Effect of Training Mode and Calcium Intake on Bone Mineral Density in Female Master Cyclists, Runners, and Non-Athletes

Donna Beshgetoor, Jeanne F. Nichols, and Inah Rego

The focus of this prospective, observational study was to determine the effect of sport-specific training and calcium intake on bone mineral density (BMD) in female master cyclists, runners and non-athletes. Thirty women (12 cyclists, 9 runners, 9 controls), mean age of 49.6 ± 7.9 years, were assessed at baseline and 18 months for calcium intake (4-day records), current exercise activity (recall questionnaire), and BMD of the lumbar spine and hip (DXA). A three (cyclists, runners, controls) by two (0 and 18 months) repeated measures ANOVA demonstrated a significant interaction effect of sport and time at the femoral neck (p < .04). Tukey post hoc analysis indicated that the BMD of the femur was maintained in cyclists and runners but declined in controls (p < .05). A significant time effect was noted in BMD at the lumbar spine (p < .001) and the trochanter (p < .003). BMD of the lumbar spine was maintained in runners but declined in cyclists (p < .007) and in controls (p < .03), while trochanteric BMD declined in all groups (p < .01). No significant interaction effect of sport and dietary calcium intake was noted for BMD at any site.

Key Words: exercise, nutrition, osteoporosis prevention

Osteoporosis is a potentially debilitating disease characterized by a progressive loss of bone mineral density. It develops as a “silent” disease without symptomatic presentation until fractures occur in later adulthood. Postmenopausal women are often considered to be at greatest risk of developing osteoporosis as the decreased estrogen production of menopause is associated with an increased turnover and loss of bone, particularly within the first five years of menopause, and a decreased efficiency of calcium absorption (9, 12). To date there is no effective treatment for fully reversing the demineralization of bone that occurs in osteoporosis. Thus, preventive strategies for maintaining bone health throughout one’s adult years are vital in protecting against age-related bone loss and subsequent fracture risk (24).

Substantial evidence suggests that adequate calcium intake (3, 4, 20, 22) and participation in regular exercise (2, 5, 7, 26, 28) may be key strategies for maintaining BMD in adulthood. The 1989 Recommended Dietary Allowance (RDA)
guidelines prescribed a calcium intake of 800 mg/day for women of both pre- and post-menopausal ages to protect against age-related bone loss (23). The new Dietary Reference Intake (DRI) guidelines for calcium intake for women 31–50 years of age and 51–70 years of age have recently been set at 1,000 mg/day and 1,200 mg/day, respectively (22). However, calcium supplementation trials focusing on women during the first 5 years of menopause, when bone loss is most rapid, indicate that the effectiveness of calcium in maintaining BMD may actually differ according to skeletal site, menopausal age, and usual calcium intake (3, 22).

Guidelines for the type, intensity, frequency, and duration of exercise that is most beneficial with regard to preventing osteoporotic bone loss have not yet been clearly established (19). There is some indication that weight-bearing or impact loading exercise is of greater benefit in maintaining BMD than is non-weight-bearing exercise (2, 7, 16, 26). A limited number of studies, however, suggest that not all weight-bearing or impact loading exercise conveys the same benefits. It is possible that the characteristic skeletal loading forces of varied sports have different osteogenic effects (7, 8, 11, 13, 16–19, 26). Greater BMD values have been observed in young female athletes involved in impact loading sports (volleyball, gymnastics) versus active loading sports (swimming; [8]) and in high strain rate sports (squash) or high peak stress sports (weight training) versus sports involving a large number of lower-force repetitions (cross country skiing, cycling; [13]).

Few studies to date have addressed site-specific skeletal effects resulting from long-term sport training in older female athletes (19). In a recent cross-sectional study, Dook and colleagues (5) reported that women with a long-term history (>20 years) of training and competitive participation in impact-loading sports (netball, running, field hockey) had greater whole body and regional leg BMD than women involved in either non-impact sport training (swimming) or a sedentary lifestyle. Etherington et al. (7) also observed markedly greater femoral neck and lumbar spine BMD measurements in women with a lifetime history of participation in impact loading sports (running, tennis) in comparison to non-active women. However, randomized, prospective studies are needed to better evaluate the effects of long-term participation in different impact loading sports (5).

Despite the growing number of master level athletes, little information exists on the BMD of female master runners and cyclists. Given the impact loading differences of cycling and running, it is of interest to compare the BMD of female master athletes who engage solely in one or the other of these sports and to monitor changes in their BMD over time. Knowledge of the bone health and of the calcium intake of this population of athletes would be helpful in determining appropriate guidelines for preventing bone loss as these athletes age. Thus, the purpose of this study was to assess and compare the BMD and calcium intake of female master cyclists and runners over an 18-month period.

**Methods**

**Participants**

Master athletes were recruited for voluntary participation in the study by word of mouth and by flyers posted at running and cycling events. Inclusion criteria included: (a) female, age 35 or greater, (b) free of cardiovascular disease, (c) no use of estrogen replacement drugs, (d) year-round training in either running or cycling,
and (c) competitive participation in their respective sport for at least 1 year prior to involvement in the study. Non-obese, non-athletic women matched for age (±2 years) and menopausal status were recruited to serve as control subjects. Inclusion criteria for control participants also included: (a) free of known cardiovascular disease, (b) no use of estrogen replacement drugs, and (c) no history of, or current participation in, any exercise training on a regular or competitive basis. The study protocol was approved by the Committee for the Protection of Human Subjects at San Diego State University.

**Menstrual History**

Menstrual history was assessed through use of a descriptive questionnaire pre-tested for reliability. The following information was obtained: age of menarche, amenorrhea history (number and time of ≥3 consecutive months of missed periods since menarche), oligomenorrhea history (number and time of missed periods for <3 consecutive months since menarche), current menstrual status, and number of years postmenopause. *Premenopause* was defined as still menstruating, *early postmenopause* was defined as complete cessation of menstruation ≤5 years of baseline, and *late postmenopause* was defined as complete cessation of menstruation >5 years of baseline.

**Dietary Measurements**

Dairy product consumption was assessed at baseline and at 18 months by a validated food frequency questionnaire specific for calcium (1). Participants reported their frequency of consumption for dairy products considered to be significant sources of calcium (milk, cheese, yogurt, and ice cream). Frequency of consumption was recorded as “more than once per day; once per day; more than once per week, but not every day; once per week; less than once per week; or never.”

Dietary calcium intake was assessed at baseline and at 18 months by 4-day diet records. Participants were instructed by a nutritionist to record food and beverage intake on 3 weekdays and on 1 weekend day. Sample records and measurement standards were provided to insure the accuracy of the dietary information obtained. Types and amounts of all dietary supplements taken were also recorded. Participants were asked to provide the investigators with labels for all supplement products used.

Individual 4-day diet records were analyzed using the Nutritionist IV computer program (North S. N Square Computing, Salem, OR). Computer analysis provided individual mean daily intakes for calcium and other nutrients and comparisons of intakes to age and gender specific RDA guidelines (21).

**Physical Activity Measurements**

The physical activity of participants at baseline and at 18 months was assessed by a 1-month activity recall questionnaire. Each participant recorded the activities (both weight-bearing and non-weight-bearing) that she had engaged in on a regular basis over the past month, the number of days per week she performed the activity, and the intensity of the activity, rated on a scale of 1 to 5 (1 = very light, 2 = light, 3 = moderate, 4 = vigorous, and 5 = competitive).
The maximal oxygen consumption ($\dot{V}O_{2\text{max}}$) of participants was measured by indirect calorimetry with open circuit spirometry. $\dot{V}O_{2\text{max}}$ testing was performed to assess the fitness level of participants. A running or walking protocol for motorized treadmill (18–60, Quinton Instruments, Seattle, WA) was used to assess the $\dot{V}O_{2\text{max}}$ of runners and controls, respectively. A cycling protocol for cycle ergometer (Excaliber Sport, LODE, Groningen, Netherlands) was used to assess the $\dot{V}O_{2\text{max}}$ of cyclists. Different modes of testing were employed to utilize a testing mode specific to the training of the participant. All subjects performed 2-min testing stages to volitional exhaustion. Subjects were given continuous verbal encouragement to exercise to exhaustion.

**Bone Mineral Density Measurements**

The participants’ BMD (g/cm²) was measured by dual energy x-ray absorptiometry (Lunar DPX; Lunar Radiation; Madison, WI; software v. 3.4) at the lumbar spine (L1–L4) and at the hip (femoral neck and trochanter). All scans were performed by the same radiological technician. A high resolution computer-generated image of the skeleton allowed for correction of possible position errors. Quality assurance tests were performed each morning of use. The tests were conducted using a tissue-equivalent standard with three bone-simulating chambers of known bone mineral content. Precision measurements for the spine were repeated seven times per subject on 6 subjects and five times per subject on 15 subjects for the femur. The mean coefficient of variation was 1.0% for the proximal femur and 0.5% for the spine.

**Statistical Analyses**

All data were analyzed by the Statistical Package for the Social Sciences (SPSS, v. 6.0, Chicago, IL). Descriptive statistics (mean ± SD and range) were computed for dependent and independent variables. One way analysis of variance (ANOVA) with Tukey post hoc tests was used to examine possible group differences in nutrient intakes. A three (cyclists, runners, controls) by two (0 and 18 month) repeated measures ANOVA was employed to examine changes in BMD and calcium over time. For dependent variables showing a significant main effect for time, paired $t$ tests were employed to determine which groups(s) changed significantly from 0 to 18 months. A three-way ANOVA (group by time by calcium intake) was employed to determine possible interaction effects in BMD between training mode and dietary calcium from baseline to 18 months. For ease of comparison in this analysis, calcium intake was defined as either greater than or less than the RDA of 800 mg calcium/day. Statistical significance was set at $p < .05$ for all analyses.

**Results**

Characteristics of the participants at baseline are shown in Table 1. The data include only those women who remained in the study for its duration ($n = 30$). Of the 33 women who began the study, 2 runners and 1 control subject dropped out after baseline measurements were completed. Reasons for dropping included injury resulting in termination of training and competing, refusal of DXA due to pregnancy and initiation of treatment for osteopenia. The final study population consisted of 12 cyclists, 9 runners, and 9 control subjects. With the exception of age at menarche, no
significant differences in physical characteristics were noted between study groups at baseline (or at 18 months). The mean age (±SD) of participants at baseline was 49.6 ± 7.9 years. The mean (±SD) body mass index (BMI) was 21.1 ± 2.3 kg/m². The mean menstrual status of subject groups was approximately 4 years postmenopause. None of the subjects became postmenopausal during the 18 months of the study. A total of 9 subjects (4 cyclists, 4 runners, 1 control) reported the occurrence of amenorrhea (≥3 consecutive months of missed periods) or oligomenorrhea (<3 consecutive months of missed periods) in early adulthood (age 20–29 years). However, only 2 of these women (1 cyclist, 1 runner) reported extended years/months of missed periods (5 years and 3 consecutive months, respectively).

The physical activity and \( \dot{V}O_{2\max} \) of participants at baseline are also shown in Table 1. The physical activity and \( \dot{V}O_{2\max} \) of participants did not differ significantly from baseline at the 18-month measurement of the study and thus are not shown. By study design, the physical activity of both athletic groups was significantly greater than that of the controls \((p < .01)\). Although control subjects reported that they engaged in periodic physical activity (<2 hr/week) of a light to moderate intensity, none had regularly trained or competed in any sport at any time. In contrast, cyclists and runners engaged in intense physical activity approximately 5 days/week for 9.4 ± 2.2 and 7.7 ± 4.5 hr/week, respectively. There was no significant difference in the volume of training (days/week or hr/week) or in the intensity of training between the cyclists and runners. In addition, the \( \dot{V}O_{2\max} \) of the cyclists and runners was similar.

Table 1  Characteristics of Subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cyclists (n = 12)</th>
<th>Runners (n = 9)</th>
<th>Controls (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>48.2 ± 8.4</td>
<td>50.9 ± 7.5</td>
<td>50.1 ± 8.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.6 ± 6.3</td>
<td>52.8 ± 3.9</td>
<td>59.2 ± 7.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.3 ± 5.6</td>
<td>161.2 ± 5.1</td>
<td>166.8 ± 7.4</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.5 ± 2.2</td>
<td>20.4 ± 1.8</td>
<td>21.3 ± 2.8</td>
</tr>
<tr>
<td>Age at menarche (year)</td>
<td>11.9 ± 1.3(^a)</td>
<td>13.9 ± 2.1(^b)</td>
<td>12.4 ± 2.0(^a)</td>
</tr>
<tr>
<td>Premenopausal (# subjects)</td>
<td>8</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Early postmenopausal (#)</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Late postmenopausal (#)</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Years postmenopause</td>
<td>3.1 ± 5.1</td>
<td>4.4 ± 5.6</td>
<td>4.0 ± 5.8</td>
</tr>
<tr>
<td>( \dot{V}O_{2\max} ) (ml/kg/min)</td>
<td>51.4 ± 7.6(^a)</td>
<td>47.2 ± 8.3(^a)</td>
<td>24.5 ± 4.2(^b)</td>
</tr>
<tr>
<td>Training (hr/week)</td>
<td>9.4 ± 2.2(^a)</td>
<td>7.7 ± 4.5(^a)</td>
<td>1.6 ± 1.1(^b)</td>
</tr>
<tr>
<td>Training (days/week)</td>
<td>5.1 ± 1.2(^a)</td>
<td>4.9 ± 1.4(^a)</td>
<td>3.1 ± 1.8(^a)</td>
</tr>
<tr>
<td>Training intensity(^d)</td>
<td>4.5 ± 0.4(^a)</td>
<td>4.2 ± 0.5(^a)</td>
<td>2.6 ± 0.5(^b)</td>
</tr>
</tbody>
</table>

Note. Values represent group mean ± SD. Different superscripts indicate statistical significance between groups \((p < .05)\).

\(^a\)Defined as still menstruating.

\(^b\)Defined as complete cessation of menstruation ≤ 5 years of baseline.

\(^d\)Defined as complete cessation of menstruation > 5 years of baseline.

\(^d\)Scored on 1-5 scale; 1 = very light, 2 = light, 3 = moderate, 4 = hard, 5 = very hard.
### Table 2  Current Calcium Intake

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cyclists (n = 12)</th>
<th>Runners (n = 9)</th>
<th>Controls (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>18 months</td>
<td>Baseline</td>
</tr>
<tr>
<td>Dietary calcium (mg - day⁻¹)</td>
<td>984 ± 583</td>
<td>961 ± 535</td>
<td>598 ± 457</td>
</tr>
<tr>
<td>Calcium from supplements (mg - day⁻¹)</td>
<td>439 ± 492</td>
<td>470 ± 668</td>
<td>901 ± 720</td>
</tr>
<tr>
<td>Total calcium (mg - day⁻¹)</td>
<td>1424 ± 719</td>
<td>1432 ± 741</td>
<td>1500 ± 827</td>
</tr>
</tbody>
</table>

*Note:* Values represent group means (± SD) of 0 and 18 month data from the average of 4-day diet records. No significant differences in calcium intake between groups or within groups from baseline to 18 months.
with both groups having a significantly higher $\text{VO}_{2\text{max}}$ than that of controls ($p < .001$). Both cyclists and runners indicated a history of participation in their perspective sport. Cyclists reported a participation of 6.67 ± 2.30 years, whereas runners reported a participation of 16.44 ± 4.16 years ($p = .001$).

Analysis of dairy product consumption indicated that there were no significant differences in frequency of dairy intake between the three study groups. On average, the cyclists, runners, and controls all consumed dairy products "more than once per week, but not every day."

A summary of dietary calcium intake (determined from 4-day diet records) is presented in Table 2. No significant differences in calcium intakes were observed between groups or within groups from baseline to 18 months. Total calcium intake was somewhat greater in the athletic groups in comparison to the control group at the baseline measurement, but this difference was not statistically significant. As noted in Table 2, use of calcium supplements contributed substantially to total daily calcium intakes.

The bone mineral density measurements at baseline and at 18 months are shown in Table 3. No significant group differences in BMD were noted at any site at baseline. A three (group) by two (time) repeated measures ANOVA showed a significant time effect in BMD of the lumbar spine ($p < .003$) and the trochanter ($p < .001$) and a significant interaction effect at the femoral neck ($p < .04$; effect size = 0.22). As depicted in Figure 1, the BMD at the femoral neck was maintained in cyclists and runners but declined in control subjects ($p < .05$). Analysis of BMD changes within each group demonstrated a significant decrease in BMD of the spine in cyclists ($p < .007$) and in controls ($p < .03$), and a significant decrease in trochanteric BMD in cyclists ($p < .001$), in runners ($p < .01$), and in controls ($p < .001$). No significant interaction effect of sport and dietary calcium intake was noted for BMD at any site.

![Figure 1 — Bone mineral density of the femoral neck at 0 and 18 months.](image-url)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Cyclists (n = 12)</th>
<th>Runners (n = 9)</th>
<th>Controls (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>18 months</td>
<td>Baseline</td>
</tr>
<tr>
<td>Spine (L1–L4)*</td>
<td>0.993 ± 0.150</td>
<td>0.970 ± 0.155</td>
<td>0.974 ± 0.142</td>
</tr>
<tr>
<td>% age-matched</td>
<td>102.4 ± 10.9</td>
<td>99.9 ± 11.5</td>
<td>106.1 ± 15.2</td>
</tr>
<tr>
<td>Femoral neck**</td>
<td>0.778 ± 0.122</td>
<td>0.776 ± 0.138</td>
<td>0.742 ± 0.076</td>
</tr>
<tr>
<td>% age-matched</td>
<td>104.7 ± 11.2</td>
<td>99.4 ± 14.7</td>
<td>100 ± 14.3</td>
</tr>
<tr>
<td>Trochanter*</td>
<td>0.805 ± 0.132</td>
<td>0.724 ± 0.149</td>
<td>0.745 ± 0.092</td>
</tr>
<tr>
<td>% age-matched</td>
<td>107.6 ± 13.8</td>
<td>104.6 ± 14.5</td>
<td>104.1 ± 11.6</td>
</tr>
</tbody>
</table>

Note. Values represent mean ± SD expressed in g/cm² and as percentages of age-matched reference values. *Significant main effect for time (p < .05); **significant group × time interaction (p = .04).
Discussion

The primary focus of this study was to determine sport-specific differences in BMD in female master cyclists and runners over an 18-month period and to compare BMD measurements of these elite athletic women with those of non-athletic women matched for age, weight, and menopausal status. A secondary focus of the study was to determine the effect of calcium intake on BMD in female master athletes and non-athletes.

This study is the first longitudinal study to report site-specific differences in BMD between female master cyclists versus runners. The differences in BMD noted in our study support the hypothesis that impact loading sports, such as running, provide the most protection to the lumbar spine, while non-weight-bearing sports such as cycling do not. This is illustrated by the observed decrease in BMD of L1–L4 from 0 to 18 months in both cyclists and controls, but not in runners. The significant group by time interaction in BMD at the femoral neck, along with the significant decrease in BMD at this site in only the control subjects, suggests that both sports provide protection from bone loss at the hip with increasing age.

To date, few studies have addressed the possibility of site-specific BMD effects resulting from different sport participation (19). Huddleston and colleagues (15) were among the first to demonstrate site-specific increases in BMD in response to the habitual physical stress on bone from individual sports. They reported greater BMDs in the dominant playing arm of tennis players in comparison to the non-dominant arm. Several more recent studies have reported findings of site-specific differences in BMD resulting from participation in different exercise training modes. Dook et al. (5) reported that female runners of similar ages to the participants in our study had greater total body BMD and regional hip BMD than non-athletes. Likewise, Etherington and colleagues (7) observed that female ex-elite runners had greater spine and hip BMD values in comparison to non-athletes even years after training ceased. The results of Lee et al. (19) and Fehling et al. (8) indicated that athletes who participated in the weight-bearing activities of either volleyball or basketball had greater BMD measurements in both the arm and leg. In contrast, the sport of swimming, a non-weight-bearing activity, has failed to demonstrate a positive influence on bone density in women of variable age (5, 19). In studies of female master swimmers (age 40+), bone density was no greater than that in non-exercising women of similar ages (5). While there is strong evidence that swimming is not beneficial to bone, we cannot readily compare the sport of cycling to swimming. Although both sports are of a high intensity, non-weight-bearing nature, cycling places high strain on the musculature of the hip and may therefore provide an osteogenic stimulus in that region.

While the rate of BMD loss in non-athletic, postmenopausal women is approximately 3% per year during the first 5 years of menopause and 1% thereafter (22), it is not known whether age-related BMD changes in female master athletes follow these patterns. We had anticipated possible differences in BMD measurements between the athletes and control subjects at baseline. However, no statistically significant differences were detected, possibly due in part to our small subject number. Other investigators have also observed only insignificant differences in BMD between active and inactive study participants (5). Although our control subjects were significantly less active than the athletic subjects throughout the study period, they did engage in low intensity, periodic physical activity (<2 hr/week). Etherington et al. (7) reported that women who participated in at least 1 hr of weight-
bearing physical activity per week in adulthood had higher regional BMDs than totally sedentary women. Thus, even minimal, weekly, long-term, weight-bearing exercise may be an important factor in maintaining BMD through life.

Although many of the athletes in our study reported episodes of oligo/amenorrhea in early adulthood, only 1 runner and 1 cyclist had extended months of menstrual irregularities. The baseline BMD of the runner averaged 72–86% (depending on site) of that in age-matched reference women (21). However, the cyclist, who reported being amenorrheic from age 20–25, had BMD values 5–16% above those of age-matched women (21).

As we were concerned that BMD changes may have been confounded by an estrogen effect, we analyzed BMD changes over time, grouping the subjects by menopausal status. However, we did not detect any significant differences in BMD measurements. It is known that high levels of physical activity, especially when associated with inadequate nutrition, can lead to menstrual dysfunction and relatively low BMD in women (6, 28). Thus, it is possible that the episodes of oligo/amenorrhea during early adulthood in some of the athletic subjects impaired BMD accrual and/or maintenance and thus masked greater differences in BMD in comparison to control subjects over time. It is also possible, as suggested by the findings of Goto and colleagues (10), that despite the continued high level of physical activity in the athletes during the pre- and peri-menopausal years, exercise was not able to fully prevent age-related bone loss.

The optimal calcium intake necessary to promote bone health and prevent osteoporosis is not fully known (22). Unfortunately, studies designed to determine the intake associated with the greatest BMD and the fewest osteoporotic fractures have been prohibitive for a variety of reasons. To date, observational studies of calcium intake and fracture risk have not shown a consistent association between calcium intake and risk of fracture in peri- and post-menopausal women (22). It is likely that results are confounded by the complex interactions of diet, exercise, menstrual history, and heredity on osteoporosis. Furthermore, determination of calcium intake is limited by common methodological measures of intake. These methods often lead to underestimations by some measures and to overestimations by others. Lastly, intakes measured at a single or limited number of time points do not truly reflect lifetime calcium consumption. Yet, a high habitual calcium intake is likely of greater importance for maintaining bone health than is calcium intake during a specific phase of life.

In the study described herein, no subjects reported daily dairy consumption. It is unlikely that the non-daily intakes of calcium-rich dairy foods by our subjects would be adequate to meet calcium needs. As outlined in the recommendations of the Food Guide Pyramid, adult women should include 2–3 servings of calcium-rich foods in their daily diet. As evidenced by the dairy product frequency data, our subjects clearly did not meet these recommendations.

Four-day diet records obtained at study initiation and at 18 months, indicated adequate intakes of macronutrients for all subjects but inadequate intakes of calcium from diet alone. Calcium supplementation accounted for approximately 30–60% of the total daily calcium intake. Thus, when supplemental intakes of calcium were added to dietary intakes, total daily calcium intakes were adequate in both athletic groups at baseline and at 18 months. In contrast, the mean total calcium intake of 756 mg/d for control subjects at baseline was below both the 1989 RDA guidelines (23) of 800 mg calcium/day for women of our subjects’ age and the more
recent DRI guidelines (22) of 1,000 mg calcium/day. However, the mean calcium intake of the control subjects increased to 1,148 mg/day by the 18-month measurement. While differences in total calcium intake were noted at baseline between the athletes and the control group, these differences were not significant. It is likely that the small sample size and the relatively large standard deviations in calcium intake within groups did not allow for detection of statistical differences.

No effect of calcium intake on BMD was noted in this study. Likewise, several other studies have failed to show a relationship between current calcium intake and BMD (5, 14). The invariably weak relationship between calcium intake and BMD may be explained by the varied diets of individuals, by the possible influence of other nutrients on calcium absorption and metabolism and by the small subject numbers. Although high calcium intakes seemingly contribute to reductions in the rate of bone loss in later life and decreases in the risk of osteoporotic fractures (2, 3, 22), it is difficult to affirm whether the lowered risk of developing osteoporosis associated with calcium is conferred by a higher intake after the attainment of optimal PBM or whether it relates to protection afforded by the attainment of PBM earlier in life. As suggested by Dook (5), it is likely that “an integrated measurement of lifetime calcium intake may be necessary to identify potential association between calcium intake and BMD.”

In summary, these data indicate that, for at least 18 months of sport-specific training, age-related changes in femoral neck BMD were similar in master female runners and cyclists. In contrast, a significant decrease in the BMD of the femur was observed in non-athletic women during this time period. However, the BMD of the lumbar spine was maintained only in runners and declined in both the cyclists and controls. Long-term data are needed to determine whether the weight-bearing and non-weight-bearing nature of running and cycling, respectively, will demonstrate further BMD differences in later adulthood. Additional well-controlled, longitudinal investigations are warranted to provide greater insight into the role of training mode and calcium intake in BMD in female master athletes.

**References**


