UNIVERSITI PUTRA MALAYSIA

EFFICACY OF CALCIUM SUPPLEMENTATION AND WEIGHT-BEARING EXERCISE ON BONE MINERAL DENSITY IN POSTMENOPAUSAL CHINESE WOMEN

CHAN YOKE MUN

FPSK (P) 2003 1
EFFICACY OF CALCIUM SUPPLEMENTATION AND WEIGHT-BEARING EXERCISE ON BONE MINERAL DENSITY IN POSTMENOPAUSAL CHINESE WOMEN

By

CHAN YOKE MUN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

May 2003
This thesis is dedicated to
my parents and my husband, Sing Ziunn
The etiology of age-related bone loss is unclear but both habitually low calcium intake and lack of physical activity have been proposed as its determinants. The objective of this two-year randomized controlled trial was to evaluate the efficacy of increasing calcium intake and weight-bearing exercise on bone mineral density (BMD) in postmenopausal Chinese women who were not on hormone replacement therapy.

Bone mineral density at the total body, lumbar spine L2-L4, femoral neck, Ward’s triangle, trochanter and total hip were measured using dual energy X-ray absorptionmetry (DEXA) at six month intervals. Information on sociodemographic background, lifestyle factors and reproductive history were assessed using a validated questionnaire. Calcium intake was evaluated by both the three-day food record and food frequency questionnaire at baseline, 12 and 24 months. Exercise habits were assessed with an exercise diary and Physical Activity Scale for the Elderly (PASE) questionnaire.
The baseline dietary data showed that dietary calcium intake was low among subjects with a mean intake of 444.0 ± 195.4 mg/day. Approximately 30% of the calcium intake was contributed by vegetables, beans and legumes while less than 15% was contributed from milk and dairy products.

The one-way within subjects ANOVA analysis indicated a significant time effect on bone loss for the control group at all skeletal sites. There were significant decreases in BMD at the total body (-0.77%), lumbar spine L2-L4 (-0.74%), femoral neck (-1.24%), Ward’s triangle (-2.60%), trochanter (-3.17%) and total hip (-2.21%) in the control group at 24 months when compared to baseline. For the calcium group, there was decrease in BMD at Ward’s triangle (-0.93%) but the decrease was not significant over time (95% confidence interval [CI]: -2.304 to 0.439; p > 0.05). There was virtually no significant bone loss in the calcium-exercise group at all the skeletal sites. There were significant increases in BMD at the femoral neck (+2.62%, p < 0.05), trochanter (+4.26%, p < 0.05) and total hip (+2.24%, p < 0.05). Inter-group comparisons on the changes in BMD over time were computed. Rate of bone loss was significantly higher in the control group as compared to the calcium or calcium-exercise group. There was a significant reduction in rate of bone loss in the calcium-exercise group as compared to calcium group at the femoral neck (+2.62% versus -0.90%), Ward’s triangle (+2.17% versus -0.93%), trochanter (+4.26% versus -0.11%) and total hip (+2.24% versus -0.26%). This indicates an additional effect of weight-bearing exercise over calcium supplementation on the hip regions.
In conclusion, increasing calcium intake and weight-bearing exercise were both effective in reducing rate of bone loss in postmenopausal women. The additional effect of weight-bearing exercise on the hip regions may suggest a site-specific effect of weight-bearing exercise on BMD. A major finding of this trial was the positive association between BMD and moderate exercise. This is important as it may be more feasible to encourage the public to engage in moderate exercises such as brisk walking rather than in strenuous exercise. These results support the implementation of a simple public health regimen to retard rate of bone loss by increasing calcium intake and encouraging moderate exercise.
Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**KEBERKESANAN KALSIUM SUPPLEMENTASI DAN SENAMAN KE ATAS KETUMPATAN MINERAL TULANG DI KALANGAN WANITA CINA MENOPAUS**

Oleh

CHAN YOKE MUN

Mei 2003

Pengerusi: Profesor Madya Dr. Zaitun Yassin, Ph.D.

Fakulti: Perubatan dan Sains Kesihatan

Walaupun etiologi kehilangan tulang berikutan penuaan tidak jelas, namun pengambilan kalsium yang rendah dan kekurangan aktiviti fizikal telah dikaitkan sebagai faktor penentunya. Objektif kajian kawalan rawak dua tahun ini adalah untuk menilai keberkesanan peningkatan pengambilan kalsium dan senaman ke atas ketumpatan mineral tulang (KMT) di kalangan wanita Cina posmenopaus yang tidak menerima terapi penggantian hormon.

Ketumpatan mineral tulang jumlah tubuh, lumbar L2-L4, pangkal pinggul, Ward, trokanter dan pinggul diukur dengan menggunakan kaedah ‘dual energy X-ray absorptionmetry (DEXA)’ setiap enam bulan. Maklumat latarbelakang sosiodemografi, faktor gaya hidup dan sejarah reproductif telah ditentukan dengan penggunaan borang soal selidik yang telah divalidasi. Pengambilan kalsium telah dikaji dengan menggunakan kaedah rekod pengambilan makanan tiga hari dan borang kekerapan pengambilan makanan tiga hari dan borang kekerapan
pengambilan makanan yang dijalankan pada permulaan kajian, 12 bulan dan 24 bulan. Senaman telah dinilai dengan menggunakan diari senaman dan borang soal selidik Physical Activity Scale for the Elderly (PASE).

Data pengambilan makanan menunjukkan pengambilan kalsium adalah rendah, dengan purata pengambilan sebanyak 444.0 ± 195.4 mg/hari. Lebih kurang 30% pengambilan kalsium disumbangkan oleh sumber sayur-sayuran dan kekacang sementara susu dan hasil tenusu pula menyumbang kurang daripada 15% daripada jumlah pengambilan kalsium.

Ujian ANOVA satu-hala antara subjek menunjukkan terdapat kesan masa yang signifikan terhadap kehilangan tulang di semua bahagian tulang di kalangan kumpulan subjek kawalan. Sebanyak 0.77% (jumlah tubuh), 0.74% (lumbar), 1.24% (pangkal pinggul), 2.60% (Ward), 3.17% (Trokanter) dan 2.21% (pinggul) kehilangan tulang telah dicatatkan di kalangan kumpulan kawalan pada bulan ke-24 berbanding dengan permulaan kajian. Untuk kumpulan kalsium, walaupun kehilangan tulang sebanyak 0.93% telah dicatatkan pada bahagian Ward tetapi kehilangan itu adalah tidak signifikan (95% jangkal keyakinan: -2.304 kepada 0.439; p> 0.05). Untuk kumpulan kalsium-senaman, tidak ada sebarang kehilangan tulang yang dicatatkan di mana-mana bahagian tulang. Terdapat peningkatan KMT pada bahagian pangkal pinggul (+2.62%, p< 0.05), trokanter (+4.26%, p< 0.05) dan pinggul (+2.24%, p< 0.05). Perubahan KMT mengikut masa telah dibandingkan di antara kumpulan kajian. Kadar kehilangan tulang adalah lebih tinggi di kalangan kumpulan kawalan berbanding dengan kumpulan kalsium senaman.
ataupun kumpulan kalsium-senaman. Juga, kadar kehilangan tulang yang lebih rendah dicatatkan di kalangan kumpulan kalsium-senaman berbanding kumpulan kalsium di bahagian pinggul (+2.24% berbanding -0.26%), pangkal pinggul (+2.62% berbanding 0.90%), ward (+2.17% berbanding -0.93%) dan trokanter (+4.26% berbanding -0.11%). Ini menunjukkan terdapat kesan tambahan akibat senaman di bahagian pinggul.

Kesimpulannya, peningkatan pengambilan kalsium dan senaman adalah berkesan untuk melambatkan kadar kehilangan tulang di kalangan wanita posmenopaus. Kesan tambahan akibat senaman di kawasan tulang pinggul mencadangkan kesan spesifik setempat senaman ke atas KMT. Perkaitan positif di antara KMT dan senaman sederhana merupakan satu keputusan yang bermakna kerana senaman sederhana seperti berjalan cepat adalah lebih mudah dilakukan berbanding dengan senaman yang lain. Data yang diperolehi menyokong implementasi regimen kesihatan awam untuk mengurangkan kadar kehilangan tulang melalui peningkatan pengambilan kalsium dan senaman sederhana.
ACKNOWLEDGEMENTS

This thesis would not have been possible without the help and expertise of many people. I wish to express my thanks, respect and gratitude to them. My deep appreciation goes to Associate Professor Dr. Zaitun Yassin for her guidance and concern in the preparation of this thesis. Her never-ending support of my work had offered me the impetus to complete my work. I am enormously grateful to my co-supervisors, Associate Professor Dr. Suriah Abdul Rahman, Professor Dr. Chan Siew Pheng and Dr. Mirnalini Kandiah for their careful review of the manuscript, encouragement and many helpful comments.

I would also like to thank the research team, Dr. Winnie Chee Siew Swee, Ms Lee Lai Fun and Mrs Yap Siew Lee for their assistance and encouragement throughout the period of this study. Special thanks to my good friend, Lai Fun, who combed the entire manuscript with her usual care and perception. To my beloved friends, S/N Cheah, Rani, Sophie and Cik Norlisa, thank you for your motivation and moral support.

To those who have helped me in the BMD scanning and biochemical analysis (technicians and laboratory assistants), thank you, for I could not have done it without you all. This thesis has been enriched by the participation of subjects whose continuing support and encouragement are priceless. Finally, I am also grateful for the financial support for this research from the Malaysian Government under the Intensified Research in Priority Research (IRPA) grant no: 06-02-05-9003.
I certify that an Examination Committee met on 5th May 2003 to conduct the final examination of Chan Yoke Mun on her Doctor of Philosophy thesis entitled “Efficacy of Calcium Supplementation and Weight-bearing Exercise on Bone Mineral Density in Postmenopausal Chinese Women” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**Khor Geok Lin, Ph.D.**
Professor  
Department of Nutrition and Health Sciences  
Faculty of Medicine and Health Sciences  
Universiti Putra Malaysia  
(Chairperson)

**Zaitun Yassin, Ph.D.**
Associate Professor  
Department of Nutrition and Health Sciences  
Faculty of Medicine and Health Sciences  
Universiti Putra Malaysia  
(Member)

**Suriah Abdul Rahman, Ph.D.**
Associate Professor  
Program of Food Science  
School of Chemical Science and Food Technology  
Faculty of Science and Technology  
Universiti Kebangsaan Malaysia  
(Member)

**Mirnalini Kandiah, Ph.D.**
Department of Nutrition and Health Sciences  
Faculty of Medicine and Health Sciences  
Universiti Putra Malaysia  
(Member)

**GULAM RUSUL RAHMAT ALI, Ph.D.**  
Professor/Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia  
Date: 28 May 2003
The thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

**Zaitun Yassin, Ph.D.**  
Associate Professor  
Department of Nutrition and Health Sciences  
Faculty of Medicine and Health Sciences  
Universiti Putra Malaysia  
(Chairperson)

**Suriah Abdul Rahman, Ph.D.**  
Associate Professor  
Program of Food Science and Nutrition  
School of Chemical Science and Food Technology  
Faculty of Science and Technology  
Universiti Kebangsaan Malaysia  
(Member)

**Chan Siew Pheng, FRCP**  
Professor  
Department of Medicine  
Faculty of Medicine  
University Malaya  
(Member)

**Miralini Kandiah, Ph.D.**  
Department of Nutrition and Health Sciences  
Faculty of Medicine and Health Sciences  
Universiti Putra Malaysia  
(Member)

---

**AINI IDERIS, Ph.D.**  
Professor/Dean,  
School of Graduate Studies,  
Universiti Putra Malaysia.

Date: 11 i 2003

---
DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

CHAN YOKE MUN

Date: 28 MAY 2003
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>vi</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>ix</td>
</tr>
<tr>
<td>APPROVALS</td>
<td>x</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>xii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xvi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xx</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xxii</td>
</tr>
</tbody>
</table>

# CHAPTER

1 INTRODUCTION

1.1 Introduction  
1.2 Statement of Problem  
1.3 Importance of Study  
1.4 Objectives of Study  
1.5 Operational Definition  

2 LITERATURE REVIEW

2.1 Bone and Osteoporosis  
2.1.1 Basic Bone Structure and Composition  
2.1.2 Bone Architecture  
2.1.3 Bone Remodeling Cycle  
2.1.4 Markers of Bone Turnover in Relation to Bone Health  
2.1.5 Bone and Calcium Homeostasis  
2.2 Epidemiology and Outcomes of Osteoporotic Fractures  
2.3 Bone Growth, Maintenance and Loss  
2.3.1 Skeletal Growth and Maturation  
2.3.2 Determinants of Bone Mass  
2.4 Risk Factors for Osteopenia and Osteoporosis  
2.4.1 Role of Genetic Factors in the Pathogenesis of Osteoporosis  
2.4.2 Body Weight, Body Composition and BMD  
2.4.3 Nutrition in the Bone Mineral Density Context  
2.4.3.1 Calcium Nutriture and Bone Health  
2.4.3.2 Vitamin D and Osteoporosis  
2.4.3.3 Protein and Bone Health  
2.4.3.4 Sodium Intake and Bone Health  

xiii
4.2.10 Baseline Comparison Between Different Treatment Group

4.3 Effects of Calcium Supplementation and Calcium-Exercise Intervention
4.3.1 Changes in Bone Mineral Density
4.3.2 Changes in Dietary Intake
4.3.3 Changes in Physical Activity
4.3.4 Changes in Physical Characteristics
4.3.5 Changes in Biochemical Indices

4.4 Calcium Tablet and Exercise Acceptance

5 CONCLUSION
5.1 Summary and Conclusion
5.2 Recommendation
5.2.1 Population-based Strategies
5.2.2 Recommendation for Reviewing Calcium Recommendation
5.2.3 Recommendation for Future Research

BIBLIOGRAPHY

APPENDICES
A Recommended daily dietary allowance (RDA) Malaysia
B Screening Questionnaire
C Consent Form
D Questionnaire
E Physical Activity Scale for the Elderly (PASE) Questionnaire
F Food Frequency Questionnaire
G Three Day Dietary Record
H DEXA description
I Example of Bone Mineral Densities Analysis
J Calcium Tablet Acceptance
K Calcium Tablet and Exercise Acceptance

VITA
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Percentage distribution of elderly by ethnic group</td>
<td>5</td>
</tr>
<tr>
<td>1.2</td>
<td>Operation definitions of variables</td>
<td>9</td>
</tr>
<tr>
<td>2.1</td>
<td>Biochemical indices of bone turnover</td>
<td>14</td>
</tr>
<tr>
<td>2.2</td>
<td>Risk factors for low bone mass and osteoporosis</td>
<td>32</td>
</tr>
<tr>
<td>2.3</td>
<td>Summary of results of randomized trials examining the effect of calcium supplementation on BMD</td>
<td>50</td>
</tr>
<tr>
<td>2.4</td>
<td>Recommended daily calcium intake from various sources</td>
<td>66</td>
</tr>
<tr>
<td>2.5</td>
<td>Calcium content of some common foods in Malaysia</td>
<td>68</td>
</tr>
<tr>
<td>2.6</td>
<td>Calcium content and estimated calcium absorbed of selected food items</td>
<td>75</td>
</tr>
<tr>
<td>2.7</td>
<td>Calcium absorption from milk and various salts preparation</td>
<td>82</td>
</tr>
<tr>
<td>2.8</td>
<td>Characteristics of RCTs of the efficacy of vitamin D supplementation on rate of bone loss</td>
<td>90</td>
</tr>
<tr>
<td>2.9</td>
<td>Recent reports relating bone status to dietary protein intake</td>
<td>99</td>
</tr>
<tr>
<td>2.10</td>
<td>Common dietary sources of vitamin K</td>
<td>102</td>
</tr>
<tr>
<td>2.11</td>
<td>Currently available BMD measurement techniques</td>
<td>127</td>
</tr>
<tr>
<td>2.12</td>
<td>Densitometer precision and minimum duration required to detect BMD change</td>
<td>131</td>
</tr>
<tr>
<td>3.1</td>
<td>Measurements/tests conducted for subjects</td>
<td>137</td>
</tr>
<tr>
<td>3.2</td>
<td>Summary of numbers of subjects screened and eligible subjects recruited</td>
<td>142</td>
</tr>
<tr>
<td>3.3</td>
<td>Estimation of cooking oil and salt used as ingredients</td>
<td>152</td>
</tr>
<tr>
<td>3.4</td>
<td>Classification of Body Mass Index according to WHO (1998)</td>
<td>163</td>
</tr>
</tbody>
</table>
4.1 Subject retention at various time-points during the study

4.2 Demographic and socioeconomic profile of the subjects

4.3 Distribution of respondents according to lifestyle habits

4.4 Characteristic of reproductive history

4.5 Distribution of respondents according to fracture history

4.6 Distribution of respondents according to anthropometric characteristics

4.7 Mean ± s.d. of bone mineral density of subjects

4.8 Differences in mean BMD of the lumbar spine among American, Singaporean and Malaysian subjects in this study

4.9 Differences in mean BMD of the femoral neck among American, Singaporean and Malaysian subjects in this study

4.10 Comparison of BMD with Hong Kong published BMD normogram

4.11 Daily energy and nutrient intakes from three-day food record (n=205)

4.12 Comparison of mean daily nutrient intakes with Malaysian RDA

4.13 Proportion of subjects meeting recommendations for dietary risk

4.14 Comparison of nutrient intake with other Malaysian data

4.15 Comparison of mean nutrient intake with other studies

4.16 Distribution of calcium intake of respondents according to Malaysian RDA and FAO/WHO Recommendation (2002)

4.17 Percentage contribution of food sources to dietary calcium in different populations

4.18 Distribution of subjects according to patterns of milk consumption

xvii
4.19 Distribution of subjects according to past physical activity

4.20 PASE item weights and contributions to total score

4.21 Current pattern of physical activity (n=205)

4.22 Mean values of selected biochemical indices of respondents (n=205)

4.23 Comparison of vitamin D status in different populations and geographical regions

4.24 Correlation of biochemical marker with age and duration of menopause

4.25 Mean values of DPD/Creatinine classified by age group and comparison with the Taiji Study

4.26 Correlation between BMD and other indices

4.27 Proportion of variability of BMD measurements explained by age

4.28 Proportion of variability of BMD explained by anthropometric measures

4.29 Correlation coefficient of body composition, age and duration of menopause

4.30 Correlation of dietary factors, past and current physical activity and milk consumption pattern with BMD

4.31 Correlation of biochemical indices with BMD

4.32 Multiple regression analysis among selected variables and BMD

4.33 Baseline characteristics of subjects (n=172)

4.34 Mean percentage change in BMD after 24 months intervention

4.35 Mean rate of BMD change in year 1 and year 2 (second-year rate minus first-year rate) in postmenopausal women

xviii
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.36</td>
<td>Between-Groups difference in BMD changes in postmenopausal women treated with calcium supplementation, calcium-exercise or control for 2 years</td>
<td>249</td>
</tr>
<tr>
<td>4.37</td>
<td>Comparison of macronutrient intake over time in the three treatment group and absolute mean changes at 24 months</td>
<td>254</td>
</tr>
<tr>
<td>4.38</td>
<td>Comparison of vitamin intake over time and absolute mean changes at 24 months</td>
<td>256</td>
</tr>
<tr>
<td>4.39</td>
<td>Comparison of intake of selected minerals over time and absolute mean changes at 24 months</td>
<td>258</td>
</tr>
<tr>
<td>4.40</td>
<td>Mean percentage change in PASE score after 24 months intervention</td>
<td>260</td>
</tr>
<tr>
<td>4.41</td>
<td>Percentage change in anthropometric indices after 24 months</td>
<td>263</td>
</tr>
<tr>
<td>4.42</td>
<td>Selected biochemical indices at baseline, 12 and 24 months</td>
<td>266</td>
</tr>
<tr>
<td>4.43</td>
<td>Mean percentage change in 25 (OH)D after 24 months intervention</td>
<td>266</td>
</tr>
<tr>
<td>4.44</td>
<td>Consumption practices with calcium supplementation</td>
<td>271</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Determinants of peak bone mass</td>
<td>28</td>
</tr>
<tr>
<td>2.2</td>
<td>Mechanism of bone loss in postmenopausal women</td>
<td>30</td>
</tr>
<tr>
<td>2.3</td>
<td>Schematic representation of the relationship between various determinants with osteoporosis and osteoporotic-complications</td>
<td>33</td>
</tr>
<tr>
<td>3.1</td>
<td>Screening and randomization of subjects into study groups</td>
<td>143</td>
</tr>
<tr>
<td>4.1</td>
<td>Randomization and disposition of subjects</td>
<td>173</td>
</tr>
<tr>
<td>4.2</td>
<td>Distribution of respondents according to T-score classification by WHO (1994)</td>
<td>185</td>
</tr>
<tr>
<td>4.3</td>
<td>Food sources of dietary calcium</td>
<td>201</td>
</tr>
<tr>
<td>4.4</td>
<td>Change in total body BMD with time. Results are mean ± SE. Treatment groups were compared over time using repeated measures ANOVA. Calcium and calcium-exercise were significant different from control group over the duration of study</td>
<td>240</td>
</tr>
<tr>
<td>4.5</td>
<td>Change in lumbar spine L2-L4 BMD with time. Results are mean ± SE. Treatment groups were compared over time using repeated measures ANOVA. Calcium and Calcium-exercise were significant different from control group over the duration of study</td>
<td>240</td>
</tr>
<tr>
<td>4.6</td>
<td>Change in femoral neck BMD with time. Results are mean ± SE. Treatment groups were compared over time using repeated measures ANOVA. Calcium-exercise group was significant different from calcium group and control group. Calcium group was significant different from control group over the duration of study</td>
<td>241</td>
</tr>
</tbody>
</table>
4.7 Change in Ward’s triangle BMD with time. Results are mean ± SE. Treatment groups were compared over time using repeated measures ANOVA. Calcium-exercise group was significant different from calcium group and control group. There was no significant different between calcium group and control group over the duration of study.

4.8 Change in trochanter BMD with time. Results are mean ± SE. Treatment groups were compared over time using repeated measures ANOVA. Calcium-exercise was significant different from calcium group and control group. Calcium group was significant different from the control group over the duration of study.

4.9 Change in total hip BMD with time. Results are mean ± SE. Treatment groups were compared over time using repeated measures ANOVA. Calcium-exercise was significant different from calcium group and control group. Calcium group was significant different from the control group over the duration of study.

4.10 Relationship between change in femoral neck BMD and duration of brisk walking
LIST OF ABBREVIATIONS

BMD  Bone Mineral Density
BMI  Body Mass Index
CI   Confidence Interval
DEXA Dual Energy X-ray Absorptionmetry
ECF  Extracellular Fluid
NIH  National Institute of Health
PBM  Peak Bone Mass
PTH  Parathyroid Hormone
RDA  Recommended Dietary Allowance
RCT  Randomized Controlled Trial
WHO  World Health Organization
WHR  Waist Hip Ratio
CHAPTER 1
INTRODUCTION

1.1 Introduction

Osteoporosis was defined in 1993 as a systemic disease characterized by low bone mass and microarchitectural deterioration of bone tissue, leading to enhanced bone fragility and increased fracture risk (Consensus Development Conference, 1993). Recently, this definition was modified as a skeletal disorder characterized by compromised bone strength predisposing to an increased risk of fracture (National Institutes of Health, 2000). Bone strength reflects the integration of two main features: bone density and bone quality. In the absence of accurate methods of measuring bone quality, the diagnosis of osteoporosis tends to be made on the basis of low bone density.

The rising incidence of osteoporosis and osteoporotic fractures is becoming a global public health problem. This is based on the recognition that it is a common disease in the developed countries and is likely to become so in the developing countries, where life span is rapidly increasing (Genant et al., 1999).

Primary osteoporosis affects mainly postmenopausal women. Women are at particular risk for fracture, and the data suggests that the incidence in women is twice that in men (Melton, 1988; Hoffenberg et al., 1989; Johnell et al., 1992). This has also been found to be true of Malaysia (Lau et al., 2001a). Above the age of 50 years, one in four women (Melton et al., 1992) and one in eight men (Melton et al., 1992; WHO, 1994) are
believed to have osteoporosis. The National Institutes of Health (NIH) of the United States (1998) pointed out that osteoporosis is about four times more common in women than in men. The higher occurrence of osteoporotic fractures in women is due to several factors. There are attainment of a lower bone mass at the time of maturity (bone mass is approximately 30% higher in men than in women (Consensus Conference, 1984)), women experiencing an accelerated loss of bone after the menopause, the greater likelihood of falls among elderly women (Winner et al., 1989) as well as to women’s greater life expectancy (Genant et al., 1999). In total, women lose about 25-30% of the cortical bone and 35-50% of the trabecular bone over their lifetime (Riggs et al., 1981) while men lose about two-thirds of this rate.

1.2 Statement of Problem

Osteoporosis is a chronic and debilitating disease that can influence every facet of a person’s life. It has been described as a primary factor contributing to deterioration of quality of life for the elderly (Birge, 1993). It affects more than 75 million people in the United States, Europe and Japan and causes more than 2.3 million fractures annually in the United States and Europe alone (Morii and Genant, 1998).

Postmenopausal bone loss is a major factor in the increasing prevalence of osteoporosis (Aloia et al., 1994). Osteoporosis is usually occult and asymptomatic until a fracture occurs. Thus, fractures are viewed as a complication of osteoporosis, and the relationship between osteoporosis and fractures is analogous to that between high blood pressure and