AN ABSTRACT OF THE THESIS OF

Title: A Comparison of Bone Mineral Density Between Active and Nonactive Men with Spinal Cord Injuries

Abstract approved: Dr. Jeffrey A. McCubbin

The purpose of this study was to compare the levels of bone mineral density (BMD) of the whole body (WB) and proximal femurs of physically active men with spinal cord injuries (SCI) to nonactive men with spinal cord injuries. Also, the lean muscle mass (LMM) of active men with SCI was compared to the LMM of nonactive men with SCI. In addition, BMD values of the radii of physically active men with SCI were compared to that of able bodied men of the same age. The subjects N= 46 were between the age of 20- 55 (μ = 37.83 ± 6.63 years), and were at least 2 years post spinal cord injury. Subjects with SCI were matched on similar level of lesion of the spinal cord, age, height, weight, and years post injury for the purpose of analyzing data. There were 14 active men with paraplegia and 14 nonactive men with paraplegia, 9 active men with quadriplegia and 9 nonactive men with quadriplegia. All BMD data was obtained utilizing a Hologic QDR 1000W dual energy x-ray absorptiometer. A two-factor (level by group) analysis of variance revealed no significant difference for
all sites (Whole body, Total hip, radii, LMM) comparing the active and nonactive men with SCI. T-scores and z-scores generated from the Hologic QDR 1000/W were analyzed using two-factor ANOVA (level by group). The active men with paraplegia had significantly higher BMD levels for all sites when compared to the other groups. These values may be explained by the number of incomplete injuries in the experimental group. Subjects in the physically active group did not clearly show a statistically significant difference on any of the dependent measures. However, values for the dependent measures were higher for the physically active group compared to the values of the nonactive group.
A Comparison of Bone Mineral Density Between Active and Nonactive Men with Spinal Cord Injuries

by

William C. Eddins, Jr.

A Thesis submitted to Oregon State University in partial fulfillment of the requirements for the degree of Master of Science

Completed June 28, 1994 Commencement June 1995
APPROVED:

Redacted for Privacy

Redacted for Privacy

Redacted for Privacy

Redacted for Privacy

Redacted for Privacy

Redacted for Privacy

Date thesis is presented June 28, 1994

Typed by researcher for William C. Eddins Jr.
ACKNOWLEDGEMENTS

My first thank you needs to be given to my wonderful mother Patricia Ann Eddins. Mom, without your never ending support and drive I would not be where I am today. I love you very much! My family- Kimmie Sue, Shannon Curtis and Patrice Nicole Eddins you all mean more to me than I could ever show. The rest of my family, too.

I would also like to thank my committee member's, Dr.'s Jeff McCubbin, Christine Snow-Harter, John Dunn, Steve Issacson, and Mary Ann Sward. I appreciate all of your guidance and input in helping me complete my thesis, as well as, taking time away from your schedules to help me.

Aaron Shelly and Karen Protiva thank you for collecting my data at the OSU Bone Laboratory. Dr. Jenny Kiratli your assistance was a lifesaver for me and without you, your data, and your input I would not have been able to complete this project.

My colleagues and friends at OSU who have helped me finish my graduate program- Nelson Sierra, Mike Senisi, John Bohle, Steve Skaggs, Steve Downs, Manny Felix and Inc., Cathy Wilson, Laurie Zittel, Lauren Lieberman, Sue Kasser, Julia Herman, John Oliver and family, Joy Johnson, Christine Snyder, Georgia Frey and Carol Leitschuh. Good luck with all that you attempt in life and thank you for your support and friendship.

Mommie !!! Karen Hayden, you have truly been a mom away from mom. You actually helped when I thought I could not go on.
Elzetta you fit into this category, also.

Dr. McCubbin and family. You treated me as if I was your own. Jeff, your time, which is all so precious, was the thing that helped me more than anyone or anything else. Thank you sir, I will do my best to represent this school, program and your teachings.

Last but not least, I must express my love and thanks to my beautiful fiance, Kirsten. Our path has been one that has changed me from boy to man and I am so very thankful for you and all that you bring to my life. Your endless support and dedication have truly helped me in completing this degree. I love you and will strive to create a world that we can both maximize our potential's.
## Table of Contents

**Introduction**
- Statement of the Problem 3
- Research Hypotheses 4
- Statistical Hypotheses 4
- Operational Definitions 5
- Assumptions 6
- Limitations 7
- Delimitations 7

**Review of Literature**
- Bone Mineral Density and Osteoporosis 8
- Factors that Contribute to BMD 13
  - Physical Activity 13
  - Diet 16
  - Age 17
  - Skeletal Loading 18
  - Genetics 20
- Effect of SCI on BMD 21
- Summary 22

**Methods and Procedures**
- Subjects 23
- Instruments 25
- Apparatus 26
- Procedures 26
- Experimental Design 28
- Statistical Analysis 28

**Results**
- Subject Characteristics 29
- Whole Body BMD Analysis 33
- Lean Muscle Mass Analysis 35
- Hip BMD Analysis 36
- Forearm Analysis 38

**Discussion**
- Complications 44
- Recommendations for Future Study 46
- Conclusions 47

**References** 49

**Appendices** 53
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Simple Regression LMM vs. Age for All Subjects</td>
<td>67</td>
</tr>
<tr>
<td>2.</td>
<td>Simple Regression WB BMD vs. Age for All Subjects</td>
<td>68</td>
</tr>
<tr>
<td>3.</td>
<td>Simple Regression Hip BMD vs. Age for All Subjects</td>
<td>69</td>
</tr>
<tr>
<td>4.</td>
<td>Interaction Line Plot for WB BMD Mean z-scores for all groups</td>
<td>74</td>
</tr>
<tr>
<td>5.</td>
<td>Interaction Line Plot for Hip Neck BMD Mean z-score for all groups</td>
<td>75</td>
</tr>
<tr>
<td>6.</td>
<td>Interaction Line Plot for Hip Trochanter BMD Mean z-score for all groups</td>
<td>76</td>
</tr>
<tr>
<td>7.</td>
<td>Interaction Line Plot for Hip Intertrochanter BMD Mean z-score for all Groups</td>
<td>77</td>
</tr>
<tr>
<td>8.</td>
<td>Interaction Line Plot for Total Hip BMD Mean z-score for All Groups</td>
<td>78</td>
</tr>
<tr>
<td>9.</td>
<td>Interaction Line Plot for WB BMD Mean t-score for All Groups</td>
<td>80</td>
</tr>
<tr>
<td>10.</td>
<td>Interaction Line Plot for Hip Neck BMD Mean t-score for All Groups</td>
<td>81</td>
</tr>
<tr>
<td>11.</td>
<td>Interaction Line Plot for Hip Trochanter Mean t-score for All Groups</td>
<td>82</td>
</tr>
<tr>
<td>12.</td>
<td>Interaction Line Plot for Hip Intertrochanter BMD Mean t-score for All Groups</td>
<td>83</td>
</tr>
<tr>
<td>13.</td>
<td>Interaction Line Plot for Total Hip BMD Mean t-score for All Groups</td>
<td>84</td>
</tr>
<tr>
<td>14.</td>
<td>Line Plot for WB BMD for All Groups</td>
<td>86</td>
</tr>
<tr>
<td>15.</td>
<td>Line Plot for LMM for All Groups</td>
<td>88</td>
</tr>
</tbody>
</table>
16. Line Plot for Total Hip BMD for All Groups  
17. Line Plot for Intertrochanter BMD for All Groups  
18. Line Plot for Femoral Neck BMD for All Groups  
19. Line Plot for Trochanter BMD for All Groups
LIST OF TABLES

Table | Page
--- | ---
1. Means and Standard Deviations for Matching Factors Between Groups | 30
2. Level and Degree of Spinal Cord Injury | 32
3. Means and Standard Deviations for Whole Body BMD, z-scores and t-scores for All Groups Tested | 34
4. Lean Muscle Mass Means, Standard Deviations and p value | 35
5. Hip BMD Means, Standard Deviations, z-scores, t-scores and p values for All Groups Tested | 37
6. One sample t-test Table for Forearm Data Analysis SCI vs. Normal | 39
7. Two Factor ANOVA Table for WB BMD | 71
8. Two Factor ANOVA Table for Total Hip BMD | 71
9. Two Factor ANOVA Table for Femoral Neck BMD | 71
10. Two Factor ANOVA Table for Intertrochanter BMD | 72
11. Two Factor ANOVA Table for Trochanter BMD | 72
12. Two Factor ANOVA Table for LMM | 72
13. Four Level One Factor ANOVA Table for WB BMD | 86
14. Scheffe's Post Hoc Analysis Table for WB BMD | 87
15. Four Level One Factor ANOVA Table for LMM | 87
16. Scheffe's Post Hoc Analysis Table for LMM | 88
17. Four Level One Factor ANOVA Table for Total Hip BMD | 89
18. Scheffe's Post Hoc Analysis Table for Total Hip BMD | 90
19. Four Level One Factor ANOVA Table for Intertrochanter BMD 90

20. Scheffe’s Post Hoc Analysis Table for Intertrochanter BMD 91

21. Four Level One Factor ANOVA Table for Femoral Neck BMD 92

22. Scheffe’s Post Hoc Analysis Table for Femoral Neck BMD 93

23. Four Level One Factor ANOVA for Trochanter BMD 93

24. Scheffe’s Post Hoc Analysis Table for Trochanter BMD 94
## LIST OF APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Appendix A</td>
<td>54</td>
</tr>
<tr>
<td>B. Appendix B</td>
<td>57</td>
</tr>
<tr>
<td>C. Appendix C</td>
<td>61</td>
</tr>
<tr>
<td>D. Appendix D</td>
<td>66</td>
</tr>
<tr>
<td>E. Appendix E</td>
<td>70</td>
</tr>
<tr>
<td>F. Appendix F</td>
<td>73</td>
</tr>
<tr>
<td>G. Appendix G</td>
<td>79</td>
</tr>
<tr>
<td>H. Appendix H</td>
<td>85</td>
</tr>
</tbody>
</table>
Chapter 1
Introduction

Approximately 240,000 individuals with spinal cord injuries (SCI) reside in the United States (Davis, 1992; Figoni, 1992). This population is expected to increase by over 10,000 each year (Huffman, 1993). Eighty percent of all spinal cord injuries are received by men (Figoni, 1992), aged 15-25 years (Stover & Fine, 1986).

The leading causes of spinal cord injuries include motor vehicle accidents, falls, diving into shallow water, sports injuries and violence. Due to improved emergency room techniques, response times of ambulances and medical technology, persons with post-traumatic spinal cord injuries are able to live longer. Life expectancy continues to improve, but has not reached that of the normal population (Stover, 1993).

Technological advancements and social acceptance have increased the health and well being of persons with SCI. Drugs can prevent urinary tract complications and reduce violent spasms, new lightweight wheelchairs can improve functional mobility and prevention and treatment of pressure sores are examples of improvements that increase the health of persons
with SCI. The population of men with spinal cord injuries is living longer even though many long term problems may be encountered. However, some of the resultant problems of spinal cord injuries are not yet successfully managed by the current practices in medicine. Examples of these problems are poor bowel and bladder control and associated infections, coronary artery disease and osteoporosis.

It is well understood that bone mineral density (BMD) decreases as people get older (Michel, Lane, Bloch, Jones, & Fries, 1991). If the level of BMD decreases beyond a healthy point, then complications such as osteoporosis can arise (Snow-Harter, 1992). Osteoporosis can be defined as a critical reduction in bone mass to the point that fracture vulnerability increases (Snow-Harter & Marcus, 1991). Once a low level of bone mineral density has been reached, activities of daily living such as walking, standing, or simply any weight bearing of the affected limbs may need to be reduced or cease.

"Osteoporosis is an inevitable sequela of traumatic spinal cord injury" (Leeds, Klose, Ganz, Serafini, & Green, 1988, p.207). This statement is based upon the following reasons: a) loss of muscle contraction; b) loss of weight bearing activity on affected limbs; c) initial period of bedrest followed by lengthy period of little to no physical activity (Garland et al., 1992; Leeds et al., 1990; Biering-Sorensen, Bohr, & Schaad, 1990).
Though physical activity has been shown to be positively correlated with BMD values on the general population (Snow-Harter, Whalen, Myburgh, Arnaud, & Marcus, 1992; Block et al., 1989), studies have not been conducted to measure the effects of physical activity on BMD of individuals with SCIs. Spinal cord injury does not mean the end of physical activity. It simply means that physical activity must take on a new form. Osteoporosis is a significant problem for individuals with spinal cord injuries who use a wheelchair for mobility. The role of physical activity in osteoporosis for persons with SCI needs to be investigated.

**Statement of the problem**

The purpose of this study was to compare the levels of BMD of the whole body, and bilateral measures of the femoral neck of physically active men with spinal cord injuries to nonactive men with spinal cord injuries. Also, the lean muscle mass (LMM) of active men with SCI was compared to the LMM of nonactive men with SCI. In addition, BMD values of the radii of physically active men with spinal cord injuries were compared to that of able bodied men of the same age. The men were between the ages of 20-55, and were at least 2 years post spinal cord injury.
Research Hypotheses

The following research hypotheses were explored in this study:

1.) Physically active men with spinal cord injuries have a higher level of whole body BMD than men with spinal cord injuries who are not active.

2.) Men with spinal cord injuries who are physically active will have equivalent BMD at the proximal femur compared to men with spinal cord injuries who do not participate in physical activity.

3.) Men with spinal cord injuries who are physically active will have a higher percentage of lean muscle mass (LMM) than men with spinal cord injuries who are not active.

4) Men with spinal cord injuries who are physically active will have a higher BMD at the radii compared to men who are not spinal cord injured.

Statistical Hypotheses

This section defines the research hypotheses in terms of statistical hypotheses.

\[ Ho1 : \text{PASCI}> \text{NSCI} \text{ for whole body BMD} \]

\[ Ho2 : \text{PASCI}=\text{NSCI} \text{ for proximal femur sites measured} \]
Ho3: PASCII > NSCI for lean muscle mass

Ho4: PASCII > ABM for both radius sites measured

PASCII = Physically active SCI, NSCI = Nonphysically active SCI
ABM = Able bodied men

**Operational Definitions**

Spinal cord injury- an injury to the spinal cord that results in complete or incomplete paraplegia or quadriplegia and received after the 10th year of life.

Physically active- participation in vigorous, organized, competitive wheelchair sport for 2 or more years, or participation in strenuous physical activity at least three times per week at an intensity of at least 50 percent of maximum heart rate and for a minimum of 20 minutes each time.

Wheelchair user- all subjects will use a wheelchair as their main mode of ambulation. Active population must use a manual wheelchair and the nonactive population may use an electrically powered wheelchair.

Osteopenia - any decrease in bone density or mass below normal amounts.
Assumptions

1.) All active subjects who participated answered the health, physical activity, and injury history questionnaire honestly and accurately and nonactive subjects, based on self report to Jenny Kiratli, Ph. D. revealed an accurate description pertaining to their level of activity.

2.) The bone densitometer worked properly and collected data that is a true reflection of each subject's bone mineral density.

3.) Tissue composition can be determined accurately by the Hologic QDR 1000/W.

4.) Subjects' medications did not affect BMD.

5.) All subjects were free of any other bone altering diseases other than spinal cord injury.

6.) Active subjects (n=23) used a manual wheelchair though some of the nonactive subjects (n=9) used a powerchair.
Limitations

Though the sample size may achieve limited levels of statistical power, the conclusions drawn were restricted to the sample size of 23 active subjects and 23 nonactive subjects. This study compared the information of two groups with the known differing factor of participation in physical activity. Many other factors such as genetics, unknown diseases, and side effects of medications may have been involved. The subjects were matched based on level of injury, age and weight. Attempts were made to match on factors known to alter BMD (e.g. smoking, race, years post injury).

Delimitations

This section addresses to what extent and to what population the conclusions are applicable. The population under investigation was men with spinal cord injuries aged 20-55 years. These subjects have been injured for at least two years. The findings of this research can be generalized to individuals matching these criteria.
Bone mineral density and exercise studies conducted involving SCI populations are few in number. In this section, research using both able bodied and SCI participants will be reviewed. The reviews of various studies conducted identify factors that contribute and detract from BMD. This review of literature is organized in sections to address the following areas: a) BMD and osteoporosis, b) factors that contribute to BMD, and c) effects of spinal cord injury on BMD. In each section, data from SCI populations will be presented first and then data from able bodied subjects will be reviewed to support each topic of discussion.

**Bone Mineral Density and Osteoporosis**

BMD is the amount of calcium phosphate crystal present in measured bone area. This measurement is usually in grams per square centimeter. BMD and bone mass are synonymous in research when measured by non invasive machines. Osteoporosis is defined as a critical reduction in bone mass to the point that fracture vulnerability increases (Snow-Harter & Marcus, 1991). Once the level of bone mass, or BMD decreases to this low level, bones fracture easily and tend not to heal properly or quickly. Bones that do heal are easily refractured.
There are two types of osteoporosis—primary and secondary. Primary osteoporosis is low bone mass not attributed to any illness. Secondary osteoporosis is linked to another disease or condition like a spinal cord injury. Some researchers state that osteoporosis is inevitable following a traumatic spinal cord injury (Leeds et al., 1990).

A spinal cord injury resulting in paralysis is followed by significant osteoporosis in all skeletal parts below the lesion (Ragnarsson & Sell, 1981). Reduced bone mass presents a higher probability that a fracture can occur. The known incidence of fractures for individuals with spinal cord injuries is higher than the one reported because not all fractures are ever realized. The incidence of fractures for this population is 4% according to a study conducted in 1963 by Eichenholtz (1963). Ragnarsson and Sell reported a 4% fracture incidence, based on data of the SCI patients from the Institute of Rehabilitation Medicine in New York, New York and 1.45% of the patients registered at the National Spinal Cord Injury Data Research Center in Phoenix, Arizona (Ragnarsson & Sell, 1981) experienced fractures.

Most of the fractures for individuals with SCI take place in the long bones of the legs, the femurs, and are the result of little trauma. Fractures happen while transferring out of the wheelchair to bed or into the car, as a result of falling out of the wheelchair, or while doing passive range of motion exercises. Lower extremity fractures are more common in individuals with paraplegia than in individuals with quadriplegia (Ragnarsson &
Sell, 1981). This may be due to the more active lifestyle of this group.

The skeleton supports numerous functions in the human body. The main function is to give support for the soft tissues of the body. Bones provide direct attachment to most of the skeletal muscles and together give the body its basic form (Crouch, 1985). Another function of bone is to protect many of the vital organs. Bones are also partly responsible for human locomotion- as levers which muscles act upon. Yet another function of bone is supplying calcium to the body to support life. The skeletal system is divided into two parts, the axial skeleton system and the appendicular skeleton. The axial skeleton system is composed of bones of the skull, vertebral column, ribs, and sternum. All bones not in the axial skeleton are part of the appendicular system (i.e., pelvic girdle, lower limbs, upper extremities, and pectoral girdle).

Another way to classify bone is according to the microstructure, trabecular and cortical bone. Trabecular bone, or cancellous bone, is spongy and porous when compared to cortical bone which is made of dense compact bone and comprises 80% of skeletal mass. The amount of these two types of bone varies in different bones and within parts of the same bone, depending on the strength requirements or lightness of that bone (Crouch, 1985). The shaft of long bones are exclusively cortical bone, whereas the metaphyses are comprised of both cortical and trabecular bone.
After a spinal cord injury, rapid atrophy of muscles and bone demineralization takes place below the level of lesion (Pacy et al., 1988). Bone adapts to imposed stress or lack of stress by forming or losing tissue. Wolff's law states that bone will modify its structure in response to the level of mechanical loading on the bone (Wolff, 1986 [Translation]). Bone hypertrophy occurs when stress is applied in excess of normal levels and bone loss occurs when less than normal magnitude of force is applied. These adaptations are the bases for bone remodeling.

In order for bone remodeling to occur, two sets of cells are needed- osteoblasts which are bone forming cells and osteoclasts which are bone resorbing cells. When osteoblastic activity exceeds osteoclastic resorption a net gain in bone is the result. Net loss occurs when resorption, osteoclastic activity, is greater than formation, osteoblastic activity (Snow-Harter & Marcus, 1991). This osteoblastic phenomenon happens when the stress or damage is gradual. If too much stress is applied, a fracture is produced; if the stress is gradually increased, bone mass or BMD increases. The skeletal system is subjected on a daily basis to external ground reaction forces and forces generated by muscle contraction (Snow-Harter & Marcus, 1991). These are some of the forces responsible for increasing or decreasing BMD. These are also the forces that are diminished, below the level of lesion, after an SCI occurs.
When muscle and skeletal activities decline, the BMD takes on a new, lower equilibrium value. This has been observed in cases of immobilization (Krolner & Toft, 1983). Bed rest, or lack of bearing weight, is noted as reducing BMD because the individual is supine for an extended period of time. This happens to all individuals who have had a traumatic SCI. In 1966, Issekutz and colleagues found that urinary calcium is more affected by the absence of longitudinal pressure, weight bearing, than the removal of physical activity (Issekutz, Blizzard, Birkhead & Rodahl, 1966). If calcium levels increase and are evident in the urine, bones are losing calcium and thus causing a reduction of BMD. As it is not possible to induce SCI in humans for the initial study of bone loss immobilization and bed rest have been used to simulate paralysis. A study that included immobilization of the legs of young rats determined the immobilization for six weeks resulted in an increase of bone resorption (bone loss) and a rapid fall in bone formation (Yeh, Liu & Aloia, 1993).

Paralysis of muscles obviously causes a reduction in skeletal activity which is one of the bases for individuals with SCIs having a lower BMD when compared to abled-bodied individuals. Bone mineral loss after SCI occurs throughout the entire skeleton except the skull (Garland et al., 1992); however, areas proximal to the pelvis show a slight gain in mineral after the initial loss but do not regain preinjury levels. The arms of individuals with paraplegia, which take on greater weight bearing activity than those of the average uninjured individual, never return to normal
bone integrity, or preinjury BMD levels (Garland et al., 1992). However, these individuals were not defined to be physically active in this study (Garland et al., 1992).

Factors that Contribute to BMD

It has been demonstrated that BMD is higher in physically active men than in sedentary controls (Snow-Harter et al., 1992). Physical activity is not the only determinate factor in the level of BMD. Research shows that genetics, diet, skeletal loading, age, amount and type physical activity all play a role in the amount of BMD for any given individual. When a spinal cord injury (SCI) occurs, these determinates and concerns are presented relating to BMD. This section will discuss the effects of a spinal cord injury and the above factors on bone mineral density.

Physical Activity

A person following SCI takes on new or different forms of physical activity. As a result, an individual may not exercise due to accessibility issues or the lack of knowledge about exercise opportunities. "For an adult with a spinal cord injury, problems of access associated with wheelchair confinement often reduce the desire to exercise, further complicating the medical sequelae of physical disability" (Davis, 1993, p. 423).

Exercise may take on a new form, but it is still beneficial to the individual with SCI or people with SCIs. The
cardiorespiratory fitness of people with SCIs is trainable and respond to physical activity similar to able-bodied counterparts (Davis, 1993).

Pacey et al. (1988) conducted research on four males with paraplegia who exercised their paralyzed quadriceps via functional electrical stimulus (FES). The exercises consisted of two regimes a) leg raises against a graded load and b) cycling on a modified bicycle ergometer. The subjects exercised five times a week for 10 weeks during the first regime and five times per week for 32 weeks for the second regime. The study concluded that an increase in size and mass of the quadriceps was produced as a result of FES, but no change in BMD was noted. It was hypothesized that the exercise regimes were too short to produce any change in BMD. Pacey et al. also concluded that FES may be beneficial in combating muscle atrophy and more than just muscle contraction is involved in increasing or decreasing BMD.

In research studies similar to the one previously discussed about FES, researchers found the same results in two separate research projects. Study 1 originated from the Miami Project To Cure Paralysis (Leeds et al., 1990) and Study 2 was conducted at Wright State University School of Medicine (Rodgers et al., 1991). Both studies used functional electrical stimulation, or functional neuromuscular stimulation to stimulate the quadriceps. The exercise programs were performed three times a week for 6 months and three times a week for 36 weeks for Studies 1 and 2 respectively. The design and methods of these two studies were
similar and thus produced similar findings and results. No increase or change in BMD (either + or -) resulted from FES.

In normal populations, physical activity and BMD appear to have a positive correlation. Athletes and/or physically active men have been observed to have higher bone density than nonathletes or sedentary controls (Snow-Harter et al., 1992). Studies have shown that individuals who participate in aerobic activities and weight lifting have a larger BMD than those involved only in aerobics (Snow-Harter & Marcus, 1991). Recent literature shows that the amount of muscle strength for a given muscle positively correlates with the density of the bone to which the muscle is attached. In a study conducted on men who play tennis, and did so for 25 to 72 years, the bone mineral content and width of radii bones of the dominate (playing arm) and nondominate arm were compared. In all but one of 35, the dominate radius had more bone content and was wider. These same results were also compared to radii of nonathletic men. The study concluded that an individual who participates in a lifetime of physical activity could produce a larger amount of bone mineralization than not participating in physical activity (Huddleston, Rockwell, Kulund & Harrison, 1980).

Snow-Harter et al. (1992) examined 50 healthy men who ranged in age from 28 to 51 years. BMD measurements were taken at the following sites- lumbar spine, proximal femur, tibia, and a whole body measurement. The measurements were obtained by dual-energy x-ray absorptiometry (Hologic QDR
Strength measurements were defined by using a one repetition maximum for the biceps, quadriceps, back extensors, hip abductors, adductors, and flexors. Grip strength was assessed by dynamometer. Subjects were designated as exercisers and non exercisers on the basis of daily walking mileage. Exercisers participated in exercise at least two times a week. BMD at all sites correlated with back and biceps strength. Body weight tended to predict tibia and whole body BMD.

There are other important facts about this study. The groups were divided in such a manner that the only difference was muscle strength and after testing, BMD was higher for the group with the most strength. Thus, in men, muscle strength appears to be an independent predictor of bone mineral density (Snow-Harter et al., 1992). This helps explain why with a lack of muscle function the level of BMD decreases and why research is being conducted on how to maintain or increase BMD in the affected limbs of individuals with SCI's.

Diet

Calcium is the largest mineral stored in the skeletal system. The skeleton is the repository for 99.5% of total body calcium (Snow-Harter & Marcus, 1991). Researchers have formulated a theory that suggests the ingestion of a large amount of calcium creates stronger or more dense bones. The research in this area is somewhat ambiguous and no definite findings have been
concluded. There is however, a recommended daily allowance that is needed for normal bone health. It is speculated that the two or three years that constitute the pubertal growth spurt are accompanied by deposition of sixty percent of final bone mass, and dietary inadequacy at this time may impose deficiencies in the formation of bone (Snow-Harter & Marcus, 1991).

Calcium is not the only element necessary for a strong skeleton. Vitamin D is of equal importance because it promotes the absorption of calcium (Fehily, Coles, Evans, & Elwood, 1992). Dietary calcium intake in males is a significant independent predictor of bone mineral density (Eisman, Sambrook, Kelly, & Pocock, 1991). A healthy diet is necessary in order to have an adequate BMD level. Excess consumption of protein, caffeine, alcohol, and phosphorous have been implicated in the development of osteoporosis (Alota, 1989). Diet is also a variable that an individual with an SCI can control. This dietary information must be taught to newly injured SCIs.

Age

In general, as people grow older there is a reduction in level of activity. It has been previously stated that the reduction of BMD follows the reduction of movement. Therefore, age may be directly related to the BMD of any given individual. Bone density at any time during adult life is the result of peak bone density achieved in early adulthood and subsequent bone loss
(Eisman et al., 1991). There is unanimous agreement using multiple techniques, that trabecular bone is lost with age, and that axial density is substantially lower in older persons than in the young (Snow-Harter & Marcus, 1991). Research shows that bone loss may begin at different times for different sites, but the traditional view is that bone is gained during adolescence, reaches a peak mass around the age of thirty, stabilizes until approximately age fifty, and then gradual loss is observed (Garn, Rohman & Nolan, 1966).

For men, BMD begins to decline around the age of fifty. Age would not be the only factor in the decline of the BMD for an individual with an SCI. The decline in bone density would directly follow the SCI (Garland et al., 1992).

**Skeletal Loading**

Osteoporosis is a major concern for the population of people with SCIs. This is due to the lack of muscle function and weight bearing on the limbs which may cause bone density to maintain a proper level no longer exists. Sir Ludwig Guttman stated that “As soon as the paraplegic is up in his wheelchair, intensive physiotherapy, including standing and, in particular, sportive activities have been invaluable in combating osteoporosis" (Leeds et al., 1990, p. 207).

Standing has been considered a valuable tool in the rehabilitation of people following a traumatic SCI. The theory has
been that as result of standing, or weight bearing, the muscles and bones in the legs will benefit from the loading. This is a theory that has not been proven, but remains a wide spread belief. In a recent study, standing in a standing frame or long leg braces did not improve bone density in the femoral neck or alter the x-ray appearance and fracture risk in subjects' lower extremity bones (Kunkel et al., 1993). Subjects did not demonstrate changes due to standing in reduction of spasticity of leg muscles, prevention of the formation of contractures, or increased BMD of lower extremities. It was stated that once profound disuse osteoporosis is established, standing does not appear to activate osteoblastic activity despite weight-loading of osteoporotic bones (Kunkel et al., 1993).

Spasticity is an involuntary muscle contraction. For many individuals with SCI, spastic muscles and contractions are a very disturbing reaction of their disability. It was thought that spasticity-created muscle contractions may be large enough to effect BMD. No significant influence on the BMC values was found in those with spasticity (Biering-Sorensen et al., 1988).

Often times, individuals with enough muscle innervation use long leg braces to ambulate. Along with the braces the individual uses crutches for support. These individuals would be expected to have a larger lower leg BMD level than people who can not use long leg braces. No significant influence on the BMC (bone mineral content) values was found in those with the daily use of long leg braces (Biering-Sorensen et al., 1988). Weight bearing
has been shown to effect BMD values, but not for this population. Possible reasons for this type of loading via standing is that in both a standing aid and long leg braces the support is dispersed throughout the braces and aid, not the bones of the leg. Also, the amount of time, 45 min. to one hr., may not be a long enough time (Biering-Sorensen et al., 1990; Kunkel et al. 1993).

Lumbar spine BMD is of great concern for all populations. Low back pain is one of America's largest growing workmen's compensation claims. The low back receives a larger load sitting then it does standing. Because of this load, the lumbar BMD level seems to remain within normal levels in those who use a wheelchair for ambulation (Biering-Sorensen et al., 1988).

**Genetics**

Some findings in bone mineral density research are related to the possibility of genetic influence over the formation of new bone. The peak bone mass that any individual can attain is most likely to be genetically determined (Aloia, 1989). One recent finding was that serum osteocalcin levels are genetically influenced, suggesting genetic regulation of bone turnover (Eisman et al., 1991). Another possible relationship between genes and BMD is that if genes determine the type and amount of muscle for a given individual, and thus the stamina for that individual, then genes would indirectly play a role in the BMD for that same individual via skeletal loading (Eisman et al., 1991). If
the genotype for a person determines the type and amount of physical activity that individual will participate in then it could be concluded that those same genes or group of genes could also predict BMD. For instance, men have a larger bone mass than women; and black men and women, are more likely to have higher bone mass figures than those of white people (Mazess, 1982).

"Eighty percent of the variance in peak bone mass is accountable by genetics, not within control of the individual. The remaining 20% may be attributed to other modifiable factors" (Snow-Harter, 1992). This is implies that the 20% of peak bone mass that can be modified is in relation to such factors as diet, physical activity, and weight bearing. An individual with a SCI needs to know that it is important to remain active and eat a healthy diet with an adequate calcium supply, especially if the genetic factors are not in their favor.

**Effect of SCI on BMD**

Once an individual has an SCI, among other things, the BMD level for that person would be reduced. Directly following the traumatic injury, collagen from the paralyzed limbs is resorbed (Garland et al. 1992). This reduction in BMD continues until 16 months to two years post injury then levels off (Garland et al., 1992 & Biering-Sorensen, 1988). The drastic reduction of BMD has been of great concern because the reduction in BMD results
in below normal levels and osteoporosis usually results (Kunkel et al., 1993; Biering-Sorensen, 1990; Leeds et al., 1990). Physiological deterioration, including bone and muscle atrophy, poor myocardial function, and a general decline of fitness often accompany traumatic neurological dysfunction (Davis, 1993). In individuals who have had a stroke, research indicates that the BMD and bone mineral content of the paralyzed side are significantly less than the nonparalyzed side (Hamdy, Krishnaswamy, Cancellro, Whalen & Harvel, 1993).

**Summary**

The loss of muscle function, the ability to bear weight, ground reaction forces, and the desire to exercise all could play a role in the reduction of BMD to osteoporotic levels in persons with SCI. To date a few attempts have been made to discover if BMD levels could be restored as a result of "reactivating" the paralyzed limbs via functional electrical stimulation and using a standing frame, but no short term treatment interventions have demonstrated positive, statistically significant changes. Long term physical activity has been shown to positively correlate with BMD for the able-bodied population, but no study has been conducted using the SCI population.
Chapter Three.
Methods and Procedures

This section describes the subjects and criteria to delineate the two subject groups. The methods, procedures, and statistical analyses used to review the data are also described in this section.

Subjects

This study examined men age 20-55 years with traumatic spinal cord injuries. One group (N=23) consisted of physically active males with SCI. The other group (N=23) were nonactive males matched with the active group by similar level of injury. All active subjects used manual wheelchairs as primary mode of ambulating, but in order to gain an adequate sample for the control group some nonactive subjects used electronically powered wheelchairs.

Subjects defined as physically active, were those who participated in rigorous wheelchair sport, and/or structured exercise training including weightlifting for at least two years after injury and up to the time of this study. The sports that were considered rigorous were wheelchair basketball, track and field, quad rugby, and weight lifting. In addition, subjects who participated in non-competitive physical exercise three times per week for 30 minutes at a 50 percent of maximum heart rate were
considered physically active. Men with spinal cord injuries who
lifted weights three times per week were considered active, even
though level of intensity could not be quantified based on heart
rate.

Subjects who did not participate in rigorous physical
activity were classified as nonactive. A nonactive subject did not
exercise consistently and chose not to participate in wheelchair
sport. Activities of daily living were carried out independently by
the subjects, but additional, structured physical activity was not.

All subjects were between the ages of 20-55 years, had a
spinal cord injury that resulted in some paralysis of the
extremities and were at least two years post injury. Based on self
report in the physical activity history questionnaire, subjects
were classified as active or nonactive. Only active subjects were
tested at Oregon State University. The subjects were then
matched on similar level of injury, approximate age, weight, race,
years post injury, and smoking.

Data for the active group were collected in the Bone
Research Laboratory at Oregon State University. Nonactive men
with SCI data were collected by Dr. Jenny Kiratli, Research
Health Scientist at the Spinal Cord Injury Center, Palo Alto VA
Medical Center. The reasons for this were as follows: a) increased
sample size, and b) improved ability to match the two groups on
bases of age and level of lesion so that comparisons could be made
with the only known differentiating factor being involvement in
physical activity.
Each subject tested at Oregon State University provided consent via a signed informed consent form (Appendix A) in accordance with the policy of the Oregon State University Institutional Review Board (IRB) for the Protection of Human Subjects. This committee reviewed the procedures for this investigation to assure the safety and protection of all subjects tested at OSU (See Appendix B).

The nonactive subjects were out-patients followed by the Spinal Cord Injury Center and consented to being scanned. Based on self report of limited physical activity, these subjects were classified as nonactive.

**Instruments**

Each subject that was scanned at OSU was required to complete a health, physical activity, and injury history questionnaire to determine activity level. This questionnaire was constructed for the purpose of this study and consisted of questions that helped match each nonactive subject from the V.A. for comparison after the data were collected. The survey used in the study was similar to the form used in the Bone Research Laboratory at Oregon State University with additional questions that were injury specific (See Appendix C). Information pertaining to each subject’s injury enabled investigators to match subjects for later comparisons.
Apparatus

The machine used to obtain all bone mineral density values and the radii data (age matched z-scores) for men with no SCI was the Hologic QDR 1000/W Bone Densitometer and software. The coefficient of variation for this machine was less than 1% (Hologic insert). The technique used to assess the BMD levels was a noninvasive dual energy x-ray absorbtimetry (DEXA), which gives both trabecular and cortical bone measurements. This technique measured BMD in units of grams per centimeter squared. This machine was also capable of determining body composition—percent body fat and percent of lean muscle mass. A recent study found that DEXA is a reasonable estimate of percent body fat (Wegner, Snow-Harter, Wilcox, Guerra, & White, 1994). This machine was operated by a qualified technician.

Procedures

The active experimental group subjects were asked to travel to the Bone Research Laboratory at Oregon State University in Corvallis, Oregon. Upon arrival, the subjects completed the health, physical activity and injury history form and signed an informed consent form. Each active subject wore attire with no metal that could negatively affect the accuracy of the bone densitometer. After the forms were completed, the subject was asked to lie supine on the bone densitometer. If assistance was needed in transferring on to the device, trained personnel were
present to assist as needed. The order in which the scans were taken was: a) whole body, b) bilateral proximal femurs and c) bilateral radii.

The subjects were instructed to lie still on the machine while the testing took place. The actual time of the testing was approximately one hour. The amount of radiation that each subject was exposed to was 1/10 the amount of a normal x-ray. This low level of exposure was very unlikely to cause any health hazards to the subjects.

Nonactive subjects who were tested at the Spinal Cord Injury Center experienced a small change in protocol. They were brought from their rooms, to the Bone Density Laboratory for testing. Like OSU, if assistance was needed there was qualified help present to assist. The order in which the scans were taken were: 1.) bilateral proximal femurs and 2.) whole body. Bilateral radii were not taken at the VA Medical Center.

The densitometer was capable of computing percent lean muscle mass. These values, as well as BMD values, were provided to the subjects following conclusion of data collection. Once the data collection was completed on the experimental group at Oregon State University subject's demographic information was matched with an individual with a similar level of injury, approximate age, weight, race and smoking status data from Palo Alto VA Medical Center.
**Experimental Design**

This quasi-experimental design (Cambell & Stanley, 1963) was analyzed using a two factor ANOVA to determine if a significant difference existed between the levels of BMD of the femoral necks and whole body between active and nonactive groups, as well as within each group between para and quad. Lean muscle mass data was analyzed using a two factor ANOVA. The z-score and t-score data were analyzed by a two factor ANOVA. Causality was not inferred from this data, or this study. As a result of the interactions produced from the two factor ANOVA a four level one factor (Group) ANOVA procedure was performed for WB BMD, all sites of the hip, and LMM data.

**Statistical Analysis**

Alpha level was set at .05 for all group comparisons. All statistical analysis were done using a Macintosh personal computer and Statview 4.0 software. With the group size of n = 23, in each group active and nonactive, statistical power was low. Power for this study was calculated to be .54. Subjects were limited due to demographics of Corvallis, OR and the surrounding areas.
Chapter Four

Results

Data from a total of 46 men with spinal cord injuries were analyzed. The sample breakdown is as follows: a) 23 active men (14 with paraplegia, 9 with quadriplegia); b) 23 nonactive men (14 with paraplegia, 9 with quadriplegia). The radii data of 23 active men with SCI were compared to 23 men with no SCI that were age matched by the densitometer software. The software within the Hologic QDR 1000/W produced age matched data compared to the subject’s data that was obtained during each scan. The age matched data was in the form of z-scores. These z-scores were then analyzed (Hologic Inc.).

Subject Characteristics

Table 1 depicts means and standard deviations of age, years post injury (YPI), height and weight for each group. A one-way ANOVA was computed to detect any differences between factors (para/quad) of each group (active and nonactive) for the characteristics of age, YPI, height and weight. The only significant difference by group was on age between the active and nonactive men with quadriplegia. Due to the significant difference for age between groups, simple regressions were performed to determine correlations between age and all the
dependent measures tested (LMM, WB BMD, and Hip BMD). In the subjects tested, no meaningful correlations were determined between age and LMM, WB BMD and Hip BMD. The regression plots can be found in figures 1-3 (Appendix D).

Table 1
Means and Standard Deviations for Matching Factors between Groups

<table>
<thead>
<tr>
<th></th>
<th>ACTIVE PARA (n=14)</th>
<th>NONACT PARA (n=14)</th>
<th>P VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>35.57 ± 7.87</td>
<td>40.64 ± 8.45</td>
<td>.1123</td>
</tr>
<tr>
<td>Years Post Inj</td>
<td>16 ± 8.2</td>
<td>15.51 ± 8.84</td>
<td>.8814</td>
</tr>
<tr>
<td>Height (in)</td>
<td>70.14 ± 2.8</td>
<td>70.78 ± 1.37</td>
<td>.4468</td>
</tr>
<tr>
<td>Weight(lbs)</td>
<td>172.14 ± 33.11</td>
<td>176.38 ± 34.92</td>
<td>.7458</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>23.77 ± 8.66</td>
<td>25.98 ± 6.71</td>
<td>.4628</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ACTIVE QUAD (n=9)</th>
<th>NON QUAD (n=9)</th>
<th>P VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>32.78 ± 5.54</td>
<td>42.33 ± 4.65**</td>
<td>.0011</td>
</tr>
<tr>
<td>Years Post Inj</td>
<td>11.11 ± 5.16</td>
<td>13.59 ± 7.42</td>
<td>.4229</td>
</tr>
<tr>
<td>Height (in)</td>
<td>71.22 ± 2.28</td>
<td>72.89 ± 1.62</td>
<td>.0925</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>160.33 ± 29.58</td>
<td>160.22 ± 25.17</td>
<td>.9933</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>19.66 ± 5.25</td>
<td>22.41 ± 6.98</td>
<td>.3602</td>
</tr>
</tbody>
</table>

** p<.05
The group of men with spinal cord injuries were similar, and yet different. Similar in respect that there were 14 subjects with paraplegia and nine with quadriplegia in each group. The levels of injuries of some subjects were matched but degree of injury varied. Some subjects had complete spinal cord injuries while others were incomplete. The following table (Table 2) describes the level of injuries and degree of injury (complete or incomplete).
### TABLE 2
Level and Degree of Spinal Cord Injury

<table>
<thead>
<tr>
<th>Level of Injury</th>
<th>ACTIVE</th>
<th>NONACTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUADS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4-C5</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>C5-C6</td>
<td>22</td>
<td>31</td>
</tr>
<tr>
<td>C6-C7</td>
<td>73</td>
<td>42</td>
</tr>
<tr>
<td>C7-C8</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>T3</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>T4</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>T5</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>T6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>T7</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>T8</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>T10</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>T11</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>T12</td>
<td>42</td>
<td>21</td>
</tr>
<tr>
<td>L1</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>PARAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEGREE OF INJURY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Incomplete</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

Lower case number indicates number of incomplete injuries for each level.

The racial make up all subjects, active and nonactive, was predominately white, n= 41 or 89%. Two subjects were Black, two were Hispanic and one was of Asian decent. Of the five
minorities three were in the active group, one Black, one Hispanic and the Asian. Two minorities were in the nonactive group, one Black and one Hispanic.

**Whole Body BMD Analysis**

The whole body (WB) BMD data were analyzed with a two factor ANOVA. No significance was found between the groups (para vs. quad) or between the combined groups (active vs. nonactive) with the two factor analysis. The WB BMD, z-scores and t-scores, mean values and standard deviations, and p values for each group are depicted in Table 3. The p values shown in all tables are between the active and nonactive groups. The ANOVA tables with p values for within and between groups as well as interactions can be found in Appendix E.

The Hologic QDR/1000W software produces t-scores and z-scores for the BMD values for each subject. The t-scores and z-scores are gender and age matched (Hologic Inc.). T-scores are given in relation to a peak bone mass amount. The z-scores are formulated according to an age match between the subject scanned and a healthy value for that particular age. A t-score of -1.0 means that the subject scanned is borderline osteopenia and -2.0 equals osteopenia. The z-score and t-score data is presented in the WB BMD and Hip BMD Tables 3 and 6 and consists z and t-score means and standard deviations for each of the four groups tested. Figures 4 - 8 showing the interactions for mean z-score
data for all groups are in Appendix F. Mean t-score interaction figures shown in 9 - 13 for all groups are located in Appendix G.

Table 3
Means and Standard Deviations for Whole Body BMD z-scores and t scores for All Groups Tested

<table>
<thead>
<tr>
<th></th>
<th>Act Para</th>
<th>Non Para</th>
<th>Act Quad</th>
<th>Non Quad</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n= 14</td>
<td>n= 14</td>
<td>n= 9</td>
<td>n= 9</td>
<td></td>
</tr>
<tr>
<td>WB BMD</td>
<td>1.17 ± .09</td>
<td>1.04 ± .08</td>
<td>1.04 ± .11</td>
<td>1.01 ± .12</td>
<td>.0748</td>
</tr>
<tr>
<td>WB z score</td>
<td>-.103 ± .907</td>
<td>-.916 ± .824</td>
<td>-.988 ± 1.21</td>
<td>-1.12 ± 1.24</td>
<td>.1412</td>
</tr>
<tr>
<td>WB t score</td>
<td>-.418 ± .904</td>
<td>-1.32 ± .836</td>
<td>-1.24 ± 1.2</td>
<td>-1.56 ± 1.25</td>
<td>.0614</td>
</tr>
</tbody>
</table>

** **p < .05

The mean WB BMD z score value for the active group was -.416 while the nonactive z-score mean was -.999. Both groups were lower than normal, but the active group mean was higher than the nonactive. Table 3 displays the WB BMD of the nonactive men with paraplegia to be similar to that of the active men with quadriplegia.

As a result of the z-score and t-score interactions and the obvious group differences, a four level one factor ANOVA was computed for the WB BMD data. This analysis also produced a p value of .0791 and the Scheffe's post hoc analysis revealed no significant difference between any of the four groups. The one
factor ANOVA tables, interaction line plots and Scheffe's post hoc analysis results can be found in Appendix H.

Lean Muscle Mass Analysis

LMM data was also analyzed utilizing a two factor ANOVA. The results were that there was no significant difference between groups (para vs. quad) \( p = .7846 \), or between groups (active vs. nonactive) \( p = .9727 \). Table 4 contains the numbers describing the LMM data. Appendix E contains the two factor ANOVA table.

A four level one factor ANOVA analysis produced a \( p = .9724 \) with no significance between any of the four groups. One factor ANOVA data analysis can be found in Appendix H.

Table 4
Lean Muscle Mass Means, Standard Deviations and P value

<table>
<thead>
<tr>
<th></th>
<th>Act Para (n= 14)</th>
<th>Non Para (n= 14)</th>
<th>Act Quad (n= 9)</th>
<th>Non Quad (n= 9)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMM (Kgs)</td>
<td>54.47 ± 10.4</td>
<td>55.25 ± 8.2</td>
<td>54.23 ± 7.9</td>
<td>53.62 ± 4.26</td>
<td>.9727</td>
</tr>
</tbody>
</table>

**\( p < .05 \)**

The nonactive men with paraplegia had the largest amount of LMM 55.25 Kilograms.
Hip BMD Analysis

Hip BMD data analysis revealed no significant difference between paras/quads or between active/non groups at the total hip (p = .1636 and .1117 respectively) (Table 5), intertrochanter (p = .1648 and .1642) (Table 5) or femoral neck (p = .2462 and .2229) (Table 5). However, there was a significant difference between groups (active vs. nonactive) at the trochanter (p = .04) with the active group having higher BMD values at this site. This was not the case within groups para vs. quad at the trochanter site p-value = .3956 (Table 5). P values reported in table 5 are between the active and nonactive groups. Two factor ANOVA tables for sites of the hip are in Appendix E.

The proximal femur was the site used for analyses of BMD in the legs of men with SCI. This was due to the data analyses capabilities of the QDR 1000/W. Most fractures in this population occur in the long bones or femur, but the QDR 1000/W was not capable of site specific analysis.

Four level one factor ANOVA's were computed for all sites of the hip. For the total hip a p value of .0995 was produced. Scheffe's post hoc analysis displayed no significant difference between the four groups. The intertrochanter site p value was .1260. Scheffe's post hoc also revealed no significant difference between the four groups. The neck analysis showed that there was no significant difference for the one factor ANOVA or the post hoc analysis. The trochanter site had a p value of .0779 and the
post hoc analysis showed that there was no significant difference between the four groups. Results of the four level one factor data analysis for all sites of the hip are located in Appendix H.

Table 5

<table>
<thead>
<tr>
<th></th>
<th>Act Para (n=14)</th>
<th>Non Para (n=14)</th>
<th>Act Quad (n=9)</th>
<th>Non Quad (n=9)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tot Hip BMD</td>
<td>.79 ± .14</td>
<td>.649 ± .107</td>
<td>.678 ± .18</td>
<td>.668 ± .192</td>
<td>.1117</td>
</tr>
<tr>
<td>Inter BMD</td>
<td>.897 ± .19</td>
<td>.734 ± .13</td>
<td>.754 ± .21</td>
<td>.753 ± .23</td>
<td>.1642</td>
</tr>
<tr>
<td>Neck BMD</td>
<td>.717 ± .10</td>
<td>.611 ± .15</td>
<td>.634 ± .14</td>
<td>.631 ± .17</td>
<td>.2229</td>
</tr>
<tr>
<td>Troch BMD</td>
<td>.631 ± .12**</td>
<td>.520 ± .09</td>
<td>.554 ± .16**</td>
<td>.508 ± .12</td>
<td>.0430</td>
</tr>
<tr>
<td>Tot hip z score</td>
<td>-1.78 ± .90</td>
<td>-2.79 ± .79</td>
<td>-2.68 ± 1.32</td>
<td>-2.6 ± 1.47</td>
<td>.1716</td>
</tr>
<tr>
<td>Inter z-score</td>
<td>-2.03 ± 1.06</td>
<td>-2.96 ± .80</td>
<td>-2.91 ± 1.32</td>
<td>-2.79 ± 1.52</td>
<td>.2636</td>
</tr>
<tr>
<td>Neck z-score</td>
<td>-1.45 ± .69</td>
<td>-2.53 ± 1.3</td>
<td>-2.52 ± 1.04</td>
<td>-2.29 ± 1.52</td>
<td>.2342</td>
</tr>
<tr>
<td>Troch z-score</td>
<td>-1.22 ± 1.06</td>
<td>-2.18 ± .81</td>
<td>-2.0 ± 1.44</td>
<td>-2.26 ± 1.14</td>
<td>.0803</td>
</tr>
<tr>
<td>Tot hip t-score</td>
<td>-2.14 ± .96</td>
<td>-3.25 ± .82</td>
<td>-2.98 ± 1.33</td>
<td>-3.11 ± 1.47</td>
<td>.0790</td>
</tr>
<tr>
<td>Inter t-score</td>
<td>-2.37 ± 1.13</td>
<td>-3.39 ± .86</td>
<td>-3.18 ± 1.33</td>
<td>-3.26 ± 1.56</td>
<td>.1442</td>
</tr>
<tr>
<td>Neck t-score</td>
<td>-2.08 ± .76</td>
<td>-3.34 ± 1.38</td>
<td>-3.03 ± 1.10</td>
<td>-3.17 ± 1.57</td>
<td>.0702</td>
</tr>
<tr>
<td>Troch t-score</td>
<td>-1.48 ±1.05</td>
<td>-2.52 ± .79**</td>
<td>-2.22 ± 1.45</td>
<td>-2.63 ± 1.14</td>
<td>.0380</td>
</tr>
</tbody>
</table>

**p < .05

The z-scores and t-scores from Table 5 further describes the hip BMD levels for all groups. In all cases, the active group
(active para and active quad) was higher than the nonactive group. The combined paraplegic group was always higher than the combined quad group. However, the nonactive paraplegic group had lower BMD values throughout the entire hip when compared to both the active and inactive men with quadriplegia groups. The active men with paraplegia had the highest values and scores for all sites of the four groups used.

Forearm Analysis

The radii of the active group were compared using a one sample t-test comparing the mean z-score of the active, paras/quads, group forearm values to the population z-score, which is 0, of forearm data of normal men. All sites except the left lower1/3 of the radius produced no significant difference. Only the left lower1/3 of the radius was significantly different than zero (p = .01). The results from these analyses are in Table 6.
Table 6
One Sample t-test Table for Forearm Data
Active SCI vs. Normal

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>DF</th>
<th>t-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF TOT Z-SCORE</td>
<td>.259</td>
<td>22</td>
<td>.993</td>
<td>.3313</td>
</tr>
<tr>
<td>LF TOT Z-SCORE</td>
<td>.244</td>
<td>22</td>
<td>.998</td>
<td>.3292</td>
</tr>
<tr>
<td>LF 1/3 Z SCORE</td>
<td>.557</td>
<td>22</td>
<td>2.735</td>
<td>.0121</td>
</tr>
<tr>
<td>RF 1/3 Z SCORE</td>
<td>.323</td>
<td>22</td>
<td>1.468</td>
<td>.1563</td>
</tr>
<tr>
<td>LF MID Z SCORE</td>
<td>.310</td>
<td>22</td>
<td>1.210</td>
<td>.2391</td>
</tr>
<tr>
<td>RF MID Z SCORE</td>
<td>.342</td>
<td>22</td>
<td>1.268</td>
<td>.2180</td>
</tr>
<tr>
<td>LF UD Z SCORE</td>
<td>.046</td>
<td>22</td>
<td>-.181</td>
<td>.8584</td>
</tr>
<tr>
<td>RF UD Z SCORE</td>
<td>.099</td>
<td>22</td>
<td>.396</td>
<td>.6960</td>
</tr>
</tbody>
</table>

** p < .05
Chapter Five
Discussion

Bone mineral density in men with spinal cord injuries is a problem that needs to be addressed. This chapter discusses the results from this investigation in the order that the statistical hypotheses were stated in Chapter One.

The first hypothesis was that physically active men with SCI would have a higher whole body BMD than nonactive men with SCI. No support for this hypothesis was determined. The results from this study show a trend that the active subjects regardless of level of injury had a larger whole body BMD than the nonactive group. Though not evident from statistical analysis to the .05 level of confidence an apparent trend may suggest that vigorous physically active men who have SCI may help maintain bone integrity. This is evident due to the whole body BMD p-value of .0748 and the z-score analysis.

The z-score analysis (Tables 3 and 6 in Chapter 4, Figures 4 - 8 in Appendix E) showed that the active group had a higher value (-.465) compared to the nonactive group (-.999). Both z-score means are in the negative, thus -.465 was a relatively lower reduction in age/gender BMD. The z-score comparison by group further describes the WB BMD of each group. The active men with paraplegia had the lowest z-score mean -.103 and the inactive men with quadriplegia had the highest z-score mean -1.119. The z-scores support the hypothesis that WB BMD would
be higher in physically active men with SCI, though not to the .05 level of statistical significance. A small sample size and other unaccounted factors such as genetics and age of onset may exist that prevented these variables from being statistically significantly different. Perhaps the more important message that comes from the z-score analysis is that nonactive men with paraplegia have BMD's comparable to that of active and nonactive men with quadriplegia.

The second hypothesis was that active and nonactive men with SCI would have equal levels of BMD at various sites of the hip. In general, the data support this hypothesis. However, there was a significant difference between groups (active/nonactive) at the trochanter site p-value = .0430. The z-score analysis again helped to further describe what actually is the case for these populations. All groups were close to or at the defined levels of osteopenia (-2.0 t-score) for all sites except the trochanter where active men with paraplegia had significantly lower z-scores.

This could be attributed to a couple of factors. First the active group had lower levels of injuries even though matched by para/quad categorization. Secondly, with the incomplete injuries comes the ability to bear weight while transferring from wheelchair to car, bed, couch etc. or maybe even the capacity to stand without the assistance of bracing thus loading bones of the lower extremities. The data that was exchanged between Dr. Kiratli and the OSU Bone Lab did not allow all levels of injuries to be directly matched (Table 2 Chapter 4). However, the data did
present the same number of men with quadriplegia and paraplegia.

Type of injury could have played a role in this area of research. Incomplete injuries can allow more muscular function to exist which equals more muscle throughout the entire body. The active group had 13 incomplete injuries compared to five in the nonactive group. Incomplete injuries usually mean additional use of muscles below the level of lesion. This plus the already lower levels of injuries for the active group may help to explain why there was a difference at the trochanter in the hip. This also may help explain the self selection of active lifestyles, more function.

The third research hypothesis was that physically active men with SCI would have a larger amount of lean muscle mass than nonactive men with SCI. This was not supported by the analysis. The values in LMM of the subjects were not statistically significant between groups p-value = .9727. This may be due to the type and definition of athlete used in the study. The active men in this investigation were not elite athletes, but individuals who regularly participated in physical activity. The absence of systematic training which is directed to body composition may may have affected the results. In addition, other factors may exist that could potentially negate their involvement in physical activity such as alcohol consumption, poor diet, and the lack of knowledge on proper training techniques to maximize performance. A possible explanation of the LMM analysis may be
that the active group may be very active outside of the home but relatively inactive at home while the nonactive group may not participate in physical activity as described by this research project but are engaged in enough activity to maintain their LMM.

The fourth research hypothesis was that active men with SCI would have a larger BMD value in the radii of the forearm than men who did not have SCI. There were relatively no significant differences in the radii data. The mean values for the active men with SCI were higher than the men with no SCI, but not large enough to establish a significant difference, at all sites. There was a significant difference at the left one third radius $p= .0121$. This may be due to the redistribution of force on the forearm as a result of loading while ambulating in a wheelchair. In the able bodied population, differences between the radius of the dominate forearm and that of the nondominate forearm have been found (Huddleston et al., 1980). Four of the 23 active subjects were left handed. Wheelchair propulsion may be an activity that produces enough change in the nondominate forearm (left) that a significant difference was detected in the left arm of active men with SCI when compared to men with no SCI. Comparing the forearms of the active group to those of the nonactive group would have been a nice addition to this project, unfortunately this was not possible with the existing sample.

Hypothesis four was that the active group with SCI would have a greater forearm BMD than men who did not have SCI thus not using a wheelchair for ambulation. The active men with SCI
did have a higher mean value than men without SCI, but there was no statistically significant difference.

Complications

Some complications did arise during data collection. Two active subjects were broader than the densitometer which forced them to place their arms and hands on their stomachs so that a whole body BMD could be obtained. One active subject was touching the tissue bar with his foot, part of the body that he could not feel nor control, so consequently his body composition data could not be calculated. Contractures, spasms, and prolonged periods on bony protusions all forced adaptations to the data collection process.

The densitometer machines, Hologic QDR 1000/W, are the same at each site, Oregon State University and Palo Alto VA Medical Center, but the protocols for data collection were different. Different in the order the scans were taken, tested by different technicians, and different questions were asked. Collaboration enhanced the scope of this research project and allowed data to be used that would not have been available from the Corvallis community. For future projects obtaining data under the same protocol would be a compliment to that project.

The subjects in this study had complete and incomplete injuries. Although comparisons were not analyzed between these two groups, potential differences may exist. Using one or the
other would have some advantages, or conducting a study comparing the two would add to the knowledge base of these types of injuries.

Metal in the body presents obvious problems for a study of this nature. Metal is detected by the densitometer as a very dense bone thus altering the results. A few of the subjects that participated in this study had various amounts of metal including Harrington rods, wire in spinal column, a bullet in neck, and numerous plates screws and pins. Delimiting all subjects who had metal in the body would be a good idea, but it may also mean a lower number of subjects. Metal appeared more in paraplegics than in quadriplegics. This may be due to the type of medical treatment to rehabilitate each injury. Quads are typically placed in a halo traction device following bone grafting surgery that does not require any rods or such along the spinal column, while injuries to lower areas along the spinal column may have required metallic fixation.

Age of onset may be a factor that was considered, but not controlled. The age of onset is of importance because potentially if an SCI occurred before full bone maturation than that person's bone may have never reach normal peak mass. With there being a large age difference and a not so large difference of years post injury, perhaps the onset of injury for the active group was earlier in life then the nonactive group. This could mean that some of the bones of subjects in the active group did not reach
normal BMD levels prior to injury and thus post injury levels were lower than normal.

There was a significant age difference between the two groups. As a result of this difference a regression analysis was performed for all measures taken that were compared between the two groups. The various correlations of age with LMM, WB BMD, Hip BMD revealed age did not correlate with any dependent measure.

Recommendations for Future Study

Despite the findings in this study, some recommendations can be made to improve future work conducted with this population:

1) Increase the sample size. Increased statistical power would assist in identifying whether statistical significance is evident.

2) Matching variables before data is collected could help reduce some possible confounding variables. Such variables as level of injury, age, type of injury, diet, onset of injury and years post injury should all be matched very closely for each subject participating in additional research.

3) Elite wheelchair athletes may need to be subjects defined as active in future research, or at least tighter definitions to divide the groups more clearly. The reason elite athletes should participate is there may be a definite training effect on
this group of athletes due to a larger motivational reward, cash and prizes, for those who excel in wheelchair athletics. The definitions used for this project were concise, yet too broad. All physical activity, including vocational activities and all activities of daily living, needed to be listed with classification based on quantitative analysis.

4) Using a single protocol for each laboratory would be strongly recommended for future studies.

5) Conducting a large cross sectional study by age of onset, level of SCI, with quantification of activity level would be of benefit to this body of research.

6) The last suggestion would be that of a longitudinal study. Randomly assign men with SCI to physically active and non physically active groups and review the BMD pre and post treatment at 6 month intervals for a period of one or two years.

Conclusions

Emerging trends may exist with active men with SCI having slightly higher BMD values than nonactive men with SCI. Future studies need to be conducted to further investigate this potential benefit for men with SCI's who participate in wheelchair sports. No information was found to suggest that physical activity is detrimental to this population and it may be of benefit to BMD levels. The body needs exercise, regardless of abilities. Due to
the apparent trends, men with spinal cord injuries should be physically active.
References


APPENDICES
APPENDIX A
Informed Consent

TITLE: A Comparison of Bone Mineral Density Between Active and Nonactive Men with Spinal Cord Injuries

INVESTIGATOR: Jeff McCubbin, Ph.D. & William C. Eddins, M.S. Candidate

PURPOSE: To determine if there is an increase in bone mineral density as a result of participating in wheelchair sports or physical activity.

It has been explained to me that the bone mineral scans will be done using the Hologic QDR 1000W Bone Densitometer a noninvasive dual energy x-ray absorptiometer, and that my body will be exposed to 1/10 of the radiation amount exposed by a normal chest x-ray. This machine will take a full body scan and a scan of the radius bone of my arm. The testing will require that I lie perfectly still while the actual scan is being taken.

I understand that the possibility of injury may exist during my testing time at the Bone Research Laboratory, but that possibility is very slight since testing will be closely monitored by trained personnel. It was also brought to my attention that if physical assistance is needed to help transfer me from my chair to the bone densitometer that I must instruct the volunteers in assisting me. The volunteers are also trained personnel in lifting and transferring individuals from wheelchair to bone densitometer.

I understand that the University does not provide a research subject with compensation or medical treatment in the event a subject is injured as a result of participation in the research project.

The benefits of my participation include contributing to the scientific study of the effect of physical activity on the bone mineral density of spinal cord injured men. I understand that I will gain knowledge concerning my body composition, and level of bone mineral density.

I understand that my participation in the project will involve approximately 1 hour.
I understand that confidentiality will be maintained at all times. At no time will my name appear on record form or in computer files in reference to the study. A code number will be used to identify my data and all records be kept using the code number. I have been informed that this study will take place at Oregon State University in the Bone Research Laboratory and that I will not be reimbursed for my mileage or other travel expenses to OSU and that it is my responsibility to get to Corvallis, OR.

I have been completely informed and understand the nature and purpose of this research. The researchers have offered to answer any further questions that I may have. I understand that my participation in this study is completely voluntary and I may withdraw from the study at any time without prejudice or loss of benefits to which my participation entitles me. Questions about the research or any aspect of my participation should be directed to Bill Eddins at 737-5927 or Jeff McCubbin at 737-5921. I have read the foregoing and agree to participate.

Subject Signature__________________________ Date________

Address______________________________

Investigator's Signature__________________________ Date________
APPENDIX B
1. Brief Description of the Study

Osteoporosis is a large problem in the American geriatric population. After a spinal cord injury (SCI), osteoporosis invariably occurs. Osteoporosis is a reduction in bone mass to the point that the chance of fracture increases drastically (Snow-Harter & Marcus, 1991). Currently there are over 2 million Americans with SCI's and the number increases annually. Studies have shown that physical activity and bone mineral density (BMD) have a positive relationship. People who are physically active have a larger BMD value than those who do not participate in physical activity (Snow-Harter, Whalen, Myburgh, Arnaud & Marcus, 1992). With osteoporosis being a direct consequence of an SCI, it is important to try and determine a way to combat its onset. Thus, the purpose of this study is the effects of physical activity on the bone mineral density of spinal cord injured men. Jennie Kiratli, PhD, Research Health Scientist at the Spinal Cord Center at the V.A. Medical Center in Palo Alto, California will provide data for the nonactive group of spinal cord injured men. This data will consist of BMD values of bilateral radius, whole body, and femoral necks. Only numbers will be given, NO NAMES. Data pertaining to each subject's lifestyle will also be shared for the purpose of matching individuals in each group for comparison. This information will be whether the person smokes, level of injury, body type, race, and years post injury. The data from the subjects that Dr. Kiratli has obtained are patients of the V.A. Medical Center in Palo Alto.

2. Methods

Dual Energy X-ray Absorptiometry (Bone Mineral Density)

The subjects, approximately 25, will be tested using the Hologic QDR 1000/W, a bone densitometer. The testing will take place in the Bone Research Laboratory at Oregon State University. Each subject will be asked come to Corvallis, Oregon to take part in this study. Before their arrival each subject will be required to fill out a health, physical activity, and injury history questionnaire before testing. After the questionnaire and informed consent forms have been obtained, testing will take place. The subjects will either position themselves or physically assisted on to the bone densitometer for scanning. The order of the scans will be 1) whole body 2) bilateral radius 3) femoral necks.
3. Risks or Benefits to the Subjects

Benefits

Subjects will learn information about their current BMD level. A whole body scan will be taken to give each subject their present, accurate body fat percentage value. A value, for this population, that can not be accurately determined in any other way. Hopefully, the results of this study will show that participation in physical activity will increase the BMD levels of SCI men.

Risks

The subjects will be exposed to a small amount of radiation, less than 1/10 the amount exposed for a chest X-Ray. The additional scans will only change the radiation exposure to the above plus that of a dental X-ray. Transferring from wheelchair to bone densitometer may present some risk, but trained personnel will be in the lab to assist each transfer. The transfer style that will be used is a two-person lift. Essentially, this simply means that two people will be utilized during the transfer, one at the lower extremities and one at the upper extremities.

4. Subject Population

The subject population will be spinal cord injured men aged 20-50 whose injuries have existed for at least two years. Each subject must use a wheelchair for ambulation at least 80% of the time. Men are the only subjects used because research shows that over 80% of spinal cord injuries are received by men.

5. Informed Consent- See Attached Form

6. Method of Obtaining Consent

Potential subjects will be contacted through community wheelchair sports programs and rehabilitation programs. Informed consent document, Physical Activity Health and Injury History Questionnaire, and a brief description of the study will be sent to the potential subjects so that an informed choice can be made about participating. Participation will be voluntary. Each subject will be familiarized with the purpose of the study, the risks and benefits of participation in the study. Once informed
consent is obtained, testing will be scheduled at a mutually agreed upon time.

7. Subject Confidentiality

Subject confidentiality will be maintained at all times. Only the researchers involved in the study will have access to the subject's information which will be stored using coded identifiers. Published scientific results will not reveal any subject's identity.

8. See Attached

9. N/A

10. N/A
APPENDIX C
OREGON STATE UNIVERSITY BONE RESEARCH LABORATORY
Health, Physical Activity, and Injury History

Last name  First Name  Middle
D.O.B.

Address, street  work, home #

City, State  Occupation and/or sports team

__________Pounds  ________ft______inches
Weight  Height

Please list your present medications and dosages here (include vitamins, minerals, and other supplements):

*********************************************************

PAST HISTORY (Check if yes) FAMILY HISTORY (Check if yes)
Have you ever had?  Have your grandparents, parents or siblings had?
High cholesterol  Diabetes
Rheumatic fever  Heart attacks
Heart murmur  High blood pressure
Disease of arteries  High cholesterol
Varicose veins  Congenital heart disease
Heart trouble  Heart Trouble
Lung disease  Other
Operations  Back injury
Other musculoskeletal injury or problems

Date of last medical exam?
Epilepsy
Physician:
If yes to any of the above, please explain
PRESENT SYMPTOMS REVIEW (Check if yes)
Have you recently had?
- Chest pain
- Shortness of breath
- Heart palpitations
- Cough on exertion
- Coughing blood
- Back pain
- Painful, stiff, swollen joints

HEALTH HABITS
Smoking
- YES
- NO

Do you smoke cigarettes
- How many/day?
- How many years?

Cigar
- How many/day?
- How many years?

Pipe
- Times/day?
- How many years?

If you have quit smoking, when did you quit?
- How many years did you?

Alcohol Consumption
Do you drink alcohol daily?
- Y
- N (circle one)

Consumption of calcium-rich dairy products
How many 8 oz glasses of milk do you drink per day?
- per week?

How many servings of cheese (1 oz) do you eat per day?
- per week?

How many servings of yogurt (1 cup) do you eat per week?

Body Weight
What was your weight 1 month ago?
- What was your weight 2 months ago?

Cola Beverages
How many cola beverages do you drink daily?

How many years have you been drinking cola beverages on a regular basis?

PHYSICAL ACTIVITY
LIST ALL SPORTS OR ACTIVITIES IN WHICH YOU HAVE PARTICIPATED DURING THE PAST YEAR: (Examples include aerobics, tennis, golf, dance, weight training, etc.)
Use the back of this sheet if necessary

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>AVE # HRS/WK</th>
<th>AVE # MONTHS/YN</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX. Aerobics</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
LIST YOUR INVOLVEMENT IN SPORTS ACTIVITIES FOR 4 YEARS PRIOR TO ABOVE:
(Use back if necessary)

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>AVE # HRS/WK</th>
<th>AVE# MONTHS/YR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex. Volleyball</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

Briefly describe your involvement in physical activity since high school.

Briefly describe your physical activity level before your injury.

OSTEOPOROSIS RISK FACTORS
Please circle true or false for the following. If you think a statement may apply to you but are not sure, place a question mark (?) by that statement.

1. true or false I have a history of rheumatoid arthritis.
2. true or false I have been treated with cortisone or similar drugs.
3. true or false I have a close relative with osteoporosis.
4. true or false I have a history of an overactive thyroid gland.
5. true or false I have a history of an overactive parathyroid gland.
6. true or false I have a history of alcoholism.
7. true or false I have a history of chronic liver disease.
8. true or false I have a history of multiple myeloma.
9. true or false I have a history of the blood tumor, leukemia.
10. true or false I have a history of stomach ulcers.
11. true or false I have lactase deficiency (inability to digest milk).
12. true or false Some of my stomach has been surgically removed.
13. true or false I take anabolic steroids now or have in the past.
14. true or false I avoid milk and other dairy products.
15. true or false I usually eat meat at least twice a day.
16. true or false I drink more than 2 cups of coffee or tea daily.
17. true or false On average, I drink 2 or more soft drinks daily.
18. true or false I have about 3 or more alcoholic beverages daily.
19. true or false I follow a vegetarian diet and have so for years.
20. true or false I am of Caucasian (white race) ancestry.
21. true or false I am of Asian (Oriental race) ancestry.
22. true or false I am of African-American (black) ancestry.
23. true or false I am of Mexican-American or Hispanic ancestry.
24. true or false I am not very physically active most of the time.
25. true or false I have lost more than 1 inch in height.
26. true or false I take or have taken thyroid hormone pills.
27. true or false I took Phenobarbital or dilantin for over a year.
28. true or false I use Maalox or Mylanta antacids frequently.
29. true or false I have taken furosadime (Lasix) for over a year.
30. true or false I have been treated with lithium for over a year.
31. true or false I have been treated with chemotherapy for cancer.
32. true or false I take or have taken cyclosporin A (Sandimmune).
33. true or false I have received an organ transplant (kidney etc.).
34. true or false I have had trouble with anorexia nervosa or bulimia.
INJURY HISTORY

What is your level of injury? 

Is your injury complete or incomplete? 

If incomplete what level do you have neuromuscular function? 

At what age did you receive your injury? 

How many years ago? 

Can you walk with assistance? 

If yes, How much do you walk (Hrs. per day)? 

Do you participate in competitive wheelchair sport? 

If yes, what sport(s)? 

If yes, how many years? 

What is your NWBA classification? 

Did you compete in sports prior to your injury? 

If yes, what sports and how long? 

How much time past, after your injury, before you began participating in physical activity?
Figure 1

Simple Regression LMM vs. Age for All Subjects

\[ Y = 56399.244 - 49.927 \times X; R^2 = .002 \]
Figure 2

Simple Regression Whole Body BMD vs. Age for All Subjects

\[ Y = 1.053 + 8.734 \times 10^{-5} \times X; \quad R^2 = 4.569 \times 10^{-5} \]
Figure 3

Simple Regression Hip BMD vs. Age for All Subjects

\[ Y = 0.825 - 0.003 \times X; R^2 = 0.028 \]
Table 7
Two Factor ANOVA Table for WB BMD

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active vs Non</td>
<td>1</td>
<td>.032</td>
<td>.032</td>
<td>3.342</td>
<td>.0748</td>
</tr>
<tr>
<td>Para vs Quad</td>
<td>1</td>
<td>.025</td>
<td>.025</td>
<td>2.629</td>
<td>.1126</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>.006</td>
<td>.006</td>
<td>.676</td>
<td>.4156</td>
</tr>
<tr>
<td>Residual</td>
<td>41</td>
<td>.388</td>
<td>.009</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8
Two Factor ANOVA Table for Total Hip BMD

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active/Nonactive</td>
<td>1</td>
<td>.060</td>
<td>.060</td>
<td>2.645</td>
<td>.1117</td>
</tr>
<tr>
<td>Para/Quad</td>
<td>1</td>
<td>.023</td>
<td>.023</td>
<td>1.004</td>
<td>.3224</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>.046</td>
<td>.046</td>
<td>2.014</td>
<td>.1636</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>.906</td>
<td>.023</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9
Two Factor ANOVA Table for Femoral Neck BMD

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Para/Quad</td>
<td>1</td>
<td>.011</td>
<td>.011</td>
<td>.535</td>
<td>.4686</td>
</tr>
<tr>
<td>Active/Nonactive</td>
<td>1</td>
<td>.031</td>
<td>.031</td>
<td>1.533</td>
<td>.2229</td>
</tr>
<tr>
<td>Interaction</td>
<td>1</td>
<td>.028</td>
<td>.028</td>
<td>1.385</td>
<td>.2462</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>.810</td>
<td>.020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 10
Two Factor ANOVA Table for Intertrochanter BMD

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Para/Quad</td>
<td>1</td>
<td>.041</td>
<td>.041</td>
<td>1.170</td>
<td>.2859</td>
</tr>
<tr>
<td>Active/Nonactive</td>
<td>1</td>
<td>.071</td>
<td>.071</td>
<td>2.008</td>
<td>.1642</td>
</tr>
<tr>
<td>Interaction</td>
<td>...</td>
<td>.071</td>
<td>.071</td>
<td>2.002</td>
<td>.1648</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>1.413</td>
<td>.035</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11
Two Factor ANOVA Table for Trochanter BMD

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Para/Quad</td>
<td>1</td>
<td>.021</td>
<td>.021</td>
<td>1.380</td>
<td>.2470</td>
</tr>
<tr>
<td>Active/Nonactive</td>
<td>1</td>
<td>.066</td>
<td>.066</td>
<td>4.369</td>
<td>.0430</td>
</tr>
<tr>
<td>Interaction</td>
<td>...</td>
<td>.011</td>
<td>.011</td>
<td>.738</td>
<td>.3956</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>.605</td>
<td>.015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12
Two Factor ANOVA Table for LMM

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active/Nonactive</td>
<td>1</td>
<td>79739.178</td>
<td>79739.178</td>
<td>.001</td>
<td>.9727</td>
</tr>
<tr>
<td>Para/Quad</td>
<td>1</td>
<td>9230093.454</td>
<td>9230093.454</td>
<td>.137</td>
<td>.7134</td>
</tr>
<tr>
<td>Interaction</td>
<td>...</td>
<td>5110423.141</td>
<td>5110423.141</td>
<td>.076</td>
<td>.7846</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>2699129088.002</td>
<td>67478227.200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 4
Interaction Line Plot for WB BMD Mean z-score for All Groups
Figure 5

Interaction Line Plot for Hip Neck BMD Mean z-score for All Groups
Figure 6

Interaction Line Plot for Hip Trochanter BMD Mean z-score for All Groups
Figure 7

Interaction Line Plot for Hip Intertrochanter BMD Mean z-score for All Groups
Figure 8

Interaction Line Plot for Total Hip BMD Mean z-score for All Groups
Figure 9

Interaction Line Plot for WB BMD Mean t-score for All Groups
Figure 10

Interaction Line Plot for Hip Neck BMD Mean t-score for All Groups
Figure 11

Interaction Line Plot for Hip Trochanter Mean t-score for All Groups
Figure 12
Interaction Line Plot for Hip Intertrochanter BMD Mean t-score for All Groups
Figure 13

Interaction Line Plot for Total Hip BMD Mean t-score for All Groups
APPENDIX H
Table 13
Four Level One Factor ANOVA Table for WB BMD

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act/Non-Para/Quad</td>
<td>3</td>
<td>.069</td>
<td>.023</td>
<td>2.428</td>
<td>.0791</td>
</tr>
<tr>
<td>Residual</td>
<td>41</td>
<td>.388</td>
<td>.009</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 14
Line Plot for WB BMD for All Groups

1 = Active, 2 = Nonactive, p = Paraplegia, q = Quadriplegia
### Table 14
**Scheffe's Post Hoc Analysis Table for WB BMD**

<table>
<thead>
<tr>
<th>Mean Diff.</th>
<th>Crit. Diff</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1p, 1q</td>
<td>.072</td>
<td>.123</td>
</tr>
<tr>
<td>1p, 2p</td>
<td>.078</td>
<td>.109</td>
</tr>
<tr>
<td>1p, 2q</td>
<td>.102</td>
<td>.123</td>
</tr>
<tr>
<td>1q, 2p</td>
<td>.006</td>
<td>.121</td>
</tr>
<tr>
<td>1q, 2q</td>
<td>.030</td>
<td>.134</td>
</tr>
<tr>
<td>2p, 2q</td>
<td>.024</td>
<td>.121</td>
</tr>
</tbody>
</table>

1 = Active, 2 = Nonactive, p = Paraplegia, q = Quadriplegia

### Table 15
**Four Level One Factor ANOVA Table for LMM**

<table>
<thead>
<tr>
<th>Act/Non-para/quad</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>15455791.588</td>
<td>5151930.529</td>
<td>.076</td>
<td>.9724</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>2699129088.002</td>
<td>67478227.200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 15
Line Plot for LMM for All Groups

1 = Active, 2 = Nonactive, p = Paraplegia, q = Quadriplegia

Table 16
Scheffe's Post Hoc Analysis Table for LMM

<table>
<thead>
<tr>
<th></th>
<th>Mean Diff.</th>
<th>Crit. Diff</th>
<th>P-Value...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1p, 1q</td>
<td>238.683</td>
<td>10570.693</td>
<td>&gt;.9999</td>
</tr>
<tr>
<td>1p, 2p</td>
<td>-780.690</td>
<td>9430.565</td>
<td>.9963</td>
</tr>
<tr>
<td>1p, 2q</td>
<td>845.994</td>
<td>10570.693</td>
<td>.9966</td>
</tr>
<tr>
<td>1q, 2p</td>
<td>-1019.374</td>
<td>10241.990</td>
<td>.9935</td>
</tr>
<tr>
<td>1q, 2q</td>
<td>607.311</td>
<td>11300.546</td>
<td>.9990</td>
</tr>
<tr>
<td>2p, 2q</td>
<td>1626.685</td>
<td>10241.990</td>
<td>.9748</td>
</tr>
</tbody>
</table>

1 = Active, 2 = Nonactive, p = Paraplegia, q = Quadriplegia
Table 17
Four Level One Factor ANOVA Table for Total Hip BMD

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act/Non-para/quad</td>
<td>3</td>
<td>.152</td>
<td>.051</td>
<td>2.230</td>
<td>.0995</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>.906</td>
<td>.023</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 16
Line Plot for Total Hip BMD for All Groups

1= Active, 2= Nonactive, p= Paraplegia, q= Quadriplegia
Table 18
Scheffe's Post Hoc Analysis Table for Total Hip BMD

<table>
<thead>
<tr>
<th>Mean Diff.</th>
<th>Crit. Diff</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1p, 1q</td>
<td>.112</td>
<td>.190</td>
</tr>
<tr>
<td>1p, 2p</td>
<td>.141</td>
<td>.172</td>
</tr>
<tr>
<td>1p, 2q</td>
<td>.121</td>
<td>.190</td>
</tr>
<tr>
<td>1q, 2p</td>
<td>.029</td>
<td>.190</td>
</tr>
<tr>
<td>1q, 2q</td>
<td>.010</td>
<td>.207</td>
</tr>
<tr>
<td>2p, 2q</td>
<td>-.019</td>
<td>.190</td>
</tr>
</tbody>
</table>

1 = active, 2 = nonactive, p = Paraplegia, q = Quadriplegia

Table 19
Four Level One Factor ANOVA Table for Intertrochanter BMD

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act/Non-para/quad</td>
<td>3</td>
<td>.215</td>
<td>.072</td>
<td>2.024</td>
<td>.1260</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>1.413</td>
<td>.035</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 17
Line Plot for Intertrochanter BMD for All Groups

Table 20
Scheffe's Post Hoc Analysis Table of Intertrochanter BMD

<table>
<thead>
<tr>
<th></th>
<th>Mean Diff</th>
<th>Crit. Diff</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1p, 1q</td>
<td>.144</td>
<td>.238</td>
<td>.3857</td>
</tr>
<tr>
<td>1p, 2p</td>
<td>.163</td>
<td>.215</td>
<td>.1968</td>
</tr>
<tr>
<td>1p, 2q</td>
<td>.144</td>
<td>.238</td>
<td>.3851</td>
</tr>
<tr>
<td>1q, 2p</td>
<td>.019</td>
<td>.238</td>
<td>.9965</td>
</tr>
<tr>
<td>1q, 2q</td>
<td>1.111E-4</td>
<td>.259</td>
<td>&gt;.9999</td>
</tr>
<tr>
<td>2p, 2q</td>
<td>-.019</td>
<td>.238</td>
<td>.9965</td>
</tr>
</tbody>
</table>

1 = Active, 2 = Nonactive, p = Paraplegia, q = Quadriplegia
Table 21
Four Level One Factor ANOVA Table for Femoral Neck BMD

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act/Non-para/quad</td>
<td>3</td>
<td>.083</td>
<td>.028</td>
<td>1.367</td>
<td>.2667</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>.810</td>
<td>.020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 18
Line Plot for Femoral Neck BMD for All Groups

1 = Active, 2 = Nonactive, p = Paraplegia, q = Quadriplegia
Table 22
Scheffe's Post Hoc Analysis Table for Femoral Neck BMD

<table>
<thead>
<tr>
<th>Mean Diff.</th>
<th>Crit. Diff</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1p, 1q</td>
<td>.083</td>
<td>.180</td>
</tr>
<tr>
<td>1p, 2p</td>
<td>.105</td>
<td>.163</td>
</tr>
<tr>
<td>1p, 2q</td>
<td>.086</td>
<td>.180</td>
</tr>
<tr>
<td>1q, 2p</td>
<td>.022</td>
<td>.180</td>
</tr>
<tr>
<td>1q, 2q</td>
<td>.003</td>
<td>.196</td>
</tr>
<tr>
<td>2p, 2q</td>
<td>-.019</td>
<td>.180</td>
</tr>
</tbody>
</table>

1 = active, 2 = nonactive, p = Paraplegia, q = Quadriplegia

Table 23
Four Level One Factor ANOVA Table for Trochanter BMD

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act/Non-para/quad</td>
<td>3</td>
<td>.111</td>
<td>.037</td>
<td>2.445</td>
<td>.0779</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>.605</td>
<td>.015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 19
Line Plot for Trochanter BMD for All Groups

Table 24
Scheffe's Post Hoc Analysis Table for Trochanter BMD

<table>
<thead>
<tr>
<th></th>
<th>Mean Diff.</th>
<th>Crit. Diff</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1p, 1q</td>
<td>.077</td>
<td>.156</td>
<td>.5639</td>
</tr>
<tr>
<td>1p, 2p</td>
<td>.111</td>
<td>.141</td>
<td>.1681</td>
</tr>
<tr>
<td>1p, 2q</td>
<td>.123</td>
<td>.156</td>
<td>.1671</td>
</tr>
<tr>
<td>1q, 2p</td>
<td>.035</td>
<td>.156</td>
<td>.9357</td>
</tr>
<tr>
<td>1q, 2q</td>
<td>.046</td>
<td>.169</td>
<td>.8862</td>
</tr>
<tr>
<td>2p, 2q</td>
<td>.012</td>
<td>.156</td>
<td>.9970</td>
</tr>
</tbody>
</table>

1 = active, 2 = nonactive, p = Paraplegia, q = Quadriplegia