**FEMALE ATHLETE TRIAD**
The Science and Practice of Proper Fueling for Performance and Health

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**Diets of Female Athletes**

- Low in energy
  - Low in carbohydrate
  - Potentially low in protein (essential AA), fat (essential FA)
- Low in bone-building (*calcium, Vit D, magnesium*) nutrients
- Low in oxygen transport (*iron, folate, vitamin B12*) nutrients
- Sometimes, low in energy (*B-vitamins*) nutrients

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**Energy Expenditure (EE), Intake (EI), and Balance (EB) of Female Athletes in Training**

- Dancers
  - EE: 3000 kcal/day
  - EI: 2800 kcal/day
  - EB: 200 kcal/day

- Elite Runners
  - EE: 3000 kcal/day
  - EI: 2800 kcal/day
  - EB: 200 kcal/day

- Elite Swimmers
  - EE: 3000 kcal/day
  - EI: 2800 kcal/day
  - EB: 200 kcal/day

- Cross-Country Skiers
  - EE: 3000 kcal/day
  - EI: 2800 kcal/day
  - EB: 200 kcal/day

- Gymnasts
  - EE: 3000 kcal/day
  - EI: 2800 kcal/day
  - EB: 200 kcal/day

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**Dietary Consequence of Unadjusted Energy Intake**

**Main Concern during intense Training**

- Carbohydrate Intake

  **Carbohydrate intake in athletes**
  - Endurance: 7.5 g/kg/d
  - Non-endurance: 5.5 g/kg/d

**Glycogen stores**

- Males: 7.5 g/kg/d
- Females: 5.5 g/kg/d

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**Energy Availability**

**ENERGY INTAKE**
- 2800 kcal

**EXERCISE ENERGY EXPENDITURE**
- 1500 kcal

**2800 kcal – 1500 kcal = 1300 kcal**

Enough to maintain basic physiologic function and health?

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**Proposed Causes of Disruption of Normal Menstrual Function**

**EARLY DATA**

- Body fat level
- Exercise stress
  - Main link was cortisol and disruption of HPA axis

**TODAY**

- Energy availability
  - LH pulsatility in hypothalamus is disrupted by inducing low energy availability by either restricting dietary intake or excessive exercise or both
  - Dietary supplementation prevents disruption of LH pulsatility in exercising women

**Loucks, 2004**
Functions of Energy from Food

- Dietary energy partitioned
  - Cellular maintenance
  - Thermoregulation
  - Locomotion
  - Growth
  - Reproduction

Low Energy Availability Risk for Menstrual Dysfunction

The Menstrual Cycle

- Menses: day 0-7
- Follicular phase:
  - Starts with menses, ends with ovulation
- Ovulatory Phase:
  - @ LH Surge results in Ovulation (~day 14)
- Luteal phase:
  - Starts after ovulation, ends with beginning of next cycle

Comparison of cyclic sedentary, cyclic athlete and amenorrheic athlete

Loucks et al. 1989

Methods
- daily urinary estrogen/progesterone metabolites in sedentary and exercising women

Results
- AA had very low E1G and PdG levels
- CA had shortened luteal phases (2 days) and 50% lower progesterone levels but no asymptomatic menstrual cycles

The Hypothalamic - Pituitary Axis

Legend for figure:
- GnRH: Gonadotropin Releasing Hormone
- LH: Luteinizing Hormone
- FSH: Follicle Stimulating Hormone
- Estrogen: Estradiol (major form)
- Progestins: Progesterone

Reproductive Hormone Alterations In Female Athletes with Menstrual Dysfunction
- ↓ LH pulsatility (frequency/amplitude)
- ↓ FSH
- ↓ Estradiol
- ↓ Progesterone

LH pulsatility in cyclic sedentary, cyclic athlete, amenorrheic athlete

Loucks et al. 1989

CA: Reduced pulse frequency; Increased pulse amplitude
AA: Reduced pulse frequency; Increased pulse amplitude
**Definitions of Menstrual Dysfunction**

- **Eumenorrhea**
  - Regular Menstrual Cycle: 10-13 cycles/year

- **Oligomenorrhea**
  - Irregular Menstrual Cycle: >35 days or less than 90 days; 6-9 cycles/year

- **Amenorrhea**
  - Absent Menstrual Cycle:
    - Primary: no menarche by age 15 yrs in girl w/ secondary sex characteristics
    - Secondary: absence of menstrual cycle for 3 consecutive months; < 1-3 menstrual cycles/year
  - Luteal Phase Defects:
    - Low estrogen in follicular phase
    - Shorter luteal phase (<10 days) with suppressed progesterone levels
    - Normal cycle length
  - Anovulation:
    - Asymptomatic follicular development that leads to absence of ovulation
    - Estrogen and progesterone are low but enough estrogen is produced to stimulate uterine lining and bleeding occurs
    - Cycle length may be shorter or longer

**Ruling out other Causes of Menstrual Dysfunction**

- **Causes of Menstrual Dysfunction**
  - Pituitary Tumor
  - Pregnancy
  - Low Energy Availability
    - Energy intake (EI) – Exercise energy expenditure (EEE)
    - Glucose, Ketones
  - Polycystic Ovarian Syndrome
    - Ovarian cysts, oligomenorrhea or anovulatory cycles, ↑ androgens
  - Psychological Stress?
    - Cortisol

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**Monitoring Chart**

**The Female Athlete Triad**

**Indirect and Direct Effects of Low Energy Availability**

- **Reduced Bone Mass, Stress Fractures Osteoporosis**
- **Subclinical Menstrual Disorders Amenorrhea**
- **Increased bone resorption**
- **Normal Menstruation**
- **Optimal Bone Health**
- **Optimal Energy Availability**
- **Reduced Energy available w/o or w/o Disordered Eating**
- **Low Energy Availability w/o or w/o Eating Disorder**
- **Normal Menstrual Function**
- **Bone Mineral Density**

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**The Female Athlete Triad**

**ACSM Position 2007**

- Low Bone Mass
- Osteoporosis
- Functional Hypothalamic Amenorrhea

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**Disordered Eating**

- Amenorrhea
- Osteoporosis

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**ACSM 1996**

**Optimal Energy Availability**

**Energy Availability**

**Bone Mineral Density**

**Menstrual Function**

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**ACSM 1996**

**Optimal Energy Availability**

**Energy Availability**

**Bone Mineral Density**

**Menstrual Function**

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Direct and Indirect Effects of Low Energy Availability on Bone

- Hypoestrogenism
  - Increased bone resorption
- Compromised metabolic hormone/substrate availability
  - Increased bone resorption
  - Suppressed bone formation
    - Insulin
    - IGF-1
    - T3
    - Cortisol
    - ...

Bone Strength

Aeral Bone Mineral Density (g/cm²)

Bone Quality
- Monarquitecture
- Bone Turnover
- Mineralization
- Geometry & Size

Z and T-Score Evaluations (DXA)

<table>
<thead>
<tr>
<th>Osteoporosis:</th>
<th>Low Bone Density:</th>
</tr>
</thead>
<tbody>
<tr>
<td>As secondary clinical factors for fracture with Z-score ≤ -2</td>
<td>Z score btw. -1 and -2 with history of nutritional deficiencies, hypoestrogenism, stress fractures and/or secondary clinical factors</td>
</tr>
</tbody>
</table>

Osteoporosis as secondary risk
Low Bone Dens Normal

Standard BMD scores

*Additional criteria: hypoestrogenism, stress fracture, eating disorder, or other risk for fall

Case Study: Triathlete w/ AA

UCS
3430 Austin Sprat Pkwy
Colorado Springs, CO 80918

Athletes should have higher Bone Mass than Controls!

- 5-30% greater BMD in athletes vs control
- Could reduce fracture risk by 50 - 80%

BMD is 10-20% Lower in Amenorrheic than Eumenorrheic Athletes

For review see: Nichols et al., 2007
**Factors contributing to Low Energy Availability**

- Disordered Eating
  - Dieting
  - Social pressure
  - Additional exercise
  - Sport-related factors
- Inadvertent, insufficient energy intake and/or high energy expenditure
  - Sport?
  - Time
  - Age, experience, knowledge?
  - Access to sport science/medicine services?
  - Adapting diet to training?

**Disordered Eating Spectrum**

- Anorexia Nervosa
  - 1%
- Bulimia Nervosa
  - 2-3%
- EDNOS
- Restrictive Eating
- Occasional Binging
- EDNOS
- Binge Eating Disorder

**Prevalence of the TRIAD**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent</th>
<th>Population</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating Disorders</td>
<td>31%</td>
<td>Elite</td>
<td>Byrne, 2001</td>
</tr>
<tr>
<td>Secondary AA</td>
<td>65%</td>
<td>Dancers</td>
<td>Abraham, 1982</td>
</tr>
<tr>
<td>Primary AA</td>
<td>67% vs 9%</td>
<td>Runners</td>
<td>Du Bois, 2001</td>
</tr>
<tr>
<td>Osteopenia*</td>
<td>1-13%</td>
<td>Cheerleaders, divers, gymnasts controls</td>
<td>Chumlea, 2003</td>
</tr>
<tr>
<td>Osteoporosis*</td>
<td>2-5%</td>
<td>Athletes vs controls</td>
<td>Kain, 2002</td>
</tr>
</tbody>
</table>

*WHO classification using T-scores

**Prevalence of TRIAD in Elite Athletes**

- 26.6% (n=58)
- 13.8% (n=26)
- 15.2% (n=29)

**Further Health and Performance Consequences of Low EA**

- Compromised nutrition
  - Glycogen depletion
  - Dehydration
  - Low micronutrient intakes
- Fatigue
- Risk for overtraining
- Immune suppression
- Infertility
- Endothelial dysfunction
- Stress fractures & other injuries
  - 2-4x risk in amenorrheic athletes
Treatment for Athletes identified with the Triad

- Triad Decision Trees
  - LEA, MD, LBMD (see IOC position paper)
- Triad Treatment Team
  - Confirm cause as athletically-induced menstrual dysfunction
  - Sports Dietitian
    - Correcting low energy availability
      - $EEE-EI = \text{kcal/kgFFM/d}$
    - Decreasing nutritional risk

Compliance with Treatment for Athletes with Eating Disorders

Participation in training and competition

- Individual basis
- Criteria listed in contract
  - Comply with all treatment strategies
  - Be monitored by treatment team
  - Prioritize treatment over training and competition
  - Modify type, duration, intensity of training and competition

Energy Recommendations for Female Athletes

<table>
<thead>
<tr>
<th>Weight Loss (kcal/kgFFM/d)</th>
<th>Maintenance (kcal/kgFFM/d)</th>
<th>Growth/Intense/Race Preparation (kcal/kgFFM/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Availability</td>
<td>30-45</td>
<td>&gt;45</td>
</tr>
<tr>
<td>Manore et al., 2007</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Meeting energy demands of high-intensity training and competition days!

Learning to Eat like an Athlete!

- Teaching female athletes to eat more when it matters...
  - High intensity/volume phases
  - High intensity/volume days
  - Competition
  - Training/Competition in environmental extremes

Periodized Eating

Changes must occur

Training Macrocycle, Mesocycle, Microcycle

Training Volume/Intensity
Environmental Factors
Peaking

Female athletes should dare to eat more when training and competing!

- Energy expenditure in cross-country skiers
  - Energy turnover DLW ~ 80 kcal/kg/day
  - Carbohydrate intake ~ 12 g/kg/day
- Carbohydrate loading in females
  - Low energy intake mainly responsible for gender difference in carbohydrate loading
  - 45 kcal/kg BW/day necessary to achieve a CHO intake of >8 g/kg/d

- Tarnopolsky et al., 2001

- Sjödin et al., 1994
### Macronutrient Recommendations for Female Athletes

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>g/kg/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td></td>
</tr>
<tr>
<td>Low to moderate intensity training</td>
<td>5-6</td>
</tr>
<tr>
<td>To maintain glycogen during repetitive training</td>
<td>~7*</td>
</tr>
<tr>
<td>Repetitive intense training</td>
<td>7-10</td>
</tr>
<tr>
<td>Carbohydrate loading</td>
<td>&gt;8 (10-12)</td>
</tr>
<tr>
<td>Protein</td>
<td></td>
</tr>
<tr>
<td>General female athlete requirement</td>
<td>1-1.3³</td>
</tr>
<tr>
<td>Adolescent female athletes</td>
<td>1.4-1.6</td>
</tr>
<tr>
<td>Endurance athletes (females ~ 15% lower than males)</td>
<td>1.2-1.6</td>
</tr>
<tr>
<td>Energy restriction/maintenance of muscle mass</td>
<td>up to 2</td>
</tr>
<tr>
<td>Fat</td>
<td></td>
</tr>
</tbody>
</table>

ICM Acceptable Macronutrient Distribution Range: 20-35%

*Burke et al., 2004 and 2006  
³Phillips, 2004; Tarnapolsky, 2004  
Manore et al., 2007  
Mettler et al. 2010

### Biochemical Assessment

- **Assessment**
  - CBC
  - Iron Profile*
  - Vitamin D
    - 25(OH) D
    - Metabolic Panel
    - Lipid Panel*
  - TSH*
  - Female Athlete Triad*
    - Estradiol, progesterone
    - FSH, LH
    - Prolactin

- **Monitoring**
  - CBC
  - Iron Profile*
  - Serum ferritin
  - Soluble transferrin receptor
  - Seasonal 25(OH) D
  - Resuming menstrual function*
  - Estradiol

*requires standardized testing

### Reference Values for Vitamin D

- **25(OH) D Reference Values: HPLC assay**
  - **Normative Range**
    - 20-100 ng/mL
  - **Preferred**
    - 30/40-60/70 ng/mL
  - **Deficient**
    - <20 ng/mL
  - **Insufficient**
    - 20-30/32 to > 20 ng/mL
  - **Toxic**
    - >150 ng/mL

**SI Conversion to mmol/L; ng/mL*2.5

### Prevalence in Athletes

<table>
<thead>
<tr>
<th>Reference</th>
<th>Type of athletes</th>
<th>Season</th>
<th>Reference</th>
<th>Type of athletes</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larson-Meyer and Willis, 2010</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Risk Factors for Deficiency

- **Sports-specific Risk**
  - Indoor sports
  - Clothing
  - Late day training
  - Sun protection
  - Low vitamin D intake

- **General Risk Factors**
  - Latitude
  - UV exposure
  - Skin pigmentation
  - Adiposity/Leaness

### Links of Vitamin D Deficiency

![Diagram of links of vitamin D deficiency](image-url)
Vitamin D and Bone Loss

- Vitamin D’s effect on bone
- Decrease in ionized serum Ca\(^{2+}\) sensed by PTH
  - Increased expression, production, and secretion of PTH
  - Increased 1,25(OH)\(_2\)D which increases Ca\(^{2+}\) absorption
- Insufficiency or deficient state not possible which reduces Ca\(^{2+}\) absorption by 15%

CONSEQUENCE
- Increased tubular Ca\(^{2+}\) reabsorption
- Mobilization of skeletal Ca\(^{2+}\) stores

Bone Building Nutrients

<table>
<thead>
<tr>
<th>Dietary Reference Intakes</th>
<th>14-18 y</th>
<th>19-30 y</th>
<th>Triad</th>
<th>Best Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (AI)</td>
<td>1300 mg</td>
<td>1000 mg</td>
<td>1500 mg(^a)</td>
<td>Dairy products</td>
</tr>
<tr>
<td>Vitamin D (RDA)</td>
<td>200 IU</td>
<td>200 IU</td>
<td>TESTING</td>
<td>Fish, milk</td>
</tr>
<tr>
<td>Vitamin K (AI)</td>
<td>75 (\mu)g</td>
<td>90 (\mu)g</td>
<td>60-90</td>
<td>Green leafy veggies</td>
</tr>
</tbody>
</table>

\(^a\)IOC Position Stand, 2008
\(^b\)probably too low (Weaver, 2004)

Treatment for Vitamin D Deficiency

- Insufficiency: supplements + sensitive sun exposure
  - 1000 IU/day over 3-4 months
  - USS: 2,000 IU/day
- Deficiency: supplements
  - USS: 35,000 IU/wk for 10-20 days + 5,000 IU maintenance dose for several wks + 2000 IU to keep elevated later
  - 50,000 IU/wk for 8 wks + maintenance
  - 10,000 IU/wk for several wks + maintenance
- Maintenance: supplements
  - 1000-5000 IU/day (absence of sun)

Toxicity at 10,000 IU/day for a long time...longer than 5 months...:
- Hypercalcemia
- Fatigue, back pain, forgetfulness, nausea, vomiting, constipation

Triad Prevention

- Screening
- Education of athletes, coaches, parents
  - Basics of Sport Nutrition
  - Illustrating negative health and performance consequences of dieting, poor body image, and inconsistent fueling
  - Promoting optimal energy availability, bone mineral accrual, and maintenance of menstrual function
- National Governing Bodies
  - Should be encouraged to eliminate policies that trigger harmful weight loss methods
- Approaches should be
  - Covert, interactive, population specific, long-term

Fueling for Females to Achieve/Maintain a Healthy Body Weight

- Less focus on scale and more on healthy eating
- Marking progress by measuring changes in performance, energy levels, prevention of injury, and normal menstrual function
- Developing lifestyle changes that maintain a healthy weight realistic to the individual

Larson-Meyer, 2010

Stice and Shaw, 2004
Summary

• Adjust eating patterns to high training & competition loads
  – Sport nutrition education
  – Quantity, quality, and timing

• Screening and monitoring
  – Triad
    • Referral
  – Biochemical testing
    • Iron (Fallon, 2004; 2007)
    • Vitamin D
  – Performance, fatigue, injury
  – Anthropometrics

• Multidisciplinary Team

Resources

Websites:
Australian Institute of Sport: http://www.ais.org.au/nutrition
PINES: http://www.sportoracle.com/pines/pines-home
English Institute of Sport: http://www.eis2win.co.uk/pages/
Women Sport International: http://www.sportsbiz.bz/womensportinternational/

Position Papers
Nattiv et al. 2007 The Female Athlete Triad
IOC Female Athlete Triad Position Paper

Books:
Burke and Deakin Clinical Sport Nutrition 2010
Burke, 2008 Practical Sport Nutrition (chapters on endurance sports)
Beals 2004 Disordered Eating among Athletes
Manore et al. 2009 Sport Nutrition for Health and Performance

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