Bone-Mineral Density and Other Features of the Female Athlete Triad in Elite Endurance Runners: A Longitudinal and Cross-Sectional Observational Study

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Low bone-mineral density (BMD) is associated with menstrual dysfunction and negative energy balance in the female athlete triad. This study determines BMD in elite female endurance runners and the associations between BMD, menstrual status, disordered eating, and training volume. Forty-four elite endurance runners participated in the cross-sectional study, and 7 provided longitudinal data. Low BMD was noted in 34.2% of the athletes at the lumbar spine, and osteoporosis in 33% at the radius. In cross-sectional analysis, there were no significant relationships between BMD and the possible associations. Menstrual dysfunction, disordered eating, and low BMD were coexistent in 15.9% of athletes. Longitudinal analysis identified a positive association between the BMD reduction at the lumbar spine and training volume ($p = .026$). This study confirms the presence of aspects of the female athlete triad in elite female endurance athletes and notes a substantial prevalence of low BMD and osteoporosis. Normal menstrual status was not significantly associated with normal BMD, and it is the authors’ practice that all elite female endurance athletes undergo dual-X-ray absorptiometry screening. The association between increased training volume, trend for menstrual dysfunction, and increased loss of lumbar BMD may support the concept that negative energy balance contributes to bone loss in athletes.

Keywords: menstrual disturbances, eating attitudes, endurance athletes, bone health

Physical activity and weight-bearing sports can increase bone-mineral density (BMD; Wolff, Van Croonenborg, Kemper, Kostense, & Twisk, 1999). However, low BMD has been recognized in female athletes participating in sports such as endurance running and gymnastics, which traditionally emphasize leanness (Torstveit & Sundgot-Borgen, 2005a, 2005c). In athletes, low BMD has been associated with menstrual dysfunction and negative energy balance, with or without disordered eating, as part of the coexisting spectrum disorder noted in the female athlete triad (Braam et al., 2003; Drinkwater et al., 1984; Hetland et al., 1993; Marcus et al. 1985; Nattiv et al., 2007; Rutherford, 1993; Wolman, Clark, McNally, Harries, & Reeve, 1990, 1992). It is recognized that low energy availability is often the underpinning pathology in the triad (Nattiv et al., 2007).

Energy availability is defined as the energy remaining for physiological functions after the energy expended in exercise is subtracted from dietary energy intake. This is an essential therapeutic concept; it has been elegantly shown that it is not the intensity or stress of training that results in menstrual or bone dysfunction but the reduction in energy availability that may be present in these athletes if nutrition is not adequate (Loucks, Verdun, & Heath, 1998). Endurance running in a negative energy balance suppresses synthesis of collagen and insulin-like growth factor-1 (Zanker & Swaine, 2000), the latter of which is known to promote cell proliferation and matrix formation in bone (Rosen, 1999).

Optimal bone health is achieved by accruing high peak bone mass in the first 3 decades of life, in combination with prevention of bone loss up to and beyond menopause (Nattiv et al., 2007). Should this not occur, athletes risk developing stress fractures and premature osteoporosis (Torstveit & Sundgot-Borgen, 2005a; Nattiv et al., 2007; Okano et al., 1995). The American College of Sports Medicine (ACSM) recommends investigating bone health in at-risk athletes by using dual-X-ray absorptiometry (DXA; Nattiv et al., 2007). The ACSM recommends using Z scores for adolescents and premenopausal females. It is not clear whether the application of the reference range based on healthy nonathletes is...
appropriate in the elite athlete population (Sangenis et al., 2005).

There have been a limited number of cross-sectional studies assessing BMD in elite athletes (Marcus et al., 1985; Torstveit & Sundgot-Borgen, 2005b). These have demonstrated lower Z scores in elite endurance athletes with menstrual dysfunction than in elite endurance-athlete controls and lower BMD in leanness sports than in elite athletes in sports defined as not emphasizing leanness (Marcus et al., 1985; Torstveit & Sundgot-Borgen, 2005b). There have been several longitudinal studies in predominantly nonelite athlete groups that noted small gains in BMD over less than a year (Bennell et al., 1997; Nichols et al., 1994). However, to our knowledge there have been no longitudinal studies over several years in elite athletes.

This study aimed to compare the distribution of BMD in UK elite endurance athletes with the parameters established in healthy nonathletic women. We assessed associations between the BMD data and training hours, menstrual status, and disordered eating. In addition, in a subgroup of athletes we evaluated longitudinal changes in BMD in elite female athletes and the relationship between the rate of change and training hours, menstrual status, and disordered eating.

Methods

Participants
A cohort of 44 elite female endurance athletes age 16–42 years (22.9 ± 6.0) supported by UK Athletics (UKA) who had attended bone-density screening at the Human Performance Laboratory, Middlesex University, between November 2003 and April 2008 were studied. The screening service was offered annually between November 2003 and 2008 to all elite endurance (>800-m) athletes representing Great Britain, regardless of medical history. All athletes who attended were included in the study. Access to this population was granted through the UK Endurance Performance Centre at St. Mary’s University College, Twickenham. This study was approved by the Middlesex University Research Ethics Committee.

Physical and Bone Measurements
BMD of the total body, anteroposterior L2–4 vertebrae, anteroposterior femoral neck, and dominant-arm distal radius was measured by DXA (fan beam, Lunar DPX-L series, GE Medical Systems, Lunar, Madison, WI, USA). The machine was calibrated using a spine phantom before each participant was scanned. BMD (g/cm²) and Z scores were collected for analysis using manufacturer-supplied normative data. All scans were performed and analyzed by the same technician.

Questionnaire Data
Athletes attending for DXA scan completed two questionnaires. The first measured training and menstrual history. This was a simple internally designed questionnaire in which athletes recorded the number of hours spent training per day in a normal training week. Current menstrual status was obtained from the reported number of menses in the preceding 12 months according to three categories: eumenorrheic (>10 cycles/year), oligomenorrheic (4–9 cycles/year), or amenorrheic (0–3 cycles/year; 19). Current use of oral contraceptive pills was recorded.

The Three-Factor Eating Questionnaire (revised 18-item; TFEQ-R18) was used to describe eating behavior (de Lauzon et al., 2004). It assesses cognitive restraint (conscious restriction of food for weight control), uncontrolled eating (tendency to eat more than normal because of loss of control or hunger), and emotional eating (inability to resist emotional cues). The answers were given on a 4-point scale from definitely true to definitely false. The sum of the raw answers was translated into a 0–100 scale: ([(raw score – lowest possible raw score)/possible raw score range] × 100) (Nichols et al., 1994). High levels of cognitive restraint or uncontrolled or emotional eating are denoted by a high score on the scale.

All questionnaires were completed in person at the time of scanning. Response rates were 84.1% and 70.4% for the menstrual-history and eating questionnaires, respectively. Questionnaire completion was voluntary, and consent was obtained before completion.

Data Analysis
Retrospective cross-sectional and longitudinal analysis of the data was carried out using SPSS version 16.0 (SPSS, Inc., Chicago, IL, USA). Background characteristics of the three menstrual groups were compared with a one-way ANOVA. Normality plots were observed to assess distribution of the BMD, training, and diet data, and all were deemed nonparametric. Menstrual status was banded into three groups—eumenorrheic, oligomenorrheic, and amenorrheic—for the cross-sectional analysis, but for the longitudinal analysis banding was into two groups of eumenorrheic and oligo-/amenorrheic, because of the small sample size.

Cross-Sectional Analysis. As recommended in the ACSM guidelines, Z scores were used for analysis. Differences in each of the regional BMD Z-scores between the three menstrual-status groups were analyzed using a Kruskall–Wallis test. To assess for differences between the Z values in each group at each body region and established diagnostic Z values (Z = 0, Z = –1, and Z = –2), a Wilcoxon signed-ranks test was used. Within each menstrual-status group, each patient’s Z score for each region was paired, in turn, with each of the three diagnostic Z values (0, –1, or –2). Spearman’s correlation analyses were used to assess associations between regional BMD Z scores and each of training hours and eating behaviors.

Longitudinal Analysis. Inclusion in the longitudinal group required availability of data from two sequential DXA scans and baseline questionnaire data from the
time of the first scan \((n = 7)\). These participants were also included in the cross-sectional analysis. Percent change in BMD from baseline to follow-up was calculated for each skeletal region and normalized to a standard unit of follow-up time (1 month).

BMD was used to observe change within individuals; a number of \(Z\) scores were not available in the youngest athletes. Results without \(Z\) scores were not included in the cross-sectional analysis. Because a change was being measured, differences between athletes in BMD because of age and ethnicity were considered unimportant. There were no longitudinal data for the femoral neck, so only longitudinal analyses for change in BMD for the total body, lumbar region, and radius were performed.

Differences in scores for each of the regional BMD rates of loss between the two menstrual-status groups were analyzed using a Mann–Whitney test. Spearman’s rank correlation analyses were used to assess associations between regional BMD rate of loss and each of training hours and eating behaviors.

**Results**

**Descriptive Statistics**

The eumenorrheic, oligomenorrheic, and amenorrheic groups did not differ in any of the characteristics listed in Table 1. The athletes in the longitudinal analysis were 18–32 years old, with an average age of 22 years \((\pm 4.8)\). There were 6–14 months between the two DXA scans, with an average of 8 months \((\pm 3.5)\).

**Cross-Sectional Analysis**

**BMD.** BMD values expressed as \(Z\) scores are shown in Figure 1. There were clear reductions in \(Z\) scores for the lumbar spine and radius but not for the femoral neck or the total body. The prevalence of low BMD \((Z = –1 \text{ to } –2 \text{ } SD)\) in the athletes was 4.9% \((n = 2)\) for the total body, 34.2% \((n = 14)\) at the lumbar spine, 13.8% \((n = 4)\) at the femoral neck, and 29.6% \((n = 13)\) at the radius. The prevalence of osteoporosis \((Z < –2 \text{ } SD)\; \text{Laughlin} \& \text{Yen, 1996; Nattiv et al., 2007}\) was 7.3% \((n = 3)\) at the lumbar spine and 33.3% \((n = 9)\) at the radius but was 0% for total body and femoral neck.

**Menstrual Status.** Of those stating current menstrual status \((n = 36)\), 38% were oligomenorrheic \((n = 14)\) and 25% amenorrheic \((n = 9)\). There were no significant differences in \(Z\) score at each of the four sites between the three menstrual-status groups (Table 2). However there was a trend \((p = .059)\) for a difference between the groups for radius \(Z\) score, with the eumenorrheic group having a lower radius \(Z\) score than the oligomenorrheic group. There was no difference between the eumenorrheic group and the amenorrheic group. When comparing with diagnostically relevant \(Z\) values, the \(L2–4\) \(Z\) values were significantly lower than \(Z = 0\) for all three menstrual-status groups (eumenorrheic \(p = .017\), oligomenorrheic \(p = .03\), amenorrheic \(p = .017\)). The radius \(Z\) values were significantly lower than \(Z = 0\) for the oligomenorrheic \((p = .036)\) and amenorrheic \((p = .018)\) groups and significantly lower than \(Z = –1\) for the eumenorrheic group \((p = .025)\). None of the total-body or femoral-neck \(Z\) values were significantly below \(Z = 0\) in any of the three groups. There were no \(Z\) values significantly below \(Z = –2\) for any of the groups at any body region (Table 2).

**Contraceptive Pill Use.** There were 12 athletes using oral contraceptives. There were 4 athletes in the amenorrheic group, 3 in the oligomenorrheic group, and 5 in the eumenorrheic group. The 5 athletes in the eumenorrheic group using the contraceptive pill were eumenorrheic before pill use.

**Training.** There was no significant correlation between number of hours training per week and regional BMD \(Z\) scores.

**Eating Behavior.** Response rate to the TFEQ-R18 was 70.4% \((n = 31)\). There were no significant correlations demonstrated between the cognitive restraint, uncontrolled eating, or emotional eating scale scores and regional BMD \(Z\) scores.

The three aspects of menstrual dysfunction, disordered eating, and low BMD were present in 15.9% \((n = 7)\) of participants. These participants were oligomenorrheic or amenorrheic at the time of scanning, with a \(Z\) score

| Table 1 Characteristics of the Participants Included in the Cross-Sectional Analysis, M (SD) |
|-----------------------------------------------|----------------|----------------|----------------|----------------|
| All, \(N = 44\) | Eumenorrheic, \(n = 14\) | Oligomenorrheic, \(n = 14\) | Amenorrheic, \(n = 9\) |
| Age (years) | 22.9 (6.0) | 22.3 (7.1) | 23.6 (6.2) | 21.6 (3.3) |
| Height (m) | 1.66 (0.1) | 1.66 (0.4) | 1.65 (0.1) | 1.66 (0.1) |
| Weight (kg) | 52.8 (4.8) | 51.2 (3.5) | 52.4 (4.1) | 53.6 (7.4) |
| Body-mass index | 19.1 (1.5) | 18.4 (0.9) | 19.5 (1.4) | 19.4 (2.7) |
| Menarche onset age | 13.9 (1.5) | 13.9 (1.7) | 13.8 (1.1) | 13.8 (1.8) |
| Training hr/week | 13.8 (5.2) | 13.4 (5.2) | 12.9 (3.5) | 16.0 (7.2) |

*Note: Data on menstrual status were not available for 7 participants. Groups did not differ significantly.*
Table 2  Participants’ Z Scores at the Four Anatomical Sites

<table>
<thead>
<tr>
<th></th>
<th>Median (Interquartile Range) Z Score</th>
<th>Eumenorrheic,</th>
<th>Oligomenorrheic,</th>
<th>Amenorrheic,</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n = 14</td>
<td>n = 14</td>
<td>n = 9</td>
<td></td>
</tr>
<tr>
<td>Total body</td>
<td></td>
<td>0.20 (–0.35 to 0.82)</td>
<td>0.15 (–0.32 to 1.20)</td>
<td>–0.50 (–0.70 to 0.30)</td>
<td>.308</td>
</tr>
<tr>
<td>L2–4</td>
<td>–0.70* (–1.32 to –0.13)</td>
<td>–1.10* (–1.40 to 0.00)</td>
<td>–0.80* (–1.60 to –0.70)</td>
<td>.609</td>
<td></td>
</tr>
<tr>
<td>Femoral neck</td>
<td>0.90 (–0.70 to 1.50)</td>
<td>–0.10 (–0.55 to 1.55)</td>
<td>–0.60 (–0.70 to –0.60)</td>
<td>.287</td>
<td></td>
</tr>
<tr>
<td>Radius</td>
<td>–2.25** (–2.85 to –1.28)</td>
<td>–1.20* (–1.75 to –0.20)</td>
<td>–1.90* (–2.40 to –0.60)</td>
<td>.059</td>
<td></td>
</tr>
</tbody>
</table>

Note. The significance of the differences between each group’s Z value and diagnostic Z values (Z = 0, Z = –1, and Z = –2) is also given.  
*Kruskall–Wallis test.  
*Z value significantly below 0. **Z value significantly below –1 but not significantly below –2.

<–1 SD, and they also scored in the upper quartile on any of the three scales of the TFEQ.

Longitudinal Analysis

Menstrual Status. Menstrual status was shown to have no significant effect on the rate of loss of BMD (Table 3). However, a trend was demonstrated between higher rates of BMD loss at both the total body (p = .064) and radius (p = .063) in the oligo-/amenorrheic group.

Oral Contraceptive Pill Use. There were no athletes in the longitudinal analysis using oral contraceptives.

Training. There was a significant negative correlation between increased hours of training per week and a change in BMD at L2–4 (p = .026, r = .87, n = 6; Figure 2). There was no significance at other regions. One athlete failed to produce a training diary.

Eating Behavior. A high emotional eating score was positively correlated with changes in lumbar-spine
Table 3  Change in Bone-Mineral Density (BMD; g/cm²) per Month

<table>
<thead>
<tr>
<th>Region</th>
<th>Median (IQR) % Change in BMD per Month</th>
<th>Eumenorrheic, n = 3</th>
<th>Oligo-/Amenorrheic, n = 4</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total body</td>
<td>0.23 (0.17–0.28)</td>
<td>-0.16 (–0.061 to –0.26)</td>
<td>.064</td>
<td></td>
</tr>
<tr>
<td>L2–4</td>
<td>-0.074 (0.00 to –0.15)</td>
<td>-0.12 (–0.25 to 0.031)</td>
<td>.814</td>
<td></td>
</tr>
<tr>
<td>Radius</td>
<td>0.24 (0.0–0.48)</td>
<td>-0.71 (–0.34 to –1.07)</td>
<td>.063</td>
<td></td>
</tr>
</tbody>
</table>

Note. IQR = interquartile range.

*Mann–Whitney test.

Figure 2 — Relationship between change in bone-mineral density (BMD) per month in the lumbar region and training hours per week. As training load increased, BMD loss in the lumbar region was evident.

BMD (rho = 0.71, p = .038, n = 7; Figure 3). There were no further significant correlations between cognitive restraint, uncontrolled eating, and emotional eating scale scores and regional BMD.

Discussion

Cross-Sectional Analysis

Some elite endurance runners in our study had lower BMD than the expected range for age in the normal nonathletic population at non-weight-bearing or relatively non-weight-bearing sites. The Z-score distributions noted in our study demonstrate the effect of mechanical loading on bone, which depends on site and type of exercise (Bennell et al., 1997). Endurance running involves high mechanical loads through the lower limb, which may be protective against bone loss. Our range of Z scores for total body and femoral neck reflect this and were within the normal range (Z = –1 to +1; Nattiv et al., 2007; Sangenis et al., 2005). However, the radius and L2–4 are relatively less loaded and therefore less protected. The assessment of these sites may identify possible underlying bone metabolism pathology.

The exact prevalence of low BMD and osteoporosis in elite athletes has been elusive in the literature. One group reported prevalence rates of osteoporosis in 6%, and osteopenia in 48%, at the lumbar spine of endurance runners (Cobb et al., 2003). However, this was probably an underestimation because World Health Organization criteria (Sangenis et al., 2005) were applied, contrary to the recommendations of the International Society of Clinical Densitometry. The ACSM defines osteoporosis as secondary clinical risk factors with a BMD Z score.
of less than –2 (Nattiv et al., 2007). Using this Z score, similar levels of osteoporosis (7.3%) and low BMD (–1 > Z score > 2; 34.1%) were noted at L2–4 in our study, as in Cobb et al.’s study. We have used the terms low BMD and osteoporosis herein to enable comparison of our Z-score data with previous investigations.

These Z scores in these elite athletes are presented in this article as suggestive of pathology associated with the female athlete triad. However, it should be noted that this may not be true for all of our elite athlete population, some of whom may be genetically predisposed to low BMD. There is some recent evidence that women with very low BMI or constitutional thinness not associated with pathology can have low bone mass and impaired bone quality despite normal hormonal and nutritional status (Galusca et al., 2008). Our study does not have sufficient further clinical investigations or follow-up to address this issue. However, given the association between low BMD, fracture risk, and energy availability, it is essential to assess for causative factors and maximize bone health through education, nutrition, exercise, and clinical practices.

The incidence of menstrual dysfunction in our study, with 63.9% (n = 23) of participants being oligomenorrheic or amenorrheic, is higher than previously reported in nonelite athletes (Hetland et al., 1993). As discussed previously, in the female athlete triad menstrual disturbance is directly mediated by reduced energy availability (Nattiv et al., 2007), with the resultant hypothalamic, insulin-like growth factor-1, and leptin level disturbance implicated in the abnormal luteinizing hormone pulsatility (Laughlin & Yen, 1996; Loucks, Mortola, Girton, & Yen, 1989). There are a number of previous articles on nonelite athletes noting significantly lower BMD in amenorrheic participants (Braam et al., 2003; Drinkwater et al., 1984; Marcus et al., 1985; Rutherford, 1993; Wolman et al., 1990, 1992). Our study found no difference between athletes with different menstrual statuses. However, we noted low BMD, particularly in relatively unloaded sites, in each of the eumenorrheic, oligomenorrheic, and amenorrheic groups. Z values were significantly lower than normal (i.e., Z = 0) for the L2–4 and radius regions, and it is interesting that this was seen across all three menstrual-status groups. Indeed, the only group to show a Z value significantly less than –1, the threshold of osteopenia, was the normal-menstrual-status group, in the radius region. These results suggest that the relationship between menstrual status and BMD is not as clear-cut as previously thought. It is recognized that menstrual dysfunction and BMD changes may have different temporal relationships (Nattiv et al., 2007), and we did not evaluate our eumenorrheic group for periods of amenorrhea or undernutrition in the past. In addition, our study would not have excluded athletes with menstrual disorders unrelated to the female athlete triad or detected subclinical menstrual disorders such as luteal-phase defects in eumenorrheic athletes, because we did not analyze reproductive hormones.

This study does confirm coexistent features of the female athlete triad in elite female endurance runners. Features of menstrual dysfunction, disordered eating, and low BMD were exhibited in 15.9% (n = 7) of
participants. These participants were oligomenorrheic or amenorrheic at the time of scanning, with a Z score less than –1 SD, and also scored in the upper quartile on any of the three scales of the TFEQ. It should be noted that this figure is probably an underestimation of the number of athletes with the female athlete triad because disordered eating and clinical menstrual disorders are not necessary components of the triad. It is essential to note that an athlete can have low energy availability in the absence of disordered eating.

**Longitudinal Analysis**

Of particular concern are the rates of bone loss in these young athletes at a time when their bone density should be increasing. There were trends between oligo-/amenorrhea and rate of loss at total body (p = .06) and the radius (p = .06) in this small group of athletes, and these may have been detected as statistically significant in a larger group. There has been no previous longitudinal work in elite athletes, that we are aware of, that has noted this relationship. Despite the small participant number, this is an important novel evidence that suggests that the pathology noted in these athletes can be progressive. This should be considered pilot work that suggests that further longitudinal work in this field is warranted.

A higher rate of loss in the lumbar spine was linked to increased time spent training (p = .026, r = .866). Unfortunately, we do not have data on the athletes’ energy intake or expenditure and are therefore unable to confirm the work of Loucks et al. (1998), who noted that the underpinning pathology is not the stress of training but the association with low energy availability. However, the increase in loss of bone mass with increased training time does suggest a plausible link to low energy availability in this group.

A lower rate of loss at L2–4 was also associated with a high level of emotional eating (p = .038, r = .782). This may be explained by higher emotional eating’s resulting in increased energy intake. High cognitive restraint has been linked with negative impacts on bone (Barrack, Rauh, Barkai, & Nichols, 2008; McLean, Barr, & Prior, 2001); however, this association was not confirmed in this study. Given the small numbers analyzed longitudinally in this study, this warrants further work.

There have been no studies with substantial follow-up of elite-level athletes with impaired bone health, and as such this study provides a reference for future investigations. Future research should focus on the longitudinal ramifications for athletes with low BMD. Mineral content is lost at a rate of 1% per year from the early 30s leading up to the menopause, and 5% per year thereafter in normal participants (Warren & Goodman, 2003). The rate of loss in amenorrheic athletes is thought to mimic this (Warren & Goodman, 2003). This study supports this, with rates of loss per year of 5.6%, 1.2%, and 4.9% for total body, L2–4, and radius, respectively. When these athletes reach menopause, BMD is likely to be severely decreased, and the prospect of further bone loss carries a high risk of morbidity. Recognition of menstrual disturbance is essential, particularly because duration of amenorrhea is negatively proportional to BMD (Drinkwater, Breunner, & Chesnut, 1990; Louis et al., 1991). Low BMD in the premenopausal stage has been linked with a doubling in fracture risk (Khan et al., 2002), and a 1% increase in BMD equates to a 7% decline in fracture risk (Wasnich & Miller, 2000). Prompt recognition and treatment should be initiated to prevent long-term irreversible bone loss (Keen & Drinkwater, 1997).

The results presented are novel and important, but we recognize some limitations. First, although inclusion in the study was offered to all funded endurance athletes, uptake was voluntary. As such, true prevalence rates cannot be calculated. Our study may overestimate the level of these pathologies because athletes may have only agreed to participate if they had concerns regarding their menstrual or bone health. Athletes who were noted to have pathology were referred back to their sports-medicine physician and may have undergone further investigation for menstrual dysfunction or bone health, but this information is not included in our study. In addition, training questionnaires were completed by participants. Recall, which may call their accuracy into question. However, high levels of self-awareness seen in athletes (Gould, Dieffenbach, & Moffett, 2002) and the fact that many kept a training diary are likely to support accuracy.

It should also be noted that the identification and assessment of oligomenorrhea and amenorrhea by questionnaire excludes subclinical abnormalities such as luteal-phase defects that form part of the continuum of menstrual dysfunction in the triad (De Souza & Williams, 2004), and this is likely to underestimate the prevalence of this pathology. Future studies should aim to collect information regarding the total number of missed menses and, if possible, information on luteal function and estrogen levels. It is a limitation of the current study that energy-availability data are not available because we commenced data collection before the ACSM position stand of 2007. Future studies should include an estimation of this through detailed nutritional and training records including mileage and intensity.

Nonetheless, the implications of the findings should not be underestimated. There are no longitudinal observational studies of this kind involving elite, international female runners, and as such novel evidence is put forward. In addition, this study adds to the limited work on BMD in elite athletes.

We recommend targeted clinical and radiological screening assessment, follow-up, and management in this at-risk patient group. It is important to note from this work that normal menstruation at the time of scanning was not protective for normal bone density, so our current practice and recommendation is that all female endurance athletes should undergo DCA screening. Further effective screening for menstrual dysfunction and energy availability is also required. Treatment strategies should emphasize the importance of optimum energy availability in this population, which is central to preventing the develop-
ment of the female athlete triad (Nativ et al., 2007). It is our opinion that involvement of athletes, parents, and coaches in education programs is critical to preventing and treating this pathology.

References


Torstveit, M.K., & Sundgot-Borgen, J. (2005c). Participation in leanness sports but not training volume is associated with


