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Mineral Density Levels in Male and Female Collegiate Cross Country Runners: Is there Reason for Concern?

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Abstract

Introduction: The results of several recent studies have questioned the consequences of high levels of running on bone mineral density (BMD). Elite endurance athletes experience high physiological stress which may negatively impact bone health. Thus, the purpose of this study was to examine the change in BMD in male and female Division I collegiate runners during a competitive Cross Country (CC) season.

Methods: T wenty-three (1 1 male and 12 female) Division I collegiate CC runners (ages 18-22 year) were recruited for this study. Total/regional BMD and body composition was determined using dual x-ray absorptiometry. Caloric intake and running mileage was obtained from self-reported diet and training logs. All measures were performed prior to the start (pre) and immediately following (post) a three month collegiate CC season.

Results: Males did not demonstrate any significant changes in body composition from pre-post CC whereas females had a significant increase (2.7 ± 1.7 lbs or 2.1%) in total mass, with non-significant increases in fat free and fat mass. From pre- post CC, males did not have any significant changes in bone density whereas females had a statistically significant decrease in bone density of lumbar vertebrae. While no other changes in total or regional BMD were observed, ~ 50% of the both male and female athletes tested in this study had total BMD lower than the age-based reference value.

Conclusion: The results of this study suggest that a single competitive CC season can result in a decrease in the lumbar spine BMD in female collegiate distance runners. Moreover, this study revealed that a large percentage (~ 50%) of both male and female distance runners had lower than age-adjusted normal BMD level, raising concerns about long-term bone health in these athletes. Verification of these findings in a larger more diverse population of young athletes is warranted to determine the long term consequences of distance running on bone health.

Keywords: Bone Health; Distance running; Osteoporosis; Cross-country

Introduction

The aging of the population has led to a growing number of adults with a reduced bone mineral density (BMD) and an increase in the prevalence of individuals with osteoporosis. In the United States, there are approximately 5 million women diagnosed with osteoporosis and approximately 1–2 million men diagnosed with osteoporosis [1,2]. Risk factors for osteoporosis include increased age, smoking, obesity, low vitamin D and calcium intake, and inadequate physical activity [3,4].

Physical activity generally provides protection against bone loss and BMD reduction [5-8]. Paradoxically, negative changes in BMD have been observed in athletes engaging in high levels of physical activity [7,9,10]. The changes in BMD are variable and may be affected by gender and specific sports. Specifically, distance runners have been reported to have lower levels of BMD than other athletes [11]. To date, most of the studies of BMD in athletes are cross sectional and without longitudinal follow-up. Moreover, majority of the BMD studies in athletes, particularly distance runners, have just included females. Thus, the purpose of this investigation was to assess the changes BMD and other body composition measures in both female and male collegiate Division I cross country (CC) runners during a competitive three-month season.

Materials and Methods

Overview

The members of a National Collegiate Athletic Association (NCAA) Division I university CC team were recruited into the study. A total of 23 subjects, 11 males and 12 females, athletes volunteered to participate in this study. Initial measurements were performed prior to the first race (pre-CC) of the season and the final measurements were taken after the final race (post-CC) of the season. Body composition, BMD (total and regional), diet, running experience, and maximal oxygen uptake were all assessed pre-CC and again after a three month season (post-CC). This study was approved by the Institutional Review Board and written informed consent was given by each participant prior to participating in the study.

Body composition and bone mineral density (BMD) assessment

A dual energy x-ray absorptiometry (DXA) scan was performed on participants at baseline (pre-CC) and follow-up (post-CC) using the GE Lunar iDXA Bone Densitometer. At each assessment separate DXA measurements were taken of the total body, anterior-posterior (AP) lumbar spine, non-dominant forearm, and dual femoral neck. In addition to total and regional BMD measurements, individual BMD levels were compared to established norms for this age group.

Dietary and running questionnaires

Prior to the start of the competitive season (Pre-CC), participants were asked to complete a 7 day food diary by recording all food and drink items consumed each day. The data was analyzed using Nutritionist Pro version 5.2 software. Nutritional analysis was performed using the average of two weekdays and one weekend day. The three day assessment was used to calculate the average daily intake for calories, carbohydrates, fat, cholesterol, and protein as well as the ratio of carbohydrates and protein intake to body weight.

Also at the pre-CC assessment, a running history questionnaire was given to each subject and inquired about running experience, current training status, and history of bone injury including stress fractures. Participants were instructed to record, in detail, their daily training and to record times, distance, and any other pertinent training information.

Maximal oxygen uptake analysis

Maximal oxygen uptake (VO_2 max) was measured pre-CC using the Parvomedics TrueOne 2400 metabolic cart and software during a maximal graded exercise test on a treadmill at pre-CC. The test began at a running speed chosen by the subject at a zero degree grade. The speed then remained constant throughout the entire test. During the test the grade increased 1.5 degrees every minute until complete exhaustion at which point they were able to signal to stop the test. This data was collected just as a "descriptive" measure of current fitness levels of the subjects.

Statistical analysis

All data was entered into SPSS (version 21) and analyzed for normality and demographics. Descriptive statistics were run on pre- and post-CC measures to determine means, standard deviations, and ranges for measured values.

The data was found to not be normally distributed, thus, nonparametric statistics were employed to compare the groups. A Mann-Whitney U test was used to compare male and female values at pre-CC. This method was also used to compare the pre- cross country season measures with normal reference values/ranges for males and females.

A Wilcoxon Signed Rank test was used to compare pre- and post-CC season values within subjects. Bivariate Spearman correlation analysis was used to examine associations between variables of interest. A p-value of <0.05 was considered to be statistically significant.

Results

Demographics

A total of 23 subjects, 11 males and 12 females, participated in this study. Descriptive statistics of demographic data pre-CC are presented in Table 1. All participants were white non-Hispanic and ranged in age from 18 to 22 years.

As expected, males were significantly taller, had a higher BMI, and weighed more than females. Males also had a significantly higher weekly running mileage, running experience, and maximal oxygen uptake pre-CC than females in this study. There were no differences in age between males and female subjects.

Of the 23 athletes that participated in the study, 16 (8 males and 8 females) were analyzed at post-CC for change in bone and body composition measures.

The seven athletes were excluded from follow-up statistical analysis due to; inability to be scheduled for post-CC testing within two weeks (n=4), non-bone related injuries causing a premature termination of training/competition (n=2), and study drop out (n=1).

	Male (n= 11)	**Female (n= 12)**
Age (years)	19.5 ± 1.3	19.2 ± 1.3
Height (cm)	181.4 ± 3.7*	167.1 ± 6.2
Weight (kg)	68.2 ± 6.1*	55.5 ± 5.2
Body Mass Index	20.7 ± 1.2	19.0 ± 1.2
Running Experience (yrs)	6.9 ± 3.0*	5.0 ± 1.9
Running Mileage (miles/week)	65.9 ± 14.8*	49.8 ± 20.5
Maximal Oxygen Uptake (ml/kg/min)	71.8 ± 4.4*	59.9 ± 2.9

Table 1: Demographics of study participants pre-cross-country season. Data are presented as mean ± SD;* indicates significantly (<0.05) different between males and females Pre- CC.

Dietary assessment

The average (± SD) dietary intake measures for baseline assessment (pre-CC) are presented in Table 2.

Males had a significantly greater intake of calories, grams of protein, and cholesterol compared to females.

There was no significant difference between males and females for daily caloric intake, daily percent calories from fat, and daily percent calories from fat, and protein to body weight ratio.

All other dietary intake measures did not differ significantly from normal reference values/ranges at pre-CC [12-14].

	Study Group Intake		Recommended Intake	
	Males (n= 7)	Females (n= 5)	Males	Females
Daily caloric intake (kcal/day)	2638.9 ± 750.0*	1947.9 ± 281.6	NA	NA
Daily carbohydrate intake (% of total)	50.1 ± 4.9	49.3 ± 4.1	50-70 [12]	50-70 [12]
Daily fat intake (% of total)	30.5 ± 4.1	32.5 ± 3.9	20-35 [13]	20-25 [13]
Protein intake to body weight per day (g/kg/day)	1.7 ± 0.3	1.6 ± 0.2	0.8-1.2 [14]	0.8-1.2 [14]

Table 2: Dietary Measures Pre- Cross-Country Season and Normal Reference Values/Ranges. Data are presented as mean ± SD, * indicates significantly (<0.05) different between males and females Pre-CC, NA=Not available/applicable.

Total body composition and bone density measures

The mean (± SD) total body composition measures for pre-CC and post-CC are presented in Table 3. There were no significant changes in the total body composition of males from pre-post CC, including total body mass, total fat mass, percent body fat, total lean mass, total BMD, and total bone mineral content.

Females did significantly increase their lean body mass by 2.7 lbs. (an increase 2.1% of total mass) from pre-post CC. There were no other significant changes in the total body composition measures in females.

Furthermore, mean total body composition measures for males and females in this study did not differ significantly from "normal" reference values/ranges pre-CC or post-CC [14-16].

	Males (n=8)		Females (n=8)		Normal Reference	
	Pre- CC	Post- CC	Pre- CC	Post- CC	Male	Female
Total Body Mass (lbs)	148.5 ± 9.3	149.2 ± 13.2	123.5 ± 11.1	125.1 ± 12.8	NA	NA
Total Lean Body Mass (lbs)	123.1 ± 8.9	125.2 ± 11.0	94.2 ± 9.1*	96.9 ± 9.8	NA	NA
Total Fat Mass (lbs)	18.8 ± 3.0	17.4 ± 2.1	23.9 ± 4.1	22.9 ± 4.3	NA	NA
% Body Fat (DXA)	13.3 ± 2.1	12.2 ± .79	20.2 ± 2.9	19.1 ± 2.6	NA	NA
% Body Fat (skinfold)	7.0 ± 1.2	6.4 ± .6	16.2 ± 2.7	15.2 ± 2.5	NA	NA
Total Bone Mineral Density (g/cm^2)	1.24 ± .07	1.25 ± .07	1.15 ± .05	1.16 ± .05	1.22 ± 0.08 [11]	1.18 ± 0.11 [14]
Total Bone Mineral Content (lbs)	6.60 ± .64	6.64 ± .62	5.32 ± .53	5.37 ± .53	6.18 ± 0.93 [14]	4.78 ± 0.62 [15]

Table 3: Total body composition measures pre and post cross-country season and normal reference values. Data are presented as mean ± SD, * indicates significantly (p<0.05), different from pre- to post, NA=Not available/applicable.

Of interest is the observation (reported in Table 3) that the mean total BMD (both pre and post CC) for females in this study is lower, although not significantly significant, than the "normal" reference range for this measure.

Furthermore, as seen in Figures 1a and 1b, 50% of both the female (4 out of 8) and male (4 out of 8) subjects in this study fall below the "normal" reference range for BMD.

Regional bone mineral density measures

The mean (± SD) lumbar spine BMD values for pre- post CC are presented in Table 3. Males did not show any significant changes in lumbar spine BMD from pre- to post CC whereas females demonstrated significant decreases of 0.03 ± 0.02 g/cm^2 in L1, 0.02 ± 0.03 g/cm^2 in L1-2 and 0.02 ± 0.02 g/cm^2 in L1-3 from pre to post CC, reflecting a decrease of 2.9 %, 2.2 % and 1.6 % g/cm^2, respectively.

Despite the significant decrease in lumbar spine BMD in females, these values were not significantly different from normal reference data values/ranges [16]. However, as seen in Figures 2a and 2b, there were several individual male and female distance runners with lumbar spine BMD levels lower than the age adjusted "normal" reference level.

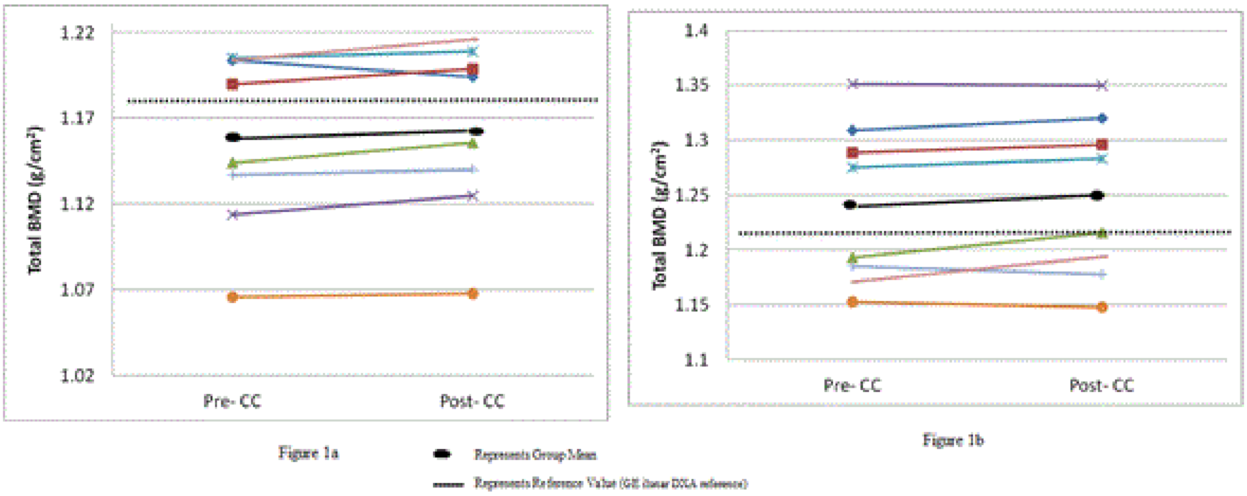

Figure 1: (a) Total bone mineral density levels of individual female subjects pre and post cross-country season, (b) Total bone mineral density levels of individual male subjects pre and post cross-country season.

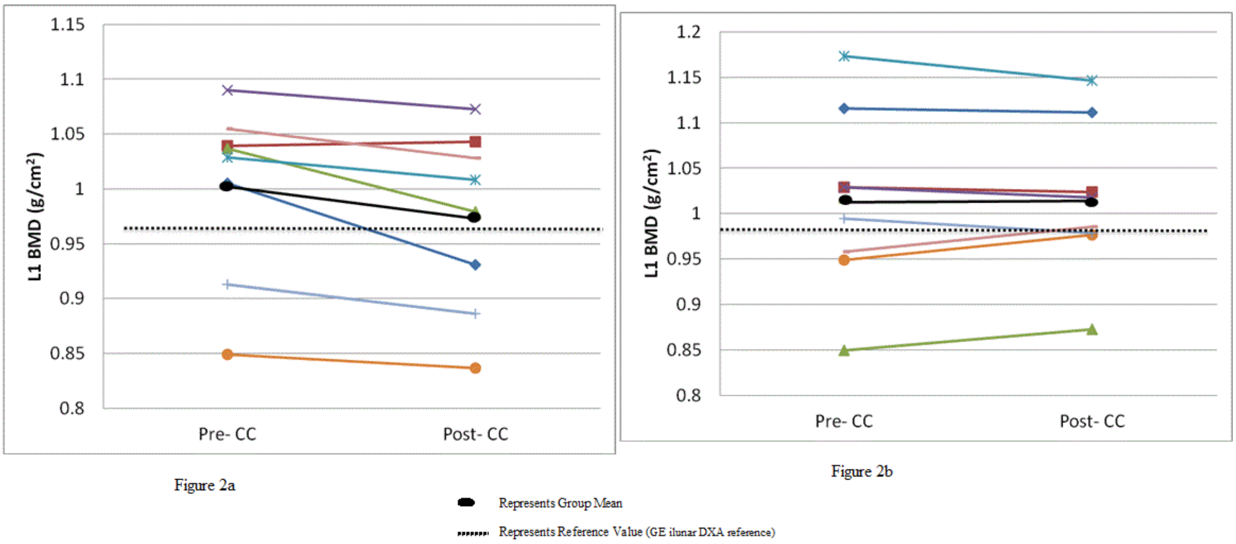

Figure 2: (a) Bone mineral density of first lumbar (l1) vertebrae in individual female subjects pre and post cross-country season, (b) Bone mineral density of first lumbar (l1) Vertebrae in individual male subjects pre and post cross-country season.

	Males (n= 8)		Females (n= 8)		Normal Reference	
	Pre- CC	Post- CC	Pre- CC	Post- CC	Males	Females
L1 BMD (g/cm^2)	1.01± 0.10	1.01 ± 0.10	1.00 ± 0.08	0.97 ± 0.08*	0.98 ± 0.11 [11]	0.96 ± 0.11 [11]
L1-2 BMD (g/cm^2)	1.08 ± 0.11	1.09 ± 0.11	1.05 ± 0.08	1.02 ± 0.08*	NA	NA
L1-3 BMD (g/cm^2)	1.14 ± 0.13	1.14 ± 0.13	1.10 ± 0.08	1.08 ± 0.09*	NA	NA

L1-4 BMD (g/cm^2)	1.15 ± 0.12	1.15 ± 0.12	1.11 ± 0.08	1.10 ± 0.08	1.22 ± 0.08 [16]	1.12 ± 0.08 [16]

Table 4: Lumbar spine bone mineral density pre and post cross-country season and normal reference values. Data are presented as mean ± SD, * indicates significantly ($p<0.05$) different from pre- to post, NA=Not available/applicable.

There were no significant changes in male or female forearm or hip/femur BMD from pre- post CC. The mean (± SD) forearm and hip/femur BMD values for pre- post CC are presented in Table 4.

Forearm BMD measures, for males or females, did not differ significantly from "normal" reference values/ranges.

Furthermore, hip/femur BMD measures for males and females in this study did not differ significantly from normal reference data values/ranges pre-CC or post-CC [Table 5].

	Males (n= 8)		Females (n= 8)		Normal Reference	
	Pre-CC	Post-CC	Pre-CC	Post-CC	Male	Female
Ultra-Distal Radius BMD (g/cm^2)	0.45 ± 0.06	0.44 ± 0.06	0.38 ± 0.03	0.33 ± 0.12	0.50 ± .05 [11]	0.47 ± 0.05 [11]
Radius Total BMD (g/cm2)	0.67 ± 0.06	0.66 ± 0.06	0.59 ± 0.04	0.58 ± 0.04	0.76 ± .07 [11]	0.68 ± 0.05 [11]
Ulna Total BMD (g/cm2)	0.63 ± 0.07	.63 ± 0.07	0.54 ± 0.03	0.53 ± 0.03	NA	NA
Femur Neck Mean BMD (g/cm^2)	1.14 ± 0.09	1.15 ± 0.09	1.06 ± 0.12	1.07 ± 0.13	0 .88 ± 0.12 [11]	0.79 ± 0.09 [11]
Trochanter Mean BMD (g/cm^2)	0.93 ± 0.08	0.94 ± 0.08	0.86 ± 0.10	0.86 ± 0.12	0.75 ± 0.11[11]	0.69 ± 0.11[11]

Table 5: Forearm and hip/femur bone mineral density pre and post cross-country season and normal reference values. Data are presented as mean ± SD, * indicates significantly ($p<0.05$) different from pre- to post, NA=Not available/applicable.

Discussion

Several studies have evaluated bone mineral density (BMD) in athletes [5,11,17,18]. This study is the first to longitudinally assess the changes in BMD in both male and female collegiate distance runners for the duration of a competitive season. At pre-CC the runners in this study were at a high level of fitness, indicated by the reported running mileage and maximal oxygen uptake. These athletes also had a low body fat percentage pre-CC as they were already training at a high level.

Consequently their pre-CC training may have potentially reduced the change observed in this study measured from pre-post CC. Although the only significant change in BMD that occurred during CC was observed in the female lumbar spine, it's important to acknowledge that ~ 50% of both the male and female CC runners participating in this study were below the reference value of BMD for their age.

The majority of other studies investigating BMD in runners have been cross-sectional and/or have only included females. Mudd et al. [19] compared the BMD of female Cross County runners with female athletes of other sports in a cross sectional study and found that the runners had significantly lower BMD than other female athletes participating in softball, track, and gymnastics.

Hind et al. [20] conducted a large cross sectional study including male runners. This study compared male and female distance runners ages 19-50 years and only included measurements of the lumbar spine and hip. A longitudinal study by Bennell et al. [17] studied the changes in BMD of both male and female runners for the duration of 12 months. Because there were only baseline and follow-up assessments of BMD, the study failed to identify when the changes took place during the observational period.

This study was limited by the small sample size and homogeneity of the subjects. With such as small sample size, this study was underpowered to detect changes in these measures. Despite this limitation, we still did observe significant changes in the lumbar spine in females as well as the observation that 50% of our subjects demonstrated BMD levels that are lower than their age-adjusted reference group.

Neither of these findings have been previously reported. Since a sample of white non-Hispanic, highly trained cross-country runners may not represent all endurance athletes, runners of other ethnicities and fitness levels need to be evaluated before making broad generalizations of these observations. Another limitation of this study is the short duration (3 months) of the observation period. A study of this length may not be long enough to see meaningful changes in bone tissue. Furthermore, the self-reported data obtained for some measures in this study also reduces the reliability of the purposed findings.

Conclusion

Based on the finding of this investigation, it can be concluded that three months of a collegiate cross country season can significantly lower BMD in the lumbar vertebrae of female, but not male, distance runners. Furthermore, a large proportion (~ 50%) of a small homogeneous sample of male and female collegiate distance runners appear to have less than "normal" levels of total BMD for their age.

This is of concern as maximal BMD is largely determined before the 3rd decade of life and those individuals with low BMD at college age may be at greater risk for the premature development of osteoporosis and other bone disorders. Future longitudinal studies should be conducted to follow young athletes with low BMD in order to assess the long-term impact of distance running on bone health.

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