David Pendergast and Ms. Anne MacLaughlin at the Royal Ontario Museum, Dr. Lorraine Saunders and Mrs. Betty Prisch at the Rochester Museum and Science Center, Dr. Jerome Cybulski and Mrs. Jean Langdon-Ford at the Canadian Museum of Civilization and Dr. Gary Heathcote and Mr. John Reid at the University of Toronto.

I'd like to thank Dr. Colin Weber, Department of Nuclear Medicine, McMaster University, for his time and advice and for providing access to the facilities in that department.

Special thanks to my friend Mr. Richard Lazenby not only for his advice, comments and criticisms during all phases of this project but also for his concern and willingness to help. I'd also like to thank Tracy Rogers for her assistance with some of the less than exciting aspects of data collection. I am also grateful to my fellow graduate students and friends in the Department of Anthropology for all of their moral support.

I'd like to thank my father, Mr. Stan Southern, for his understanding, encouragement and pride in all my endeavours. I'd also like to thank the other members of my family for their continuing support. Finally, I'd like to thank Philip Woodley for his patience and for believing in me.

Funding for this project was generously provided by the Ontario Heritage Foundation (Grant no. ARG-433).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

Statement of the Problem

Some loss of cortical bone is a normal characteristic of advancing age. The magnitude of bone loss and the rate at which the loss occurs can be influenced by race, sex and a number of environmental factors. Osteoporosis is a metabolic bone disease characterized by a marked reduction in bone quantity and accompanied by an increase in fracture risk, particularly in the hip, wrist and spine. There is growing concern among both health professionals and the general public about the social and economic impact of this disease. It is becoming increasingly important to determine the factors responsible for osteoporosis and to be able to differentiate those individuals and groups which are at risk for the disease.

Research by Evers and associates (1985) was designed to assess cortical bone quality among a sample of present-day postmenopausal Indian and Caucasian women from southwestern Ontario and to determine factors which would identify individuals at greatest risk for developing osteoporosis. This investigation demonstrated that the Indian women had less cortical bone than Caucasian women of similar age. In addition to the number of years since menopause, factors such as obesity and smoking were identified as significant predictors of bone density among the Indian women. The possibility of a population-based difference in cortical bone quality was not addressed.

The present research project is designed to investigate the possibility that population-based factors are involved in the control of cortical bone quality among Indian women. Seven skeletal samples from archaeological sites in the lower Great Lakes region were studied in an

attempt to assess cortical bone quality among pre-Iroquoian and Iroquoian populations. The data obtained from this investigation make it possible to draw inferences concerning the effects and significance of environmental and population-based factors in the control of cortical bone quality among Iroquoian populations.

Research Objectives

The objectives of this research project are:

1. To quantitatively assess cortical bone quality among the pre-Iroquoian and Iroquoian populations of the lower Great Lakes region. This includes comparisons of bone quality indicators by sex and by age both within and between skeletal samples, comparisons to modern population data, an examination of patterns that emerge and a comparison of these patterns through time and space.
2. To account for any variability, or lack of variability, through time and/or space that may be found in cortical bone quality. This involves a consideration of the factors implicated in the etiology of cortical bone loss as they are presently understood and, also, a consideration of the archaeological and ethnohistoric data concerning the settlement patterns, subsistence activities and social organization of the pre-Iroquoian and Iroquoian groups of this geographic region, insofar as they may have an effect on cortical bone quality.
3. To consider briefly the implications of the results of this analysis for an understanding of the control of cortical bone quality among living Iroquoian populations of the lower Great Lakes area.

Overview of Research Materials and Methods

Excavated human bone from Serpent Mounds, the Roebuck site, and the MacPherson and MacKenzie-Woodbridge sites in Ontario and the Sackett, Castle Creek and Tram sites in New York State was included in the analysis. These samples were initially chosen on the basis of three criteria:

1. Collectively they provide adequate numbers of articulated adult skeletons.
2. They cover a broad temporal span (approximately A.D. 100 to A.D. 1600).
3. They differ slightly in geographic place of origin.

The sex of each individual was determined and the age was estimated using a combination of morphological and metric observations of the cranial and postcranial remains.

Single photon absorptiometry (SPA) of the radius was one of the techniques used to assess cortical bone quality. This is a non-destructive technique which provides a measure of bone mineral content (BMC), or mass, in g/cm. It has been demonstrated that SPA of the radius provides a measure of bone mineral content that correlates well with other cortical sites in the skeleton and with total body calcium ($r > .90$) (Johnston 1983). SPA is a simple technique which provides highly replicable results. It is also a very common clinical technique. As a result, there is a substantial body of published data with which comparisons could be made.

Radiography of the radius and of the second metacarpal were also used to assess cortical bone quality. Measurements were taken directly from x-rays and the cortical bone status of each individual was determined using the techniques for calculating percent cortical area (PCA) outlined by Garn (1970) and Meema and Meema (1973). As with SPA, there were a number of advantages to using x-rays in this analysis. Radiography is completely non-destructive and is a very common clinical technique. Again, a broad data base exists which could be used for comparison.

Once all of the relevant data were obtained, comparisons were made by age and by sex both within and between samples. In addition, comparisons were made to published data on modern populations.

Interpretation of the Data

It is well known that sex influences the proportion of cortical bone lost with advancing age and the rate at which the loss occurs. There are, however, a number of factors in addition to sex which appear to influence the magnitude and rate of cortical bone loss. Race, exercise, weight, smoking, long-term drug and alcohol use, disease, pregnancy and lactation and dietary factors have all been implicated in the maintenance or loss of cortical bone (eg. Auwerx et al 1988; Clochon et al 1989; Christiansen and Riis 1989; Daniell 1976; DeSimone et al 1989; Draper and Scythes 1981; Mazess and Mather 1974, 1975; Smith and Gilligan 1989; Wardlaw and Pike 1986).

This research project is intended to distinguish environmental from population-based influences on cortical bone quality among pre-Iroquoian and Iroquoian populations of the lower Great Lakes region. The skeletal samples used in this project represent both the late Middle Woodland and the Late Woodland periods. Substantial changes in the subsistence activities, settlement pattern and social organization of Iroquoian populations occurred over this time. The most significant of these changes involved the transition from a hunting and gathering lifestyle to the full scale adoption of maize agriculture and the development of large permanent villages. It has been estimated that, by the early historic period, maize provided 50% (Schwarcz et al 1985) to 65% (Heidenreich 1978) of the diet and the largest Iroquoian villages had 1500 or more inhabitants (Trigger 1978: 802).

There were also a number of other changes in Iroquoian life which took place over this time span. There is evidence that the adoption of agriculture and village development were

accompanied by population growth (Noble 1975). Intervillage warfare may have begun prior to A.D. 1000 (Stothers 1977) and escalated thereafter. This warfare ultimately resulted in the destruction and dispersal of the Ontario Iroquoians by the Five Nations Iroquois during the first half of the seventeenth century. Trade between Europeans and Iroquoians may have begun by the early 1500's (Ramsden 1978) and is postulated to be a motivating factor behind Iroquoian warfare during the early historic period (Heidenreich 1978). It is also evident that a general decline in health status had occurred by late prehistoric-early historic times (eg. Patterson 1986; Pfeiffer 1984; Pfeiffer et al 1986; Wray et al 1987). Pfeiffer (1986) suggests that a complex or interaction of factors best accounts for this decline. Not only nutritional deficiencies but also warfare would have taken its toll on Iroquoian populations. Warfare could have resulted in village crowding, the interruption of subsistence activities and the breakdown of social support systems, all of which could have further affected disease and diet.

To reiterate, this project is intended to differentiate environmental from population-based influences on cortical bone quality. Clearly, the skeletal samples used in this project represent populations subject to a range of environmental factors which could have had an adverse affect on cortical bone status. The rationale behind this study was that if continuity and consistency in cortical bone quality could be demonstrated through time and space then it would be possible to argue that population-based factors are of primary importance. Conversely, if discontinuities or inconsistencies were evident, then it would be possible to argue for environmental control.

A fundamental assumption behind this study is that all the skeletal samples under consideration represent populations which were genetically or biologically related. Linguistic, archaeological and biological evidence may be cited in direct and indirect support of this assumption. While distinctions can be made between individual languages of the Iroquoian group, all share similar underlying structures which show them to be related to one another and to be

separated from other language families (Lounsbury 1978). According to Lounsbury (1978: 334), it must be assumed that the languages of the Iroquoian family are descended from a single ancestral language. A common linguistic origin may imply a common biological origin (Spuhler 1972; 1979). The skeletal samples used in this study date between A.D. 100 and A.D. 1600. It is assumed that Iroquoian groups in this region originated locally prior to 0 A.D. and developed in-situ thereafter (Tuck 1978: 322). MacNeish (1952) has demonstrated an in-situ development of Iroquoian populations from at least Point Peninsula through to the historic period in both Ontario and New York State. The striking similarities in material culture between contemporaneous pre-Iroquoian and Iroquoian groups in Ontario and New York State cannot be ignored. Finally, Molto's (1983) analysis of discontinuous cranial morphology has demonstrated that the Middle Woodland populations in Ontario were ancestral to the Ontario Iroquois and that the Late Woodland Iroquois populations in Ontario represent a relatively homogeneous biological population.

Chapter 2: Aging Bone Loss

According to Heaney (1988: 360) there are three broad categories of factors which interact and contribute to individual bone mass: genetic, mechanical and nutritional/endocrine factors. During growth, the peak bone mass attained by an individual is determined largely by genetic factors with mechanical loading and nutrition enhancing or diminishing this genetic tendency. After maturity, mechanical factors and nutritional intake become increasingly important to the maintenance of peak bone mass. Peak bone mass must be used biomechanically in order to be sustained and nutritional intake of calcium and phosphorus must be sufficient to meet extraskeletal demands if the removal of these minerals from skeletal tissue is to be minimized.

The etiology of age-associated cortical bone loss is not simple or straightforward. There are many specific factors, especially within the category of nutritional/endocrine factors, which are known or are suspected to contribute to the maintenance or loss of skeletal mass. This chapter reviews what is known about the magnitude, rate and etiology of adult cortical bone loss among modern populations.

The Magnitude and Rate of Adult Cortical Bone Loss

Formation and resorption of bone are processes ongoing throughout the lifetime of an individual. However, with advancing age, bone formation becomes impaired (Riggs and Melton 1986: 1677). Bone resorption exceeds deposition and, as a result, individuals experience a net

loss of bone. Over a lifetime, females can lose up to 35% of their cortical bone and 50% of their trabecular bone. Males lose about two-thirds of these proportions (Riggs and Melton 1986: 1676).

It is well established that sex influences not only the amount of bone lost with advancing age but also the rate at which the loss occurs. There has been some discrepancy in the literature, however, regarding age at the onset of cortical bone loss and the magnitude of the rate of loss. Based on a survey of the research to date, Mazess (1982) reported that the onset of loss of compact bone in males begins in the fifth decade of life and bone mass declines thereafter at a rate of 3-5% per decade. Peak mass of compact bone in females is attained by approximately 35 years of age and then declines at 3% per decade until the onset of menopause at which time the rate of loss accelerates to 10% per decade. This loss persists until approximately 75 years of age at which time the rate of loss decreases, again to 3% per decade.

More recent studies report somewhat different findings. Based on their study of a large Belgian Caucasian population, Geusens et al (1986) report that males achieve peak bone mass in the radius and metacarpal by age 25 but that significant loss of compact bone does not occur until 65 years of age. Females attain peak bone mass at 35 years of age but there is no significant age-associated loss of compact bone from the peripheral skeleton until the onset of menopause. Thomsen et al (1986) found a significant overall decrease in forearm bone mineral content of 4% per decade in males between the ages of 20 and 90 years but found no significant change in forearm bone mineral content in females until menopause. After menopause, the loss of bone mineral amounted to 10-15% per decade. Similarly, Riggs and associates (1986) found no change in the bone mineral density of the radius of women until menopause after which there was a decrease of 10% per decade.

At all ages, males have more bone than females (Geusens et al 1986; Thomsen et al 1986). Despite discrepancies regarding the exact pattern of bone loss and the absolute magnitude of the

rate of loss, it remains clear that females experience a greater overall reduction in bone mass than males and end up with less bone. It is likely that the decrease in compact bone experienced by females is due to a rapid, menopause-induced loss superimposed on an underlying, slower, age-related loss (Geusens et al 1986; Mazess 1982; Thomsen et al 1986).

Genetic Factors

Twin studies (eg. Smith et al 1973; Pocock et al 1987) have shown high intrapair correlations for bone mineral density measured at the proximal femur and at the lumbar spine and for bone mineral content measured at the forearm, the correlations being stronger for monozygotic than dizygotic twin pairs. These results are believed to demonstrate a significant genetic component to the determination of bone mass. Pocock et al (1987) found the highest correlation between monozygotic twins at the lumbar spine and suggest a greater contribution of genetic factors in determining bone mass at this site. Lower correlations at the wrist and hip may suggest that environmental factors are of greater significance at these two sites.

The effect of genetic factors on bone mass in persons other than twins is still unclear (Evans et al 1988: 870). Evans et al (1988) found that relatives of osteoporotic patients failed to achieve normal peak bone mass and, although the data do not exclude the possibility of environmental influences, the authors suggest that this failure is most likely due to genetic factors. Seeman and associates (1989) found daughters of women with postmenopausal osteoporosis, in comparison to daughters of normal postmenopausal women, to have reduced bone mass in the lumbar spine and femoral neck but acknowledge that similarities in both lifestyle and genetic makeup could contribute to this finding.

It has also been suggested that population or race affects cortical bone status. Mazess and Mather (1974, 1975) have argued that Alaskan and Canadian Eskimo populations exhibit a more

marked loss of bone than U.S. Caucasians. The onset of bone loss seems to occur earlier among Eskimo men and women and proceeds at a higher rate. While Mazess and Mather suggest that the high protein diet of Eskimo populations may account for these differences, Laughlin et al (1979) argue that this explanation may be inadequate. These authors point out that Aleuts have a similar high protein diet yet have considerably more cortical bone than the Eskimo groups and hypothesize that inherent differences in rates of biological aging may be responsible.

Existing data also suggest that American Black women have more cortical bone at all ages than American Caucasian women (Garn 1972) as well as greater bone mineral density of the radius (Luckey et al 1989) and of the hip and lumbar spine (DeSimone et al 1989). Luckey and associates (1989) report that significant racial differences persisted even after the data had been adjusted for age and body mass index and could not be attributed to other variables such as socioeconomic class or smoking. These authors suggest that Black women may have a higher peak bone mass at skeletal maturity and/or a delayed onset of bone loss.

The mechanism which may account for this racial difference is unknown. Luckey et al (1989) found evidence for a lowered urinary calcium excretion among a small subset of the premenopausal Black women participating in their study and suggest that this may be a contributing factor. Bell and coworkers (1985) found a similar reduction in urinary calcium among nonobese Blacks as well as increased serum parathyroid hormone and 1,25-dihydroxyvitamin D and suggest that these results indicate alterations or modifications of the vitamin D endocrine system. Such alterations may contribute to greater bone mass in Black populations.

Mechanical Factors

During the late nineteenth century, Wolff (1892 cited in Kennedy 1989) hypothesized that bone mass is influenced by mechanical forces of the environment. In simple terms, bone mass increases or decreases to reflect the amount of functional pressure or loading. In recent years, numerous studies of animals and humans have clearly demonstrated that bone does respond to both decreased mechanical loading, such as that associated with immobilization, bedrest and weightlessness, and to increased mechanical loading such as that accompanying increased weightbearing, dynamic loading and exercise. Reduced loading of bone can result in disuse osteoporosis, moderate overloading may cause an increase in bone mass and severe overloading may cause an increase in bone mass or, if too severe, may cause fracture (Smith and Gilligan 1989).

However, the exact mechanisms by which mechanical loading promotes an increase or decrease in bone mass or density are unknown. Treharne (1981) has reviewed several theories that have been offered to explain the exact mechnism by which Wolff's law may operate. These theories include electrical events in collagen, microfractures in bone mineral, hydrostatic pressure in the extracellular fluid and direct damage and/or response of bone cells themselves.

Smith and Gilligan (1989: 161) point out that the pattern of bone response to loading may differ according to the level of loading or strain experienced. For example, reduced loading may result in endosteal widening and increased intracortical porosity. The rate of bone resorption exceeds the rate of bone formation. Increased mechanical loading may cause a decrease in intracortical porosity or medullary diameter or an increase in periosteal diameter. The rate of formation exceeds the rate of resorption. Studies have shown that the bone resorption seen in extreme cases of decreased mechanical loading (eg. in paraplegia) can lead to hypercalcemia and increased urinary calcium and phosphorus. These changes result in depressed levels of serum

parathyroid hormone, lowered plasma 1,25 dihydroxyvitamin D and diminished intestinal calcium absorption (Sinaki 1988: 459). Similar changes have also been noted in bedrest studies (Smith and Gilligan 1989).

Because females at all ages have less bone than men and because females sustain a proportionally greater loss of bone, a number of recent studies have focused attention specifically on the potential effects of exercise to eliminate or reduce bone loss among pre- and postmenopausal women. Halioua and Anderson (1989) found a significant association between high levels of physical activity maintained over the lifetime of an individual and greater bone mineral content of the radius. The authors state that these findings suggest an important role for physical activity in enhancing peak skeletal mass, a critical factor in susceptibility to osteoporosis later in life. Smith and associates (1989) found that exercise significantly lowered the rate of bone loss in the forearm of pre- and postmenopausal women. Moroz and associates (1989) reported an increase in bone mineral content of the lumbar spine in a group of postmenopausal women as the result of increased physical activity. Although they could not demonstrate a difference in bone mineral content of the radius, Aloia et al (1978) did report an increase in total body calcium among postmenopausal women participating in an exercise program.

In contrast to the above reports, intensive exercise among female athletes has been said to increase the risk for excessive bone loss (Drinkwater et al 1984; Marcus et al 1985; Nelson et al 1986). Intense physical training may be accompanied by amenorrhea (the absence of menstrual cycles). This condition is characterized by low circulating estrogens and results from a complex of factors involving not only exercise but also dietary intake (Nelson et al 1986: 910-911).

Nutritional and Endocrine Factors

Calcium Homeostasis

It is essential that the nutritional intake of calcium and phosphorus be sufficient to meet extraskeletal demands if bone mass is to be maintained. The extracellular concentration of calcium must be held relatively constant if normal function and life are to be sustained. Individuals with a low serum calcium concentration may suffer from hypocalcemic tetany, a potentially fatal condition causing increased excitability of nerve and muscle cell membranes and resulting in skeletal muscle spasms (Yander et al 1985: 448). An excess of extracellular calcium can cause cardiac arrhythmia as well as depressed neuromuscular excitability. It is not surprising, therefore, that there are a number of metabolic pathways through which the body regulates plasma calcium concentration.

The hormones important to calcium homeostatis are parathyroid hormone (PTH), vitamin D and, possibly, calcitonin. A decrease in plasma calcium stimulates the production of PTH which in turn exerts at least four distinct effects intended to restore plasma calcium levels to normal (Yander et al 1985: 450):

1. It stimulates the formation of $1,25(OH)_2D_3$, the active form of vitamin D, by the kidneys. $1,25(OH)_2D_3$ increases intestinal absorption of calcium and phosphorus.
2. It increases renal tubular reabsorption of calcium thus decreasing urinary calcium excretion.
3. It reduces renal tubular reabsorption of phosphate causing an increase in urinary excretion of phosphate and thus lowering the plasma phosphate concentration. This stimulates a release of calcium from bone into the plasma.
4. It directly promotes bone resorption thus releasing calcium into plasma.

PTH levels have been found to increase with advancing age (Eastell et al 1988: 374).

Calcitonin is secreted by the thyroid in response to an increase in plasma calcium levels (Eastell et al 1988: 381). Pharmacologic doses of this hormone have been shown to cause a decrease in bone resorption and in the reabsorption of phosphate and calcium in the renal tubule but the overall contribution of calcitonin to calcium homeostasis is uncertain and is likely to be very minor in comparison to PTH (Eastell et al 1988: 381). It is interesting to note that lower values of calcitonin in females as compared to males have been reported (Riggs and Melton 1986: 1678).

Vitamin D

The physiologically active form of vitamin D is $1,25(OH)_2D_3$. Vitamin D is absorbed from the diet or is synthesized from precursors in the skin in response to exposure to ultraviolet light (Eastell et al 1988: 376). It undergoes transformation in the liver to 25(OH)D and is then converted to $1,25(OH)_2D_3$ in the kidneys. As stated above, the principal action of $1,25(OH)_2D_3$ is to increase intestinal absorption of calcium (Eastell et al 1988: 376).

Plasma levels of 25(OH)D have been shown to decrease with age (Baker et al 1980; Tsai et al 1987). Explanations for this decline may include reduced dietary intake and absorption of vitamin D as well as reduced exposure to the sun. Plasma $1,25(OH)_2D_3$ levels have also been shown to decline with age. Eastell et al (1988: 378) report that decreased renal 1-alpha-hydroxylase is the most likely cause. (Renal 1-alpha-hydroxylase is necessary for the production of $1,25(OH)_2D_3$.) There is also some evidence that intestinal mucosa become resistant to $1,25(OH)_2D_3$ with age (Heaney 1988: 365). Without an effective increase in vitamin D intake, these age-related changes could force an elevation in PTH levels and, thus, in bone resorption.

Calcium

Approximately 1.5% of total body weight is calcium (Steele and Bramblett 1988: 14) and 99% of this calcium is stored in the skeleton (Draper and Scythes 1981: 2434). A number of studies (eg. Black-Sandler et al 1985; Halioua and Anderson 1989; Riis et al 1987) have been designed to qualify the role of calcium intake in achieving and maintaining bone mass and in preventing bone loss. However, the results have been confusing and sometimes conflicting (Heaney 1988). The effects of a given quantity of dietary calcium may vary between individuals as well as between sites within a given individual. For example, Riis and associates (1987) found that a calcium supplement of 1,500 mg per day given to postmenopausal women did not cause significant retardation of bone loss from the vertebrae or from the total skeleton but did result in retardation of bone loss from the midradius. There is even lack of consensus about the recommended daily allowance (RDA) of calcium. The current RDA of calcium for Canadian adults, male and female, is 800 mg per day (Health and Welfare Canada 1983) but in 1984 the NIH Consensus Conference on Osteoporosis recommended 1000 mg per day and 1500 mg per day for peri- and postmenopausal women respectively. While evidence exists to support this recommendation, no evidence proves that such high levels of daily calcium intake are required (Heaney 1988: 362).

Calcium may be a 'threshold nutrient' and this may account, at least in part, for the inconclusive nature of the research to date (Heaney 1988). Intakes of calcium below a given threshold may have limiting effects but intakes above that threshold may produce no noticeable change. The absolute value of this threshold is difficult to determine since there are a number of factors which may cause it to vary considerably between individuals.

First, there may be genetic or population differences in end-organ responses to parathyroid hormone and to $1,25(OH)_2D_3$ (Heaney 1988: 363). As mentioned previously,

American Blacks appear to have increased serum PTH relative to Whites yet have greater bone mass. This increase in PTH appears to enhance renal tubular reabsorption of calcium and to increase circulating $1,25(OH)_2D_3$ (Bell et al 1985). Thus, for any given level of calcium, Blacks appear to make better use of available calcium and protect their skeletons (Heaney 1988: 363). Second, there are a number of studies which suggest that individual calcium requirements increase with menopause (Riis et al 1987: 75). Estrogen deficiency accompanying menopause may be related to a decrease in intestinal absorption of calcium and to an increase in calcium excretion (Heaney et al 1978). Third, the body has the ability to adjust to a wide range of calcium intakes by modifying the efficiency of intestinal absorption (Draper and Scythes 1981; Hegsted 1986). There is also some evidence to suggest that aging impairs this adaptation (Riggs and Melton 1986: 1680). Fourth, there is a wide range of nutrient-nutrient reactions which may result in raising or lowering individual calcium requirements (Heaney 1988).

Phosphorus reacts with calcium in such a way that the product of serum phosphorus and serum calcium levels remains a constant (Yander et al 1985: 450). An increase in dietary phosphorus relative to calcium promotes an increase in the plasma phosphorus level and a decrease in plasma calcium. This decrease can stimulate PTH and thus promote bone resorption (Draper and Scythes 1981). It is interesting to note, however, that research has shown phosphorus levels up to 2000 mg per day have no adverse effect on calcium metabolism (Spencer and Kramer 1986). An increase in dietary protein and sodium have been shown to cause an increase in urinary calcium excretion (Nordin and Polley 1987: S4). High caffeine levels may have a direct deleterious effect on bone or may have a diuretic effect and thus increase urinary calcium loss (Christiansen and Riis 1989: 319). An increase in dietary fiber may cause a decline in intestinal absorption of calcium (Heaney 1988: 363). Without an increase in dietary calcium intake, all of the above dietary factors could promote bone resorption.

Other dietary factors

Marked alcohol abuse is often associated with excessive bone loss in both males and females (Christiansen and Riis 1989: 319). The effect of alcohol may be due to the impact it exerts on vitamin D metabolism or to direct toxic action on bone cells. Crilly et al (1988) state that alcohol consumption in males has clear detrimental effects on bone formation with less pronounced suppressive effects on bone resorption. Spencer and Kramer (1986: 317) point out that the etiology of excessive bone loss associated with chronic alcohol abuse is likely to be multifactorial and poor dietary intake of calcium, phosphorus and vitamin D may be a contributing factor.

Long-term drug use has also been implicated in bone loss. Clochon and associates (1989) report that long-term use of corticosteroids induces a significant decrease in bone mineral density even when low doses of the drug are consumed. Excessive use of aluminum-containing antacids may also promote calcium loss and bone demineralization, especially if accompanied by low calcium intake. Calcium loss in this case is due, in part, to increased urinary and fecal calcium excretion (Spencer and Kramer 1986: 318). Tetracycline, isoniazid and diuretics may also influence skeletal status (Spencer and Kramer 1985). There is some evidence for a significant positive correlation between contraceptive use and bone mass (Heytmanek et al 1989) although other studies (eg. Lepsanovic et al 1989) have failed to corroborate this report.

Smoking

Investigations into the effect of cigarette smoking on bone mass (eg. Daniell 1976; Elders et al 1989; McDermott and Witte 1988; Rundgren and Mellstrom 1984) have yielded conflicting results. McDermott and Witte (1988) suggest that cigarette smoking has no direct effect on

appendicular bone mass but may exert indirect influence by affecting age at menopause, body weight, diet and, possibly, physical activity levels.

Obesity

Studies have found a significant positive association between obesity and bone mass (eg. DeSimone et al 1989). There are a number of explanations which can be offered for this association. There is evidence for increased production of estrogen from androgens in the peripheral adipocytes (Kley et al 1980). Excess body weight is an additional source of mechanical loading. There is also evidence that obesity is accompanied by alterations in the vitamin D endocrine system (Bell et al 1985; Liel et al 1988). Obese individuals exhibit increased serum PTH and $1,25(OH)_2D_3$ as well as decreased urinary calcium. The end result is enhanced intestinal absorption and renal tubular reabsorption of calcium. Skeletal mass appears to be unaffected by the increase in PTH and this could be due in part to the protective effects of increased estrogen production and increased mechanical loading.

Pregnancy and Lactation

Because of the increased nutritional demands placed on the body during pregnancy and lactation, several investigations have examined the possible effects on skeletal status. Again, the research yields conflicting results. Lamke and associates (1977) found a significant loss of mineral from trabecular bone in the forearm of pregnant adult women but found no significant difference in bone mineral content associated with lactation. Similarly, Chan et al (1982) found no evidence of bone demineralization accompanying lactation. Wardlaw and Pike (1986) did find a significant reduction in bone mass accompanying multiple episodes of long-term lactation among

adult women but a subsequent investigation (Koetting and Wardlaw 1988) failed to corroborate these findings. Greer and associates (1984) found elevations of PTH, calcitonin and $1,25(OH)_2D_3$ in adult mothers nursing twins compared to single infants and suggest that mothers are able to compensate for excessive calcium losses, and thus preserve skeletal integrity, by increasing serum PTH, calcitonin and vitamin D and by consuming additional dietary calcium.

Research involving adolescents has provided different results. There is evidence (eg. Chan et al 1982, 1987) that lactating adolescents are at risk for bone demineralization because of low dietary intake of calcium or phosphorus.

Diabetes Mellitus

It has been observed that individuals with both juvenile and adult-onset diabetes mellitus also have reduced bone mass in comparison to sex- and age-matched non-diabetic controls (Levin et al 1976). Levin and associates (1976: 243) hypothesize that this reduction may reflect a decrease in bone formation rather than an increase in bone loss and may be part of the basic disease process rather than a complication of hyperglycemia or insulin insufficiency. They claim support for this hypothesis from the observation that bone loss among diabetics occurs early and does not appear to correlate with the severity or duration of the disease. Patients treated with insulin appear to experience less bone loss than less severe diabetics and this may be due to the beneficial effects of insulin including the stimulation of intestinal calcium absorption and the inhibition of cyclic AMP. (Cyclic AMP promotes bone resorption.).

In a more recent study, Auwerx and associates (1988) also found lower bone mineral content in the radius of adults with insulin-dependent diabetes compared to non-diabetic controls. They state that the basic pathogenic mechanisms of this loss are still unknown. Rico et al (1989)

suggest that deficient osteoblast function rather than an insulin deficit is responsible for osteopenia among diabetic individuals.

Other studies (eg. Meema and Meema 1967, DeLeeuw and Abs 1977) have reported a normal or increased bone mass in adults and elderly diabetic women. Auwerx et al (1988: 11) suggest that this finding may be because the patient groups in these studies were mainly non-insulin-dependent diabetics and individuals with this form of the disease tend to be obese. Obesity may provide relative protection against bone loss.

Chapter 3: Archaeological Background and Sample Descriptions

Skeletal samples from the Serpent Mounds, Roebuck, MacPherson and MacKenzie-Woodbridge sites in Ontario and the Sackett, Castle Creek and Tram sites in New York State were utilized in this study. These samples represent populations that differ in time and in space. Each of these populations was subject to a range of environmental influences that may or may not have had an effect on cortical bone quality. In order to explain any variability that is found between the samples in cortical bone quality, these enviromental influences must be considered.

This chapter briefly outlines what is known about the settlement patterns, subsistence activities and social organization of the pre-Iroquoian and Iroquoian populations of the lower Great Lakes region.

Archaeological Background

Middle Woodland

The Middle Woodland period commenced ca. 350-300 B.C. (Spence and Pihl 1984: 38). Three cultural complexes have been identified from this period: Point Peninsula in southeastern Ontario, eastern Quebec and New York, Saugeen in southwestern Ontario and Western Basin Middle Woodland in the southwest corner of Ontario and adjacent parts of Michigan and Ohio (Spence and Pilh 1984). The Middle Woodland skeletal sample used in this study, the Serpent Mounds sample, has been assigned to the Point Peninsula cultural complex.

Sites assigned to the Point Peninsula cultural complex range from small campsites to large stations located along major river and lake systems in the Lake Ontario-St. Lawrence River

drainage area (Spence and Pihl 1984). The economy of Point Peninsula people was characterized by hunting, fishing and gathering (Spence et al 1984: 118) and most of the investigated sites of this period represent seasonal occupations of brief duration. Spence and Pihl (1984: 39) suggest a subsistence-settlement model for Point Peninsula people which includes residence in large band settlements along the major waterways during the spring and summer months where subsistence activities would have focused on the exploitation of aquatic resources. During the winter months, these large bands may have dispersed inland to family hunting camps where subsistence would have been based on large mammal hunting and the utilization of some dried foods.

Most Point Peninsula groups were probably small, egalitarian bands, however, in both the Trent River-Rice Lake district of Ontario and in Western New York, there is evidence for a more complex level of sociopolitical organization (Spence et al 1984: 118). Mortuary patterns associated with sites in these areas are characterized by earthen mound complexes. There is evidence within these mounds for mortuary ceremonialism, status differentiation between individuals and Hopewellian influence (Spence et al 1984: 118).

The Point Peninsula culture in Ontario is perhaps best known from the Rice Lake region and the Serpent Mounds skeletal sample comes from this area. Spence et al (1984) summarize the subsistence pattern suggested for groups in this region. From April to mid-November, primary subsistence activities would have included collecting and fishing along the lakeshore and inland among swamps, marshes and forests. An immense variety of food resources would have been available including fish, shellfish, waterfowl and nuts and could have supported large, aggregated populations. Wild rice may also have been utilized although the relative importance of this resource is unknown. Wild rice may have only been a supplemental food, not a staple (Spence et al 1984). November to the end of March would have been characterized by dispersal inland and dependence on hunting of mammals such as deer, bear, beaver and raccoon as well as the utilization of storable foods such as nuts, rice, dried fish and dried mussels.

As mentioned above, some of the sites in the Rice Lake region are characterized by earthen mound complexes. Serpent Mounds is an example of this type of site. Spence et al (1984) suggest that the mounds at any given site were not contemporaneous but were successive, each one containing the members of the community who had died over a given period of time. Furthermore, each mound in a group, or each addition to a mound, is believed to represent a burial episode involving the whole community, not just a particular segment. Mound construction may have been initiated by the death of the community leader.

The basic social unit beyond the nuclear family and winter camp is postulated to have been the local band, some 50-100 individuals who shared the resources of a particular area (Spence et al 1984: 135). Two or more local bands may have shared the resources of a particular locale yet maintained separate settlements and cemeteries. These larger groupings may be called a territorial band. The elite members of the local bands were probably closely interrelated.

The Princess Point cultural complex in southwestern Ontario has been identified as transitional between the Middle and Late Woodland periods in that region. This complex is dated from about A.D. 500 to A.D. 900 and can be divided into three temporally sequential phases (Stothers 1977). The earliest two phases are characterized by spring-summer encampments located along rivers and/or near lakes. Subsistence activities included hunting, fishing and limited maize agriculture.

The latest phase of the Princess Point complex, represented by the Porteous site in Brantford, suggests considerable dependence on maize agriculture. General characteristics of this phase include larger social aggregates, year-round occupation of sites, the construction of permanent dwelling structures within palisades and a shift from settlement on lowland floodplains and mudflats to settlement on well-drained, sandy upland areas (Stothers 1977). Noble (1975: 44) suggests that this shift in settlement pattern, soon after the earliest use of maize, indicates that maize agriculture was rapidly adopted by prehistoric southern Ontario populations. It is

possible that once prehistoric populations realized that an easily controllable food resource was available in the form of maize, and that a surplus could be stored for less plentiful times of the year, they became sedentary, living in permanent villages such as Porteous (Stothers 1977: 135). A sedentary lifestyle would have been necessary to adequately care for and protect the maize crops. According to Stothers (1977), the palisade at Porteous suggests that the pattern of endemic warfare characteristic of later Iroquoian groups was already in place and may have been the result of competition for land suitable for maize agriculture.

The origins of the Princess Point complex are unclear. Stothers (1977) suggests that Princess Point represents a cultural intrusion into Ontario from the southwest whereas Finlayson (1977) argues that Princess Point evolved out of the southern portion of Saugeen. Princess Point developed into the Glen Meyer culture of the Early Ontario Iroquois (Wright 1972).

Princess Point was relatively contemporaneous with the Hunter's Home phase in New York State. Sites assigned to the Hunter's Home phase have been dated from A.D. 905 to A.D. 955 and represent the transition from Point Peninsula to the Owasco cultures in central and eastern New York. Although few components of this phase have been found and excavated, some of the general characteristics appear to include a shift in ceramic and tool styles, a proliferation of pipes, indicating general popularity of pipe smoking, and a reduction in the mortuary ritualism seen in the preceding phase (Ritchie 1980). While specific information relative to the subsistence and settlement pattern of Hunter's Home people seems to be lacking, Ritchie (1980: 258) does point out that the Hunter's Home type site is located in an area favourable as a camping ground, especially for food-gathering people.

Late Woodland

Wright (1966) has divided the Ontario Iroquois development during the Late Woodland period into three temporally sequential phases: Early Ontario Iroquois (A.D. 1000 - A.D. 1300), Middle Ontario Iroquois (A.D. 1300 - A.D. 1400) and Late Ontario Iroquois (A.D. 1400 to mid 17th century).

Two independent and simultaneous branches of the Early Ontario Iroquois stage can be identified: Glen Meyer, in a restricted area of southwestern Ontario, and Pickering in southeastern Ontario. As mentioned previously, Glen Meyer is believed to have evolved out of Princess Point. Pickering is believed to have developed out of Point Peninsula. Both branches practiced corn agriculture and also continued to rely on hunting and fishing (Wright 1966). Fecteau (1985, cited in Esler 1989) states that there is little evidence for cultigens on any Pickering site prior to A.D. 1100 but by A.D. 1200 - 1300 the number of Pickering sites with cultigens increased and by the end of the Early Ontario Iroquois period all of the major cultigens (maize, beans, squash and sunflowers) were present in southern Ontario. Isotopic analysis of human remains dating to this period confirms that the utilization of maize was well-advanced by this time (Schwarcz et al 1985). The settlement pattern of Glen Meyer people was characterized by large, tightly grouped villages surrounded by palisades and located in defensible locations. Sites assigned to the Pickering branch include large, palisaded villages found in defensible locations as well as numerous small campsites located at fishing areas. The burial pattern characteristic of both the Glen Meyer and Pickering people includes bundle and flexed burials located in and around village sites.

According to Wright (1966), the Early Ontario Iroquois stage ended with the conquest and absorption of the Glen Meyer people by the Pickering. Although this conquest hypothesis has been questioned (eg. Ramsden 1977, Noble 1982), the Early Ontario Iroquois stage does seem to be

succeeded by a broad, homogeneous cultural base over much of southern Ontario and adjacent southwestern New York by A.D. 1300. In general, the Middle Ontario Iroquois stage is represented by numerous small campsites and the occasional large village site. Noble (1975: 42) suggests that a significant population increase had occurred by A.D. 1300. Even though hunting and fishing remained important subsistence activities (Noble 1975), dependence on maize increased so that by A.D. 1400 it provided up to 50% of the diet (Schwarcz et al 1985). By A.D. 1350, an elaborate pipe complex had been introduced from the northeast and, from that point on, smoking became a dominant trait of Ontario Iroquois society (Wright 1966: 99). There is evidence that cannibalism was practiced (Wright 1966). The burial pattern characteristic of this period is ossuary interment.

The Late Ontario Iroquois stage represents the divergence of the Huron, Petun, Neutral and Erie (Noble 1975; Wright 1966). Two branches, the Huron-Petun and the Neutral-Erie, can be identified. The Huron-Petun branch had two further divisions, a southern and a northern division, which closely resembled each other.

There are a number of features which serve to distinguish the Late Ontario Iroquois stage as a whole. In general, the settlement pattern characteristic of this stage consisted of clusters of large, palisaded villages located in defensible positions away from navigable water (Wright 1966). Tuck (1978: 327) suggests that the trend toward increasing village size that was characteristic of this stage was due to village fusion, not to natural population increases. The trend to clusters of villages is in contrast to the more homogeneous population distribution seen in the preceding stage and resulted in the "crystallization" of the ethnic units seen in the historic period (Tuck 1978: 326).

Maize continued to provide up to 50% of the diet (Schwarcz et al 1985) and hunting and fishing continued to be important subsistence activities. Archaeological evidence (Noble 1975), ethnohistoric data (Tooker 1964) and isotopic analysis (Katzenberg and Schwarcz 1986;

Schwarcz et al 1985) suggest that meat and fish remained important sources of protein throughout the Ontario Iroquois tradition. Beans were cultivated and were incorporated into the diet (Tooker 1964) but were not used as a substitute for the traditional protein sources (Schwarcz et al 1985). Squash and sunflowers were also grown, wild berries and fruits were gathered to supplement the diet and acorns, pumpkins and roots were eaten during times of famine (Tooker 1964). Cannibalism and the use of dogs as food peaked by mid-16th century (Wright 1966).

In general, the Late Ontario Iroquois buried their dead in ossuaries. Ossuaries consist of the mixed remains of most individuals who had died during an 8 to 12 year period preceding ossuary construction. Ethnohistoric accounts of the Huron (Tooker 1964) indicate that infants, warriors and suicides were excluded from ossuary interment.

Trade for European goods was common during the historic period and may have involved the Hurons of southcentral Ontario as early as the beginning of the 16th century (Ramsden 1978). Ethnohistoric data (Tooker 1964) suggests that warfare was an important part of Iroquoian life. Ramsden (1978: 104-105) has suggested that the significant expansion seen in some villages around Lake Ontario during the early 1500's may have been closely related to the establishment of a trade network to the east and to the intensification of warfare. The Huron may have been competing for control over sources of beaver and trade routes to and from the St. Lawrence. Because of their location along travel routes, certain villages were able to attract Iroquoians from other areas of southern Ontario and may have maintained control over trade routes through warfare (Ramsden 1978: 106).

The Ontario Iroquois were attacked and dispersed by the League of Five Nations during the period 1649-1654 (Wright 1966: 93). The motivation for this attack likely centered around the desire to obtain access to the fur-bearing areas to the north (Heidenreich 1978) and to obtain

control of trade with the Europeans. A large number of the Ontario Iroquois were adopted by the Five Nations people (Wright 1966: 93).

The St. Lawrence Iroquois represent a distinct group of northern Iroquoians that occupied several groups of villages on the north shore of the St. Lawrence and in New York at the eastern end of Lake Ontario (Tuck 1978: 324). Representing an in-situ development in this region from at least A.D. 1250 (Pendergast 1975), this group of Iroquoians is believed to be the result of Pickering and Middleport influences exerted westward into the St. Lawrence valley onto an indigenous Point Peninsula culture (Trigger and Pendergast 1978). These Iroquoians were first encountered by French explorers who visited the St. Lawrence valley between A.D. 1535 and A.D. 1541, but had disappeared by the time of Champlains's arrival in the area in A.D. 1603 (Pendergast 1975). The reasons for the disappearance of the St. Lawrence Iroquois are unclear. Archaeological evidence suggests that conflict with other native groups during the terminal prehistoric period may have been a contributing factor (Pendergast 1985). This conflict may have arisen out of competition for control of European trade along the St. Lawrence River. The St. Lawrence Iroquois that survived may have found refuge among the Ontario Iroquois, the Five Nations Iroquois and the Ottawa Valley Algonquins (Trigger and Pendergast 1978).

Roughly contemporaneous with the Early Ontario Iroquois was the Owasco culture in New York State. Owasco evolved out of Point Peninsula, was spatially confined to central and eastern New York and was temporally restricted to the 11th, 12th and 13th centuries. This culture has been divided into three temporally sequential phases: Carpenter Brook (ca. A.D. 1000-1100), Canandaigua (ca. A.D. 1100-1200) and Castle Creek (ca. A.D. 1200-1300) (Ritchie 1980).

According to Ritchie (1980: 298), Owasco culture contained all the essential elements of the succeeding Iroquois culture in the same area. Owasco is the earliest culture in New York state for which the cultivation of corn, beans and squash can be positively asserted (Ritchie 1980: 276). Gourds were also cultivated. Hunting, fishing and gathering remained an important aspect

of subsistence activities. Habitation sites associated with this period include camps, hamlets and villages. Palisades appear during the middle Owasco period and may suggest that warfare was occurring. Although few have been found and excavated, burials associated with Owasco sites are randomly dispersed in old cache pits. Owasco people were almost certainly Iroquoian speakers (Tuck 1978: 322).

Wright (1966: 95) has pointed out a number of similarities between the Early Ontario Iroquois and the Canandaigua and Castle Creek phases of Owasco culture. In both cases, there is evidence for agriculture as a major element in the subsistence pattern. The settlement pattern includes the presence of large, sedentary villages, frequently palisaded and located away from navigable water. Burials are found in and around villages with little or no grave goods. There are also specific similarities in artifact assemblages.

Ritchie (1980) has divided the cultural continuum from Owasco to historic Iroquois into a number of phases: the Oak Hill phase (ca. A.D. 1300-1400), the Chance phase (ca. A.D. 1400-1500), the Garoga (late prehistoric) phase (ca. A.D. 1500 to 1550 or 1575), and, finally, the protohistoric and historic Iroquois, ca. A.D. 1550 to the present. In general, Iroquois development in New York State was characterized by a number of features seen in the Ontario Iroquois including settlement in large, palisaded villages, and a subsistence pattern which included corn agriculture as well as hunting, fishing and gathering. In contrast to the Ontario Iroquois tradition of ossuary interment, the New York Iroquois appear to have buried their dead in cemeteries. These cemeteries consisted of individual and occasional multiple interments.

Ritchie's sequence is very general and does not account for the origin or development of the Five Nations Iroquois known from the historic period (Niemczycki 1984: 9). The prehistory of the Five Nations Iroquois (the Seneca, Cayuga, Onondaga, Oneida and Mohawk) seems to be characterized by the in-place development of all five tribal groups and regional sequences have been established for all five tribal areas (Tuck 1978: 322) . According to Iroquoian tradition,

the League of Five Nations (the Confederacy composed of the above tribes) was established to eliminate conflict which had been occurring between the tribes (Tooker 1978). All suggested dates for the founding of this Confederacy fall in the period from A.D. 1400 or slightly before to A.D. 1600 or slightly before (Tooker 1978). As mentioned above, the Ontario Iroquois were attacked and dispersed by the League between A.D. 1649 and A.D. 1654.

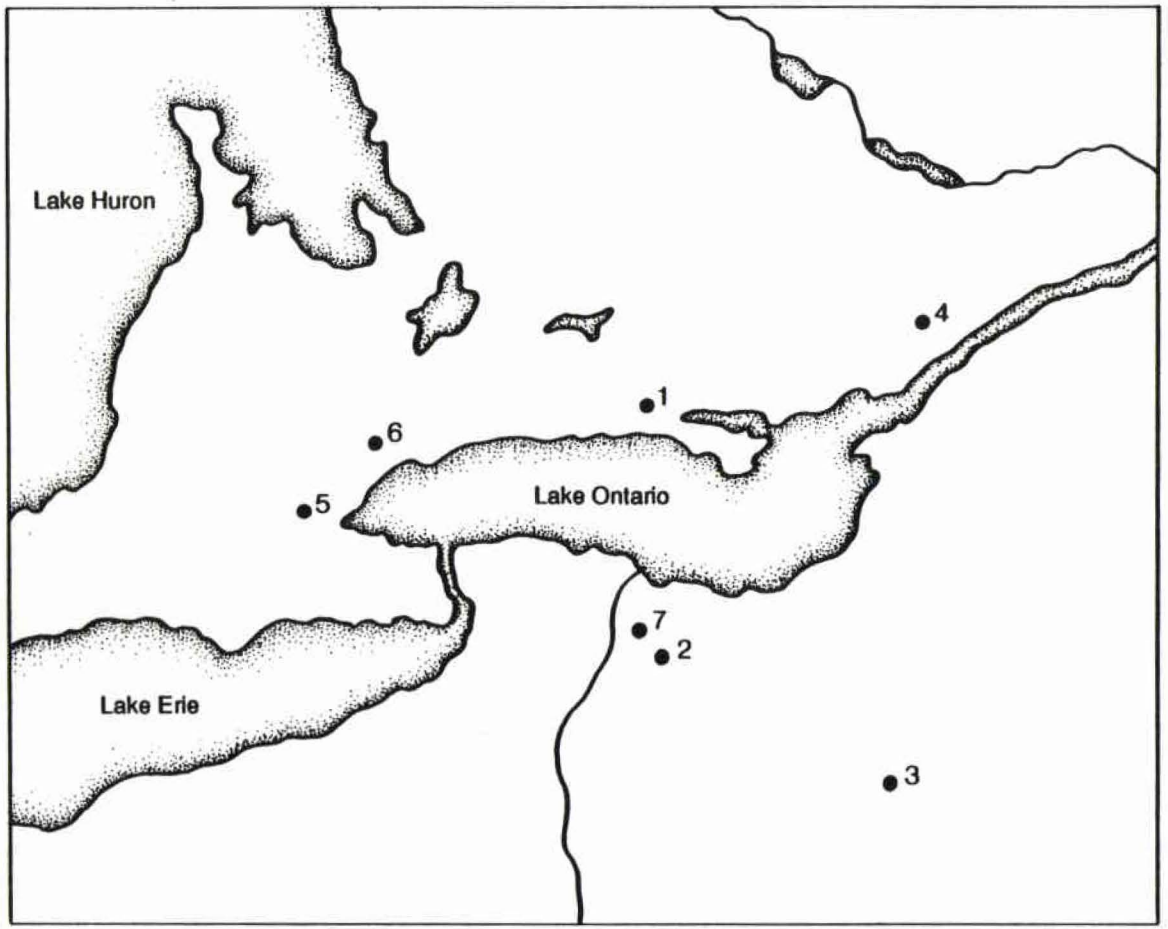
Site and Sample Descriptions

Serpent Mounds

The Serpent Mounds site is located along the north shore of Rice Lake in Otonabee Township, Peterborough County, Ontario and consists of nine earth mounds, a habitation site and an extensive shell midden (Johnston 1968). This site was partially excavated by Henry Montgomery in 1908 and later by the Royal Ontario Museum between 1955 and 1959. Three radiocarbon dates have been obtained for Serpent Mounds: A.D. 128 ± 200 years, A.D. 302 ± 150 years and 58 B.C. ±150 years (Johnston 1968). As discussed previously, this site is affiliated with Point Peninsula culture.

Johnston (1968) describes the Royal Ontario Museum excavations in detail. Four of the mounds, E, G, H, and I, were excavated and all but H yielded human remains. Mound E, the Serpent Mound, is the most northeast structure in the mound group. This mound yielded the remains of 32 individuals plus disturbed human bone representing an additional 42 (Anderson 1968). Interments were primary and secondary and cremations and charred bone were evident. Seven individuals from Mound E were included in this study, all of which came from the east end of the structure. Four of these burials were primary and three were secondary. Mound G contained the remains of twenty individuals (Anderson 1968). Four of these were included in this study. Two

Figure 3.1: Map of Site Locations



1 = Serpent Mounds, 2 = Sackett, 3 = Castle Creek, 4 = Roebuck, 5 = MacPherson, 6 = MacKenzie, 7 = Tram

Table 3.1: Summary of the Samples

Site	Location	Institution	Sample Size	Date	Cultural Affiliation
Serpent Mounds	Otonabee Township, Peterborough Co., Ontario	Royal Ontario Museum	20	A.D. 128 ± 200; A.D. 302 ± 150	Point Peninsula
Sackett	Canandaigua Township, Ontario Co., New York	Rochester Museum and Science Center	8	A.D. 1040 ± 150	Canandaigua Owasco
Castle Creek	Chenango Township, Broome Co., New York	Rochester Museum and Science Center	7	A.D. 1200 to A.D. 1300	Castle Creek Owasco
Roebuck	Augusta Township, Grenville Co., Ontario	Canadian Museum of Civilization	22	A.D. 1390 ±100	St. Lawrence Iroquois
MacPherson	Flamborough Township, Wentworth Co., Ontario	—	9	approx. A.D. 1530 to A.D. 1570	Neutral
MacKenzie	Metro Toronto, Ontario	University of Toronto	4	A.D. 1520 ±10 to 15 years	Huron
Tram	Livonia Township, Livingston Co., New York	Rochester Museum and Science Center	18	A.D. 1565 to A.D. 1590	Seneca Iroquois

of these burials were primary, one was secondary and one was disturbed. Mound I contained the remains of forty-two individuals although many of these were represented only by a limited number of fragments (Johnston 1968). Nine individuals from Mound I were included in this study. Five were primary burials and four were secondary.

It is important to note that the mounds at the Serpent Mounds site are not considered to be contemporaneous. Spence et al (1979: 117) suggest that Mounds G and I are later than Mound E and could be placed in the 4th to 6th centuries. Even Mound E was not constructed all at once but appears to have resulted from additions to the mound over time (Johnston 1968). There is evidence, however, that the populations represented by the individuals in these mounds are related. The unusually high incidence of os inca among the burials in Mound E suggests genetic relatedness between them (Spence et al 1984: 126). Anderson's (1968) analysis of non-metric traits suggests a close biological relationship between all three sets of mound skeletons (Anderson 1968). For this study, the individuals from all three mounds were combined, resulting in a total sample size of 20. Of these 20 skeletons, 15 were observed by Anderson (1968) to exhibit pathological changes in the form of osteoarthritis of the appendicular skeleton, spinal osteophytosis, dental caries, dental abscesses or premortem tooth loss.

Sackett and Castle Creek

The Sackett or Canandaigua site is located in Canandaigua Township, Ontario County, New York. This site consists of a large, palisaded village and two associated cemeteries, one located north and one east of the village. This site was originally excavated by the Rochester Museum of Arts and Sciences in 1935 and again by Ritchie in 1959. Sackett, with an estimated maximum population of 300 to 350 individuals at any one time, represents one of the largest known Owasco

villages (Ritchie 1980: 287). A radiocarbon date of A.D. 1040 ± 150 years was obtained from the site. Sackett has been assigned to the Canandaigua phase of the Owasco period.

A total of 57 burials were recovered from the two cemeteries at Sackett, eight of which were included for analysis in this study[1]. As mentioned previously, most Owasco burials that have been found were randomly dispersed in old cache pits (Ritchie 1980). The cemeteries at Sackett are clearly an exception to this burial pattern. It is of interest that six of the adult male skeletons recovered from the Sackett cemeteries were riddled with arrowheads (Ritchie 1980: 294). Ritchie (1980: 294) suggests that these skeletons, coupled with the evidence for fortification of Owasco sites, may be indicative of war or conflict among Owasco people.

The Castle Creek site is located in Chenango Township, Broome County, New York. This site, excavated by the Rochester Museum of Arts and Sciences between 1931 and 1933, also consists of an Owasco village and burials. Two radiocarbon dates were obtained for the site: A.D. 1196 ±200 years and A.D. 1435 ±200 years. Ritchie (1980: 275) suggests that the true date for this site lies between A.D. 1200 and A.D. 1300, or within the span of the standard deviations of the two radiocarbon dates. Castle Creek has been assigned to the Castle Creek phase of the Owasco period.

The exact number of burials found and/or excavated at the Castle Creek site in unknown. Seven of the individuals that were excavated were suitable for inclusion in this study.

Because of the spatial and temporal proximity of the Sackett and Castle Creek sites to each other, the individuals from them were combined and considered as a single sample in this study. The combined sample size was 15.

---

[1]The criteria used to determine if a particular burial was suitable for inclusion in this study are outlined in chapter 4.

Roebuck

Roebuck is a prehistoric, palisaded, St. Lawrence Iroquoian village site located in Augusta Township, Grenville County, Ontario. This site was excavated by Wintemberg in 1912 and1915 (Wintemberg 1936: 1) and again by Wright in 1970 (Pendergast 1983). Roebuck covers approximately 8 acres (Wintemberg 1936: 2) and may have been occupied by as many as 2,000 individuals at one time (Wright 1979: 69). A radiocarbon date of A.D. 1390 ± 100 years has been obtained for the site (Wilmeth 1978 cited in Jamieson 1983).

The remains of 85 individuals were recovered from the Roebuck site (Wintemberg 1936: 118-119). These individuals were found in single graves and the occasional multiple grave both within and outside the palisade walls. A great number of these burials were found in refuse heaps. Scattered human bone representing as many as 35 individuals (Knowles 1937: 5) was also recovered from the refuse heaps. Wintemberg (1936: 120) states that the scattered human bone likely represents the enemies or captives of the village's inhabitants who were roasted or eaten alive. Jamieson's (1983) analysis of this scattered human bone and the human bone artifacts from the site strongly indicates that prisoner-sacrifice and cannibalism were being practiced.

Twenty-two of the 85 individuals recovered from Roebuck were included in this study. It should be pointed out, however, that it is uncertain whether or not these individuals are truly representative of the population that occupied the village. Wintemberg's excavations focussed on the middens and palisade. It is estimated that only one-quarter of the entire village has been excavated (Pendergast 1983:50) and it is unknown how many burials remain uncovered. If the population at Roebuck did peak at 2000 and if the village was occupied for approximately 20 years, then the number of dead expected ranges from 1,080 to 1,600 (Pendergast 1983: 51). Even assuming an average annual population of 1,000, the number of dead expected would be at least 540. Both of these figures are substantially higher than the 85 individuals recovered from

the site. Knowles (1937) found that most of the adult skeletons recovered from Roebuck are female and observations made during this study confirm this finding. It is unknown where the males were buried or what the reasons were for their exclusion from burial at the village site. It also seems questionable whether or not the burials found even represent the village's inhabitants or, if they do, if they represent special or unique cases. Interment in middens does not fit the burial pattern that was characteristic of other Iroquoian groups during the late prehistoric and historic periods.

MacPherson and MacKenzie-Woodbridge

The MacPherson site is located in Flamborough Township, Wentworth County, Ontario. This Neutral village site was excavated in 1987 under the direction of Mr. William Fitzgerald and Dr. Shelley Saunders of McMaster University. Based on an analysis of the artifact assemblage recovered, it has been suggested that the site dates somewhere between the 1530's and the late 1570's (Saunders and Fitzgerald 1988). A total of 31 burials were recovered from 30 burial features either within the houses or within the area of the village (Saunders 1988: 2). There is also an ossuary associated with the village but it has not been excavated (Saunders 1988: 2).

Infants, children and adults were represented among the human remains recovered from MacPherson. Nine of the adults were included in the present study. Again, an important question to be addressed is whether or not the individuals interred in the village represent 'special cases' (Saunders and Fitzgerald 1988). As mentioned previously, ethnohistoric accounts of the Huron (Tooker 1964) indicate that individuals who had died a violent death (i.e. warriors or suicides) as well as infants were not interred in the ossuaries with the rest of the dead. With the exception of one, there are no indications that any of the individuals interred at the MacPherson village site suffered a violent death (Saunders and Fitzgerald 1988). There are, however, a number of adult

skeletons which exhibit pathological conditions, including eight of the nine individuals included in this study.

The MacKenzie or Woodbridge site is located near metropolitan Toronto on the Humber River drainage system (Johnson 1980: 77). This is a single component village assigned to the southern division of the Huron-Petun branch of the Late Ontario Iroquois tradition (Johnson 1980: 77). Based on the artifact assemblage as well as the presence of European trade goods, the site has been dated to approximately A.D. 1520 ±10 to 15 years (Johnson 1980: 77).

Human remains have been recovered on four separate occasions from the site between the period1963-1982 (Saunders 1986: 9). Eighteen individuals, infant, child, adolescent and adult, are represented. Four of the adults were included for analysis in this study. Again, it is possible that the individuals interred at the MacKenzie-Woodbridge village site represent special cases. Of the four individuals included in this study, three were observed by Saunders (1986) to exhibit marked pathological changes.

The skeletal samples from MacPherson and MacKenzie-Woodbridge were combined and treated as a single sample in this analysis. These two samples are relatively close to each other in space and in time. According to Ramsden (pers. comm.1989), the archaeological evidence suggests that several groups of people occupied the MacKenzie-Woodbridge site. Given the nature of Iroquoian social organization at the time of occupation of these two sites, and considering the kinds of changes that were occurring in Iroquoian society at this time (eg. village fusion, population movements and migrations), it is as reasonable to combine the MacPherson and MacKenzie-Woodbridge skeletal samples as it is to consider either one individually (P. Ramsden, pers. comm.1989).

Tram

The Tram site is an early, palisaded, Seneca Iroquois village site located in Livonia Township, Livingston County, New York (Sempowski 1989: 1). Wray and Schoff (1953) first proposed a chronological sequence for the historically known Seneca village sites based, in part, on the assumption that two principal Seneca villages, a western and an eastern village, co-existed simultaneously from at least the last half of the 16th century to the end of the 17th century (Wray et al 1987: 2). Tram has been identified as the second village in the eastern sequence of Seneca village sites. Based on an analysis of the artifacts recovered from the site, Tram is believed to have been occupied between A.D. 1565 and A.D. 1590 (Wray 1973; Wray et al 1987).

The Tram site has been excavated on numerous occasions beginning as early as 1848 (Sempowski 1989: 1). Most of the excavation and investigation at the site has been confined to burials. Three cemeteries are known from Tram: cemetery 1, cemetery 2 and cemetery 3 from the south, north and northeast edges of the site respectively. Sempowski (1989: 3) reports that a minimum of 71 burials were recovered from cemetery 1. Cemeter 2 yielded the remains of 68-69[2] individuals (Wray and Cameron 1970). No excavation of burials from cemetery 3 has been reported. A total of 18 adult skeletons from this site were included in this analysis. All of these were recovered from cemetery 2.

---

[2]The field notes are contradictory. It is reported that 68 and 69 skeletons were recovered from cemetery 2. It is unknown which of the two figures is correct.

Chapter 4: Methods

A total of 88 adults were included in this study. The decision to include or exclude individuals from each sample was initially made on the basis of the following criteria:

1. the presence of a second left metacarpal suitable for x-ray and/or a left radius suitable for single photon absorptiometry and/or x-ray. In cases where the left metacarpal or radius was damaged or missing, the right was substituted.
2. the presence of remains which would allow sex of the individual to be determined and the approximate age at death to be estimated with confidence.

Once the individuals were selected and observations relevant to sex determination and age estimation were made[1], the radii and metacarpals were transported to McMaster University Medical Centre where all x-rays and single photon absorptiometry were done. Resulting data were analyzed primarily by nonparametric techniques. The data were compared by age and by sex both within and between samples. Comparisons were also made to published data on modern populations.

Sex Determination

Determination of the sex of each individual was based primarily on a combination of morphological and metric observations of the pelvic remains. Morphological criteria included the presence or absence of a ventral arc, subpubic concavity and median ridge (Phenice 1969), the presence of a preauricular sulcus, dorsal pubic pitting and an interosseous groove (Kelley

[1]The skeletal material from the MacPherson site was reinterred before most of these observations could be made. The sex and age estimates for the individuals in this sample were taken from Saunders (1988).

1979b), the shape of the subpubic angle, the shape of the sciatic notch and the presence or absence of an elevation of the posterior margin of the auricular surface (Krogman 1962). In addition to these criteria, the ischio-pubic index (Washburn 1949), the greater sciatic notch-acetabular index (Kelley 1979a) and the acetabular-pubis index (Schulter-Ellis et al 1985) were calculated whenever it was possible to obtain the appropriate measurements.

A number of criteria independent of the pelvis were also considered in determining the sex of each individual. These criteria include measurements of the humerus (Dittrick and Suchey 1986), femur (Dittrick and Suchey 1986; MacLaughlin and Bruce 1985) and tibia (Iscan and Miller-Shaivitz 1984). In most cases, individuals could be classified as male or female on the basis of the published standards and, in most cases, this classification was in agreement with the determination of sex from the pelvic remains.

In some instances, however, the individual could not be clearly identified as male or female on the basis of the published standards. Furthermore, the observations from the pelvis were limited and therefore inconclusive with respect to sex. In these cases, the sex of the individual was determined through a comparison to individuals of known sex from the same sample from which that individual was drawn. This comparison was done in the following manner:

1. Variables shown to correctly classify a high percentage of individuals as male or female were chosen. In this case, maximum diameter of the femoral head, bicondylar width of the femur and transverse and vertical diameter of the head of the humerus (Dittrick and Suchey 1986) were selected.
2. A plot of the values of these variables was made for individuals of known sex. Known sex refers to individuals that have been identified as male or female on the basis of specific morphological criteria such as Phenice criteria. A separate plot was made for each of the variables.

3. The male and female values for each variable were examined. The midpoint of the overlap between the male and female values was taken as the sectioning point for that variable.
4. The value of the variable for the individual of unknown sex was plotted to see where it fell with respect to the sectioning point.

A total of nine individuals were classed as male or female using this method.

It should be noted that observations of cranial morphology were also taken but were found to be less reliable in determining sex and were therefore only given secondary consideration. Table 4.1 provides a breakdown of each sample by sex and by age category.

Age Estimation

A number of criteria were employed in deriving an estimate of age at death for each of the individuals. The present study requires adults only. Therefore, the first step was to examine the skeletal remains for degrees of epiphyseal union. To be included in the analysis, each skeleton had to exhibit complete union of the medial epicondyle of the humerus, the proximal radius, the proximal ulna, the proximal femur, the distal tibia and the distal fibula. This would place individuals at a minimum of 19-20 years of age at the time of death (McKern 1970 cited in Bennett 1987). All other epiphyses of the infracranial skeleton were also inspected. Observations of ectocranial suture closure (Meindl and Lovejoy 1985), dental attrition (Melbye 1983), osteoarthritis of the lumbar spine (Stewart 1958) and osteoarthritis of other joints were also made.

For the most part, however, these observations were only given secondary consideration in estimating age at death. Primary consideration was given to features of the pelvic remains. The standards developed for aging based on degenerative changes of the pubic symphysis (Gilbert and McKern 1975; Katz and Suchey 1986; McKern and Stewart 1957) and of the auricular surface

(Lovejoy et al 1985) were utilized whenever possible. If it was not possible to obtain an age estimate from either the pubic symphysis or the auricular surface of an individual skeleton, then that skeleton was excluded from the analysis.

Most of the methods for estimating age listed above are population specific. They also lack precision and accuracy. For these reasons, in addition to making written observations, photos were taken and casts were made of the pubic symphyses and/or auricular surfaces of each individual skeleton included in the analysis. This was done to ensure consistency in observations and to allow for the construction of comparable age profiles and cohorts between samples. By using the observations, photos and casts in conjunction with one another, it was possible to seriate the individuals within each sample from youngest to oldest, to assign a rank age to each individual, to divide each sample into two broad age categories, 20-39 and 40+, and then to compare rank ages and age categories across all samples.

In most cases, the pubic symphyses were missing or were not suitable for making an age estimate. As a result, the age profiles of each sample were constructed largely on the basis of auricular surface morphology. Age estimates thus obtained were refined on the basis of observations of the other criteria listed above.

Again, table 4.1 provides a breakdown of each sample by sex and by age category. While the majority of individuals in the 40+ age category were estimated to be between 40 and 60 years of age at the time of death, each sample does contain at least one markedly old individual.

Table 4.1 Age and sex composition of the samples

Sample	Total size	Males 20-39	Males 40+	Females 20-39	Females 40+
Serpent Mounds	20	5	9	3	3
Sackett/ Castle Creek	15	5	2	3	5
Roebuck	22	1	3	7	11
MacPherson/ MacKenzie	13	5	1	5	2
Tram	18	4	4	4	6
	88				

Radiography

As mentioned previously, the decision to include or exclude individuals was made, in part, on the basis of the presence of a second left metacarpal and/or a left radius suitable for x-ray. The left elements were chosen for the following reasons:

1. To ensure consistency in sampling.
2. To control for the possible effects of bilateral asymmetry.
3. Because studies of modern populations tend to use x-rays of the nondominant arm. This study assumes that the left arm is most likely to be nondominant.

However, it was not always possible to use the left metacarpal or radius, either because the element was missing or because it was seriously damaged. A total of nine second right metacarpals and thirteen right radii had to be included. This represents 13.4% and 15.5% of the total sample of metacarpals and radii respectively. The right elements were randomly distributed throughout all the samples.

Posterior-anterior radiographs of the second metacarpals were taken on Kodak T-mat L film at an exposure of 60kV, 2.5 mA and at a tube-to-film distance of 102 cm. The maximum length of each metacarpal was measured to the nearest millimeter using a ruler and midshaft was marked. The external width (W) of the metacarpal and the medullary width (M) were measured at midshaft to .05 millimeters using Helios needle-point calipers and a magnifying glass. The magnifying glass was used since the endosteal surface sometimes appeared hazy to the unaided eye.

The measurements W and M were used to calculate percent cortical area (PCA) (Garn 1970). Percent cortical area, given by the formula $(W^2 - M^2/W^2) \times 100$, expresses the ratio of cortical area to total area.

Anterior-posterior radiographs of the radii were taken on Kodak T-mat L film at an exposure of 60 kV, 3.2 mA and at a tube-to-film distance of 102 cm. The variable of interest was

percent cortical area of the proximal radius. The site of measurement of W and M is defined by Meema and Meema (1973) as a distance 2.5 times the diameter of the radius measured distally from the capitulum of the humerus. Clearly, it was not possible to measure the distance from the capitulum of the humerus in this case. Meema (pers. comm. 1988) recommended that a distance of 2.5 times the maximum diameter of the radial head minus three millimeters be measured distally from the center of the concavity at the front of the radial head and marked. Three millimeters are subtracted to account for the articular space between the head of the radius and the humerus. Once this site was defined on the x-rays, W and M were measured to .05 millimeters using Helios needle-point calipers and a measuring glass. Percent cortical area was calculated using the formula cited above.

Radiography has been shown to be a fairly precise technique for evaluating bone mass. Intraobserver error in measuring W and M of the metacarpal has been reported to range between 0.7 and 4.8% (Andresen and Nielsen 1986: 610). Interobserver error in measuring these parameters has been reported to have a range of 1.0 to 6.4%. Meema and Meema (1987: 406) report that the overall precision for metacarpal and radial measurements is approximately 3%.

The accuracy of this method, however, is questionable. Measurements of cortical thickness do not assess intracortical porosity and endosteal erosion (Wahner et al 1983: 283). Variations of intracortical porosity may account for as much as 30% of aging changes (Mazess 1981). According to Huddleston (1988: 13), bone density must be decreased by at least 30% before a significant reduction can be seen in radiographic images. Because of this inaccuracy, this method can not be used by itself for the diagnosis or monitoring of individuals. However, it can still be useful epidemiologically (Mazess 1981: 29).

Single Photon Absorptiometry

Single photon absorptiometry (SPA) is a simple noninvasive technique which provides a measure of bone mineral content (BMC) in g/cm. Initially developed by Cameron and Sorenson in 1963, this technique is based on the transmission through bone of a collimated beam of low energy monochromatic radiation, in this case ^{125}I. The amount of radiation transmitted as the beam passes over the bone, recorded in counts per second, is measured by a scintillation counter which is coupled to the collimated beam (Figure 4.1). This amount is inversely related to the amount of bone mineral in its path (Boyd et al 1974: 1202) and is calculated according to the following equation:

$$M_\beta = p_\beta \ln(I_0^*/I)(u_\beta p_\beta - u_s p_s)$$

where p_β=microscopic density of bone mineral, p_s=microscopic density of soft tissue, u_β=mass absorption coefficient of bone mineral (cm^2/gm), u_s=mass absorption coefficient of soft tissue (cm^2/gm), I_0^*=count rate through soft tissue and I=count rate through bone and soft tissue. M_β is the amount of mineral per unit area for a single point measurement (Sorenson and Cameron 1967: 483). The transmission rate of the beam varies as the beam crosses over the bone. This reflects variation in the amount of mineral encountered.

A curve based on the natural logarithms of I and I_0^* are constructed and displayed on a monitor. Bone mineral content, or mass of mineral per unit length of bone, is proportional to the area enclosed by these two curves (Figure 4.2) (Sorenson and Cameron 1967: 483). Bone width is determined by assigning edges to the bone where the count rate through bone and soft tissue (I) is a percentage of the baseline count rate (I_0^*). This is referred to as the search threshold.

Single photon absorptiometry has been shown to be accurate and precise to within 2% (Boyd et al 1974; Cameron et al 1968; Sorenson and Cameron 1967). Furthermore, bone mineral content determined by this technique is independent of the thickness of the overlying tissue,

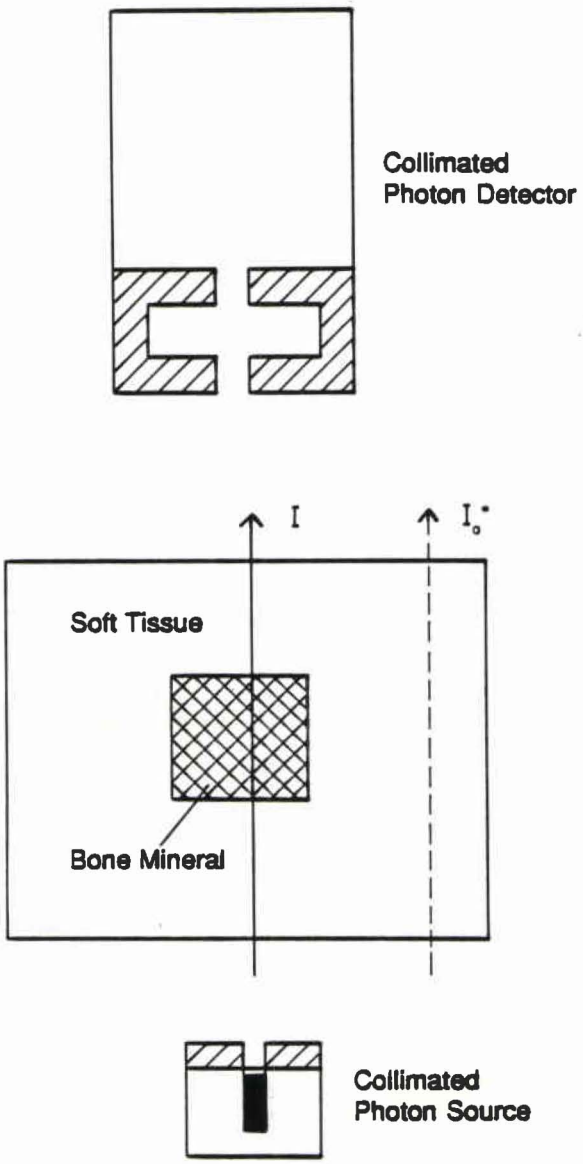


Figure 4.1 Essentials of bone mineral measurement (Sorenson and Cameron 1967: 482)

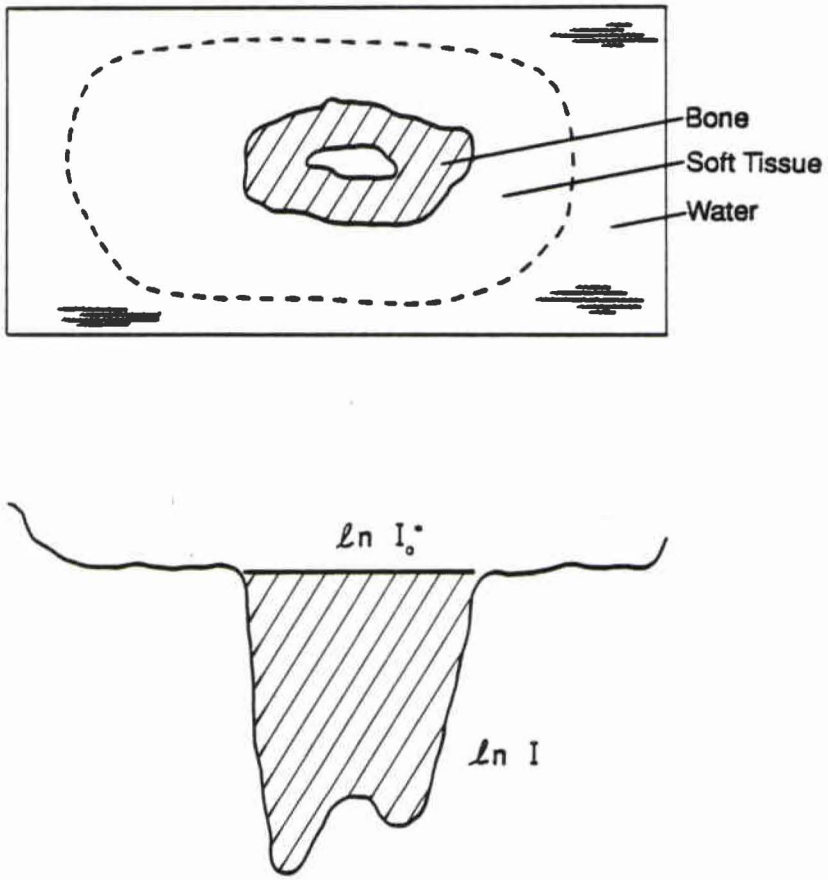


Figure 4.2 Relation between beam transmission and bone mineral content (Sorenson and Cameron 1967: 483).

independent of the bone position relative to the top and bottom of the soft tissue and independent of the orientation of the bone in the soft tissue (Sorenson and Cameron 1967: 488). The technique does, however, depend on constant thickness of the scan path. This requires that water or form-fitting pieces of tissue-equivalent material be placed around the scan site. Equal thickness is necessary if the equation cited above is to hold true (Cameron and Sorenson 1963).

Single photon absorptiometry was carried out on the radii using facilities at the Department of Nuclear Medicine, McMaster University Medical Centre. All measurements were done on the Norland 278 Bone Densitometer. This is a direct readout system which provides values of bone mineral content (g/cm), bone width (cm) and the bone mineral index (BMI=BMC ÷ BW) to three decimal places. Although single photon absorptiometry is designed primarily for use with living populations, it can and has been (eg. Perzigian 1973; Sumner 1984) adapted for use with archaeological samples.

The standard site for single photon absorptiometry of the radius is 1/3 of the distance from the ulnar styloid process to the olecranon, measured proximal to the styloid process. In the present study, the radial shaft site was defined as 1/3 of the maximum length of the radius measured proximal to the radial styloid process. This site was clearly marked on the shaft of each radius prior to scanning.

Single photon absorptiometry is based on a two component system: bone and soft tissue or its equivalent. Archaeological bone is likely to contain air. In order to remove as much air as possible, and thus reduce the error in measurement that could be caused by the presence of air, the radii were placed under a vacuum for 24 hours prior to testing. While still contained under a vacuum, the radii were flooded with distilled, de-ionized water. The radii were then placed in a bath of this water for testing. The water served as the soft tissue equivalent.

The water bath consisted of a plastic container, 45x15x10cm, filled with water to a depth of five centimeters. A longitudinal axis was marked along the bottom of the bath and a mirror marked

with a vertical axis was fixed at one end. Each radius was placed in the bath, anterior surface down, along the longitudinal axis with the distal articular surface facing the mirror. Each radius was checked to ensure that the distal and proximal ends were on the axis, touching the bottom of the bath, and that the dorsal tubercle was directly over the axis (Figure 4.3). Each radius was also checked to see that the notches separating the medial and lateral aspects of the distal articular surface were lined up along the vertical axis on the mirror (Figure 4.3). A metal clamp was placed around the neck of the radius to hold it in position during scanning. The search threshold was set at 75%. The plastic container was positioned so that the measurement site on the radius was directly below the beam. Each radius was scanned four times and bone mineral content, bone width and the bone mineral index (BMI) were recorded each time. An average value for each variable was calculated. The average values for the bone mineral index were used in this analysis.

A total of 55 radii (11 right, 44 left) were tested for bone mineral content. The radii from the Sackett and Castle Creek sites were excluded from this part of the analysis since they were less well-preserved than the others and immersion in the water bath may have resulted in further damage.

Accuracy and Precision

Sokal and Rohlf (1969: 13) define accuracy as the closeness of a measured or computed value to its true value and precision as the closeness of repeated measurements of the same quantity. An attempt was made to evaluate precision error in the x-ray study and both precision error and error in accuracy in the single photon absorptiometry. The design and results of these evaluations are discussed below. Precision error was calculated according to the following formula:

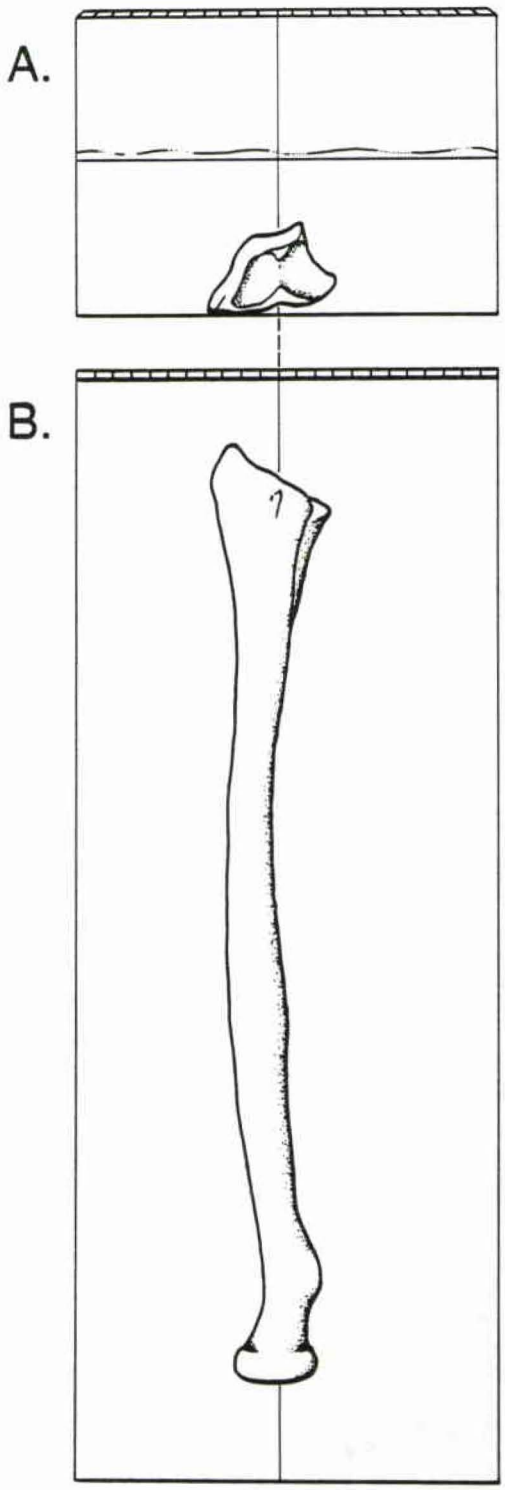


Figure 4.3 Position of radius in the water bath

$$\%error = \frac{/original - repeat/}{(original + repeat)/2} \times 100$$

This statistic yields information on the magnitude of the precision error (Utermohle, Zegura and Heathcote 1983 cited in Sumner 1984: 70). The paired t-test (two-tailed) was used to test the significance of the difference between the original and the repeat measurements. If true values are known, percent error in accuracy can be assessed using the following formula:

$$\%error = \frac{/true - measured/}{true} \times 100$$

(Sumner 1984: 70). Since true values are not known in this study, percent error in accuracy was calculated using the precision formula cited above.

Precision error in x-ray measurement

Two types of precision error can be identified: intraobserver and interobserver error. Only intraobserver error was evaluated for the x-ray measurements of the metacarpals. Identification of the measurement site and the measurement technique itself are straightforward. Both intraobserver and interobserver error were assessed for the measurements of the radii since the identification of the measurement site is more complex and therefore more prone to error. Since percent cortical area is the variable of most interest in this study, the results of the error studies are reported for this variable only.

A sample of 20 metacarpals was chosen. Repeat measurements of total width and medullary width were made six months after the original measurements were taken. Percent cortical area was calculated and compared to the original values. Percent error in percent cortical area had a mean value of 2.32 and a standard deviation of 1.72. The t-value obtained from the comparison of original and repeat values was -1.104. This was not significant at $p \leq .05$.

A sample of 14 radii was chosen. The measurement site was marked, total width and medullary width were measured at the site and percent cortical area was calculated. The mean intraobserver error in percent cortical area was 3.37% (S.D.=6.90). In one case, the % error was substantially higher than this (27.707%). Eliminating this case, the mean intraobserver error was 1.50% (S.D.=1.50). Including this case, the t-value obtained from the comparison of original and repeat measures was 3.367. This was not significant at $p \leq .05$.

The interobserver error had a mean of 5.37% (S.D.=6.34). Again, there was one case in which the % error was substantially higher (25.91%). Eliminating this case, the mean interobserver error was 3.79% (S.D.=2.68). Including this case, the t-value obtained from the comparison of original and repeat measures was -1.351. Again, this was not significant at $p \leq .05$.

Accuracy and Precision in Single Photon Absorptiometry

According to Sumner (1984: 91-93) there are two sources of error which may affect the accuracy of bone mineral content values obtained from archaeological bone: error inherent in the system and error due to differential filling of the medullary cavity. In an effort to control system error the machine was routinely calibrated on the day of use or on the day before. Calibration coefficients were determined by scanning a bone phantom for which the true value of bone mineral content and bone width are known. To evaluate error due to differential filling of the medullary cavity the experimental design outlined by Sumner (1984: 93) was used. Ten radial shaft fragments were collected, a measurement site was marked on each and the ends of the fragments were plugged with clay. The fragments were placed under a vacuum for 24 hours, then flooded with water and placed in a water bath for single photon testing. Each fragment was scanned four times. While still under water, the plugs were removed, the shaft was allowed to fill completely

with water and the fragment was again scanned four times. Percent error in the bone mineral index had a mean of 3.44 (S.D.=2.49). The t-value was -.092. This was not significant at $p \leq .05$.

Sumner (1984: 94-95) identifies four potential sources of precision error:

1. repositioning error
2. system error
3. differential filling of the medullary cavity
4. variation in the activity of the source

An attempt was made to evaluate the error due to these sources that may have occurred in the present study. Again, the experimental design outlined by Sumner was followed.

A sample of ten radii[2] was chosen and measured for bone mineral content, bone width and bone mineral index following the procedure outlined above (i.e. measurement site defined, bones placed under a vacuum, flooded with water, each scanned in the water bath). The radii were allowed to dry then prepared again and a series of three rescans was done. For each rescan each bone was scanned four times. The bone was not moved between the first and second rescans therefore any differences found should be due solely to error inherent in the system. Each bone was repositioned for the third rescan. The difference between the first and third rescan should be due to error in the system and repositioning error. The difference between the original scan and the first rescan should be due to error from all sources combined. Error is reported for the bone mineral index only.

Error due to all sources had a mean value of 3.40% (S.D.=1.95). The t-value was 0.288 and was not significant at $p \leq .05$. System error and repositioning error combined had a mean value of 2.42% (S.D.=1.43). The t-value was 0.385. Again, this was not significant. System

---

[2]One of the radii was damaged during the initial scan and had to be eliminated from further testing. As a result the sample size was reduced to nine.

error was shown to have a mean value of 2.10% (S.D.=0.80). The t-value was -0.215. This was also not significant. This suggests that repositioning error averaged 0.32%. Error due to other sources (i.e. differential filling of the medullary cavity and variations in the activity of the source) appears to have been less than 1.0%. These results are summarized in Table 4.2.

Diagenesis

Garland (1987) has described 3 categories of histological change which can be identified in buried human bone:

1. Destructive changes
   a) generalized destruction - disintegration, dissociation and disaggregation of osteons
   b) focal - invasion by fungus, bacteria or protozoans

   These changes result in the demineralization of bone tissue.
2. Inclusions - biological material or mineral

   The inclusion of mineral results in the hypermineralization of bone.
3. Infiltrations - extraneous material within the bone substance itself.

   This results from the exchange of components of bone with those of the environment.

Hanson and Buikstra (1987) discuss the leaching of mineral from bone. While this process results in no apparent destruction or change in the histomorphology of bone, it may result in the demineralization of bone tissue.

Recent research (eg. Hanson et al 1987; Klepinger et al 1986; Pfeiffer 1989) has demonstrated that the degree of diagenetic change occurring in buried human bone can be considerable. It has been found that the degree of diagenesis may vary between samples, between individuals within a sample and even between elements from the same individual (eg. Lambert et al

Table 4.2 Mean precision error in single photon absorptiometry

Source of error	$\bar{x}$	s.d.	t-value
All sources combined	3.40%	1.95	0.288
System error and repositioning error	2.42%	1.43	0.385
System error	2.10%	0.80	-0.215
Repositioning error	0.32%		
Activity of source/ depth of water bath/ differential filling of the medullary cavity	0.98%		

1985). Furthermore, the degree of histological preservation has been found to be independent of the degree of gross morphological preservation (eg. Hanson and Buikstra 1987). It has been argued, therefore, that an assessment of diagenetic change is important to any analysis involving noninvasive measures of bone mineral content including single photon absorptiometry. Any health-related inferences made on the basis of this kind of analysis, without the benefit of an assessment of diagenesis, must be regarded with caution (Hanson and Buikstra 1987). The most accurate method for evaluating the degree of diagenesis of a particular bone is to examine a thin section of that bone microscopically.

It is recognized that diagenesis is a potential problem in the present study. Unfortunately, it was not possible to examine the radii for histological destruction or alteration using thin sections of each bone. As an alternative, values of the bone mineral index and percent cortical area of the radius were examined for indirect evidence of bone diagenesis. Since the bone mineral index and percent cortical area are both intended to serve as indicators of bone quality, it is reasonable to expect high bone mineral index values to be associated with high percent cortical area values and low bone mineral index values with low percent cortical area values.

To look for a possible association between percent cortical area of the radius and the bone mineral index, the Spearman rank correlation coefficient was used. The value of rho that was obtained was .537 thus indicating a significant positive relationship between the two variables ($p \leq .01$). If the radii had been subject to demineralization the bone mineral values obtained would be altered. However, this kind of diagenetic change would not necessarily affect the corresponding values for percent cortical area. Similarly, if hypermineralization had occurred, bone mineral values would again be affected but percent cortical area would not. It is unlikely that a significant positive relationship would be found between bone mineral index values and percent cortical area had any diagenetic change occurred at all. While it does not conclusively prove that diagenesis has

not occurred, the significant value of rho obtained provides some evidence that it may not be a significant or particularly serious problem in this study.

Data Analysis

Percent cortical area of the metacarpal, percent cortical area of the radius and bone mineral index values were analyzed for the following:

1. Significant differences between age groups, all samples combined and within each sample. The Mann-Whitney U test was used in this case.
2. Significant differences between males and females, all samples combined and within each sample. Again, the Mann-Whitney U test was used.
3. Significant differences between samples. The Kruskal-Wallis ANOVA was used to determine if the samples were significantly different from one another and then the Mann-Whitney U was used in a series of pairwise comparisons to determine which samples in particular were significantly different.
4. Significant differences between samples and modern populations, all samples combined and within each sample. The unpaired t-test was used.

The nonparametric approaches to data analysis were preferred because of the small and unequal sample sizes that were used in this study. Also, the assumptions of a normally distributed population and of populations with equal variance which underly the parametric approaches could not necessarily be met. All analysis was done on a Macintosh® computer using the Statview 512+® software package.

Each variable was examined separately. Because of the size of the samples used in this analysis and because the magnitude of the expected differences between the groups is small, the significance level was set at $p \leq .10$. Hodges and Schell (1988) point out that the small samples

typically available to biological anthropologists are inadequate for discriminating small differences between groups and suggest relaxing the significance level to increase the power (i.e. the probability of rejecting a false null hypothesis) of the analysis.

Chapter 5: Results

The results of the analysis of PCA of the metacarpal, PCA of the radius and BMI are presented separately. Basic descriptive statistics are provided for all three variables for the following groups: all samples combined, male and female combined, young and old combined; all samples combined, male and female combined, young or old only; all samples combined, male or female only, young and old combined; all samples combined, male or female only, young or old only. These are presented in the appendix. In addition, descriptive statistics are provided for the same age- and sex-specific groups within each sample (eg. Serpent Mounds, male and female combined, young only). These are also presented in the appendix. This breakdown of data into the nine different age- and sex-specific categories represents all the different groups that were examined in various parts of the analysis.

Age-Group Differences

As discussed previously, individuals within each sample were divided into two broad age categories: 20-39 and 40+. The aim of this part of the analysis was to determine if significant differences exist between these age groups with respect to PCA of the metacarpal, PCA of the radius and BMI. The data were analyzed for all samples combined and for each sample individually. In each case the data were analyzed with males and females combined as well as with males and females examined separately. The Mann-Whitney U was used to test the null hypothesis that there are no significant differences between age groups.

The results of this part of the analysis are shown in table 5.1. This table lists the values of U that were obtained as well as the number of young and old individuals that were involved in each case. With one exception, none of the values of U obtained from the metacarpal data from individual samples are significant. There are, however, significant differences ($p \leq .01$) between the young and old age groups when all samples are combined, both when males and females are combined and when females are considered separately. The differences between age groups with respect to PCA of the radius are also significant ($p \leq .001$) when all samples are combined, both when males and females are combined and when females are analyzed separately. There are also significant differences between young and old males from Sackett-Castle Creek ($p \leq .05$), young and old males and females combined ($p \leq .01$) and females only ($p \leq .10$) from MacPherson-MacKenzie, and young and old males and females combined from Tram ($p \leq .01$). There are significant differences in BMI between young and old adults when all samples are combined, both when males and females are combined ($p \leq .10$) and when males and females are each considered separately ($p \leq .05$). In all of the cases where a significant value of U was obtained except one (Sackett-Castle Creek males) , the mean rank of the young adult group is higher than the mean rank of the old adult group. This indicates that young adult values for PCA of the radius, PCA of the metacarpal and BMI are significantly higher than those of the old.

In general, significant differences in all three variables are expected to occur between the young and old age groups. Values for PCA of the metacarpal, PCA of the radius and BMI should be greater among young adults than among the old. The failure to find age-group differences in these variables in some of the individual samples could be due to small sample sizes and the fact that the magnitude of the expected difference between age groups may be relatively small. Alternatively, the lack of significant age-group differences could be a reflection of the age distribution of the samples. As outlined in chapter 2, there is some evidence that adults do not experience a significant loss of cortical bone until relatively late in life (i.e. after menopause or after 65 years

Table 5. 1 Results of the Mann-Whitney U test for significant differences between age groups with respect to PCA metacarpal, PCA radius and BMI

PCA metacarpal

	U	No. young	No. old
All samples combined			
a) males and females	335.5 ●	34	34
b) males	63	14	12
c) females	105.5●	20	22
Serpent Mounds			
a) males and females	8	5	6
b) males	2	2	5
c) females	1	3	1
Sackett-Castle Creek			
a) males and females	8	6	3
b) males	-	-	-
c) females	3	3	3
Roebuck			
a) males and females	27	7	13
b) males	1	1	3
c) females	15	6	10
MacPherson-MacKenzie			
a) males and females	1*	8	3
b) males	1	4	1
c) females	0	4	2
Tram			
a) males and females	30	8	9
b) males	5	4	3
c) females	9	4	6

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$ (one-tailed)

continued. . .

Table 5.1

PCA radius

	U	No. young	No. old
All samples combined			
a) males and females	546●●	40	45
b) males	160	20	19
c) females	119●●	20	26
Serpent Mounds			
a) males and females	31	8	12
b) males	12	5	9
c) females	3	3	3
Sackett-Castle Creek			
a) males and females	20	7	6
b) males	0*	5	2
c) females	2	2	4
Roebuck			
a) males and females	36	8	14
b) males	1	1	3
c) females	21	7	11
MacPherson-MacKenzie			
a) males and females	1●	9	3
b) males	0	1	5
c) females	0◇	4	2
Tram			
a) males and females	13●	8	10
b) males	2	4	4
c) females	5	4	6

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$ (one-tailed)

continued. . .

Table 5.1

BMI

	U	No. young	No. old
All samples combined			
a) males and females	287◇	27	28
b) males	46.5*	12	14
c) females	61.5*	15	14
Serpent Mounds			
a) males and females	16	5	10
b) males	8	4	7
c) females	1	1	3
Roebuck			
a) males and females	27	7	11
b) males	-	-	-
c) females	15	7	8
MacPherson-MacKenzie			
a) males and females	2	9	2
b) males	0	5	1
c) females	0	4	1
Tram			
a) males and females	13	6	5
b) males	3	3	3
c) females	2	3	2

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$ (one-tailed)

of age). The number of individuals in the skeletal samples who fall into this category may be insufficient to allow for detection of a significant difference between the age groups.

Sex Differences

The aim of this part of the analysis was to determine if significant differences exist between males and females in PCA of the metacarpal, PCA of the radius and BMI. Again, the data were analyzed looking at all samples combined and each sample individually. In each case the data were analyzed using young and old adults combined as well as young and old adults separately. The Mann-Whitney U was used to test the null hypothesis that there are no significant differences between males and females.

The results of this part of the analysis are presented in table 5.2. Again, this table provides the values of U that were obtained as well as the number of males and females that were included in each case. There are no significant differences between males and females in PCA of the metacarpal in any of the groups examined. There are, however, significant differences in PCA of the radius. When all samples are combined the differences between the sexes are highly significant, both when young and adults are combined and when each age group is considered separately. With the exception of Tram, there are also significant differences between the sexes within each sample in at least one case. Significant differences between males and females are also found in BMI values. The values of U obtained are highly significant when all samples are combined, both when young and old adults are combined and when each age group is analyzed separately. Except for Roebuck, there are also significant differences between the sexes in each individual sample in at least two of the groups examined. The small number of males relative to the large number of females in the Roebuck sample may, in part, account for the nonsignificant values of U obtained. In all cases where a significant value of U was obtained except one (PCA of

Table 5.2 Results of the Mann-Whitney U test for significant differences between males and females with respect to PCA metacarpal, PCA radius and BMI.

PCA metacarpal

	u	No. males	No. females
All samples combined			
a) young and old	506.5	26	42
b) young	126.5	14	20
c) old	98	12	22
Serpent Mounds			
a) young and old	11	7	4
b) young	2	2	3
c) old	2	5	1
Sackett-Castle Creek			
a) young and old	7	3	6
b) young	3	3	3
c) old	-	-	-
Roebuck			
a) young and old	22	4	16
b) young	1	1	6
c) old	8	3	10
MacPherson-MacKenzie			
a) young and old	13	5	6
b) young	7	4	4
c) old	0	1	2
Tram			
a) young and old	35	7	10
b) young	7	4	4
c) old	8	3	6

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$, ●●● $p \leq .0001$ (one-tailed)

continued. . .

Table 5.2

PCA radius

	u	No. males	No. females
All samples combined			
a) young and old	427●●●	39	46
b) young	118*	20	20
c) old	104●●	19	26
Serpent Mounds			
a) young and old	18*	14	6
b) young	1*	5	3
c) old	16	9	3
Sackett-Castle Creek			
a) young and old	7*	7	6
b) young	3	5	2
c) old	0◇	2	4
Roebuck			
a) young and old	17◇	4	18
b) young	0	1	7
c) old	10	3	11
MacPherson-MacKenzie			
a) young and old	13	6	6
b) young	3◇	5	4
c) old	-	-	-
Tram			
a) young and old	33	8	10
b) young	7	4	4
c) old	12	4	6

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$, ●●● $p \leq .0001$ (one-tailed)

continued. . .

Table 5.2

BMI

	u	No. males	No. females
All samples combined			
a) young and old	107●●●	26	29
b) young	14●	12	15
c) old	33●	14	14
Serpent Mounds			
a) young and old	2●	11	4
b) young	0	4	1
c) old	2*	7	3
Roebuck			
a) young and old	16	3	15
b) young	-	-	-
c) old	7	3	8
MacPherson-MacKenzie			
a) young and old	4*	6	5
b) young	2*	5	4
c) old	-	-	-
Tram			
a) young and old	5*	6	5
b) young	1◇	3	3
c) old	1	3	2

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$, ●●● $p \leq .0001$ (one-tailed)

the radius - MacKenzie-MacPherson young), the male mean rank for PCA of the metacarpal, PCA of the radius and BMI is higher than the female mean rank. This indicates that the male values for these variables are significantly higher than the female values in these cases.

Sample Differences

The objective of this part of the analysis was to determine if significant differences exist between samples with respect to each of the variables. There were 2 steps involved:

1. The Kruskal-Wallis ANOVA by ranks was used to test the null hypothesis that all samples come from the same population or from identical populations. The groups examined included all samples, male and female, young and old; all samples, male or female, young and old; all samples, male and female, young or old; all samples, male or female, young or old.
2. In cases where the null hypothesis was rejected, the Mann-Whitney U was used in a series of pairwise comparisons to determine which samples in particular are significantly different.

The results of the Kruskal-Wallis ANOVA by ranks for all 3 variables are presented in table 5.3. There are no significant differences between samples in PCA of the metacarpal in any of the groups examined. None of the H values obtained even approach significance at $p \leq .10$. In 6/9 cases there is a significant difference ($p \leq .10$) between samples in PCA radius. There is a significant difference ($p \leq .05$) between samples in BMI in only 1 case.

Table 5.4 provides the results of the pairwise comparisons of samples for PCA of the radius. Serpent Mounds is significantly different from each of the other samples in at least two of the groups considered. Examination of the Kruskal-Wallis data shows that in each case where there is a significant difference between Serpent Mounds and another sample, the mean rank of

Table 5.3 Results of the Kruskal-Wallis ANOVA by Ranks

Group	PCA metacarpal	PCA radius	BMI
All samples, males and females, young and old	1.818	17.350●	9.278*
All samples, young and old			
a) males only	1.175	3.594	2.112
b) females only	1.627	10.241*	0.899
All samples, males and females			
a) young only	3.317	11.997*	6.177
b) old only	2.101	12.141*	3.433
All samples			
a) young males	2.471	8.053◇	0.214
b) old males	0.682	4.101	1.207
c) young females	3.067	8.410◇	0.549
d) old females	2.307	6.141	0.969

This table lists the value of H that were obtained.
◇ $p \leq .10$, *$p < .05$, ● $p \leq .01$

Table 5.4 Results of Mann-Whitney U test for differences between pairs of samples in PCA radius

Pair	All Individuals	Females Only	Young Only	Old Only	Young Males	Young Females
SM-R	68●	19**	8**	29●	0	6
SM-MM	94	13	25	1●	3◇	3
SM-SCC	88	13	10*	28	0●	3
SM-T	121◇	24	31	27*	7	4
R-MM	61●	18**	8●	19	1	0●
R-SCC	71.5**	31.5	12◇	21.5	1	2
R-T	121*	44◇	11*	48	1	6
MM-SCC	71	3*	19	4	8	0
MM-T	96	14	33	11	3	6
SCC-T	111	27	19	22	5	3

◇ $p \leq .10$, * $p \leq .05$, ** $p \leq .02$, ● $p \leq .01$ (two-tailed)

This table lists the values of U that were obtained.

SM=Serpent Mounds, MM=MacPherson/MacKenzie, R=Roebuck, SCC=Sackett/Castle Creek, T=Tram

Serpent Mounds is considerably higher. Roebuck is significantly different from each of the other samples in at least two of the groups examined. The Kruskal-Wallis data shows that in each case where there is a significant difference between Roebuck and another sample, the mean rank of Roebuck is considerably lower. Sackett-Castle Creek, MacPherson-MacKenzie and Tram are not significantly different from each other in any of the groups considered except in the case of MacPherson-MacKenzie and Sackett-Castle Creek females, young and old combined. These two groups are significantly different from each other at $p \leq .05$. The Kruskal-Wallis data shows that the mean rank of MacPherson-MacKenzie is higher than that of Sackett-Castle Creek.

It could be argued that Roebuck mean values are significantly lower than all other sample means because of the unusually high proportion of females in the Roebuck sample. This difference would be expected in comparisons that do not control for sex. However, in comparisons of females only, Roebuck mean values are still consistently lower than other sample means. Roebuck and Sackett-Castle Creek females are not significantly different from each other but the mean rank of Roebuck is still lower than the mean rank of Sackett-Castle Creek.

A significant difference between samples with respect to BMI occurs only when all individuals, young and old, male and female, are combined. Results of the pairwise comparisons are provided in table 5.5. Significant differences occur between Serpent Mounds and Roebuck and Roebuck and MacPherson-MacKenzie only. Serpent Mounds has the highest mean rank overall and Roebuck the lowest. Because there is no control for sex in this particular case, the results may be slightly biased due to the high proportion of females in the Roebuck sample. No significant differences were found in BMI between Serpent Mounds and Tram and between Roebuck and Tram. This contradicts findings based on PCA of the radius for the same groups.

Table 5.5 Results of the Mann-Whitney U test for differences between sample pairs in BMI

Pair	All Individuals
SM-R	58.5●
SM-MM	77
SM-T	53.5
R-MM	54.5*
R-T	67.5
MM-T	46.5

* $p \leq .05$, ● $p \leq .01$ (two-tailed)

This table lists the values of U that were obtained.

SM=Serpent Mounds, MM=MacPherson-MacKenzie, R=Roebuck, T=Tram

Comparisons to Modern Population Data

The data from all three variables were compared to published data on modern populations. PCA of the metacarpal was compared, by age- and sex-specific groups, to a U.S. White and Mexican-American population (Garn et al 1973). The modern population data are reported for 10-year cohorts. To facilitate the comparison to the data from this study, the 20-29 and 30-39 age categories and the 40-49, 50-59 and 60-69 age categories were combined to provide a mean value for young adults and old adults respectively. PCA of the radius was compared, again by age- and sex-specific groups, to a Canadian White population (Meema and Meema 1973). These data are reported for young adults only (mean age of 30.5 years). Therefore, comparisons could only be made to young adults from this study. BMI values were compared, again by age- and sex-specific categories, to a sample of Wisconsin Whites (Mazess and Cameron 1974), Belgian Whites (Geusens et al 1986), St. Lawrence Island Eskimos (Harper et al 1984), North Alaskan Eskimos (Mazess and Mather 1974) and Canadian Eskimos[1] (Mazess and Mather 1975). These data are also reported for 10-year cohorts. To facilitate comparisons to data from this study, age categories were combined in the same manner as above to provide mean values for young and old adults.

The modern population data are presented in tables 5.6 to 5.8. All of the above comparisons were done using the unpaired t-test. All samples were combined and each sample was also considered individually. The results of the t-tests are provided in tables 5.9 to 5.11. The negative values obtained indicate that skeletal sample means for PCA of the metacarpal are lower than U.S. White and Mexican-American population means. Significant t-values occur when all samples are combined and when Serpent Mounds, Roebuck and Tram are each considered

---

[1]In this case the age groups included in the old adult category are 40-49, 50-59 and 60-73 for females and 40-49, 50-59 and 60-76 for males.

separately. Sample means for PCA of the radius are lower than the Canadian White population means. The t-values are significant in every case considered except one. Young females from Sackett-Castle Creek are not significantly different. The majority of sample means for BMI are also lower than the population means to which they were compared. In all cases except one, the sample means are significantly different from the Wisconsin White population means. There are a number of significant differences between the samples and the Belgian White population as well, but the number of these differences is reduced. Each sample is also significantly different from one or more of the Eskimo populations in at least one of the age- and sex-specific groups.

Table 5.6 PCA of the metacarpal data[1] for young and old adults[2] from U.S. White (USW) and Mexican-American (MA) populations

	USW			MA		
Group	N	Mean	SD[3]	N	Mean	SD[3]
young males	859	85.77	6.91	72	85.85	5.84
old males	1117	83.58	7.23	51	85.35	7.04
young females	1465	88.39	7.23	151	88.97	6.47
old females	1745	85.10	7.23	141	87.80	6.06

Table 5.7 PCA of the radius data[1] for young adults from a Canadian White (CW) population

Group	N	Mean	S.D.
young males	89	82.61	6.66
young females	89	86.31	6.19

Table 5.8 Bone mineral index data[1] for young and old adults[2] from the following populations: Wisconsin Whites (WW), Belgian Whites (BW), St. Lawrence Island Eskimos (SLE), North Alaskan Eskimos (NAE) and Canadian Eskimos (CE)

	Young males			Old males			Young females			Old females		
	N	$\bar{X}$	SD[3]	N	$\bar{X}$	SD[3]	N	$\bar{X}$	SD[3]	N	$\bar{X}$	SD[3]
WW	177	.890	.074	141	.850	.088	155	.772	.060	198	.693	.079
BW	48	.783	.054	52	.748	.057	62	.720	.048	87	.647	.071
SLE	41	.791	.058	27	.687	.046	40	.683	.039	38	.602	.074
NAE	33	.838	.077	47	.761	.078	33	.750	.057	59	.613	.073
CE	45	.792	.056	35	.684	.056	47	.689	.044	30	.587	.042

[1] See text for sources of data

[2] See text for a discussion of the division of data into young and old age categories.

[3] The value for young adults is an average of the standard deviation values reported for the 20-29 and 30-39 age categories. Similarly, the value for old adults is an average of the values reported for the 40-49, 50-59 and 60+ age categories.

Table 5.9 T-values resulting from comparisons of sample means for PCA of the metacarpal to U.S. White (USW) and Mexican-American (MA) population means

	All samples combined	
Group	USW	MA
young males	-3.184●	-3.853●
old males	-5.051●●	-6.092●●
young females	-5.642●●	-6.006●●
old females	-6.528●●	-7.421●●
	Serpent Mounds	
young males	-15.979*	-15.932*
old males	-3.500*	-4.154*
young females	-3.014◇	-3.167◇
old females	-	-
	Sackett-Castle Creek	
young males	-1.910	-1.924
old males	-	-
young females	-2.222	-2.386
old females	-1.522	-1.890
	Roebuck	
young males	-	-
old males	-1.789	-2.259
young females	-4.301●	-4.527●
old females	-4.119●	-4.850●●
	MacPherson-MacKenzie	
young males	-0.654	-0.669
old males	-	-
young females	-1.258	-1.431
old females	-2.196	-2.412
	Tram	
young males	-4.434*	-4.468*
old males	-1.789	-2.165
young females	-1.864	-1.973
old females	-4.574●	-5.656●

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$ (two-tailed)

Table 5.10 T-values resulting from comparisons of sample means for PCA of the radius to Canadian White (CW) population means

	All samples combined
Group	
young males	-10.684●●
young females	-12.708●●
	Serpent Mounds
young males	-3.593*
young females	-3.866◇
	Sackett-Castle Creek
young males	-13.495●●
young females	-5.824
	Roebuck
young males	-
young females	-12.664●
	MacPherson-MacKenzie
young males	-6.774●
young females	-10.114●
	Tram
young males	-3.768*
young females	-4.434*

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$ (two-tailed)

Table 5.11 T-values resulting from comparisons of sample means for BMI to Wisconsin White (WW), Belgian White (BW), St. Lawrence Island Eskimo (SLE), North Alaskan Eskimo (NAE) and Canadian Eskimo (CE) population means

All samples combined

Group	WW	BW	SLE	NAE	CE
young males	-8.699●●	-2.986*	-3.413●	-5.922●●	-3.466●
old males	-8.571●●	-3.816●	-0.972	-4.422●●	-0.832
young females	-11.574●●	-8.143●●	-5.701●●	-10.122●●	-6.097●●
old females	-4.962●●	-3.782●	-2.628*	-2.910*	-2.244*

Serpent Mounds

young males	-9.045●	-2.919◇	-3.377*	-6.068*	-3.435*
old males	-8.189●●	-2.883*	0.290	-3.560*	0.446
young females	-	-	-	-	-
old females	-2.089	-1.346	-0.619	-0.797	-0.377

Roebuck

young males	-	-	-	-	-
old males	-3.194◇	-1.806	-0.975	-1.983	-0.935
young females	-7.374●●	-5.249●	-3.737●	-6.475●●	-3.982●
old females	-3.529●	-2.787*	-2.062◇	-2.239◇	-1.820

MacPherson-MacKenzie

young males	-4.745●	-1.369	-1.622	-3.104*	-1.653
old males	-	-	-	-	-
young females	-4.144*	-2.763◇	-1.780	-3.560*	-1.939
old females	-	-	-	-	-

Tram

young males	-3.346◇	-1.465	-1.606	-2.432	-1.623
old males	-3.041◇	-1.379	-0.386	-1.591	-0.337
young females	-8.153*	-5.957*	-4.393*	-7.224*	-4.647*
old females	-1.769	-1.297	-0.836	-0.949	-0.682

◇ $p \leq .10$, * $p \leq .05$, ● $p \leq .01$, ●● $p \leq .001$ (two-tailed)

Chapter 6: Interpretations

As outlined in chapter one, this project is intended to differentiate environmental from population-based influences on cortical bone quality among pre-Iroquoian and Iroquoian populations of the lower Great Lakes region. Collectively, the skeletal samples studied in this project span a long period of prehistory in this region and the populations represented by these samples were subject to a range of environmental conditions which had the potential to affect cortical bone quality. The rationale behind this study is that if continuity and consistency in cortical bone quality can be demonstrated through time and space, then it is possible to argue that population factors were involved. Conversely, if discontinuities or inconsistencies are evident, then it can be argued that environmental factors are of primary importance.

Modern population studies have shown PCA of the metacarpal and radius and BMI of the radius to vary between males and females and to vary with age. The first two parts of this analysis (i.e. looking for differences between males and females and looking for differences between young and old adults) serve to demonstrate that these differences are also found in the skeletal samples. The last two parts of this analysis, looking for sample differences in PCA of the metacarpal, PCA of the radius and BMI and comparing sample means for each of these variables to modern population means, are directly relevant to the problem being addressed in this study.

Sample Differences

No significant differences were found between samples with respect to PCA of the metacarpal. Significant differences in BMI were found only when all individuals, young and old, male and female, were combined. PCA of the radius, however, showed a number of significant

differences between skeletal samples. The trends in the data suggest that the Serpent Mounds skeletal sample is different from all of the other skeletal samples in that PCA values are significantly higher. Roebuck is different from all other skeletal samples with PCA values that are significantly lower. The Sackett-Castle Creek, MacPherson-MacKenzie and Tram skeletal samples are not significantly different from each other. These results raise two important questions:

1. Why do agriculturalists, as represented by the Sackett-Castle Creek, MacPherson-MacKenzie and Tram skeletal samples, differ from hunter-gatherers, as represented by the Serpent Mounds skeletal sample, in PCA of the radius?
2. Why are the individuals from Roebuck unique? More specifically, why do Roebuck females have consistently and, in many cases, significantly lower values for PCA of the radius than any other group of females?

A number of studies of archaeological populations (eg. Cassidy 1984; Nelson 1984; Perzigian 1973) have noted a decrease in cortical bone quality accompanying the adoption and intensification of agriculture. Explanations for this decrease have traditionally centered around specific dietary deficiences associated with dependence on agricultural products such as corn. Inadequate dietary calcium intake and/or an inappropriate calcium to phosphorus ratio are often implicated.

Deficiencies in dietary calcium or a relatively high proportion of dietary phosphorus could be implicated in the low values for PCA of the radius found among the agricultural populations represented in this study. However, the exact role and significance of these dietary factors are difficult to evaluate. It is almost impossible to accurately quantify dietary calcium and/or phosphorus intake among prehistoric populations. Even if this were possible, it would not be possible to determine the amount of dietary calcium required by these groups to maintain a positive calcium balance. As previously outlined, there are number of factors which influence

individual calcium requirements. An apparently low dietary calcium intake may not necessarily result in bone resorption or impaired bone formation. Pfeiffer and King (1983: 27) estimate that the ratio of calcium to phosphorus, at least in the Huron diet, was probably close to 1:2. The magnitude of the effect of this ratio on adult or juvenile human bone is unknown.

Chronic protein-energy malnutrition has also been cited as an explanation for poor cortical bone quality in both archaeological (eg. Huss-Ashmore 1978) and contemporary (eg. Crosby et al 1985; Garn et al 1968; Garn and Rohmann 1964; Himes et al 1975) populations and provides an alternative explanation for the reduction in PCA of the radius seen in the Sackett-Castle Creek, MacPherson-MacKenzie and Tram skeletal samples. Protein-energy malnutrition can result from a protein deficit, a deficiency of essential amino acids or a calorie deficit. In the latter case, dietary protein is utilized to meet individual energy requirements. The skeletal response to chronic protein-energy malnutrition includes decreased bone formation and increased bone resorption (Huss-Ashmore et al 1982: 403-404). The net result is a reduction in cortical bone.

The Sackett-Castle Creek, MacPherson-MacKenzie and Tram skeletal samples date from approximately A.D. 1000 to A.D. 1590. A number of conditions existed during this period which support the hypothesis of general nutritional stress among these Iroquoian populations. Archaeological evidence suggests that intervillage warfare was occurring. In Ontario, there is evidence for an increase in population size, an increase in the size and number of villages and an increase in the concentration of people in these villages (Saunders et al 1989: 2). Population movements and village coalescence were occurring by the 16th century. Longhouse living became exceptionally crowded and the conditions created by the demographic changes that were occurring were ideal for the spread of chronic infectious diseases and possibly even epidemics.

The skeletal material from the late prehistoric and protohistoric period in the lower Great Lakes region provides evidence that Iroquoian populations also experienced a general decline in

health status during this time. Antemortem tooth loss, caries and periodontal disease were prevalent (eg. Wray et al 1987). There is evidence that tuberculosis (Hartney 1978; Pfeiffer 1984) and treponemal disease (Saunders and Fitzgerald 1988) were present. There are also numerous examples of nonspecific infection (eg. Pfeiffer 1984; Wray et al 1987). The Sackett-Castle Creek, MacPherson-MacKenzie and Tram skeletal samples used in this study all provide examples of antemortem tooth loss, caries and nonspecific infection.

All of the above factors could have contributed to chronic protein-energy malnutrition among the Sackett-Castle Creek, MacPherson-MacKenzie and Tram populations. Population movements, village coalescence and warfare could have interrupted subsistence activities (Pfeiffer 1986). Increased population density could have put pressure on available food resources. Disease and infection could have promoted malnutrition (i.e. through appetite suppression and malabsorption of essential nutrients). Malnutrition, in turn, would have further exacerbated disease and infection. The relatively low values for PCA of the radius seen in the Sackett-Castle Creek, MacPherson-MacKenzie and Tram skeletal samples could represent part of an adaptive response to malnutrition. The dietary protein and energy that was available could have been used to maintain normal body growth and function at the expense of cortical bone formation and maintenance.

The values for PCA of the radius for Roebuck females are exceptionally low in comparison to all of the other female groups. Pregnancy and prolonged lactation could have contributed to these low values. There is some skeletal evidence for pregnancy among Roebuck females. There is no direct evidence for prolonged lactation among the Roebuck Iroquois but ethnohistoric accounts of the Huron state that infants were breast-fed for 2 to 3 years (Tooker 1964: 123). It has been estimated that pregnancy and lactation require increases of 40-50% in the daily dietary intake of calcium (Health and Welfare Canada 1983; Kübler 1988; Worthington-Roberts et al 1985). Daily requirements for protein and energy are also substantially increased. If the daily calcium

needs of the mother plus those of lactation are not met through dietary intake then maternal skeletal reserves of calcium may be utilized.

Modern population studies of the effects of pregnancy and lactation on maternal bone status are inconclusive. However, there is some evidence to suggest that lactation, accompanied by low dietary calcium or phosphorus intake, may promote demineralization among adolescent mothers (eg. Chan et al 1982, 1987). Moser and associates (1988) found that lactating Nepalese mothers maintained a calcium content of breast milk comparable to that of lactating American mothers despite a significantly lower dietary calcium intake. The Nepalese mothers appeared to maintain this calcium concentration through bone resorption.

Again, other studies of archaeological populations (eg. Armelagos et al 1972; Smith et al 1984) have also cited pregnancy and lactation as contributing to poor cortical bone quality among females. Pregnancy and lactation, in conjunction with relatively low dietary calcium or chronic protein-energy malnutrition, could account for the low values of PCA of the radius among Roebuck females. It is unknown, however, why Roebuck females might have been more susceptible to the effects of pregnancy and lactation than the females in the other skeletal samples.

Perhaps the explanation for this finding lies in the unusual nature of the Roebuck burials. There are no direct, detailed ethnohistoric accounts of the Roebuck village or its inhabitants. As noted earlier, a great number of the burials excavated from the site were found in or around refuse heaps. It has been estimated that only 1/4 of the entire village site has been excavated and it is unknown how many burials remain uncovered. The vast majority of the individuals excavated are female. It is unknown where the males are buried or what the reasons were for there exclusion from the village site. Jamieson's (1983) analysis of the scattered human bone and the human bone artifacts recovered from the site suggests that prisoner-sacrifice and cannibalism were being practiced. Perhaps the individuals excavated from the Roebuck site were captives of

the inhabitants of the village. If this was the case, the relatively low values for PCA of the radius could be a reflection of the ancestry of these captives.

Comparisons to Modern Populations

Comparisons of the skeletal sample data to modern population data showed sample values for PCA of the metacarpal, PCA of the radius and BMI to be consistently and, in many cases, significantly lower. Clearly, the populations compared (i.e. Iroquoian with modern Eskimos and Caucasians) differ with respect to the range of environmental conditions or factors which could be affecting cortical bone quality, however, environmental factors alone may not adequately account for the differences observed. As pointed out many times, the skeletal samples themselves represent populations subject to a range of differing environmental conditions. Regardless of the skeletal sample and the age- and sex-specific group being compared, there are consistent differences between the skeletal sample data and the modern population data.

These differences are not only restricted to the skeletal samples used in this study. Pfeiffer and King (1983) evaluated PCA of the second left metacarpal for two protohistoric Iroquoian ossuary samples and also found mean values for this variable to be consistently below modern population means. Mean values for PCA of the second left metacarpal obtained in this study were compared[1] to those obtained by Pfeiffer and King. No significant differences were found, regardless of the skeletal sample being compared.

The differences found between the young adult groups, male and female, are important. The consistently lower group means for young adults in the skeletal samples suggests that the pre-Iroquoian and Iroquoian populations of the lower Great Lakes region may have achieved lower peak bone mass than the modern Eskimos and Caucasians to which they were compared. The persistence

[1] An unpaired t-test (two-tailed) was used for this comparison.

of these differences regardless of the skeletal sample being compared suggests that population factors may have influenced the peak skeletal mass achieved.

The interpretations of this part of the analysis are clearly limited by a number of factors and, as a result, are made with caution. For example, in many cases the skeletal samples being compared are exceptionally small. Also, the skeletal samples could not be precisely matched to the modern samples for age, body mass or menopause. Despite these limitations, the data are still suggestive of a trend. The data suggest lower PCA of the metacarpal, PCA of the radius and BMI of the radius among pre-Iroquoian and Iroquoian populations of the lower Great Lakes region. Because this trend is present in young adults, a lower peak skeletal mass is suggested. Because this trend is persistent through time and space, population-based control of peak skeletal mass may be implicated.

Chapter 7: Summary and Conclusions

The objectives of this research were:

1. To assess cortical bone quality among the pre-Iroquoian and Iroquoian populations of the lower Great Lakes region. This included comparisons of cortical bone quality both within and between skeletal samples and as well as between the skeletal samples and modern populations.
2. To account for any variability, or lack of variability, found in cortical bone quality through time and/or space.
3. To briefly consider the implications of the results of this analysis for an understanding of the etiology of cortical bone loss among extant Indian populations of the lower Great Lakes region.

The first two of these objectives have been addressed in the previous chapter. Briefly, significant differences were found in PCA of the radius between the Serpent Mounds skeletal sample and the Sackett-Castle Creek, MacPherson-MacKenzie and Tram skeletal samples. It is suggested that these differences could be attributed to dietary deficiencies associated with dependence on corn agriculture or to general protein-calorie malnutrition in the latter groups. An evaluation of the cortical bone quality among juveniles from each of the samples as well as observations of other skeletal indicators of dietary stress (eg. Harris lines, enamel hypoplasia) among juveniles and adults would test these interpretations. Females from the Roebuck site were found to have consistently and significantly lower values for PCA of the radius than females in any of the other skeletal samples. These low values could be due to the demands of pregnancy and lactation in combination with a dietary deficit of calcium and/or protein-calorie malnutrition.

Alternatively, the explanation for these values could lie in the unusual nature of the Roebuck burials.

Consistent differences were found between the skeletal samples and modern population means for PCA of the metacarpal, PCA of the radius and BMI. Regardless of the skeletal sample or the age- and sex-specific group being compared, sample means for each of these variables were consistently and, often, significantly reduced in comparison to modern Eskimo and Caucasian population means. This suggests that population factors could have had significant influence on cortical bone quality among the pre-Iroquoian and prehistoric Iroquoian groups of the lower Great Lakes region.

The implications of these results for an understanding of the etiology of cortical bone loss among extant Iroquoian populations of this region are difficult to assess. These results are certainly in agreement with the finding of Evers and associates (1985) that present-day postmenopausal Indian women have less bone than Caucasian women and seem to suggest that a distinct population difference in cortical bone quality may exist. From a clinical point of view, it is becoming increasingly important to distinguish individuals which are at greatest risk for excessive cortical bone loss. The diagnosis of such loss depends on a comparison of measures such as PCA of the metacarpal and radius or BMI obtained from that individual to published "normal" values for these parameters. There is a lack of normative data specific to non-Caucasian Canadian populations. The results of this analysis emphasize the need for normative data which are population-specific. Population-specific values would facilitate greater accuracy in the detection and diagnosis of bone loss among Iroquoian populations.

REFERENCES

Aloia, J. F., S. H. Cohn, J. A. Ostune, R. Cane and K. Ellis
1978 Prevention of involutional bone loss by exercise. Annals of Internal Medicine 89: 356-358.

Anderson, J. E.
1968 The Serpent Mounds Site Physical Anthropology. Royal Ontario Museum, Art and Archaeology, Occasional Paper # 11. Toronto.

Andresen, J. and H. E. Nielsen
1986 Assessment of bone mineral content and bone mass by non-invasive radiologic methods. Acta Radiologica 27: 609-617.

Armelagos, G. J., J. H. Mielke, K. P. Owen and D. P. Van Gerven
1972 Bone growth and development in prehistoric populations from Sudanese Nubia. Journal of Human Evolution 1: 89-119.

Auwerx, J., J. Dequeker, R. Bouillon, P. Geusens and J. Nijs
1988 Mineral metabolism and bone mass at peripheral and axial skeleton in diabetes mellitus. Diabetes 37: 8-12.

Baker, M. R., M. Peacock and B. E. C. Nordin
1980 The decline in vitamin D status with age. Age and Ageing 9: 249-252.

Bell, N. H., S. Epstein, A. Greene, J. Shary, M. J. Oexmann and S. Shaw
1985 Evidence for alteration of the vitamin D-endocrine system in obese subjects. Journal of Clinical Investigation 76: 370-373.

Bell, N. H., A. Greene, S. Epstein, M. J. Oexmann, S. Shaw and J. Shary
1985 Evidence for the alteration of the vitamin D-endocrine system in blacks. Journal of Clinical Investigation 76: 470-473.

Black Sandler, R., C. W. Slemenda, R. E. LaPorte, J. A. Cauley, M. M. Schramm, M. L. Barresi and A. M. Kriska
1985 Postmenopausal bone density and milk consumption in childhood and adolescence. American Journal of Clinical Nutrition 42: 270-274.

Bennett, K. A.
1987 A Field Guide for Human Skeletal Identification. Springfield, Illinois: Charles C. Thomas.

Boyd, R. M., E. C. Cameron, H. W. McIntosh and Y. R. Walker
1974 Measurement of bone mineral content *in vivo* using photon absorptiometry. Canadian Medical Association Journal 111: 1201-1205.

Cameron, J. R., R. B. Mazess and J. A. Sorenson
1968 Precision and accuracy of bone mineral determination by direct photon absorptiometry. Investigative Radiology 3: 141-150.

Cameron, J. R. and J. Sorenson
1963 Measurement of bone mineral *in vivo*: An improved method. Science 142: 230-232.

Cassidy, C. M.
1984 Skeletal evidence for prehistoric subsistence adaptation in the central Ohio River Valley. In Paleopathology at the Origins of Agriculture, M. N. Cohen and G. J. Armelagos, eds., pp. 307-345. Orlando: Academic Press.

Chan, G. M., M. McMurry, K. Westover, K. Engelbert-Fenton and M. R. Thomas
1987 Effects of increased dietary calcium intake upon the calcium and bone mineral status of lactating adolescent and adult women. American Journal of Clinical Nutrition 46: 319-323.

Chan, G. M., C. C. Roberts, D. Folland and R. Jackson
1982 Growth and bone mineralization of normal breast-fed infants and the effects of lactation on maternal bone mineral status. American Journal of Clinical Nutrition 36: 438-443.

Chan, G. M., N. Ronald, P. Slater, J. Hollis and M. R. Thomas
1982 Decreased bone mineral status in lactating adolescent mothers. Journal of Pediatrics 101: 767-770.

Christiansen, C. and B. J. Riis
1989 Is it possible to predict the fast bone loser just after menopause? In Bone and Mineral Research, Volume 6, W. A. Peck, ed., pp. 317-332. Amsterdam: Elsevier Science Publishers B. V.

Clochon, P., M. Audran, J. C. Renier, J. L. Yerret, E. Tuchais, J. L. Racineux, Y. Simon and P. Jallet
1989 Bone mineral density in patients receiving long term corticosteroid therapy. Calcified Tissue International 44: S50.

Cohen, M. N. and G. J. Armelagos, eds.
1984 Paleopathology at the Origins of Agriculture. Orlando: Academic Press, Inc.

Crilly, R. G., C. Anderson, D. Hogan and L. Delaquerrière-Richardson
1988 Bone histomorphometry, bone mass and related parameters in alcoholic males. Calcified Tissue International 43: 269-276.

Crosby, L. O., F. S. Kaplan, M. J. Pertshcuk and J. L. Mullen
1985 The effect of anorexia nervosa on bone morphometry in young women. Clin. Orthop. 201: 271-277.

Daniell, H. W.
1976 Osteoporosis of the slender smoker. Archives of Internal Medicine 136: 298-305.

De Leeuw, I. and R. Abs
1977 Bone mass and bone density in maturity-type diabetics measured by the ^{125}I photon-absorption technique. Diabetes 26: 1130-1135.

DeSimone, D. P., J. Edwards, J. Shary, L. Gordon and N. H. Bell
1989 Influence of body habitus and race on bone mineral density of the radius, hip and spine in aging women. Calcified Tissue International 44: S51.

Dittrick, J. and J. Myers Suchey
1986 Sex determination of prehistoric Central California skeletal remains using discriminant analysis of the femur and humerus. American Journal of Physical Anthropology 70: 3-9.

Draper, H. H. and C. A. Scythes
1981 Calcium, phosphorus, and osteoporosis. Federation Proceedings 40: 2434-2438.

Drinkwater, B. L., K. Nilson, C. H. Chesnut III, W. J. Bremner, S. Shainholtz and M. B. Southworth
1984 Bone mineral content of amenorrheic and eumenorrheic athletes. New England Journal of Medicine 311: 277-281.

Eastell, R., H. Heath III, R. Kumar and B. L. Riggs
1988 Hormonal factors: PTH, vitamin D and calcitonin. In Osteoporosis: Etiology, Diagnosis and Management, B. L. Riggs and L. J. Melton III, eds., pp. 373-388. New York: Raven Press.

Elders, P. J. M., J. C. Netelenbos, E. Khoe, P. Lips and F. C. van Ginkel
1989 Perimenopausal bone mass and risk factos. Calcified Tissue International 44: S51.

Ericksen, M. F.
1976 Cortical bone loss with age in three Native American populations. American Journal of Physical Anthropology 45: 443-452.

Esler, J. G.
1989 An Assessment of the Nutritional Health Status of Prehistoric Aboriginal Populations from Southern Ontario. M. A. thesis. McMaster University. Hamilton.

Evans, R. A., G. M. Marel, E. K. Lancaster, S. Kos, M. Evans, S. Y. P. Wong
1988 Bone mass is low in relatives of osteoporotic patients. Annals of Internal Medicine 109: 870-873.

Evers, S. E., J.W. Orchard and R.G. Haddad
1985 Bone density in postmenopausal North American Indian and Caucasian females. Human Biology 57: 719-726.

Fecteau, R. D.
1985 The Introduction and Diffusion of Cultivated Plants in Southern Ontario. M. A. thesis. York University. Toronto.

Garland, A. N.
1987 A histological study of archaeological bone decomposition. In Death, Decay and Reconstruction, A. N. Garland and R. C. Janaway, eds., pp. 109-126. Great Britain: Manchester University Press.

Garn, S. M.
1970 The Earlier Gain and Later Loss of Cortical Bone. Springfield, Illinois: Charles C. Thomas.

1972 The course of bone gain and the phases of bone loss. Orthop. Clin. N. Amer. 3: 503-520.

Garn, S. M., M. A. Guzman and B. Wagner
1968 Subperiosteal gain and endosteal loss in protein-calorie malnutrition. American Journal of Physical Anthropology 30: 153-156.

Garn, S. M., A. K. Poznanski and K. Larson
1973 Metacarpal lengths, cortical diameters and areas from the10-state nutrition survey. In Proceedings of the 1st Workshop on Bone Morphometry, Z. F. G. Jaworski, ed., pp.367-391. Ottawa: University of Ottawa Press.

Garn, S. M. and C. G. Rohmann
1964 Compact bone deficiency in protein-calorie malnutrition. Science 145: 1444-1445.

Geusens, P., J. Dequeker, A. Verstraeten and J. Nijs
1986 Age-, sex-, and menopause-related changes of vertebral and peripheral bone: Population study using dual and single photon absorptiometry and radiogrammetry. Journal of Nuclear Medicine 27: 1540-1549.

Gilbert, B. M. and T. W. McKern
1973 A method for aging the female os pubis. American Journal of Physical Anthropology 38: 31-38.

Greer, F. R., J. Lane and M. Ho
1984 Elevated serum parathyroid hormone, calcitonin and 1,25-dihydroxyvitamin D in lactating women nursing twins. American Journal of Clinical Nutrition 40: 562-568.

Halioua, L. and J. J. B. Anderson
1989 Lifetime calcium intake and physical activity habits: independent and combined effects on the radial bone of healthy premenopausal Caucasian women. American Journal of Clinical Nutrition 49: 534-541.

Hanson, D. B. and J. E. Buikstra
1987 Histomorphological alteration in buried human bone from the Lower Illinois Valley: Implications for paleodietary research. Journal of Archaeological Science 14: 549-563.

Harper, A. B., W. S. Laughlin and R. B. Mazess
1984 Bone mineral content in St. Lawrence Island Eskimos. Human Biology 56 (1): 63-77.

Hartney, P. C.
1978 Paleopathology of archaeological aboriginal populations from southern Ontario and adjacent region. Unpublished Ph.D thesis, University of Toronto.

Health and Welfare Canada
1983 Recommended nutrient intakes for Canadians. Ottawa: Health and Welfare Canada.

Heaney, R. P.
1988 Nutritional factors in bone health. In Osteoporosis: Etiology, Diagnosis and Management, B. L. Riggs and L. J. Melton III, eds., pp. 359-372. New York: Raven Press.

Heaney, R. P., R. R. Recker and P. D. Saville
1978 Menopausal changes in calcium balance performance. Journal of Labratory and Clinical Medicine 92: 953-963.

Hegsted, D. M.
1986 Calcium and osteoporosis. Journal of Nutrition 116: 2316-2319.

Heidenreich, C. E.
1978 Huron. In Handbook of North American Indians, volume 15, Northeast, B. G. Trigger, ed., pp. 368-388. Washington, D. C.: Smithsonian Institution.

Heytmanek, G., H. Enzelsberger, and M. Metka
1989 Bone density under the influence of oral contraception. Calcified Tissue International 44: S60.

Himes, J. H., R. Martorell, J.P. Habicht, C. Yarbrough, R. M. Malina and R. E. Klein
1975 Patterns of cortical bone growth in moderately malnourished preschool children. Human Biology 47: 337-350.

Hodges, D. C. and L. M. Schell
1988 Power analysis in biological anthropology. American Journal of Physical Anthropology 77: 175-181.

Huddleston, A. L.
1988 Quantitative Methods in Bone Densitometry. Boston: Kluwer Academic Publishers.

Huss-Ashmore, R.
1978 Nutritional determination in skeletal populations. American Journal of Physical Anthropology 48: 407 (Abstract).

Huss-Ashmore, R., A. H. Goodman and G. J. Armelagos
1982 Nutritional inference from paleopathology. In Advances in Archaeological Method and Theory, volume 1, M. B. Schiffer, ed., pp. 395-474. Orlando: Academic Press, Inc.

Iscan, M. Yasar and P. Miller-Shaivitz
1984 Discriminant function sexing of the tibia. Journal of Forensic Sciences 29: 1087-1093.

Jamieson, J. B.
1983 An examination of prisoner-sacrifice and cannibalism at the St. Lawrence Iroquoian Roebuck site. Canadian Journal of Archaeology 7: 159-175.

Johnson, D. S.
1980 The McKenzie or Woodbridge site (AkGv-2), and its place in the Late Ontario Iroquois Tradition. Archaeology of Eastern North America 8: 77-87.

Johnston, C. C., Jr.
1983 Noninvasive methods for quantitating appendicular bone mass. In The Osteoporotic Syndrome, L.Y. Avioli, ed., pp. 73-84. New York: Grune and Stratton, Inc.

Johnston, R. B.
1968 The Archaeology of the Serpent Mounds Site. Royal Ontario Museum, Art and Archaeology, Occasional Paper # 10. Toronto.

Katz, D. and J. Myers Suchey
1986 Age determination of the male os pubis. American Journal of Physical Anthropology 69: 427-435.

Katzenberg, M. A. and H. P. Schwarcz
1986 Paleonutrition in southern Ontario: Evidence from strontium and stable isotopes. Canadian Review of Physical Anthropology 5: 15-21.

Kelley, M. A.
1979a Sex determination with fragmented skeletal remains. Journal of Forensic Sciences 24: 154-158.

1979b Parturition and pelvic changes. American Jouranl of Physical Anthropology 51: 541-546.

Kennedy, K. A. R.
1989 Skeletal markers of occupational stress. In Reconstruction of Life from the Skeleton, M. Yasar Iscan and K. A. R. Kennedy, eds., pp. 129-160. New York: A. R. Liss, Inc.

Klepinger, L. L., J. K. Kuhn and W. S. Williams
1986 An elemental analysis of archaeological bone from Sicily as a test of predictability of diagenetic change. American Journal of Physical Anthropology 70: 325-331.

Kley, H. K., T. Deselaers, H. Peerenboom and H. L. Kruskemper
1980 Enhanced conversion of androstenedione to estrogens in obese males. Journal of Clinical Endocrinology and Metabolism 51: 1128-1132.

Knowles, Sir Frances
1937 Physical Anthropology of the Roebuck Iroquois with Comparative Data from Other Indian Tribes. National Museums of Canada, Bulletin # 87. Ottawa.

Koetting, C. A. and G. M. Wardlaw
1988 Wrist, spine, and hip bone density in women with variable histories of lactation. American Journal of Clinical Nutrition 48: 1479-1481.

Krogman, W. M.
1962 The Human Skeleton in Forensic Medicine. Springfield, Illinois: Charles C. Thomas.

Kübler, W.
1988 Vitamin and mineral requirements of pregnant and lactating women. In Nestle Nutrition Workshop Series, Volume 16, Vitamins and Minerals in Pregnancy and Lactation, H. Berger, ed., pp. 15-23. New York: Raven Press, Ltd.

Lambert, J. B., S. Vlasak Simpson, C. B. Szpunar and J. E. Buikstra
1985 Bone diagenesis and dietary analysis. Journal of Human Evolution: 14: 477-482.

Lamke, B., J. Brundin and P. Moberg
1977 Changes of bone mineral content during pregnancy and lactation. Acta Obstet Gynecol Scand 56: 217-219.

Laughlin, W. S., A. B. Harper and D. D. Thompson
1979 New approaches to the pre- and post-contact history of Arctic peoples. American Journal of Physical Anthropology 51: 579-588.

Lepsanovic, L., B. Segedi, L. Dilas, M. Pavlov, M. Medic and N. Babic
1989 Some risk factors for development of osteoporosis evaluated by DPA. Calcified Tissue International 44: S56.

Levin, M. E., B. Boisseau and L. Y. Avioli
1976 Effects of diabetes mellitus on bone mass in juvenile and adult-onset diabetes. New England Journal of Medicine 294: 241-245.

Liel, Y., E. Ulmer, J. Shary, B. W. Hollis and N. H. Bell
1988 Low circulating vitamin D in obesity. Calcified Tissue International 43: 199-201.

Lounsbury, F. G.
1978 Iroquoian Languages. In The Handbook of North American Indians, volume 15, B. G. Trigger, ed., pp. 334-343. Washington, D.C.: Smithsonian Institution.

Lovejoy, C. Owen, R. S. Meindl, R. P. Mensforth and T. J. Barton
1985 Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of adult skeletal age at death. American Journal of Physical Anthropology 68: 15-28.

Luckey, M. M., D. E. Meier, J. P. Mandeli, M. C. DaCosta, M. L. Hubbard and S. J. Goldsmith
1989 Radial and vertebral bone density in White and Black women: Evidence for racial differences in premenopausal bone homeostasis. Journal of Clinical Endocrinology and Metabolism 69: 762-770.

MacLaughlin, S. M. and M. F. Bruce
1985 A simple univariate technique for determining sex from fragmentary femora. American journal of Physical Anthropology 67: 413-417.

MacNeish, R. S.
1952 Iroquois Pottery Types. National Museum of Canada, Bulletin # 124. Ottawa.

Malec, M. A.
1977 Essential Statistics for Social Research. Philadelphia: J. B. Lippincott Company.

Marcus, R. C. Cann, P. Madvig, J. Minkoff, M. Goddard, M. Bayer, M. Martin, L. Gaudiani, W. Haskell and H. Genant
1985 Menstrual function and bone mass in elite women distance runners: Endocrine and metabolic features. Annals of Internal Medicine 102: 158-163.

Martin, D. L., A. H. Goodman and G. J. Armelagos
1985 Skeletal pathologies as indicators of quality and quantity of diet. In The Analysis of Prehistoric Diets, R. I. Gilbert and J. H. Mielke, eds., pp. 227-279. Orlando: Academic Press, Inc.

Mazess, R. B.
1981 Noninvasive measurement of local bone in osteoporosis. In Deluca, Frost, Lee, Johnston and Parfitt, eds., Osteoporosis: Recent Advances in Pathogenesis and Treatment, pp. 25-36. Baltimore: University Park Press.

1982 On aging bone loss. Clinical Orthopaedics 165: 239-252.

Mazess, R. B. and J. R. Cameron
1974 Bone mineral content in normal U.S. Whites. In R. B. Mazess, ed., Proceedings of the International Conference on Bone Mineral Measurement, pp. 228-237. Washington, D.C.: U.S. Government Printing Office.

Mazess, R. B. and W. E. Mather
1974 Bone mineral content of North Alaskan Eskimos. American Journal of Clinical Nutrition 27: 916-925.

1975 Bone mineral content in Canadian Eskimos. Human Biology 47 (1): 45-63.

McDermott, M. T. and M. C. Witte
1988 Bone mineral content in smokers. Southern Medical Journal 81: 477-480.

McKern, T. W.
1970 Estimation of skeletal age: From puberty to about 30 years of age. In Personal Identification in Mass Disasters, T. C. Stewart, ed., pp. 41-56. Washington: National Museum of Natural History.

McKern, T. W. and T. D. Stewart
1957 Skeletal age changes in young American males. Headquarters, Quartermaster Research and Development Command, Technical Report E P-45. Natick, Mass.

Meema, E. F. and S. Meema
1967 The relationship of diabetes mellitus and body weight to osteoporosis in elderly females. Canadian Medical Association Journal 96: 132-139.

Meema, H. E. and S. Meema
1987 Postmenopausal osteoporosis: Simple screening method for diagnosis before structural failure. Radiology 164: 405-410.

Meema, S. and H. E. Meema
1973 Improved recognition of bone loss by concurrent measurements in the second metacarpal and radius. In Proceedings of the 1st Workshop on Bone Morphometry, Z. F. G. Jaworski, ed., pp. 48-54. Ottawa: University of Ottawa Press.

Meindl, R. S. and C. Owen Lovejoy
1985 Ectocranial suture closure: A revised method for the determination of skeletal age at death based on the lateral-anterior sutures. American Journal of Physical Anthropology 68: 57-66.

Melbye, J.
1983 The people of the Ball site. Ontario Archaeology 40: 15-36.

Molto, J. E.
1983 Biological relationships of southern Ontario Woodland peoples: The evidence of discontinuous cranial morphology. National Museum of Man Mercury Series, ASC Paper # 117. Ottawa.

Moroz, D. E., D. G. Sale, C. E. Webber and J. D. MacDougall
1989 The effect of strength and endurance training on bone in postmenopausal women. Unpublished manuscript.

Moser, P. B., R. D. Reynolds, S. Acharya, M. P. Howard and M. B. Andon
1988 Calcium and magnesius dietary intakes and plasma and milk concentrations of Nepalese lactating women. American Journal of Clinical Nutrition 47: 735-739.

Nelson, D. A.
1984 Bone density in three archaeological populations. American Journal of Physical Anthropology 63: 198 (Abstract).

Nelson, W. E., E. C. Fisher, P. D. Catsos, N. Meredith, N. Turksoy, and W. J. Evans
1986 Diet and bone status in amenorrheic runners. American Journal of Clinical Nutrition 43: 910-916.

NIH
1984 Consensus Conference, Osteoporosis (1984). Journal of the American Medical Association 252: 799-802.

Niemczycki, M. A. Palmer
1984 The origin and development of the Seneca and Cayuga tribes of New York State. Rochester Museum and Science Center Research Records No. 17. Rochester, New York.

Noble, W.C.
1975 Corn and the development of village life in Southern Ontario. Ontario Archaeology 25: 37-47.

1975 Canadian Prehistory: The Lower Great Lakes-St. Lawrence Region. Canadian Archaeological Association Bulletin 7: 96-121.

1982 Potsherds, potlids and politics: an overview of Ontario archaeology in the 1970's. Canadian Journal of Archaeology 6: 167-194.

Nordin, B. E. C. and K. J. Polley
1987 Metabolic consequences of the menopause. Calcified Tissue International, Volume 41, Supplement No. 1.

Patterson, D. K.
1986 Changes in oral health among prehistoric Ontario populations. Canadian Review of Physical Anthropology 5: 3-13.

Pendergast, J. F.
1975 An in-situ hypothesis to explain the origin of the St. Lawrence Iroquois. Ontario Archaeology 25: 47-55.

1983 St. Lawrence Iroquoian burial practices. Ontario Archaeology 40: 49-56.

1985 Huron-St. Lawrence Iroquois relations in the terminal prehistoric period. Ontario Archaeology 44: 23-40.

Perzigian, A. J.
1973 Osteoporotic bone loss in two prehistoric Indian populations. American Journal of Physical Anthropology 39: 87-96.

Pfeiffer, S.
1984 Paleopathology in an Iroquoian ossuary with special reference to tuberculosis. American Journal of Physical Anthropology 65: 181-189.

1986 Morbidity and mortality in the Uxbridge ossuary. Canadian Review of Physical Anthropology 5: 23-31.

1989 Characterization of archaeological bone decomposition in a sample of known length of interment. American journal of Physical Anthropology 71: 283.

Pfeiffer, S. and P. King
1983 Cortical bone formation and diet among protohistoric Iroquoians. American Journal of Physical Anthropology 60: 23-28.

Pfeiffer, S., K. Stewart and C. Alex
1986 Growth arrest lines among Uxbridge ossuary juveniles. Ontario Archaeology 46: 27-31.

Phenice, T. W.
1969 A newly developed visual method of sexing the os pubis. American Journal of Physical Anthropology 30: 297-302.

Pocock, N. A., J. A. Eisman, J. L. Hopper, M. G.Yeates, P. N. Sambrook and S. Eberl
1987 Genetic determinants of bone mass in adults: A twin study. Journal of Clinical Investigations 80: 706-710.

Ramsden, P. G.
1977 A Refinement of Some Aspects of Huron Ceramic Analysis. National Museum of Man Mercury Series, ASC Paper # 63. Ottawa.

1978 An hypothesis concerning the effects of early European trade among some Ontario Iroquois. Canadian Journal of Archaeology 2: 101-106.

Richman, E. A., D. J. Ortner and F. P. Schulter-Ellis
1979 Differences in intracortical bone remodelling in three aboriginal American populations: Possible dietary factors. Calcified Tissue International 28: 209-214.

Rico, H., E. R. Hernandez, J. A. Cabranes and F. Gomez-Castresana
1989 Suggestion of a deficient osteoblastic function in diabetes mellitus: The possible cause of osteopenia in diabetics. Calcified Tissue International 45: 71-73.

Riggs, B. L. and L. J. Melton III
1986 Involutional osteoporosis. New England Journal of Medicine 314: 1676-1686.

Riggs, B. L., H. W. Wahner, L. J. Melton III, L. S. Richelson, H. L. Judd and K. P. Oford
1986 Rates of bone loss in the appendicular and axial skeletons of women. Journal of Clinical Investigations 77: 1487-1491.

Riis, B., K. Thomsen and C. Christiansen
1987 Does calcium supplementation preavent postmenopausal bone loss? New England Journal of Medicine 316: 173-177.

Ritchie, W. A.
1980 The Archaeology of New York State. Revised edition. New York: Harbor Hill Books.

Rundgren, A. and D. Mellstrom
1984 The effect of tobacco smoking on the bone mineral content of the ageing skeleton. Mechanisms of Ageing and Development 28: 273-277.

Runyon, R. P. and A. Haber
1984 Fundamentals of Behavioral Statistics. 5th edition. New York: Random House.

Saunders, S. R.
1986 The MacKenzie site human skeletal material. Ontario Archaeology 45: 9-26.

1988 The MacPherson Site: Human Burials (A Preliminary Descriptive Report). Unpublished manuscript on file at McMaster University, Hamilton, Ontario.

Saunders, S. R. and W. Fitzgerald
1988 Life and Death in 16th Century Ontario: Archaeology and Osteology of the MacPherson Indian Village. Paper presented at the McMaster Symposium. Hamilton, Ontario.

Saunders, S. R., P. G. Ramsden and D. A. Herring
1989 Transformation and disease: Precontact Ontario Iroquoians. Paper presented at the Disease and Contact Conference, Smithsonian Institution, Washington, D. C.

Schulter-Ellis, F. P., L. C. Hayek and D. J. Schmidt
1985 Determination of sex with a discriminant analysis of new pelvic bone measurements: Part II. Journal of Forensic Sciences 30: 178-185.

Schwarcz, H. P., J. Melbye, M. A. Katzenbery and M. Knyf
1985 Stable isotopes in human skeletons of southern Ontario: reconstruction palaeodiet. Journal of Archaeological Science 12: 187-206.

Seeman, E., J. L. Hopper, L. A. Bach, M. E. Cooper, E. Parkinson, J. McKay and G. Jerums
1989 Reduced bone mass in daughters of women with osteoporosis. New England Journal of Medicine 320: 554-558.

Sempowski, M.
1989 The Tram Site Description. Unpublished manuscript. Rochester Museum and Science Center.

Siegel, S.
1956 Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company.

Sinaki, M.
1988 Exercise and physical therapy. In Osteoporosis: Etiology, Diagnosis and Management, B. L. Riggs and L. J. Melton III, eds., pp. 457-479. New York: Raven Press.

Smith, E. L. and C. Gilligan
1989 Mechanical forces and bone. In Bone and Mineral Research, Volume 6, W. A. Peck, ed., pp. 139-174. Amsterdam: Elsevier Science Publishers B.V.

Smith, E. L., C. Gilligan, M. McAdam, C. P. Ensign and P. E. Smith
1989 Deterring bone loss by exercise intervention in premenopausal and postmenopausal women. Calcified Tissue International 44: 312-321.

Smith, D. M., W. E. Nance, K. W. Kang, J. C. Christian and C. C. Johnston, Jr.
1973 Genetic factors in determining bone mass. Journal of Clinical Investigation 52: 2800-2808.

Smith, P., R. A. Bloom and J. Berkowitz
1984 Diachronic trends in humeral cortical thickness of Near Eastern populations. Journal of Human Evolution 13: 603-611.

Sokal, R. R. and F. J. Rohlf
1969 Biometry. San Francisco: W. H. Freeman and Company.

Sorenson, J. A. and J. R. Cameron
1967 A reliable *in vivo* measurement of bone mineral content. Journal of Bone and Joint Surgery 49A: 481-497.

Spence, M. W., W. D. Finlayson and R. H. Pihl
1979 Hopewellian influences on Middle Woodland cultures in southern Ontario. In Hopewell Archaeology: The Chillicothe Conference, D. S. Brose and N. Gerber, eds., pp. 114-121. Ohio: Kent State University Press.

Spence, M. W. and R. H. Pihl
1984 The Early and Middle Woodland occupations of southern Ontario: Past, present and future research. Arch Notes 84(2): 32-48.

Spence, M. W., R. H. Pihl and J. E. Molto
1984 Hunter-gatherer social group identification: A case study from Middle Woodland southern Ontario. In Exploring the Limits: Frontiers and Boundaries in Prehistory, S. P. DeAtley and F. J. Findlow, eds., pp. 117-142. BAR International Series #223. Oxford.

Spencer, H. and L. Kramer
1985 Nutritional and other factors influencing skeletal status. In Body Composition Assessment in Youth and Adults, A. F. Roche, ed., pp. 33-38. Columbus: Ross Laboratories.

1986 Factors contributing to osteoporosis. Journal of Nutrition 116: 316-319.

Spuhler, J. N.
1972 Genetic, linguistic and geographical distances in Native North America. In The Assessment of Population Affinities in Man, J. S. Weiner and J. Huizinga, eds., pp. 72-95. London: Oxford University Press.

1979 Genetic distances, trees, and maps of North American Indians. In The First Americans: Origins, Affinities and Adaptation, W. S. Laughlin and A. B. Harper, eds., pp. 135-183. New York: Gustav Fischer.

Steele, D. G. and C. A. Bramblett
1988 The Anatomy and Biology of the Human Skeleton. Texas: A & M University Press.

Stewart, T. D.
1958 The rate of development of vertebral osteoarthritis in American Whites and its significance in skeletal age determination. The Leech (Johannesburg) 28 (4-5): 144-151.

Stothers, D. M.
1977 The Princess Point Complex. National Museum of Man Mercury Series, ASC Paper 58. Ottawa.

Sumner, D. R., Jr.
1984 Size, shape and bone mineral content of the human femur in growth and aging. Ph.D. dissertation. The University of Arizona.

Thomsen, K., A. Gotfredsen and C. Christiansen
1986 Is postmenopausal bone loss an age-related phenomenon? Calcified Tissue International 39: 123-127.

Tooker, E.
1964 An Ethnography of the Huron Indians: 1615-1649. Smithsonian Institution, Bureau of American Ethnology, Bulletin 190.

1978 The League of the Iroquois: Its history, politics and ritual. In Handbook of North American Indians, volume 15, Northeast, B. G. Trigger, ed., pp. 418-441. Washington, D. C.: Smithsonian Institution.

Treharne, R. W.
1981 Review of Wolff's Law and its proposed means of operation. Orthopaedic Review 10(1): 35-47.

Trigger, B. G.
1978 Cultural unity and diversity. In Handbook of North American Indians, volume 15, Northeast, B. G. Trigger, ed., pp. 798-804. Washington, D. C.: Smithsonian Institution.

Trigger, B. G. and J. F. Pendergast
1978 Saint Lawrence Iroquoians. In Handbook of North American Indians, volume 15, Northeast, B. G. Trigger, ed., pp. 357-361. Washington, D. C.: Smithsonian Institution.

Tsai, K. S., H. W. Wahner, K. P. Offord, L. J. Melton III, R. Kumar and B. L. Riggs
1987 Effect of aging on vitamin D stores and bone density in women. Calcified Tissue International 40: 241-243.

Tuck, J. A.
1978 Northern Iroquoian prehistory. In Handbook of North American Indians, volume 15, Northeast, B. G. Trigger, ed., pp. 322-333. Washington, D.C.: Smithsonian Institution.

Utermohle, C. J., S. L. Zegura and G. M. Heathcote
1983 Multiple observers, humidity, and choice of precision statistics: Factors influencing craniometric data quality. American Journal of Physical Anthropology 61: 85-95.

Vander, A. J., J. H. Sherman and D. S. Luciano
1985 Human Physiology: The Mechanisms of Body Function. Fourth edition. New York: McGraw-Hill Book Company.

Von Endt, D. W. and D. J. Ortner
1984 Experimental effects of bone size and temperature on bone diagenesis. Journal of Archaeological Science 11: 247-253.

Wahner, H. W., W. L. Dunn and B. L. Riggs
1983 Noninvasive bone mineral measurements. Seminars in Nuclear Medicine 13: 282-289.

Wardlaw, G. M. and A. M. Pike
1986 The effect of lactation on peak adult shaft and ultra-distal forearm bone mass in women. American Journal of Clinical Nutrition 44: 283-286.

Washburn, S. L.
1948 Sex differences in the pubic bone. American journal of Physical Anthropology 6: 199-207.

Wilmeth, R.
1978 Canadian Archaeological Radio Carbon Dates. National Museum of Man Mercury Series, ASC Paper # 77. Ottawa.

Wintemberg, W. J.
1936 Roebuck Prehistoric Village Site, Grenville County, Ontario. National Museums of Canada, Bulletin # 83. Ottawa.

Worthington-Roberts, B. S., J. Vermeersch and S. R. Williams
1985 Nutrition in pregnancy and lactation. Third edition. St. Louis: C.V. Mosby Company.

Wray, C. F.
1973 Manual for Seneca Iroquois Archeology. Cultures Primitive, Honeoye Falls, New York.

Wray, C. F. and D. G. Cameron
1970 Archeological excavations on the Tram site, Livonia, New York. Unpublished field notes on file at the Rochester Museum and Science Center, Rochester, New York.

Wray, C. F. and H. L. Schoff
1953 A preliminary report on the Seneca sequence in western New York (1550-1687). Pennsylvania Archaeologist 23: 53-63.

Wray, C. F., M. L. Sempowski, L. P. Saunders and G. C. Cervone
1987 The Adams and Culbertson Sites. Rochester Museum and Science Center Research Records No. 19. Rochester, New York.

Wright, J. V.
1966 The Ontario Iroquois Tradition. National Museums of Canada, Bulletin # 210. Ottawa.

1972 Ontario Prehistory: An Eleven-thousand Year Archaeological Outline. Archaeological Survey of Canada, National Museum of Man. Ottawa.

1979 Quebec Prehistory. Archaeological Survey of Canada, National Museum of Man. Ottawa.

APPENDIX : DESCRIPTIVE STATISTICS

Table A.1 PCA metacarpal, PCA radius and BMI: All samples combined

Group	N	Mean	S.D.	C.V.	Range
		PCA metacarpal			
males and females, young and old	68	75.43	9.10	12.1	45.22-92.77
males and females, young only	34	78.72	7.37	9.4	62.46-92.77
males and females, old only	34	72.13	9.57	13.3	45.22-87.80
males,young and old	26	76.49	7.02	9.2	62.46-92.77
males, young	14	77.77	7.85	10.1	62.46-92.77
males, old	12	74.99	5.89	7.9	65.64-83.90
females,young and old	42	74.77	10.21	13.7	45.22-90.72
females, young	20	79.38	7.14	9.0	67.13-90.72
females, old	22	70.57	10.89	15.4	45.22-87.80
		PCA radius			
males and females, young and old	85	59.42	11.95	20.1	27.39-81.68
males and females, young only	40	63.88	8.44	13.2	46.67-81.08
males and females, old only	45	55.44	13.24	23.9	27.39-81.68
males, young and old	39	64.78	10.53	16.3	28.94-81.68
males, young	20	67.14	6.48	9.6	55.38-81.08
males, old	19	62.29	13.31	21.4	28.94-81.68
females, young and old	46	54.87	11.27	20.5	27.39-73.86
females, young	20	60.63	9.05	14.9	46.67-73.86
females, old	26	50.43	10.92	21.7	27.39-68.64

BMI

Group	N	Mean	S.D.	C.V.	Range
males and females, young and old	55	0.618	0.124	20.1	.302-.832
males and females, young only	27	0.655	0.089	13.7	.489-.832
males and females, old only	28	0.538	0.143	24.6	.302-.774
males, young and old	26	0.694	0.078	11.3	.469-.832
males, young	12	0.727	0.065	8.9	.600-.832
males, old	14	0.666	0.080	12.1	.469-.774
females, young and old	29	0.550	0.119	21.6	.302-.752
females, young	15	0.597	0.059	9.8	.489-.703
females, old	14	0.499	0.146	29.2	.302-.752

Table A.2 PCA metacarpal, PCA radius and BMI: Serpent Mounds

Group	N	Mean	S.D.	C.V.	Range
		PCA metacarpal			
males and females, young and old	11	75.34	5.02	6.7	65.64-83.29
males and females, young only	5	76.76	4.67	6.1	70.18-83.29
males and females, old only	6	74.15	5.41	7.3	65.64-82.52
males, young and old	7	74.78	5.08	6.8	65.64-82.52
males, young	2	76.45	0.83	1.1	75.86-77.04
males, old	5	74.12	6.05	8.2	65.64-82.52
females, young and old	4	76.30	5.52	7.2	70.18-83.29
females, young	3	76.96	6.57	8.5	70.18-83.29
females, old	1	74.33	-	-	-
		PCA radius			
males and females, yound and old	20	66.51	8.36	12.6	47.73-81.68
males and females, young only	8	68.48	9.91	14.5	47.73-81.08
males and females, old only	12	65.20	7.32	11.2	56.29-81.68
males, young and old	14	69.16	7.43	10.7	58.45-81.68
males, young	5	73.10	5.92	8.1	67.19-81.08
males, old	9	66.97	7.55	11.3	58.45-81.68
females, young and old	6	60.34	7.55	12.5	47.73-69.19
females, young	3	60.77	11.46	18.9	47.73-69.19
females, old	3	59.90	3.26	5.4	56.29-62.63

BMI

Group	N	Mean	S.D.	C.V.	Range
males and females, young and old	15	0.672	0.084	12.5	.443-.778
males and females, young only	5	0.707	0.064	9.0	.607-.778
males and females, old only	10	0.654	0.090	13.8	.443-.771
males, young and old	11	0.707	0.048	6.8	.630-.778
males, young	4	0.732	0.035	4.8	.693-.778
males, old	7	0.693	0.051	7.3	.630-.771
females, young and old	4	0.574	0.090	15.7	.443-.648
females, young	1	0.607	-	-	-
females, old	3	0.564	0.107	19.0	.443-.648

Table A.3 PCA metacarpal and PCA radius: Sackett-Castle Creek

Group	N	Mean	S.D.	C.V.	Range
		PCA metacarpal			
males and females, young and old	9	76.26	9.33	12.2	62.46-87.80
males and females, young only	6	77.42	8.37	10.8	62.46-86.48
males and females, old only	3	73.95	12.69	17.2	62.88-87.80
males, young and old	3	74.29	10.41	14.0	62.46-82.05
males, young	3	74.29	10.41	14.0	62.46-82.05
males, old	0	-	-	-	-
females, young and old	6	77.25	9.61	12.4	62.88-87.80
females, young	3	80.55	6.11	7.6	74.28-86.48
females, old	3	73.95	12.69	17.2	62.88-87.80
		PCA radius			
males and females, young and old	13	61.27	8.46	13.8	42.67-72.40
males and females, young only	7	63.01	3.63	13.1	57.72-66.85
males and females, old only	6	59.24	12.12	20.5	42.67-72.40
males, young and old	7	65.63	4.61	7.0	59.42-72.40
males, young	5	63.44	3.18	5.0	59.42-66.85
males, old	2	71.11	1.82	2.6	69.82-72.40
females, young and old	6	56.18	9.41	16.8	42.67-66.11
females, young	2	61.92	5.93	9.6	57.72-66.11
females, old	4	53.31	10.15	19.0	42.67-63.22

Table A.4 PCA metacarpal, PCA radius and BMI: Roebuck

Group	N	Mean	S.D.	C.V.	Range
		PCA metacarpal			
males and females, young and old	20	73.83	9.87	13.4	54.70-89.76
males and females, young only	7	78.17	6.10	7.8	72.01-89.76
males and females, old only	13	71.50	10.89	15.2	54.70-87.18
males, young and old	4	78.34	6.13	7.8	71.05-83.90
males, young	1	82.93	-	-	-
males, old	3	76.85	6.52	3.5	71.05-83.90
females, young and old	16	72.70	10.44	14.4	54.70-89.76
females, young	6	77.37	6.28	8.1	72.01-89.76
females, old	10	69.89	11.68	16.7	54.70-87.18
		PCA radius			
males and females, young and old	22	50.59	13.28	26.3	27.39-76.57
males and females, young only	8	55.46	7.74	14.0	46.67-66.65
males and females, old only	14	47.80	15.16	31.7	27.39-76.57
males, young and old	4	59.60	20.99	35.2	28.94-76.57
males, young	1	66.65	-	-	-
males, old	3	57.25	25.06	43.8	28.94-76.57
females, young and old	18	48.59	10.81	22.3	27.39-64.25
females, young	7	53.86	6.79	12.6	46.67-64.25
females, old	11	45.23	11.80	26.1	27.39-63.35

BMI

Group	N	Mean	S.D.	C.V.	Range
males and females, young and old	18	0.543	0.142	26.2	.302-.752
males and females, young only	7	0.592	0.065	10.9	.489-.703
males and females, old only	11	0.513	0.171	33.3	.302-.752
males, young and old	3	0.615	0.127	20.7	.469-.700
males, young	0	-	-	-	-
males, old	3	0.615	0.127	20.7	.469-.700
females, young and old	15	0.529	0.144	27.3	.302-.752
females, young	7	0.529	0.065	10.9	.489-.703
females, old	8	0.474	0.175	37.0	.302-.752

Table A.5 PCA metacarpal, PCA radius and BMI: MacPherson-MacKenzie

Group	N	Mean	S.D.	C.V.	Range
		PCA metacarpal			
males and females, young and old	11	77.69	13.64	17.6	45.22-92.77
males and females, young only	8	83.23	8.32	10.0	70.84-92.77
males and females, old only	3	62.92	15.41	24.5	45.22-73.36
males, young and old	5	80.49	10.08	12.5	70.84-92.77
males, young	4	82.28	10.87	13.0	70.84-92.77
males, old	1	73.36	-	-	-
females, young and old	6	75.35	16.62	22.1	45.22-90.72
females, young	4	84.18	6.70	8.0	77.29-90.72
females, old	2	57.70	17.65	30.6	45.22-70.72
		PCA radius			
males and females, young and old	12	61.92	9.98	16.1	39.34-73.86
males and females, young only	9	66.33	5.34	8.0	55.38-78.86
males and females, old only	3	48.72	9.25	19.0	39.34-57.84
males, young and old	6	61.75	8.27	13.4	48.98-71.84
males, young	5	64.31	6.04	9.4	55.38-71.84
males, old	1	48.98	-	-	-
females, young and old	6	62.10	12.28	19.8	39.34-73.86
females, young	4	68.85	3.50	5.02	66.43-73.86
females, old	2	48.59	13.08	26.93	39.34-57.84

BMI

Group	N	Mean	S.D.	C.V.	Range
males and females, young and old	11	0.661	0.107	16.1	.468-.832
males and females, young only	9	0.685	0.094	13.8	.540-.832
males and females, old only	2	0.555	0.123	22.2	.468-.642
males, young and old	6	0.723	0.075	10.4	.642-.832
males, young	5	0.740	0.071	9.6	.665-.832
males, old	1	0.642	-	-	-
females, young and old	5	0.586	0.093	15.8	.468-.701
females, young	4	0.616	0.075	12.2	.540-.701
females, old	1	0.468	-	-	-

Table A.6 PCA metacarpal, PCA radius and BMI: Tram

Group	N	Mean	S.D.	C.V.	Range
		PCA metacarpal			
males and females, young and old	17	75.45	6.99	9.3	64.00-90.46
males and females, young only	8	76.89	7.79	10.1	67.13-90.46
males and females, old only	9	74.17	6.37	8.6	64.00-82.92
males, young and old	7	75.20	5.80	7.7	66.63-82.92
males, young	4	75.24	4.75	6.3	69.26-80.86
males, old	3	75.14	8.17	10.9	66.63-82.92
females, young and old	10	75.63	8.02	10.6	64.00-90.46
females, young	4	78.54	10.58	13.5	67.13-90.46
females, old	6	73.69	6.11	8.3	64.00-80.52
		PCA radius			
males and females, yound and old	18	59.31	11.30	19.1	37.61-75.38
males and females, young only	8	65.75	8.77	13.3	49.64-75.38
males and females, old only	10	54.15	10.71	19.8	37.61-68.64
males, young and old	8	61.23	12.91	21.1	37.61-75.38
males, young	4	67.98	7.77	11.4	57.04-75.38
males, old	4	54.48	14.40	26.4	37.61-67.42
females, young and old	10	57.77	10.27	17.8	45.28-71.40
females, young	4	63.52	10.29	16.2	49.64-71.40
females, old	6	53.93	9.05	16.8	45.28-68.64

BMI

Group	N	Mean	S.D.	C.V.	Range
males and females, young and old	11	0.624	0.107	17.1	.423-.797
males and females, young only	6	0.639	0.094	14.8	.538-.797
males and females, old only	5	0.606	0.129	21.2	.423-.774
males, young and old	6	0.682	0.094	13.8	.562-.797
males, young	3	0.700	0.099	14.1	.600-.797
males, old	3	0.663	0.106	16.0	.562-.774
females, young and old	5	0.556	0.081	14.7	.423-.620
females, young	3	0.579	0.041	7.1	.538-.620
females, old	2	0.520	0.138	26.5	.423-.618