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ORIGINAL ARTICLE

# Low bone mineral density in highly trained male master cyclists

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**Abstract** The purpose of this study was to determine total and regional bone mineral density (BMD) in highly competitive young adult and master male cyclists. Three groups of men were studied: older cyclists ($51.2 \pm 5.3$ years, $n = 27$); young adult cyclists ($31.7 \pm 3.5$ years, $n = 16$); and 24 non-athletes matched by age ($\pm 2$ years) and body weight ($\pm 2$ kg) to the master cyclists. All of the master cyclists had been training and racing for a minimum of 10 years (mean $20.2 \pm 8.4$ years) and engaging in little to no weight-bearing exercise. The younger cyclists also engaged in little weight-bearing exercise and had been training and racing for $10.9 \pm 3.2$ years. Age-matched controls were normally active. The History of Leisure Activity Questionnaire was used to determine the influence on BMD of self-reported total and weight-bearing exercise during three periods of life: 12–18 years, 19–34 years, and 35–49 years. BMD (measured by DXA) of the spine (L2–L4) and total hip was significantly ($P < 0.033$) lower in the master cyclists compared to both age-matched controls and young adult cyclists. Total body BMD was lower in the master cyclists compared to the young-adults ($P < 0.033$). Furthermore, four (15%) of the master cyclists, but none of the men in the other groups, had *T*-scores (spine and/or hip) lower than –2.5. Weight-bearing exercise performed during teen and young adult years did not appear to influence BMD, as there were no differences at any site between those within the upper and lower 50th percentiles for weight-bearing exercise during the 12–18, 19–34, or 35–49 year time periods. These data indicate that master cyclists with a long history of training exclusively in cycling have low BMD compared to their age-matched peers. Although highly trained and physically fit, these athletes may be at high risk for developing osteoporosis with advancing age.

**Keywords** Bicycling · Bone mass · Bone density · DXA · Exercise · Master athletes

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## Introduction

Osteoporosis has become a serious health problem in many countries, and although more prevalent in women, the incidence is rising in men [1]. Attainment of high peak bone mass in young adulthood is a determinant of bone mass later in life. In addition to genetic, hormonal and nutritional influences, exercise positively affects bone mass accretion during adolescence and is beneficial in preserving bone mass throughout adult years [2,3,4].

Animal studies on the mechanisms by which bone adapts to mechanical strain provide the basis for understanding why various modes of exercise have differential effects on bone [5]. That is, activities that produce high strain magnitudes and high strain rates distributed unevenly across the bone provide the greatest osteogenic stimulus [6]. Furthermore, the degree of mechanical strain applied to bone in weight-bearing activities increases proportionally with increased ground reaction forces [7]. Evidence from cross-sectional studies of athletes from a variety of sports, including gymnastics, volleyball, karate and running, supports the notion that bone undergoes a positive adaptive response to high impact activities [8,9,10]. Intervention studies, most of which are reported for women, have shown increases in bone mass induced by high strain activities such as jumping and running in children [11] as well as older adults [2]. In stark contrast, weightless environments experienced by astronauts or individuals participating in bed-rest studies cause rapid and marked bone loss [12,13]. Similarly, non-weight-bearing activities such as swimming and cycling afford few, if any, benefits to bone health in young adults [14,15].

Much less is known regarding the long-term effects of participation in various sports, although it is probable that participation in weight-bearing activities throughout one's lifetime reduces the risk of osteoporosis. Of concern, however, is whether there are possible detrimental effects to bone health from participating solely in non-weight-bearing activities. Studies of master athletes from various sports provide data that may help distinguish the effects on BMD of age per se from those associated with a decrease in exercise participation with advancing age. Furthermore, knowledge of the apparent effects of lifelong participation in a particular activity can help determine the benefits and/or risks of such participation. Such studies may also guide health promotion practitioners, coaches and exercise instructors in making appropriate recommendations regarding the types of physical activity that are most beneficial to bone health.

Our interest in the bone health of older athletes, along with very limited published data for older male athletes in general, and particularly for men participating in non-impact sports, prompted us to examine BMD in master male cyclists. Therefore, the primary purpose of this study was to determine and compare total body and regional BMD in young adult and master cyclists and in normally active men matched by age and body weight to the older cyclists. We postulated that there would be no differences in BMD of master cyclists compared to age-matched non-athletes. A secondary purpose was to determine the influence on BMD of exercise participation during various stages of life. We studied two groups of highly trained, competitive male cyclists, aged 40–60, and 25–35 years, who had participated exclusively in the sport of cycling for a minimum of 10 and 5 years, respectively.

## Materials and methods

### Subjects

Potential participants were recruited via announcements in newsletters and on web pages of masters racing clubs in southern California. Twenty-seven male master cyclists, 16 young adult male cyclists and 24 non-athletic male controls volunteered to serve as subjects. All subjects completed a health history questionnaire to screen for conditions and medications known to affect bone health. Individuals were excluded from the study if they were taking, or had ever taken medications or had any condition known to affect bone mass and/or bone metabolism, including: inhaled steroids, anticonvulsants, calcitonin, alendronate, thyroid hormone, corticosteroids, cyclosporine, and anabolic steroids; thyroid or parathyroid disease; adrenal gland problems. Additionally, cyclists who participated in regular (2 or more days per week for more than 3 months per year), weight lifting, body-building, and/or any impact exercise were not eligible to participate. These exercise exclusion criteria had to be met for at least the past 10 years for master cyclists, and 5 years for the young adult cyclists. Other exclusion criteria included past or present smoking (more than 3 years) and heavy (>2 drinks per day) alcohol use.

Inclusion criteria for the master cyclists included: age 40–60 years; year-round training consistently at least 150 miles per week or a minimum of 10 h per week for a minimum of 10 years; competing in USCF (United States Cycling Federation) races for a minimum of 10 years. Young adult cyclists between 25 and 35 years of age were recruited to compare age differences within this population of athletes. Inclusion criteria for the young adult cyclists included training and racing profiles similar to those of the masters, with the exception of a minimum of 5 years in competition. Non-athletic, but otherwise healthy men were recruited to serve as a comparison group to the master athletes. These control subjects were non-smokers who met the same inclusion criteria specific to medication use. They were excluded from the study if they engaged in regular (2 or more days per week) weight training and/or competition in any sport; however, recreational exercisers were not excluded from participating. The non-athletes were matched to the master cyclists by age (±2 years) and body weight (±2 kg).

The study was approved by the University's Institutional Review Board, and all subjects gave written, informed consent to participate.

### Bone density measurements

Bone mineral density (BMD, g/cm$^2$) of the lumbar spine (L2–L4), proximal femur, and total body was assessed by dual energy X-ray absorptiometry (DXA) using a Lunar DPX-NT densitometer (GE/Lunar Corp, Software Version 4.0). Soft tissue mass was also obtained from the total body scan to determine body composition. All scans were conducted by the same technologist. Quality assurance (QA) tests were performed each morning of use, using a standard with tissue-equivalent material with three bone-simulating chambers of known bone mineral content. In vivo BMD precision in our laboratory is 0.6–1.2% for the spine, 0.6–1.7% for total hip, and 0.6–0.8% for total body.

### Lifetime physical activity

The Historical Leisure Activity Questionnaire [16] was used to assess participation in total and weight-bearing physical activity during three different stages of life (age 12–18, 19–34, and 35–49 years) in the master cyclists and non-athletes only. This questionnaire has moderate to good reliability when self-administered [17]. To maximize subjects' ability to accurately and reliably recall exercise participation, a trained interviewer used a standardized script to cue subjects in recalling participation in activities for each life stage. Subjects were asked to recall the number of months per year and hours per week in structured and unstructured sports and activities during these three periods of life. The subjects first recorded from a checklist any organized sport, e.g. school or community teams, in which they participated, then asked to recall and check any unstructured activities they did at least 1 day per week. For analysis, activities were categorized as weight-bearing, e.g. running, tennis, basketball, baseball, or non-weight-bearing. The non-weight-bearing activities most frequently reported were swimming, fishing and cycling. Data are reported for weight-bearing and total physical activity per time period.

### Training regimen (athletes)

The cyclists recorded their training regimen for a typical week during the competitive season. Since, by design, athletes were excluded if they participated in weight-bearing activities 2 or more days per week, they were asked only to record their cycle training regimens. Most of the athletes kept training diaries and referred to them for these data. They recorded the number of days per week and hours per day spent riding.

### Current exercise

The non-athletes were asked to report for a typical week all recreational exercise they performed 2 or more days per week at moderate or vigorous intensity for at least 20 min at a time (cyclists were excluded if they engaged in other sports 2 or more days per week). They recorded the number of days per week and minutes per session for each activity. Separate questions were asked of all subjects for current participation in weight lifting/strength training for both the upper and lower body musculature. Participants recorded the number of months per year and days per week they typically lifted weights. The cyclists who engaged in weight training up to 3 months per year (excluded from study if > 3 months per year) were asked whether this was typical of their annual training program. In addition, all subjects were asked to report (yes/no) if their jobs required heavy physical labor.

### Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) software (Chicago, Ill., USA, version 10.0). Separate one-way ANOVAs were used to compare the three study groups for bone mineral density at the lumbar spine, hip and total body, as well as all physical characteristics. Post hoc Tukey's HSD tests were used to determine the source of any significant effects. Bivariate correlations were performed on variables of interest. Separate 2 (master cyclists/non-athletes)×2 (high/low) ANOVAs were conducted to examine the effect of cycling status and weight-bearing and total exercise history on BMD. High and low categories were designated as the upper and lower 50% of weight-bearing alone and total exercise hours for three different stages of life: teen (12–18 years); young adult (19–34 years); adult (35–49 years). The initial alpha level was set to 0.10, as the study was considered exploratory in this population and minimal risk was involved in participation, and to increase the power to detect what might be small effect sizes due to the limitations on sample size caused by inclusion criteria. Alpha was then adjusted using the Bonferroni method for the multiple comparisons of BMD by anatomical site (three sites) and for the three life stages. Thus, the adjusted level of significance was $P<0.033$.

## Results

Among the cyclists were regional, national and international competitors, several of whom were age-group national ($n=5$) and world champions ($n=1$). The physical characteristics and training history of the subjects are shown in Table 1. By design, there were no differences between the master cyclists and non-athletes in age or body weight; there were also no differences in body weight between young and older cyclists. Percentage of body fat was lower, while lean tissue mass was greater in both groups of cyclists compared to non-athletes ($P<0.033$). The master cyclists reported $12.1\pm3.9$ h (mean ± SD) of training per week, which was significantly lower than that reported by the younger cyclists. Other than weight lifting in the off-season (3 months), none of the master cyclists participated in any sport other than cycling. The non-athletes reported a mean of $4.5\pm1.4$ days/week and $4.5\pm2.6$ h/week of regular recreational exercise, in addition to weight/resistance exercises. The types of exercise reported most frequently by the non-athletes, in order of most to least frequent, were jogging/running, hiking, cycling, swimming and tennis. By design, none of the non-athletes was involved in training for competition. Eleven non-athletes, 11 master cyclists and nine young cyclists reported engaging in weight training. The non-athletes ranged from 2 to 12 months per year (mean 9.8 months), while both groups of cyclists trained two to 3 months per year. In addition, one non-athlete and four cyclists (three young; one master) reported doing heavy physical labor in their jobs (construction and landscape work).

Group mean (± SD) BMD values for the lumbar spine (L2–L4), total hip, femoral neck, trochanter, and total body are reported in Table 2. One-way ANOVAs with Tukey post-hoc tests indicated that the master cyclists had significantly lower BMD at L2–L4 and total hip compared to both the non-athletes (L2–L4, $P=0.032$; hip, $P=0.026$) and younger cyclists (L2–L4, $P=0.032$; hip, $P=0.005$). The trochanteric region of the hip showed a strong trend ($P=0.06$) toward lower BMD in the master athletes compared to non-athletes. The master cyclists also had lower trochanteric, femoral neck, and total body BMD ($P<0.033$) than the young adult cyclists. Both total and regional BMD were similar in the non-athletes and young adult cyclists. The *T*-scores of the younger cyclists indicated that their total body BMD was 3% higher, while BMD of the spine was approximately 3% lower than that of the age-matched reference population (Lunar/GE data base). Total hip BMD of the younger cyclists was similar to the reference values for men.

Chi-square analysis comparing the percentage of master cyclists and non-athletes classified at risk (i.e. osteopenia/osteoporosis: *T*-scores of –1 SD or below the young peak reference value at each of the three measurement sites) revealed a significantly greater incidence of osteopenia/osteoporosis at both the spine ($P<0.025$) and hip ($P<0.02$) in the master cyclists (Fig. 1). Two-thirds of the master cyclists met the criteria for osteopenia/osteoporosis at the spine, while 63% met the criteria at the hip. An examination of *T*-scores further indicated that four of the master cyclists were classified as osteoporotic. Among the non-athletes, 42% and 33% were classified as osteopenic at the spine and hip, respectively, while none was osteoporotic. Although the percentages for total body BMD were not significantly

**Table 1** Physical characteristics and training history of subjects. Values are group mean ± SD

| | Young adult cyclists ($n=16$) | Master cyclists ($n=27$) | Non-athletes ($n=24$) |
|---|---|---|---|
| Age (years) | $31.7\pm3.5$ | $51.82\pm5.1$ | $51.6\pm4.7$ |
| Height (cm) | $176.7\pm6.4$ | $178.4\pm5.2$ | $175.7\pm6.5$ |
| Weight (kg) | $73.1\pm9.2$ | $71.9\pm6.4$ | $73.8\pm8.8$ |
| Body fat (%)[a] | $15.3\pm5.9$* | $13.9\pm4.1$* | $22.2\pm5.4$ |
| Lean tissue mass (kg)[a] | $58.7\pm5.2$* | $59.9\pm5.4$* | $54.4\pm5.9$ |
| Years of cycling | $10.9\pm3.2$ | $20.2\pm8.4^{++}$ | N/A |
| *Training regimen (cyclists); recreational exercise (non-athletes)* | | | |
| Days per week | $5.5\pm0.8$ | $4.7\pm1.3$ | $4.5\pm1.4$ |
| Hours per week | $15.8\pm3.8$ | $12.1\pm3.9^{++}$ | $4.5\pm2.6$ |

*$P<0.033$ compared to non-athletes; $^{++}P<0.033$ compared to young adult cyclists. ANOVAs with Tukey post-hoc tests were used to compare the three groups

[a]Body composition determined by DXA

different between the master cyclists and non-athletes, 41% of the cyclists were classified as osteopenic/osteoporotic, while 21% of the non-athletes met the criteria for osteopenia. Results from the History of Leisure Activity questionnaire are presented in Table 3. Differences in self-reported hours of weight-bearing and total exercise between master cyclists and non-athletes were not significant for the 12–18 or 19–34 year time periods. From age 35–49, when they were devoting more time to cycling, the master cyclists engaged in nearly twice as much total exercise as the non-athletes ($P < 0.001$).

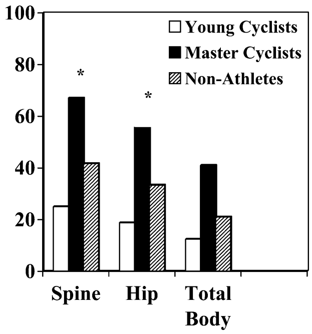


**Fig. 1** Percentage of participants within each group classified as osteopenic/osteoporotic. *$P = 0.023$ (spine); $P = 0.01$ (hip) compared to non-athletes

Table 4 shows the mean ± SD BMD of the master cyclists and non-athletes grouped by the upper and lower 50th percentiles for weight-bearing exercise during each of the three life stages. When divided into these ''high'' and ''low'' categories for weight-bearing exercise, separate 2×2 ANOVAs yielded no significant interactions between cycling status and weight-bearing exercise at any stage of life at each BMD measurement site ($P > 0.033$).

## Discussion

Compared to the non-athletes in this study, as well as to the reference group of age-matched men (GE/Lunar

**Table 2** Bone mineral density (g/cm$^2$) of subjects. Values are group mean ± SD. ANOVAs with Tukey post-hoc tests were used to compare the three groups

| | Young adult cyclists ($n = 16$) | Master cyclists ($n = 27$) | Non-athletes ($n = 24$) |
|---|---|---|---|
| Lumbar spine (L2–L4) | 1.20 ± 0.13 | 1.07 ± 0.15* | 1.19 ± 0.19 |
| Total hip | 1.10 ± 0.16 | 0.93 ± 0.11* | 1.05 ± 0.18 |
| Femoral neck | 1.05 ± 0.18 | 0.91 ± 0.18$^{++}$ | 0.99 ± 0.16 |
| Trochanter | 0.91 ± 0.15 | 0.79 ± 0.11$^{++}$ | 0.89 ± 0.18 |
| Total body | 1.26 ± 0.10 | 1.16 ± 0.09$^{++}$ | 1.22 ± 0.11 |

*Master cyclists significantly lower than non-athletes and young adult cyclists ($P < 0.033$)
$^{++}$Master cyclists significantly lower than young adult cyclists ($P < 0.033$)

**Table 3** Group mean ± SD of hours per week of historical physical activity of master cyclists and non-athletes. Data are reported for the three life stages indicated in the History of Leisure Activities Questionnaire

| | Age 12–18 | | Age 19–34 | | Age 35–49 | |
|---|---|---|---|---|---|---|
| | Weight-bearing exercise (h/week) | Total exercise (h/week) | Weight-bearing exercise (h/week) | Total exercise (h/week) | Weight-bearing exercise (h/week) | Total exercise (h/week) |
| Master cyclists | 3.9 ± 4.6 | 6.4 ± 6.4 | 3.2 ± 3.9 | 7.0 ± 7.4 | 3.3 ± 4.9 | 14.1 ± 7.8* |
| Non-athletes | 4.9 ± 4.2 | 6.6 ± 5.9 | 4.4 ± 2.6 | 5.7 ± 3.8 | 5.3 ± 3.9 | 7.5 ± 4.5 |

*$P < 0.001$ compared to non-athletes

**Table 4** BMD of master cyclists and non-athletes grouped by upper and lower 50th percentiles for weight-bearing exercise. Values are group mean ± SD expressed in g/cm$^2$

| | | Age 12–18 | | Age 19–34 | | Age 35–49 | |
|---|---|---|---|---|---|---|---|
| | | High[a] | Low[a] | High[a] | Low[a] | High[a] | Low[a] |
| Lumbar spine | Master cyclists | 1.05 ± 0.15 | 1.08 ± 0.17 | 1.02 ± 0.14 | 1.12 ± 0.17 | 1.07 ± 0.19 | 1.07 ± 0.13 |
| | Non-athletes | 1.18 ± 0.22 | 1.17 ± 0.18 | 1.12 ± 0.18 | 1.22 ± 0.20 | 1.12 ± 0.19 | 1.22 ± 0.20 |
| Total hip | Master cyclists | 0.93 ± 0.11 | 0.96 ± 0.12 | 0.93 ± 0.12 | 0.96 ± 0.12 | 0.95 ± 0.12 | 0.94 ± 0.12 |
| | Non-athletes | 1.07 ± 0.22 | 1.01 ± 0.17 | 1.02 ± 0.21 | 1.06 ± 0.18 | 0.98 ± 0.20 | 1.10 ± 0.17 |
| Total body | Master cyclists | 1.17 ± 0.09 | 1.18 ± 0.09 | 1.16 ± 0.09 | 1.19 ± 0.09 | 1.17 ± 0.09 | 1.17 ± 0.09 |
| | Non-athletes | 1.21 ± 0.14 | 1.23 ± 0.08 | 1.20 ± 0.12 | 1.24 ± 0.10 | 1.19 ± 0.12 | 1.25 ± 0.09 |

[a]High and Low refer to upper and lower 50th percentiles, respectively, for weight-bearing activity

data base), the bone mass of the master cyclists was approximately 10% lower at both the proximal femur and the lumbar spine. The group mean *T*-scores of the non-athletes indicated that since achieving peak bone mass their BMD had declined, in theory, by approximately 4% at the hip and spine, with no decrease in the total body. *Z*-Scores of the non-athletes indicated that their spine, hip and total body BMD was 99%, 103% and 102%, respectively, of that of their peers matched for age, weight, height and ethnicity. Thus, as a group the non-athletes appear to be fairly representative of the population. However, according to self-reported physical activity, the non-athletes are more active than the literature suggests is typical for their age, and none reported a sedentary lifestyle. Although they were not currently competitive athletes, many had participated in organized sports during high school and beyond. Still, ten of the non-athletes had BMD *T*-scores between −1 and −2.0 SD at the spine and/or hip. This is puzzling, but may be associated with their low body weight. Body weight was moderately related to BMD ($r=0.37$ for spine and hip; $r=0.50$ for total body); however, there were no group differences in body weight. Thus, although body weight likely contributes to the low BMD of some of the non-athletes, it does not explain the group differences between them and the cyclists.

Peak muscular force is the primary external stimulus for postnatal bone mass accretion [18]. The pull of muscle at its attachment site momentarily bends the bone; the resultant strain is the stimulus for new bone. Sports involving large ground reaction force loading, as in jumping and landing [9], or large dynamic muscle/joint reaction forces, such as those associated with lifting heavy weights [10], produce the greatest osteogenic stimulus. As shown from animal studies, high magnitude, high rate, and irregular distribution of strain appear to play the largest role in the stimulus of new bone production [5]. Unlike sports such as volleyball or tennis/squash, in which bone undergoes uneven distribution of high magnitude strain at high frequency [9,19], the relatively fixed body position while riding a bicycle induces a repetitive muscular strain pattern of relatively low magnitude and regular or even distribution. Thus, it is possible that cycling provides a rather poor osteogenic stimulus due to both the biomechanics of the sport as well as its lack of impact.

To our knowledge, this is the first report of bone mass in master cyclists, all of whom had been training and racing for an average of 20 years and had engaged in little to no weight-bearing activity. When compared to healthy men matched for age and body weight, the older cyclists in the present study had lower BMD at both the hip and spine. Other factors known to affect BMD, including smoking, alcohol consumption and certain medications and medical conditions were controlled by initial screening. Thus, the group differences in BMD are more likely due to differences in exercise patterns during their adult years. Previous studies of adult athletes have shown that other non-impact sports, even if performed vigorously, do not provide an osteogenic stimulus [10,14]. However, total and regional bone mass of competitive mountain cyclists, due perhaps to the impact of riding on rough terrain, was recently reported to be significantly higher than that of young adult road cyclists [20].

We used the History of Leisure Activities questionnaire [16] to gain a better understanding of the influence on BMD of physical activity during different periods in life. With these data, we investigated the interaction between current BMD and self-reported total and weight-bearing activity during different periods of life, specifically, age 12–18, 19–34, and 35–49 years. Previous research has shown that exercise during youth is associated with higher adult bone mass [4]. However, among the master cyclists and non-athletes, there were no significant within group differences in BMD in those within the upper versus lower 50th percentiles for weight-bearing exercise at each stage of life. Moreover, there were no significant interaction effects between groups and weight-bearing activity at any stage of life for any skeletal site. Thus, impact exercise during youth and earlier adult years was not reflective of greater BMD in this small sample of middle-aged athletic men. We speculate whether BMD may be declining at a faster rate during their older adult years. It is possible that the observed difference in bone mass between these two groups matched for age and body weight is due to the very little time spent in weight-bearing activity since age 35. Longitudinal data are needed to determine the rate of bone loss in this athletic population.

It is possible that the cumulative effect of the large percentage of waking hours spent by the master cyclists in activities in which their body weight was supported had an effect on the remodeling of bone. These athletes had been cycle training consistently for approximately 20 years, with very little time reported for weight-bearing activity, especially during middle age. The cumulative effect of their lifestyle may be compared to shorter periods of skeletal un-weighting, such as that shown in bed rest studies [13]. Some of the master athletes reported up to 30 h per week on their bikes.

Anecdotally, cyclists are known to avoid unnecessary weight-bearing activity during heavy training periods. Thus, although not directly assessed, it is likely that the master cyclists spend little time on their feet. With such a large training volume, much additional waking time must be spent resting and recovering. An old saying from the Tour de France is often quoted by coaches and practiced by many highly competitive cyclists: "If you are not riding, you should be resting, if you do not have to stand, you should sit, if you do not have to sit, you should lie down."

Using the World Health Organization's criteria for osteoporosis in women (*T*-score at or below –2.5 SD below peak young-adult BMD) and osteopenia (*T*-score between –1 and –2.5), 67% of the master cyclists would be classified as either osteopenic (52%) or osteoporotic (15%) at either or both the spine and hip. Ten non-athletes (42%) would be classified as osteopenic, while none was osteoporotic. In addition, four (25%) young adult cyclists would be classified as osteopenic in the lumbar spine. This latter finding is alarming, especially in light of the fact that at least one other study reported low spinal BMD in cyclists of similar age, body weight, and training regimen [14].

Although cross-sectional in design and therefore not able to establish a causal relationship, the present study provides evidence that long-term participation solely in cycling, with little to no participation in impact or resistance activities may be detrimental to bone health in later years. Given the findings in this study, coupled with the high risk of fractures due to crashes associated with competitive cycling, we recommend that: (1) these athletes be screened periodically to determine their BMD; (2) supplement their cycling with resistance or impact exercise; (3) consume a balanced diet with adequate intake of calcium and vitamin D. Those at high risk for fractures, as recognized by low *T*-scores, should discuss possible pharmacological treatment with their physicians.

## References


1. Rizzoli R, Schaad MA, Uebelhart B (2001) Osteoporosis in men. Nurs Clin North Am 36:467–479
2. Dalsky GP, Stocke KS, Ehsani AA, Slatopolsky E, Lee WC, Birge SJ (1988) Weight-bearing exercise training and lumbar bone mineral content in postmeopausal women. Ann Int Med 108:824–828
3. Menkes A, Mazel S, Redmund RA et al. (1993) Strength training increases regional bone mineral density and bone remodeling in middle-aged and older men. J Appl Physiol 74:2478–2484
4. Welten, DC, Kemper HC, Post GB et al. (1994) Weight-bearing activity during youth is a more important factor for peak bone mass than calcium intake. J Bone Miner Res 9:1089–1096
5. Rubin CT, Lanyon LE (1985) Regulation of bone mass by mechanical strain magnitude. Calcif Tissue Int 37:411–417
6. Umemura Y, Ishiko T, Tsujimoto H (1995) The effects of jump training on bone hypertrophy in young and old rats. Int J Sports Med 16:364–367
7. Bassey EJ, Littlewood JJ, Taylor SJ (1997) Relations between compressive axial forces in an instrumented massive femoral implant, ground reaction forces, and integrated electromyographs from vastus lateralis during various osteogenic exercises. J Biomech 30:213–223
8. Andreoli A, Monteleone M, Van Loan M, Prmenzio L, Tarantino U, De Lorenzo A (2001) Effects of different sports on bone density and muscle mass in highly trained athletes. Med Sci Sports Exerc 33:507–511
9. Calbet JAL, Diaz P, Herrera, Rodriguez LP (1999) High bone mineral density in male elite professional volleyball players. Osteoporos Int 10:468–474
10. Morel J, Combe B, Francisco J, Bernard J (2001) Bone mineral density of 704 amateur sportsmen involved in different physical activities. Osteoporos Int 12:152–157
11. Mackelvie KJ, McKay HA, Khan KM, Crocker PR (2001) A school-based exercise intervention augments bone mineral accrual in pubertal girls. J Pediatr 139:501–508
12. Baldwin KM, White TP, Arnaud SB et al. (1996) Musculoskeletal adaptations to weightlessness and development of effective countermeasures. Med Sci Sports Exerc 10:1247–1253
13. Leblanc AD, Schneider VS, Harlan JE, Engelbretson DA, Krebs JM (1990) Bone mineral loss and recovery after 17 weeks of bed rest. J Bone Miner Res 5:843–850
14. Stewart AD, Hannan J (2000) Total and regional bone density in male runners, cyclists, and controls. Med Sci Sports Exerc 32:1373–1377
15. Taaffe DR, Snow-Harter C, Connolly DA, Robinson TL, Brown MD, Marcus R (1995) Differential effects of swimming versus weight-bearing activity on bone mineral status of eumenorrheic athletes. J Bone Miner Res 10:586–593
16. Kriska AM, Sandler RB, Cauley JA, LaPorte RE, HomDL, Pambianco G (1988) The assesement of historical physical activity and its relation to adult bone parameters. Am J Epidemiol 127:1053–1063
17. Chasan-Taber L, Ericson JB, McBride JW, Nasca PC, Chasan-Taber S, Freedson PS (2002) Reproducibility of a self-administered lifetime physical activity questionnaire among female college alumnae. Am J Epidemiol 155:282–289
18. Frost HM (1997) Why do marathon runners have less bone than weight lifters? A vital-biomechanical view and explanation. Bone 20:183–189
19. Heinonen A, Oja P, Kannus P, Sievanen H, Haapasalo H, Manttari A, Vuori I (1995) Bone mineral density in female athletes representing sports with different loading characteristics of the skeleton. Bone 17:197–203
20. Warner SE, Shaw JM, Dalsky GP (2000) Bone mineral density of competitive male mountain and road cyclists. Bone 30:281–286