

2017 Ohio Association of Track and Cross
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Training Female Distance Runners: What's Estrogen Got to Do With It?

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Physiological Sex Differences

- 46 chromosomes, distributed in 23 pairs
- 22 pairs are same in both sexes
- The 23rd pair—the sex chromosomes—makes all the difference!
- Women: 2 X chromosomes
- Men: 1 X & 1 Y chromosome
- Sex chromosomes are responsible for all sexual characteristics—reproductive anatomy, muscle mass, heart size, & body fat

Hormonal Sex Differences

Testosterone



Estrogen



Estrogen

- Discovered in 1920s
- Includes estrone, estradiol, & estriol
- From menarche to menopause, predominant estrogen is estradiol. Estriol is primary estrogen during pregnancy & estrone is produced during menopause.
- Endometrium & uterine growth & vaginal wall thickening for preparation of pregnancy
- Bone protection
- Blood coagulation
- Menstrual cycle functioning
- Cholesterol production
- Salt and water retention

Other Hormones

Progesterone

- produced in ovaries & placenta during pregnancy
- supports many actions to prepare for receipt of fertilized egg & in development of fetus
- actions often amplified in presence of estrogen
- stimulates breathing & increases severity of asthma symptoms, which may increase perception of effort during exercise

Luteinizing hormone & follicle stimulating hormone

- stimulates ovulation, production of progesterone, & conversion of testosterone to estrogen

Anatomical Sex Differences

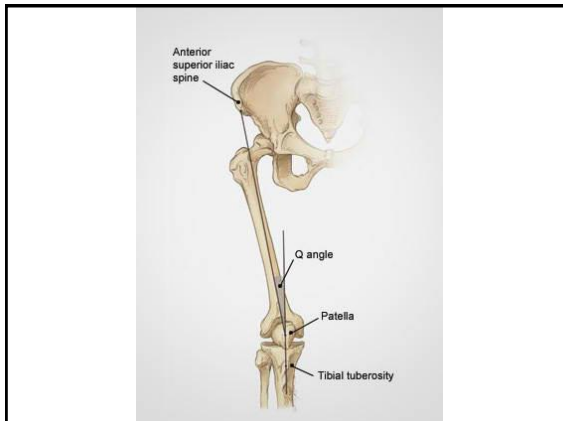
- Women have lower bone mineral density than men.
- Most important determinant of bone mineral density in women is circulating concentration of estrogen.
- Any condition that reduces estrogen concentration negatively affects bone remodeling.
 - risk for osteoporosis & fractures increases dramatically with amenorrhea & after menopause, when there is lack of estrogen.
- Estrogen deficiency caused by amenorrhea is most significant risk factor for osteoporosis in active women.

Anatomical Sex Differences

- Women have smaller shoulders, making it more difficult to develop upper body strength, giving women weaker upper bodies than men throughout adulthood.
- Since women have narrower shoulders & are typically shorter than men, they have larger pelvic width-to-height ratio and shoulder-to-hip ratio than men.

Anatomical Sex Differences

- Women's wider hips create more pronounced angle between pelvis & knee (quadriceps-angle or Q-angle), as femur occurs at more oblique angle compared to man's femur.
- Large Q-angle causes patella to be more off-center from tibia. Wide Q-angle = more lateral movement of patella as quadriceps contract.
 - can potentially put females at greater risk for knee injuries than males
- Large Q-angle puts women at mechanical disadvantage when running because femur strikes ground at angle. Narrow hips allow you to direct more of the muscular force into forward propulsion.



Body Weight & Composition Sex Differences

- Women adjust energy intake to energy expenditure better than men, making weight loss more difficult for women.
- Women have more fat and less muscle than men.
 - Essential fat = 3% men, 12% women
- During exercise, women must move more body fat with less muscle mass than men.
- Greater body fat slows release of body heat while exercising because fat acts as insulator.
- Too low body fat percentage can lead to menstrual cycle dysfunction & increase risk for bone injuries.

Cardiovascular Sex Differences

- Men have larger hearts than women, causing greater stroke volume & cardiac output.
 - Maximum cardiac output averages 20 liters/min in trained women vs. 30 liters/min in trained men
- Men have greater blood volume & more hemoglobin in blood.
 - Hemoglobin concentration averages 13.7 grams (normal range 12-16 grams) per 100 mL of blood in women vs. 15.8 grams (normal range 14-18 grams) per 100 mL of blood in men
- Since each gram of hemoglobin transports 1.34 mL of oxygen when hemoglobin is fully saturated, men carry 2.8 more mL of oxygen per 100 mL of blood:
 - 15.8-13.7 = 2.1 grams
 - 2.1 grams x 1.34 mL/gram = 2.8 mL
- During max exercise, men send 280 more mL of oxygen to muscles every minute compared to women:
 - 2.8 mL /100 mL of blood x 10,000 mL = 280 mL

Cardiovascular Sex Differences

Together, the larger heart, greater blood volume, & greater blood hemoglobin concentration create a cardiovascular system that supplies more blood & oxygen to muscles, giving men greater cardiovascular endurance than women.

$$VO_2 = SV \times HR \times (a-v O_2 \text{ difference})$$

$$VO_2 = CO \times (a-v O_2 \text{ difference})$$

↓

Muscular Sex Differences

- Women have smaller muscle mass than men
 - total amount of stored ATP & creatine phosphate—and therefore the total energy available from these fuel sources—is less in women
 - women cannot produce as much muscular force or power as men

Metabolic Sex Differences

Carbohydrate Metabolism

- males typically have more glycogen stored in muscles
- females use less carbohydrate than males when exercising at similar intensities
- women do not increase muscle glycogen as much as men in response to consuming carbohydrates
- while men simply need to increase percentage of calories coming from carbohydrates in order to “carbo load” and store more glycogen, women need to also increase number of calories to get same effect

Metabolic Sex Differences

Fat Metabolism

- women use more fat during exercise
- when male rats are given estrogen, they have less depletion of glycogen during exercise, increased concentration of fatty acids in blood, & can exercise longer before becoming exhausted
- difference in metabolism between sexes may give females advantage for very long endurance activities, during which there is greater need to conserve carbohydrate & greater use of fat because of relatively slow pace
 - In 2002 & 2003, Pam Reed won 135-mile Badwater Ultramarathon

Metabolic Sex Differences

Protein Metabolism

- accounts for only 3-6% of energy expended during exercise
- can be used for energy when there is inadequate amounts of fat & carbohydrates
- females use less protein during exercise than do males
 - since endurance-trained females use less muscle glycogen & rely more on fat than endurance-trained males, protein breakdown seems to be inhibited in females by virtue of greater muscle glycogen

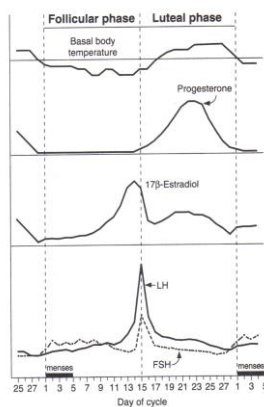
The Menstrual Cycle

Follicular Phase

- typically 14 days (11-21 days)
- menses of 3-5 days
- estrogen rises, peaking on day 14, right before ovulation
- burst of estrogen causes surge in luteinizing hormone on day 15 to initiate ovulation
- low progesterone

Luteal Phase

- always lasts 14 days
- estrogen drops after ovulation & rises again mid-phase
- progesterone rises, causing increased body temp to prepare for fertilization
- if no fertilization, estrogen & progesterone decrease
- increased progesterone causes water & electrolyte loss
- decreased progesterone causes excess premenstrual water & electrolyte retention, causing bloated feeling



Premenstrual Syndrome (PMS)

- Variety of physical and/or psychological & emotional symptoms that occur toward end of luteal phase in days leading up to menses.
- Incidence higher among separated & divorced women than among married or single women.
- Characterized by rapid drop in estrogen & progesterone.
- Common symptoms include headache, breast swelling & tenderness, cramping, bloating, fatigue, depression, & irritability.

Premenstrual Syndrome (PMS)

Specific cause of PMS is unknown

- progesterone deficiency or withdrawal
- excessive amounts of estrogen
- estrogen withdrawal
- changes in estrogen-to-progesterone ratio
- changes in prolactin levels
- drop in endorphin levels
- psychological issues
- cramping may be due to increase in prostaglandin, a hormone produced by uterus that causes uterus to contract
 - birth control pills & over-the-counter anti-inflammatory drugs can reduce severity of cramps by inhibiting prostaglandin release
- breast tenderness may be due to increase in prolactin, a hormone secreted by pituitary glands
- not much research on effects of exercise on PMS; research that has been done has shown that exercise reduces its symptoms

Menstrual Irregularities

- Affect women who train hard & a lot who have a low body fat %.
- In response to heavy training, first change in menstrual cycle is shortening of luteal phase, followed by cycles without ovulation & cessation of menses (amenorrhea).
- Amenorrhea (0-3 periods/year) results in constant low levels of estrogen & progesterone.
- High training volumes, low body weight, & endurance sports increase incidence.
- Inadequate caloric intake to match caloric expenditure, rather than stress of exercise, is responsible for loss of menstrual activity.
- Consuming more calories to compensate for large caloric expenditure from exercise can prevent amenorrhea.
- Any disruption to menstrual cycle can cause decrease in bone mineral density, increasing risk for osteoporosis & stress fractures.
- Take extra care in planning female runners' training so they don't increase volume or intensity too quickly, & they may need to increase dietary intake of calcium & vitamin D to protect bones.

Female Athlete Triad

- Collection of 3 associated characteristics—menstrual irregularities, disordered eating, & osteoporosis.
- Irregular or absent menstrual cycles (amenorrhea) increase risk for osteoporosis & stress fractures since athletes with irregular menstruation or amenorrhea have lower BMD than athletes with normal menstruation.
- Osteoporosis (“porous bones”) is a reduction in BMD 2½ standard deviations below average for healthy young women at age of peak bone mass.
- Disordered eating, common among female athletes due to external or self-imposed pressure to lose weight, may result in caloric restriction, & is independently associated with both irregular menstruation & low BMD. Female runners can have normal menstruation & still have low BMD if their diet is inadequate to meet caloric needs.

Physiological Effects of Menstrual Cycle

Physiological changes resulting from menstrual cycle-induced fluctuations in estrogen & progesterone are exacerbated during exercise, especially if it's intense. When female runners do a hard workout, estrogen & progesterone increase during both phases.

Physiological Effects of Menstrual Cycle

Body Temperature

- Progesterone acts on brain's hypothalamus, increasing set-point temp
 - body must reach higher temp before thermostat compensates & begins to cool itself
- Estrogen has opposite effect on hypothalamus, decreasing body temp, which explains why body temp is lower during estrogen-dominant follicular phase
- Increased body temp during luteal phase remains elevated during exercise & when exercising in heat
 - harder to run in heat, as females don't begin sweating to dissipate heat until they have reached higher body temp
 - increased body temp increases risk of heat illnesses

Physiological Effects of Menstrual Cycle

Cardiovascular Characteristics

- Progesterone-induced increase in body temp during luteal phase can cause heart rate to rise during exercise. Some studies show that women's heart rates are higher when exercising during luteal phase, while other studies have shown that heart rate is not different between phases.
- From a body temp control standpoint, better to run long race like half-marathon or marathon during follicular phase, when body temp is lower, especially if it's hot/humid.
- If a female bleeds a lot during menstruation, hemoglobin concentration may decrease, which negatively impacts ability to transport oxygen in blood.
 - since iron is important component of hemoglobin, may need iron supplement

Physiological Effects of Menstrual Cycle

Metabolism

- Estrogen may improve endurance performance by altering carbohydrate, fat, & protein metabolism
- Muscle glycogen content is greater during mid-luteal phase compared to mid-follicular phase
- Greater fat use & lower carbohydrate use during submaximal exercise in mid-luteal phase (high estrogen & progesterone) compared to early-follicular (low estrogen & progesterone) or mid-follicular (high estrogen & low progesterone) phases
- With less reliance on carbohydrate for energy, less lactate (& therefore other metabolic byproducts) is produced.
 - some studies have found less lactate is produced during exercise in mid-luteal phase, but other studies have not.
 - when men are given synthetic version of progesterone, they produce less lactate during maximal exercise, suggesting that progesterone, which is elevated during luteal phase, may lower lactate levels.

Physiological Effects of Menstrual Cycle

Breathing

- Progesterone stimulates breathing, which may make females feel more winded during luteal compared to follicular phase workouts since perceived effort is often linked to breathing.
- Women have more trouble breathing during luteal phase, which can affect women with asthma since exercise is a powerful trigger of asthma symptoms.
- Females with asthma experience a worsening of asthma symptoms & increased bronchodilator use during mid-luteal phase.
- Lung function & asthma symptoms vary cyclically. 33-52% of asthmatic women report premenstrual worsening of asthma symptoms, & additional 22% report that asthma is worse during menses.

Physiological Effects of Menstrual Cycle

Muscle Contraction & Strength

- Muscle strength is not affected by menstrual cycle.
- Women's responsiveness to strength training has been shown to be influenced by menstrual cycle.
 - weight training (3 sets of 12 reps) every second day during follicular phase & once per week during luteal phase increased maximal quadriceps strength by 32.6% compared to just 13.1% by training once every third day over whole menstrual cycle.
 - ratio of maximal strength to muscle cross-sectional area was also greater following former training program (27.6%) compared to latter, more traditionally-used program (10.5%).
- Many studies have shown that women's muscles do not hypertrophy as much as do men's because women have much less testosterone.

Physiological Effects of Menstrual Cycle

Muscle Contraction & Strength

- Estrogen has a protective effect on muscle tissue, diminishing skeletal muscle damage after a workout & inhibiting inflammation. It also influences activation & proliferation of satellite cells, which help repair muscle tissue after it has been damaged. Estrogen can therefore help women recover faster, enabling them to do strength workouts more often during times of month when estrogen level is high.
- Given estrogen's role in muscle damage & repair & its possible role in development of muscle strength, women with low estrogen levels (menstrual irregularities, amenorrhea, post-menopausal) may take longer to recover from strength training workouts & may have harder time increasing muscle strength.

Physiological Effects of Menstrual Cycle

Endurance Performance

- Research is not totally clear, but it seems that performance is best immediately post-menses & worst during the premenstrual interval & first few days of menstruation.
- Endurance performance may be improved in mid-luteal phase compared with early follicular phase when ratio of estrogen to progesterone is high in mid-luteal phase.
- Improved performance also tends to occur in late follicular phase, when estrogen is high & progesterone is low.
- It seems that women can expect to perform better during times of menstrual cycle when estrogen is dominant hormone & perform worst when progesterone is dominant hormone.

Oral Contraceptives

- Most common form of birth control.
- Reduce natural production of estrogen & progesterone, inhibiting ovulation & preventing pregnancy.
- Monophasic pills (most common)
 - regulate hormonal environment, decreasing hormonal fluctuations across cycle, which minimizes potential variations in physiological variables
 - provide fixed doses of estrogen & progesterone over 21 days, followed by 7 days placebo
- Biphasic pills
 - switch dosage of hormones once during 21-day cycle
- Triphasic pills
 - supply 3 different doses of estrogen that are increased throughout cycle

Oral Contraceptives

- Force regular 28-day cycle, which makes it easier to plan training and races.
- Some research has shown that runners consume less O₂ while running at submaximal speeds (i.e., running economy is improved) when taking oral contraceptives. However, both the maximum ability to consume oxygen (VO₂max) & running performance does not seem to be affected.
- May result in an increased bone mineral density only if taken at the onset of menopause.
 - Any benefit to bones seems to be specific to active women with menstrual irregularities who have compromised skeletal health.
- Increase body mass & % body fat

Pregnancy

- Characterized by expanding uterus & increases in estrogen & progesterone to provide nutritional support to developing fetus & prepare woman's body for delivery.
- Frequent complaints of pregnancy (nausea, heartburn, insomnia, varicose veins, leg cramps) are reduced in women who remain active during pregnancy.
- Exercise reduces risk of developing obstetrical complications, including preeclampsia, pregnancy-induced hypertension, & gestational diabetes.
- Extra weight in front of body shifts center of gravity, making you more likely to lose balance & contributes to back pain.
- Resting heart rate increases 10-15 beats/minute.
- Pregnant women use carbohydrates at greater rate & are thus predisposed to low blood glucose (hypoglycemia) during exercise lasting more than 45 minutes.
- While exercising during pregnancy is beneficial, pregnancy is not a time to try to improve fitness or lose weight.

Training Recommendations for Women

The female's training program incorporates adjustments based on fluctuations of hormones & other female-specific conditions. It must always be open to change, moving a workout here or there based on how she feels, or backing off on training load altogether when certain conditions arise, like menses, amenorrhea, pregnancy, or anemia.

Training Recommendations for Women

- Since estrogen has such a big effect on bone health, don't increase weekly training volume during menses or early part of follicular phase & latter part of luteal phase, as those are times of month when estrogen is low.
- Increase weekly training volume during latter part of follicular phase & mid-luteal phase, when estrogen is high.
- Given women's predisposition for aerobic training, embrace it.
- Many women find that during days corresponding to low estrogen levels (week 1) high-intensity workouts are easier, with lower heart rates & breathing rates that contribute to less perceived exertion.
- Many women find that hard workouts during last 2 weeks of menstrual cycle are very difficult. Times of month when estrogen is low would be better time to do hard workouts.

Training Recommendations for Women

- Include strength training in training program.
 - increases strength
 - increases bone mineral density
 - increases emotional well being & body image
 - reduces social physique anxiety
 - enhances physical self-efficacy

Sample Base Building Training Program

Week of Training Cycle	Week of Menstrual Cycle	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Total Miles
1	4 or 2	3 miles	5 miles	6 miles	4 miles	5 miles	Rest	7 miles	30 miles
2	1 or 3	3 miles	4 miles	6 miles	4 miles	5 miles	Rest	8 miles	30 miles
3	2 or 4	4 miles	5 miles	7 miles	4 miles	6 miles	Rest	9 miles	35 miles
4	3 or 1	2 miles	3 miles	5 miles	3 miles	4 miles	Rest	6 miles	23 miles
5	4 or 2	4 miles	5 miles	7 miles	4 miles	6 miles	Rest	9 miles	35 miles
6	1 or 3	4 miles	5 miles	7 miles	4 miles	6 miles	Rest	9 miles	35 miles
7	2 or 4	5 miles	6 miles	8 miles	5 miles	6 miles	Rest	10 miles	40 miles
8	3 or 1	2 miles	4 miles	5 miles	3 miles	5 miles	Rest	7 miles	26 miles

Weeks 1, 3, 5, 7 good times to increase mileage since estrogen is on the rise, coinciding with weeks 2 & 4 of menstrual cycle. When estrogen is decreasing—weeks 1 & 3—either maintain weekly mileage (weeks 2 & 6 of training cycle) or decrease it (weeks 4 & 8 of training cycle). Notice recovery weeks (weeks 4 & 8 of training cycle) occur at same time that estrogen is low (weeks 1 or 3 of menstrual cycle). Since many runners do not feel good when running during menses (first few days of week 1 of menstrual cycle), use that time to back off on mileage (weeks 4 & 8 of training cycle).