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13. ABSTRACT (Maximum 200 Words) Objective: The objective of this study is to determine the major predictors of stress fracture and peak bone mass in elite military cadets entering the USMA class of 2002. Methods: The initial cadet sample size was 851 and baseline data included demographic information as well as dietary assessment, physical activity, lifestyle information, and menstrual function history during the year prior to entry to the academy. Upon entry to USMA, measurements on the cohort included dual x-ray absorptiometry (DXA) of the calcaneus (Lunar PIXI), peripheral QCT of the tibia (Norland pQCT) and central DXA of the spine and hip on a subset of cadets. Annual dietary assessments, menstrual function assessment in females and bone density measures at heel, tibia, spine and hip have been performed annually on 786 cadets in the summer of 1999 and 527 cadets in the summer of 2000. Body composition was measured in the full cohort, using the Tanita 305 total body fat analyzer in 1999 and in 2000. The Orthopedics department on post has diagnosed stress fractures and the diagnoses are adjudicated at Helen Hayes Hospital by review of cadet sick call data and review of x-ray or bone scan reports. Results: From summer 1998 at cadet basic training through June of 2000, there have been 94 stress fractures diagnosed and 72 stress reaction/possible fractures awaiting confirmation. For confirmed stress fractures, the female annual incidence is 14% and male incidence is 3.7%. For as yet unconfirmed cases or stress reactions, there are an additional 10% female and 3% male incidence. The data are currently being evaluated for the major factors other than gender which influence the risk of stress fracture. In both genders, baseline calcaneal, spine and hip BMD values were approximately one standard deviation above young normal at age 20. Past exercise history, fitness test scores, BMI, and calcium intake were all highly correlated with BMD at different sites in both genders, while history of smoking, alcohol use (both of which were very infrequent), salt and caffeine intakes were not related to BMD. Body composition is also a predictor of BMD at various sites. In female cadets the number of menstrual cycles prior to entering the academy was predictive of bone density in the calcaneus. Women who had regular menstrual cycles during the first year at the academy gained bone in the spine and hip compared to cadets who had fewer than 6 cycles during the year, in whom bone mass decreased in the spine and hip over this time period. Conclusion: Dietary, gonadal and physical/exercise/fitness factors all play a role in determining BMD gain and possibly occurrence of stress fracture.				
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SECTION I - INTRODUCTION:

The study "The Determinants of Peak Bone Mass and Stress Fractures in Elite Military Cadets" was designed to examine four specific aims. They have been modified slightly because full funding for multiple phlebotomies was not granted. This will be annotated in the text of the specific aims. Measurement of body composition as a predictor of stress fracture and bone mass has also been added. The specific aims of the study are:

- (1) To determine the epidemiology of stress fractures in West Point Cadets during their four years at the Academy. To identify the relative importance of bone mass, quality and turnover, calcium intake, physical training and body composition in determining the risk of stress fractures.
- (2) To examine the relationship of allelic variation in three separate genetic markers (Vitamin D Receptor, Type I Collagen and Estrogen receptor) to stress fractures and bone mass. (Although this was not funded through the Department of Defense, the investigative team believes that this aim is important and is seeking funding from additional sources to complete these tests from blood samples obtained in July 1998).
- (3) To determine the incidence of abnormal menstrual function in female cadets during intensive physical training and its effect on acquisition of peak bone mass. (The proposed laboratory tests to evaluate male gonadal dysfunction were not funded so this aim has been modified accordingly).
- (4) To determine prospectively the relative importance of gonadal function, calcium intake, body composition and physical activity as determinants of bone turnover, mass and quality at multiple sites in male and female cadets. (Because the investigative team believed that the turnover markers might be important as predictors of fracture risk, additional non-DOD funding sources are being pursued to perform these measurements using serum obtained July 1998).

SECTION II - BODY:

The determinants of peak bone mass and stress fractures are of both immediate and continuing interest to members of the military community. When higher bone mass is attained at a young age there is a subsequent reduction in the risk of osteoporosis and osteoporotic fracture later in life. There is also evidence that greater bone mass acquisition may reduce the incidence of both stress fractures and traumatic fractures. Therefore predictors of stress fracture and peak bone mass are the two main areas of research being conducted on the class of 2002 over a 4-year period at the United States Military Academy. The data collection efforts this year included measurements of bone density at multiple skeletal sites, incidence and distribution of stress fracture, measurements of body composition, dietary intakes and female menstrual function data.

During the summer of 1999, the research team was stationed at the range to complete data collection in an area convenient to the cadets. During the summer of 2000 the research team was stationed in the cadet area and collected this information by appointment. The cadets signed up for these appointments on the study website that

allowed them to choose a time that was most convenient for them. The same 3 tools were used to assess various quantitative properties of bone (Lunar PIXI peripheral DXA for calcaneus, Norland peripheral XCT 2000 scanner for tibia, and mobile Lunar DPX-IQ for spine and hip). The Tanita 305 total body fat analyzer was used to assess weight, BMI, impedance, percent body fat, fat mass, lean body mass and total body water. The food frequency questionnaire and the menstrual function questionnaire were provided to all cadets during their visit. (Appendix A and Appendix B).

The website (<http://sql3.pica.army.mil/CadetStudy/htm>), and e-mail continues to be the prime method of communication between the cadet participants and the study researchers. Additionally, it provides information to academy personnel who are interested in the study.

TABLE 1- DATA COLLECTION (sample size) for 1998 - 2000

Data Collection	Baseline 1998	Summer 1999	2000
Body Composition	0	767	527
Calcaneus (PIXI)	841	786	527
Spine/Hip DXA	292	261	211
Tibia (PQCT)	768	700	527
Food Frequency Survey	786	786	527
Menstrual Function	118	92	73

The orthopedics department at USMA, on the basis of physical examination and confirmation through x-ray or radionuclide scan, is continually assessing stress fractures. The Class of 2002 had a total of xx fractures in xx cadets, which occurred between initiation of cadet basic training in June 1998 through June 2000. Table 3 provides a distribution of the site of fracture by gender (of cadets in our study) and Table 4 provides the distribution of stress reaction or possible fracture cases where review of xray reports is pending.

TABLE 2. Fracture Sites of Cadets thru June 2000

	Metatarsal/Foot	Tibia	Fibula	Femur/Hip	Other	Total
Female	20	12	1	6	0	39
Male	36	8	1	3	7	55
Total	56	20	2	9	7	94

TABLE 3. Stress Reaction or Stress Fracture: awaiting confirmation by review of X-ray or bone scan reports

	Metatarsal/Foot	Tibia	Fibula	Femur/Hip	Total
Female	13	10	0	4	27
Male	26	19	0	0	45
Total	39	29	0	4	72

Standardized fitness scores and sport specific information have also been collected on cadets through the PT department. These variables will be included in analyses of stress fractures, bone mass and body composition data.

SECTION 7- KEY RESEARCH ACCOMPLISHMENTS

- Maintained and updated the study website to collect data, questionnaires and keep study participants informed. Established a web page for the cadets to schedule their appointment times for the summer of 2000.
- Collected dietary assessment information on 786 cadets in 1998 and 1999 and 527 cadets in 2000.
- Collected past menstrual function history on 118 female cadets in 1998, and prospectively assessed menstrual function in 92 cadets in 1999, and 73 cadets in 2000.
- Obtained detailed sports and exercise activities for all cadets over 2 years at USMA.
- Calcaneus bone mineral density measurements were taken on 841 cadets in 1998, 786 cadets in 1999 and 527 cadets in 2000.
- Performed 292 spine and hip BMD measurements in 1998, 261 in 1999 and 211 in 2000.
- Performed tibial bone measurements on 768 cadets in 1998, 700 in 1999 and 527 in 2000.
- Collected Body Composition measurements on 767 cadets in 1999 and 527 cadets in 2000
- Performed assessments of biochemical indices of bone formation and bone resorption on 866 cadets from serum samples collected in summer of 1998.
- Analyzed predictors of baseline bone mineral density at different skeletal sites.
- Determined predictors of change in BMD over 1 year in female and male cadets.
- Confirmed stress fracture cases for cadets over the first year at the USMA.
- Analyzed predictors of stress fractures in cadets over 1 year.

SECTION VIII- REPORTABLE OUTCOMES

PRESENTATIONS

- Plenary Poster Presentation – Cosman F, Ruffing J, Nieves J, Formica C, Lindsay R. Predictors of stress fractures in elite military cadets. American Society of Bone Mineral Research (ASBMR), St. Louis MO, October 1999
- Oral Presentation—Nieves J, Exercise and Milk Intake are Determinants of Bone Mass In Male Elite Military Cadets, 4th International Symposium on Nutritional Aspects of Osteoporosis, Switzerland, May 2000.
- Poster Presentation – Nieves J, Zion M, Ruffing J, Lindsay R, Cosman F, Exercise and Milk Intake are Determinants of Bone Mass in Male Elite Military Cadets (Abstract 161) National Osteoporosis Foundation (NOF) Annual Meeting, Chicago, Illinois, June 2000
- Poster Presentation- J. Nieves, J. Ruffing, M Zion, R Lindsay, Cosman F. Menstrual Function Predicts Change in Bone Mass in Elite Female Cadets. American Society of Bone Mineral Research (ASBMR), Toronto, Canada, September, 2000

MANUSCRIPTS

Ruffing J, Nieves J, Zion M, Lindsay R, Cosman F. Determinants of bone mineral density in a cohort of elite military cadets entering the US Military Academy at West Point. (in preparation)

J Nieves, C. Formica, J. Ruffing, M. Zion, V. Shen, R. Lindsay, F. Cosman. Males Have Larger Skeletal Size Than Females, Despite Comparable Body Size (submitted).

SECTION IX- CONCLUSIONS

Predictors of Baseline BMD.

The relationship between bone mineral density (BMD) at different sites upon entry to USMA was analyzed in relationship to body mass index (BMI), fitness scores, past exercise and dietary habits and other lifestyle factors. Past history of alcohol, tobacco, salt and caffeine consumption were not related to BMD at any skeletal site in either males or females. This could be due to the low incidence or degree of usage or that the high level of fitness and load bearing activity in cadets prior to academy entrance might mitigate the reported deleterious effect of these lifestyle factors.

The general bone health by BMD of the cadets is high. In both genders, calcaneal BMD values were approximately one standard deviation above young normal at age 20. Correlations between heel BMD and BMI were significant for both men and women; $r=0.45$; $p=.0001$ and $r =0.34$ $p=0.0007$, respectively. Past exercise history, fitness test scores, BMI, and calcium intake were all highly correlated with BMD at different sites. Both genders also had higher than expected lumbar and total hip density. In female cadets the number of menstrual cycles prior to entering the academy was predictive of bone density in the calcaneus with women who had 6 or fewer than cycles the year prior to entering the academy having significantly lower density ($p <0.05$).

A sample of 557 male cadets entering the United States Military Academy (USMA) had multiple bone density assessments to determine the relative importance of milk intake and physical activity on bone mass at various skeletal sites. Dietary intakes of calcium, salt, caffeine and physical activity over the year preceding entry to the USMA were assessed by written questionnaire. Calcium intake was almost solely determined by milk intake in this population. A Lunar DPX-IQ Dual x-ray absorptiometry (DXA) was used to assess bone density (BMD) at the lumbar spine and total hip in a randomly chosen subset of 131 male cadets. A peripheral DXA (Lunar) was used to assess heel BMD in 557 male cadets and a peripheral pQCT (Norland) was used to measure tibial bone content and cortical thickness in 503 male cadets. On average the cadets had spine, hip and heel BMD values that were one standard deviation above the manufacturers young normal reference population. Higher milk intakes (3 cups/day or more) were significantly related to greater total tibial content ($p=0.01$); cortical thickness ($p=0.02$) and heel BMD ($p=0.05$). There was also a trend toward higher BMD of the spine and hip in those with higher milk intakes. In male cadets, intense physical activity in the past year (exceeding 12 hours per week) was associated with significantly higher bone mass throughout the skeleton including the spine, hip, heel and tibia (3 and 6% higher; all $p<0.02$) as compared to cadets with less intense levels of physical activity. Salt and caffeine were not associated with bone mass. In conclusion, males with bone mass at the high end of normal, can still maximize bone mass at all skeletal sites by high levels of exercise and adequate calcium intake through milk consumption.

Factors Predicting Change in Bone Density In Female Cadets:

A sample of 73 female cadets (average age 19) entering the United States Military Academy (USMA) had bone density assessments at baseline and after one year. The relative importance of menstrual function and calcium intake on the peak mass accrual at various skeletal sites was evaluated. Menstrual function and calcium intake were assessed prospectively by questionnaire during the year. Menstrual function was defined as regular (≥ 10 menstrual cycles/year); mild oligomenorrhea (7-9 cycles per year) and oligomenorrhea/ amenorrhea (6 or fewer cycles per year). A Lunar DPX-IQ Dual x-ray absorptiometry (DXA) was used to assess bone mineral density (BMD) at the lumbar spine and total hip. On average these female cadets had spine and hip BMD values that were one standard deviation above the manufacturers young normal reference population. Women who had regular menstrual cycles during the year gained bone in the spine and total hip ($+0.020$ gm/cm² and $+0.014$ gm/cm² respectively) as compared to women who had oligomenorrhea/ amenorrhea (fewer than 6 menstrual cycles per year) who lost spinal

and hip bone mass (-0.012 gm/cm^2 and -0.014 gm/cm^2 respectively; $p\text{-value} < 0.05$ versus regular menstrual cycles). Women in the mild oligomenorrhea category gained bone in the spine ($+0.020 \text{ gm/cm}^2$) and had an insignificant change in the total hip ($+0.005 \text{ gm/cm}^2$), a change intermediate to the two extreme categories of menstrual function. In the group of women ($n=49$) who had regular menstrual cycles, there was no significant difference in change in spine or hip BMD between women using oral contraceptives and women with naturally occurring regular menses. On average, female cadets in each category of menstrual function had calcium intakes that were at or above the levels recommended (mean intake of 1200 mg/day). Calcium intake was not independently related to bone loss or gain in this population of women. Other differences in bone mass accrual may relate to physical activity level, which is currently being assessed in this population. Consistent with what has been seen in retrospective studies of elite athletes; normal menstrual function is a major determinant of bone gain in the spine and hip.

Factors Predicting Occurrence of Stress Fractures:

The annual incidence rate of stress fractures in female cadets over the first two years was 14.3% for confirmed fractures and 10% for stress reaction/unconfirmed fractures. In male cadets these rates were 3.7% and 3%. Relationships between stress fracture occurrence with past and current physical activity, fitness scores upon entry and while at the academy, body composition, bone mass, calcium intake (past and current), and bone turnover at all skeletal sites are now being evaluated.