



# FEMALE ATHLETE TRIAD: RELATIVE ENERGY DEFICIT IN SPORT

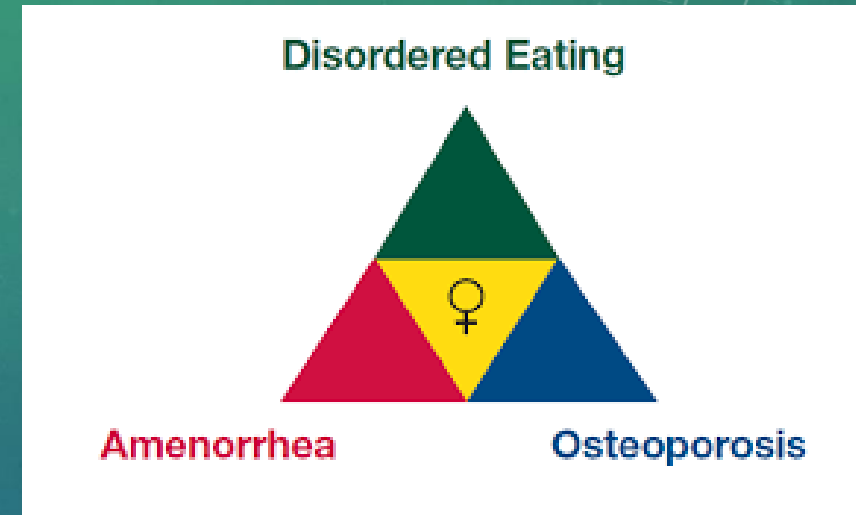
KIM FAGAN M.D.

CHIEF OF SPORTS MEDICINE

FAMILY AND COMMUNITY MEDICINE UAB

# FEMALE ATHLETE TRIAD

- Recognized in late 80's / early 90's
- ACSM Consensus Statement – 1997
  - Disordered Eating
  - Amenorrhea
  - Osteoporosis
- Updated position statement – 2007
  - “low energy availability” with or without eating disorder
- Female Athlete Triad Coalition Consensus Statement- 2014 /2018



# RELATIVE ENERGY DEFICIT IN SPORT (RED-S)

International Olympic  
Committee- 2014/ 2018

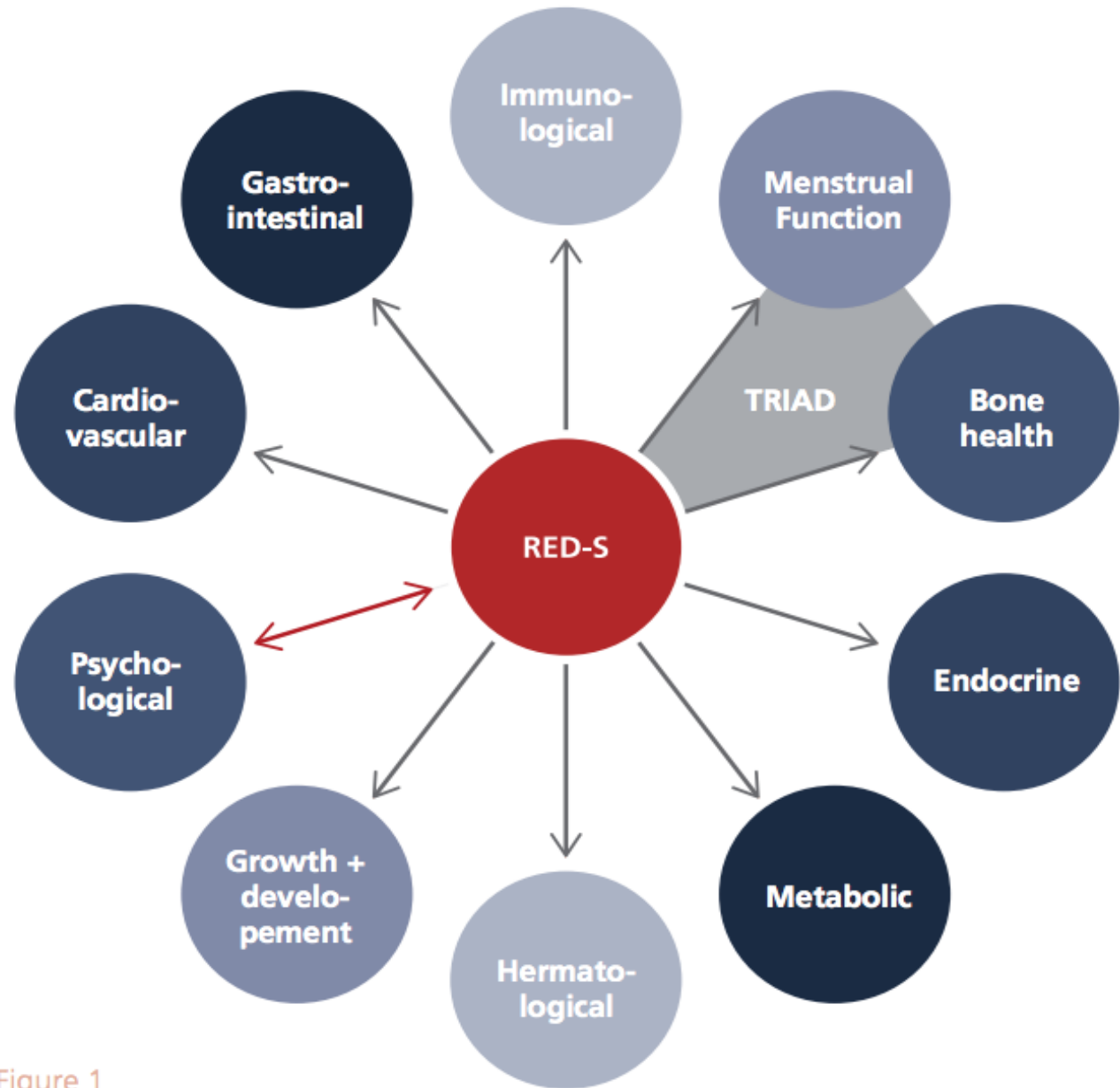
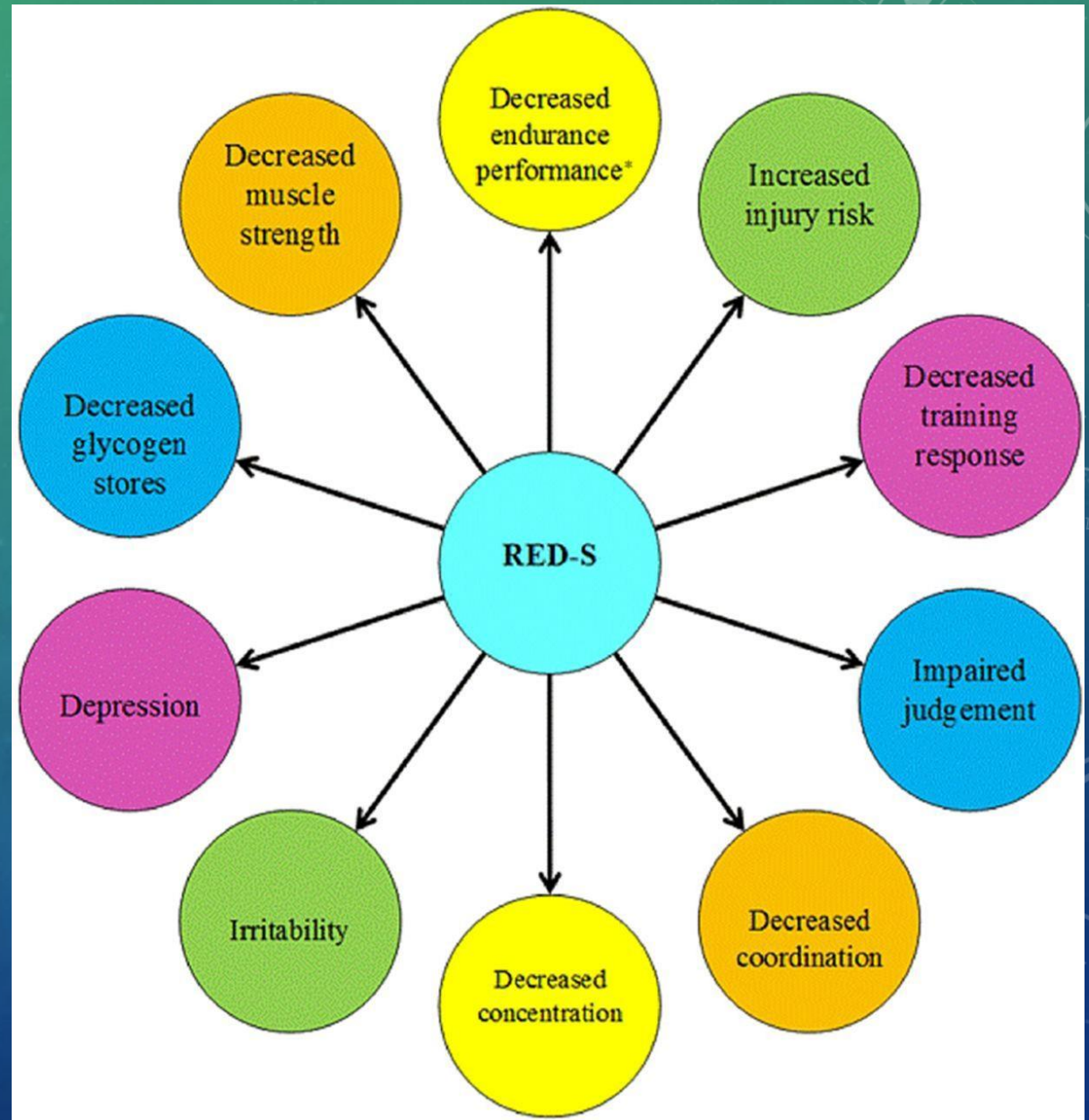


Figure 1



## RELATIVE ENERGY DEFICIT IN SPORT (RED-S)

- Affects performance
- Result of insufficient caloric intake or excessive caloric expenditure



# ENERGY AVAILABILITY

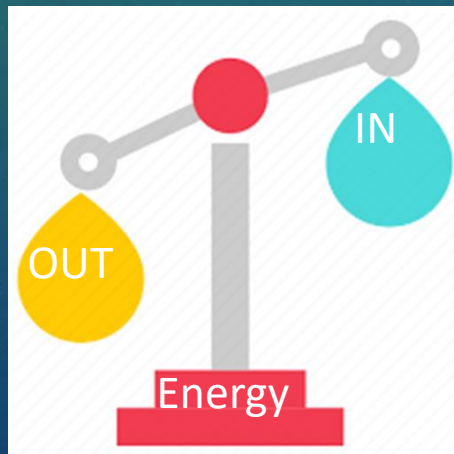
$$\text{Energy Availability (EA)} = \frac{\text{EI (kcal)} - \text{EEE (kcal)}}{\text{FFM (kg)}}$$



*EI- energy intake*

*EEE- energy expenditure with exercise*

*FFM- fat free mass*



Optimal Energy Availability for healthy physiologic function in women: 45 kcal/kg fat free mass/day. (<30 affects hypothalamic-pituitary axis)



### Football

57kgs  
15yrs



- Consumes 1,854 Calories
- Expendes 885 calories (2 hour training)

**Low Energy Availability: 20KCal / KG / FM**

*\*Health implications with impairment of many body systems including training adaptation & Performance*



### Football

57kgs  
15yrs



- Consumes 2,239 Calories
- Expendes 885 calories (2 hour training)

**Moderate Energy Availability: 30KCal / KG / FM**

*\*May be tolerated for short periods such as a well-constructed weight loss program*



### Football

57kgs  
15yrs

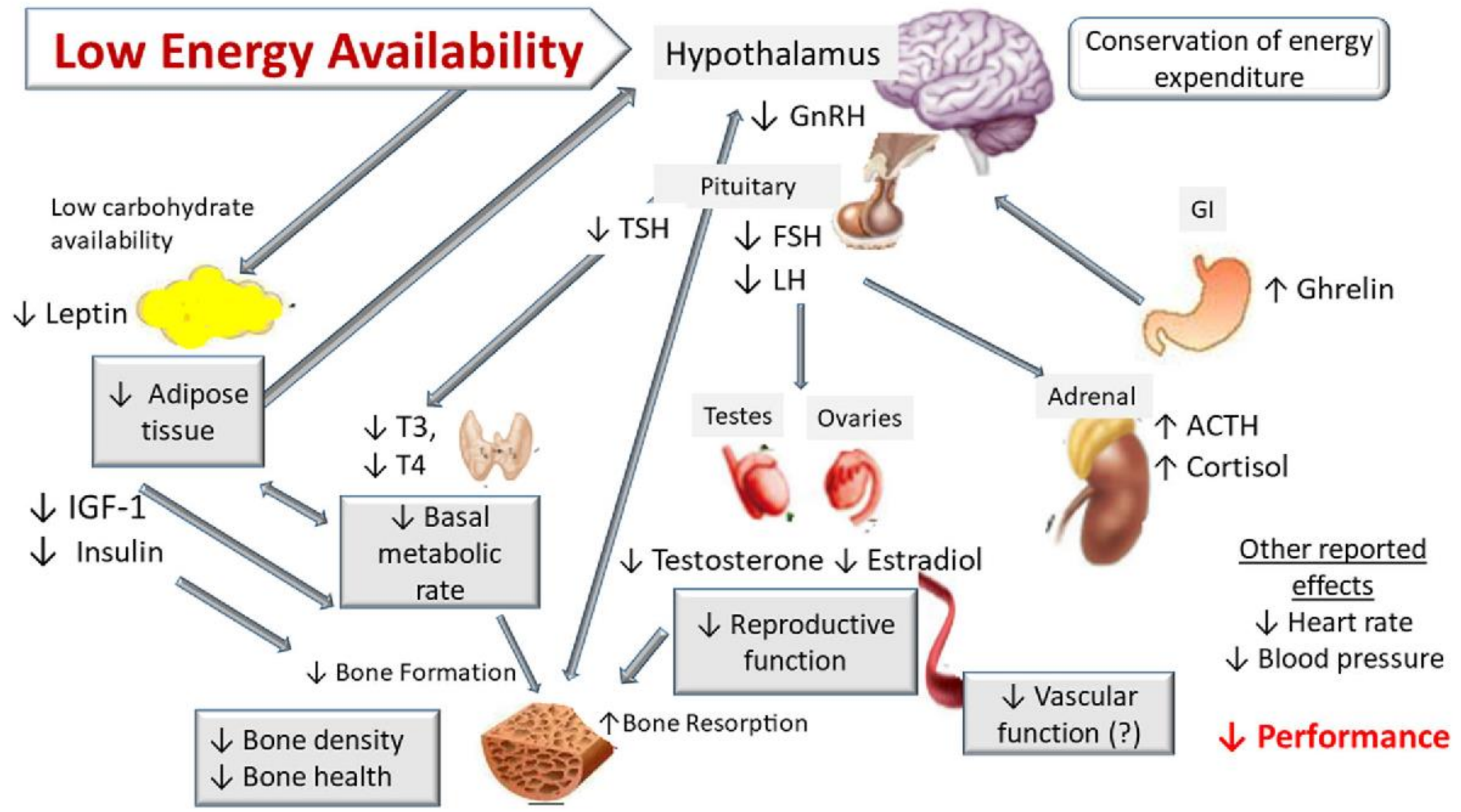


- Consumes 3,066 Calories
- Expendes 885 calories (2 hour training)

**Adequate Energy Availability: 45KCal / KG / FM**



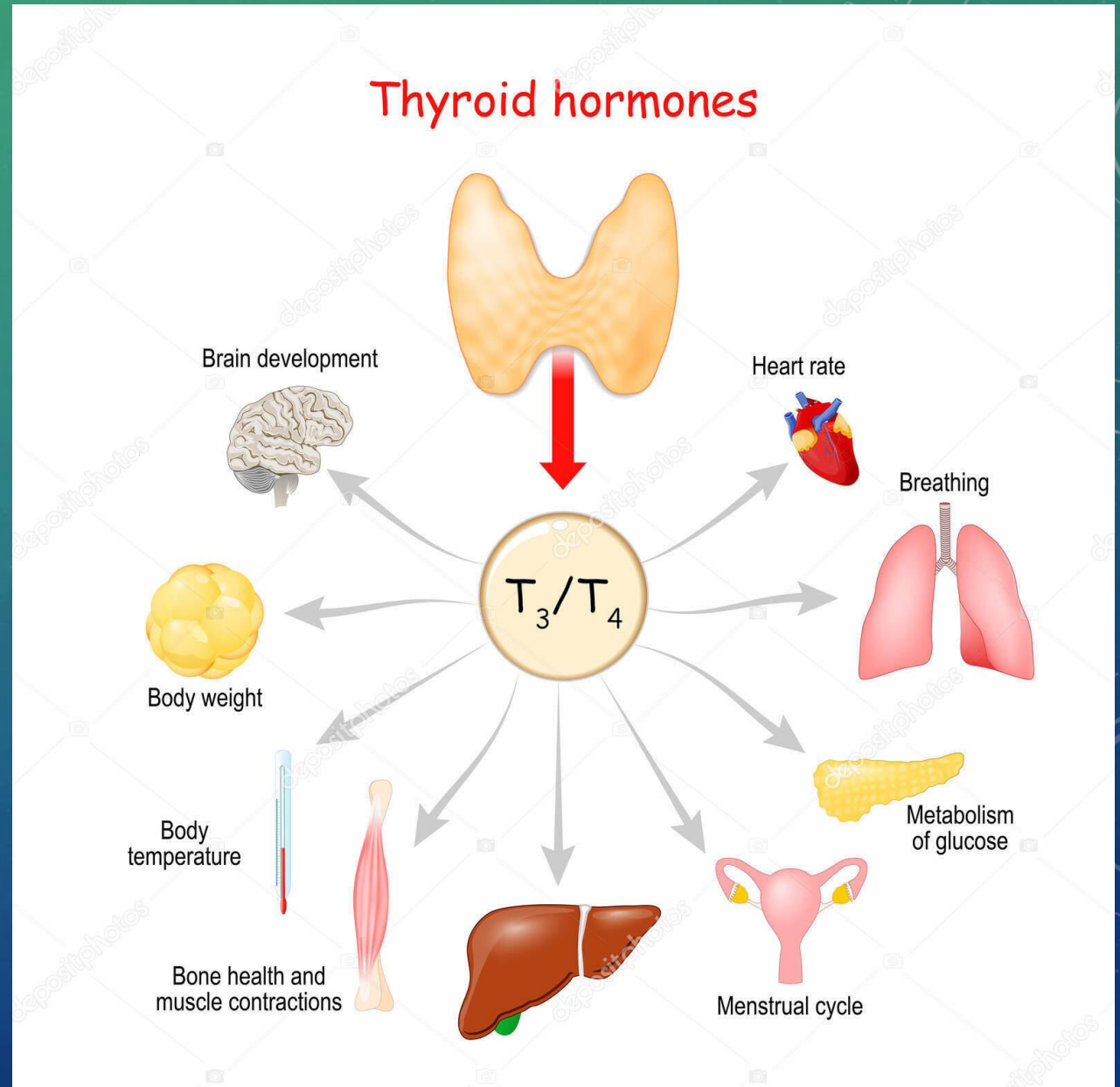
# Low Energy Availability



Stressors such as a low energy availability (LEA) activate the \_\_\_\_\_ molecules that are able to cross the blood-brain barrier and regula

## ENDOCRINE: THYROID

- Thyroid- “sick euthyroid” profile
  - Low T3
  - Variable T4 and TSH





# ENDOCRINE: APPETITE REGULATING HORMONES

- Decreased
  - Leptin
  - Oxytocin
- Increased
  - Ghrelin

\*Markers of Energy Status

## The hormones that control our hunger

Where the hormones are created and their function in controlling hunger

Examples of hormones that control the hypothalamic neurons and the effect they have on hunger:

### Pancreas:

- Amylin
- Insulin
- Pancreatic polypeptide (PP)

> **inhibit hunger**

### Lower small bowel:

- Peptide YY
- Glucagon-Like Peptide 1 (GLP-1)
- Oxyntomodulin
- Uroguanilin

> **inhibit hunger**

### Upper small bowel:

- Cholecystokinin (CCK)

> **inhibit hunger**

### Fat cells:

- Leptin

> **inhibits hunger**

### Colon:

- Insulin-like Peptide 5 (ILP-5)

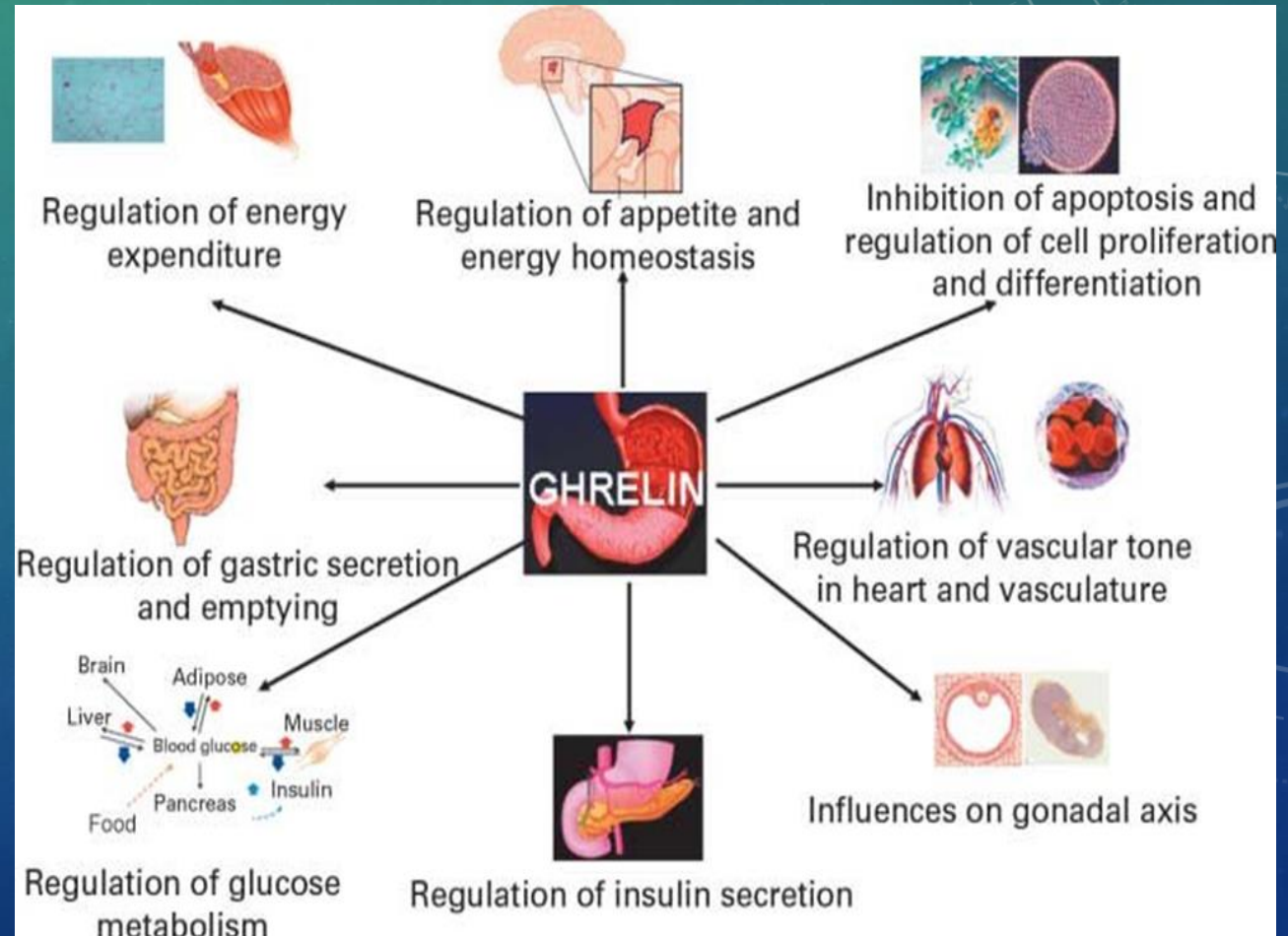
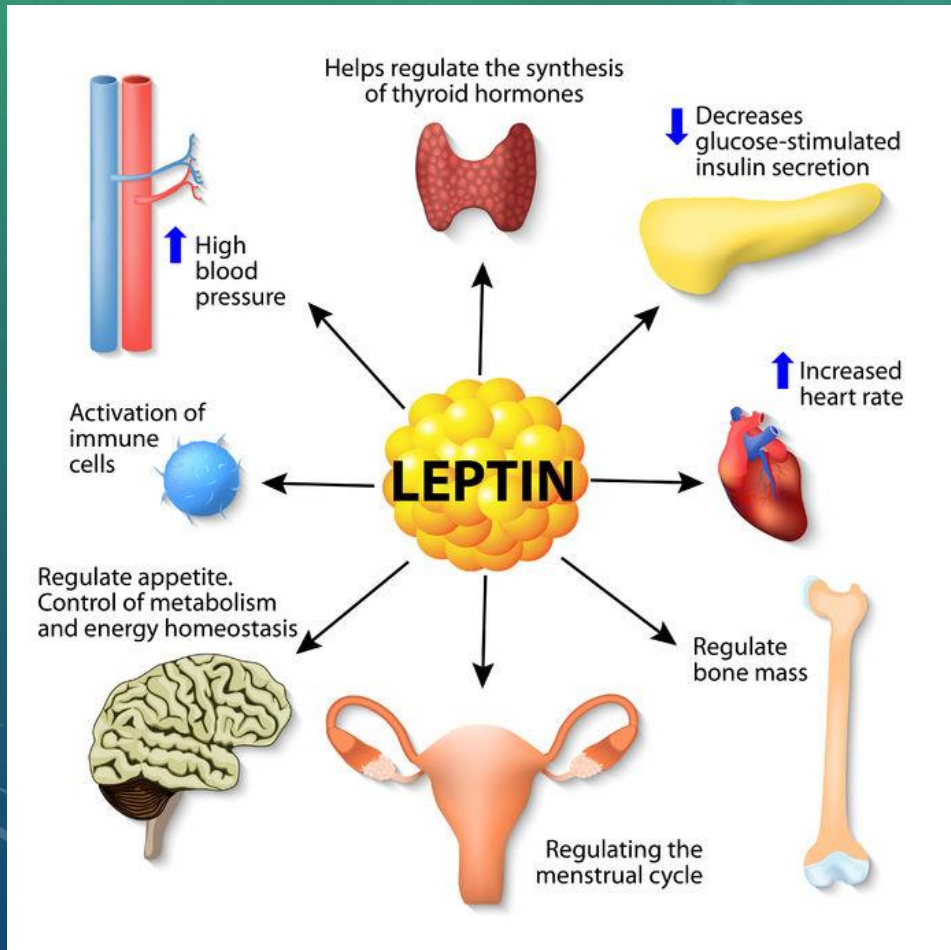
> **stimulates hunger**

### Stomach:

- Ghrelin

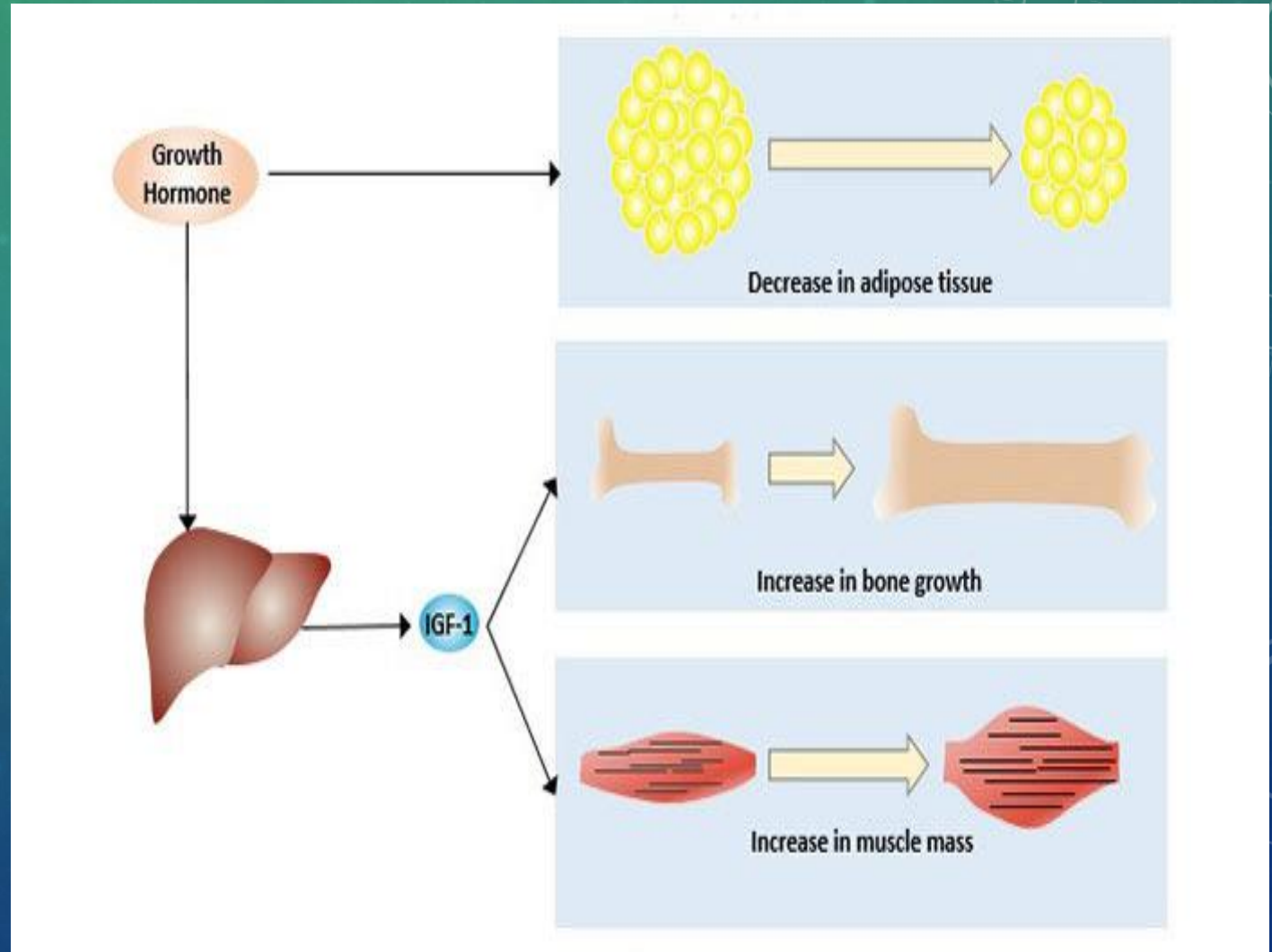
> **stimulates hunger**

# APPETITE REGULATING HORMONES



# ENDOCRINE: GROWTH HORMONE IG-F

- Growth hormone- increased
  - Muscle and bone anabolism
  - CHO, protein, lipid metabolism
  - Stimulated by ghrelin
  - Mediated by IGF-1
    - Fat and CHO metabolism are not
- IGF- 1- decreased
  - Suggest GH resistance at level of liver





## ENDOCRINE: CORTISOL

- Cortisol demonstrates a U shaped relationship between BMI and adiposity.
- Extremely over and under weight noted to have elevated cortisol levels
- Contributes to increased adiposity in overweight.
- Catabolic in underweight

# THE CONSEQUENCES OF A CATABOLIC STATE

Loss of  
muscle mass



Low  
energy levels



Reduced ability  
to handle stress



Loss of  
subcutaneous fat



Exercise  
intolerance

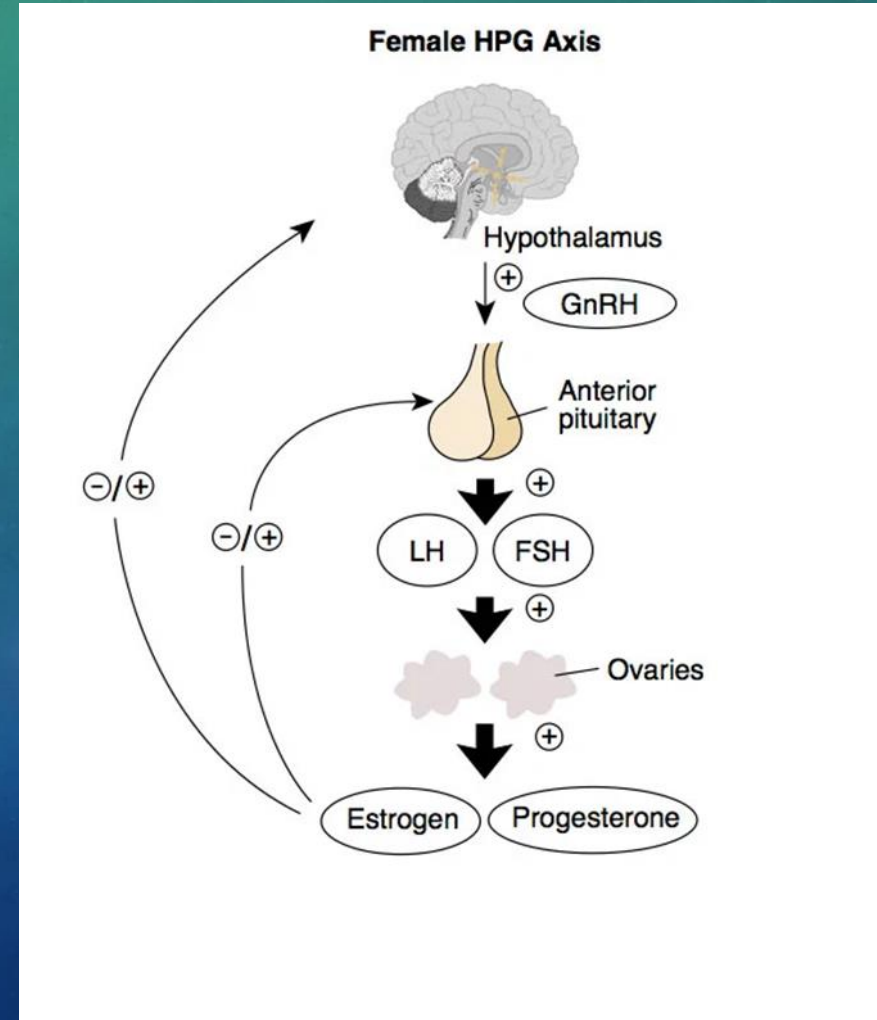


Cachexia, or  
catabolic wasting



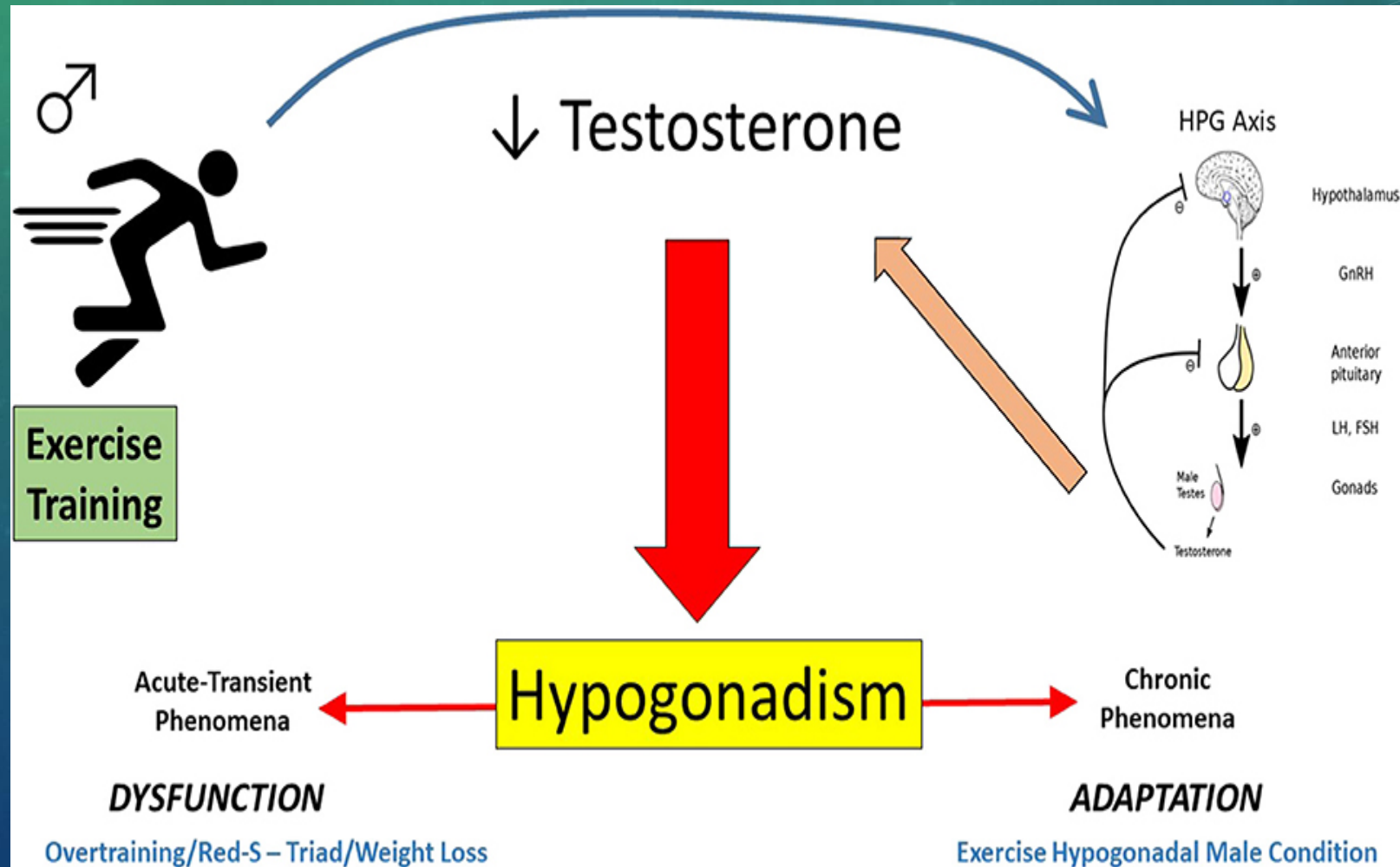
# ENDOCRINE: HYPOTHALAMIC PITUITARY GONADAL AXIS

- Functional Hypothalamic Amenorrhea
  - Energy Deficit
    - Weight loss
    - Exercise induced
  - Suppression of the GnRH secretion
    - Decreased gonadotropin pulsation
    - Low/normal LH secretion
    - Low estradiol
    - FSH usually normal range
    - \*mimics pre-pubertal state



# ENDOCRINE: HYPOTHALAMIC- PITUITARY-GONADAL AXIS

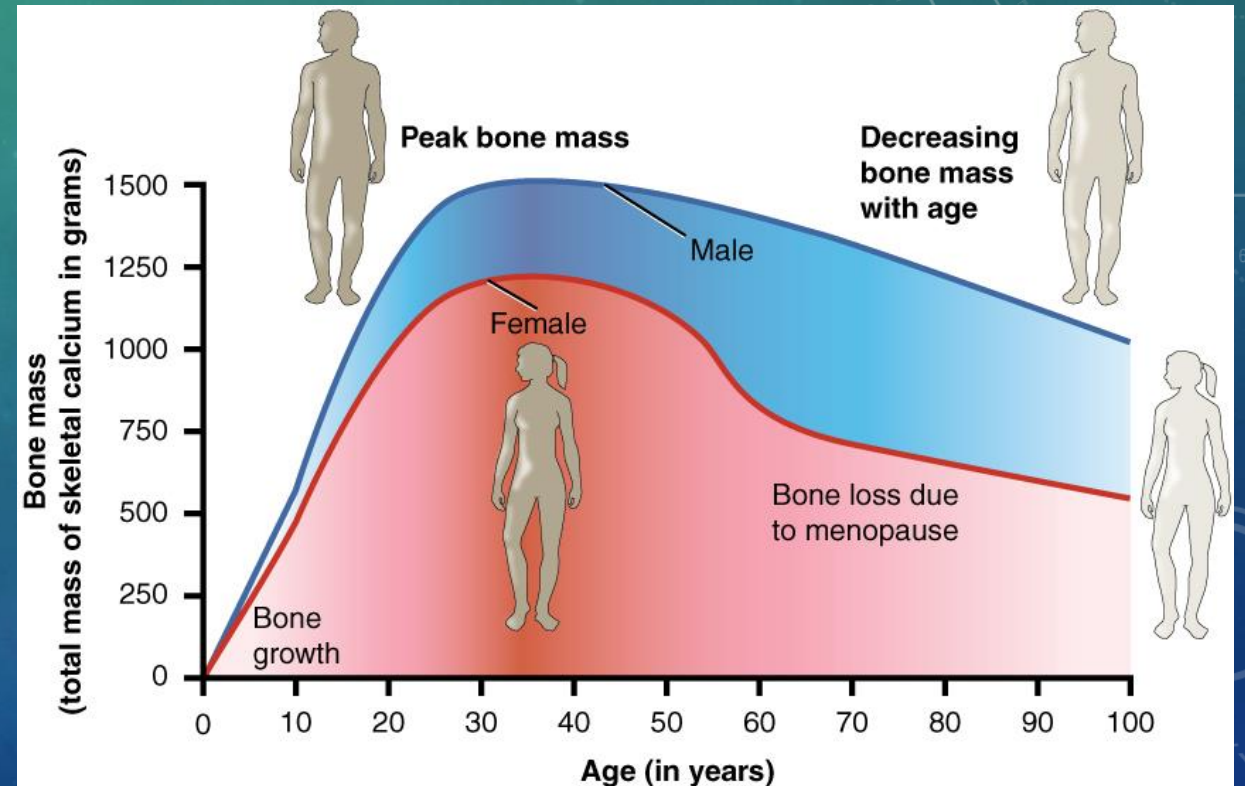
- Males





# ENDOCRINE BONE

- Endocrine organ and endocrine target
- Hormonal changes noted in women with amenorrhea have detrimental effects on the bone.
  - HPA suppression
  - Decreased leptin, insulin, IGF-1
  - Increased cortisol



# EATING DISORDERS/ ENERGY DEFICIT

- Anorexia
- Bulimia
- Binge/ Purge
- Eating disorder not otherwise specified
- Relative energy deficit



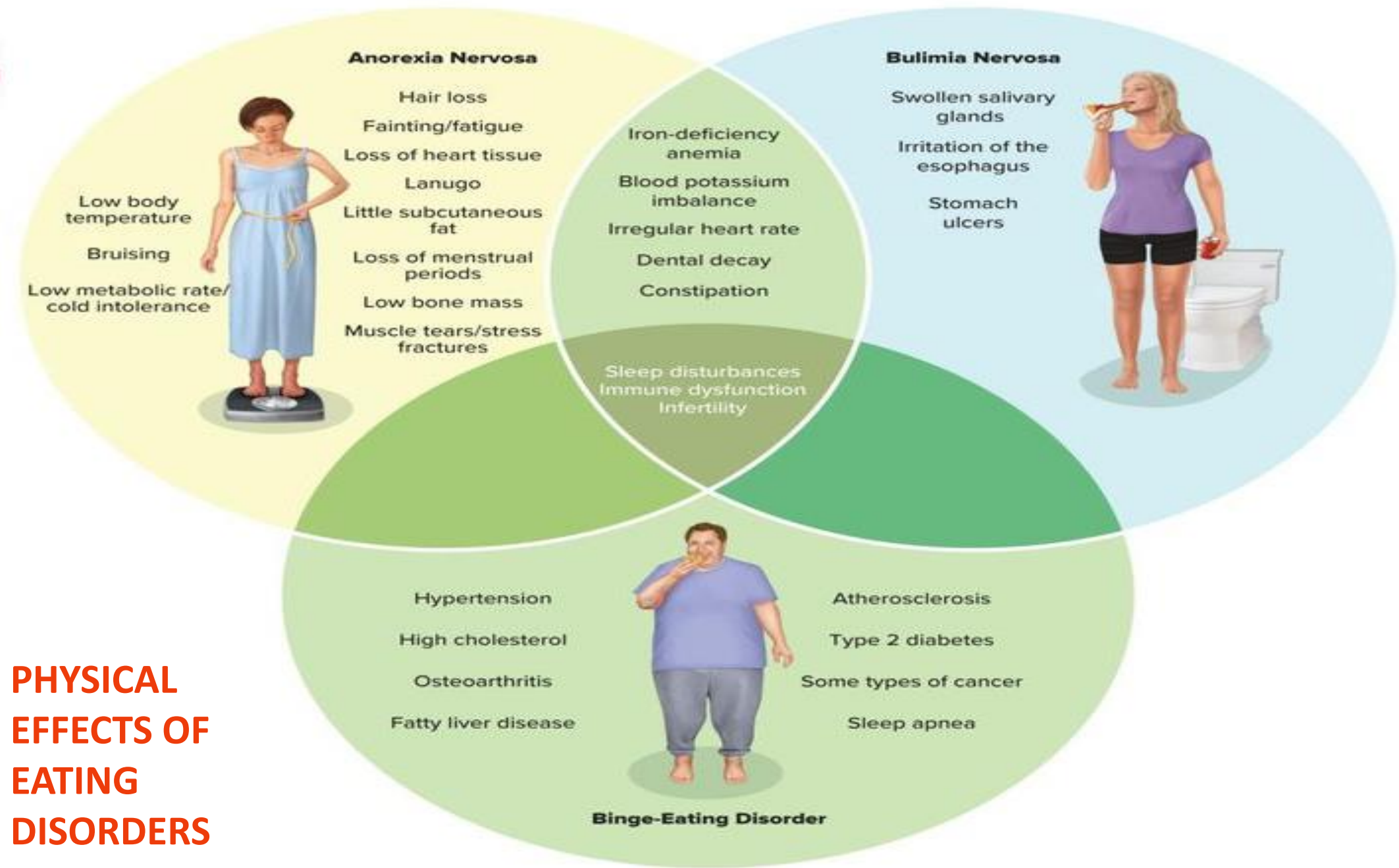
**TABLE. Summary of eating disorder diagnostic criteria**

<b>Diagnosis</b>	<b>Major criteria</b>
Anorexia	Significantly low body weight, significant weight and shape concerns
Bulimia nervosa	Recurrent binge eating and compensatory behaviors (eg, purging, laxative use); significant weight and shape concerns
Binge eating disorder <sup>a</sup>	Recurrent binge eating; at least 3 of 5 additional criteria related to binge eating (eg, eating large amounts when not physically hungry, eating alone due to embarrassment); significant distress

<sup>a</sup> Binge eating disorder is specified as a diagnosis only in DSM-5; in ICD-10 a person meeting the criteria would have a diagnosis of “other eating disorder.”



Eating Disorder	Symptoms
Anorexia Nervosa	<ul style="list-style-type: none"><li>Ψ Eating in secret, avoiding eating with other people</li><li>Ψ Loss of or disturbed menses for women</li><li>Ψ Decreased libido in men</li><li>Ψ Fainting/dizziness</li></ul>
Bulimia Nervosa	<ul style="list-style-type: none"><li>Ψ Calluses on knuckles and discoloured/stained teeth (from induced vomiting)</li><li>Ψ Dislike eating with others or in public</li><li>Ψ Disappearing to bathroom after eating</li><li>Ψ New food diets (eg. cutting out entire food groups)</li></ul>
Binge Eating Disorder	<ul style="list-style-type: none"><li>Ψ Eating even when full</li><li>Ψ Eating alone or in secret</li><li>Ψ Fluctuations in weight (both up and down)</li></ul>



**PHYSICAL  
EFFECTS OF  
EATING  
DISORDERS**

# AT RISK SPORTS

- “Aesthetic”
  - Cheer
  - Gymnastics
  - Figure skating
  - Dance
- Weight classes
  - Rowing
  - Wrestling
- Endurance
  - Running
  - Cycling
- Anti-gravity

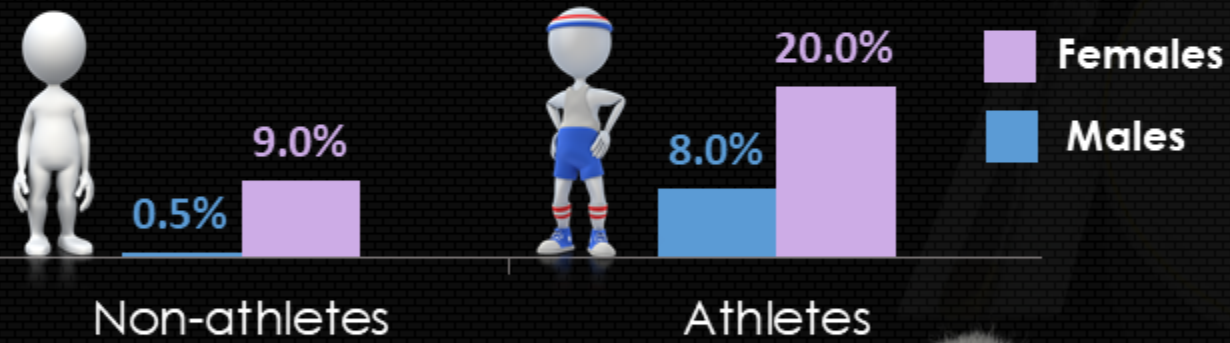




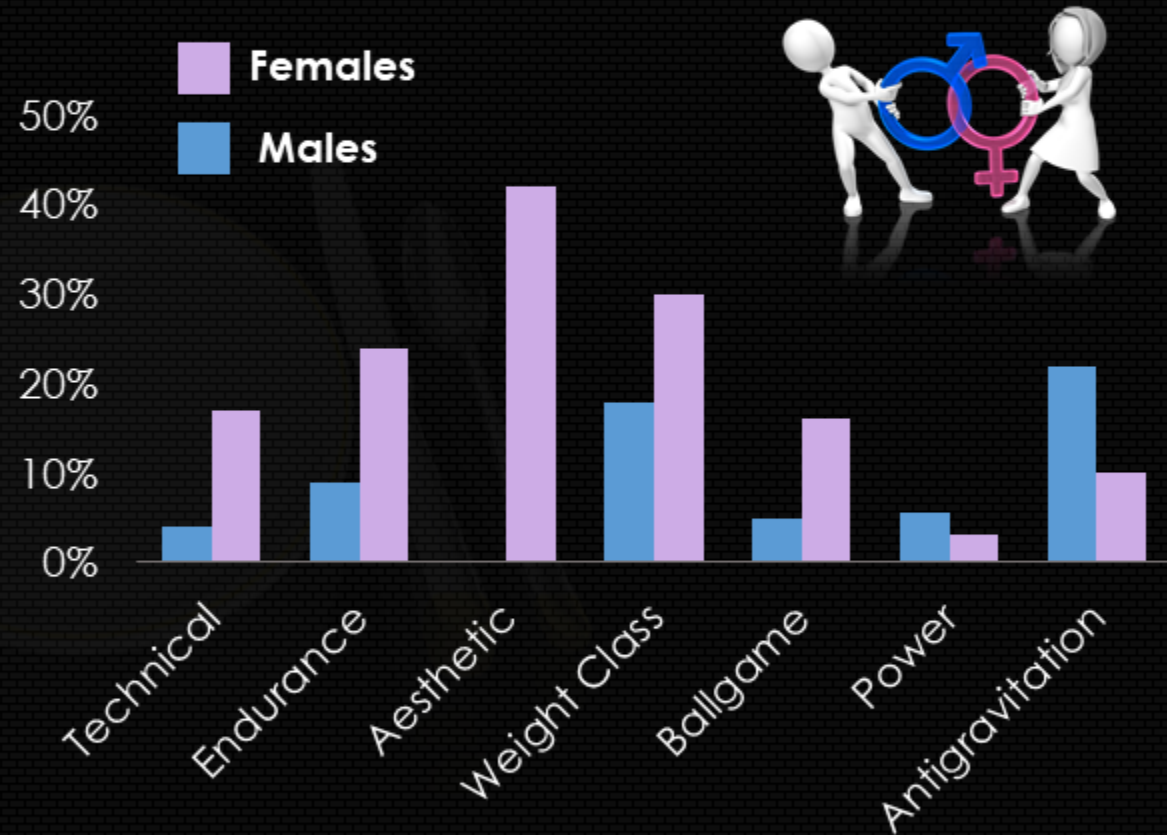
# PREVALENCE OF EATING DISORDERS IN ELITE ATHLETES IS HIGHER THAN IN THE GENERAL POPULATION

1259 elite Norwegian athletes (687 F; 572 M;) and 1203 age-matched controls from the general population (629 F; 574 M) were screened for eating disorders

## OVERALL PREVALENCE OF EATING DISORDERS: ELITE ATHLETES vs. NON-ATHLETES



## PREVALENCE OF EATING DISORDERS: ELITE ATHLETES ONLY, BY SPORT TYPE



### Prevalence of eating disorders was:

- 1 Higher in athletes than in non-athletes
- 2 Higher in female athletes than in male athletes
- 3 Higher in those competing in leanness & weight-dependent sports than in other sport types

**REFERENCE:** Sundgot-Borgen, J. and Torstveit, M.K., 2004. Prevalence of eating disorders in elite athletes is higher than in the general population. *Clinical Journal of Sport Medicine*, 14(1), pp.25-32.

**MORE INFO:** Designed by Adam Virgile  
Learn more here:  
<https://blog.shakebot.co/>



@shakebotapp

# IRON DEFICIENCY

- Direct and indirect contributor to energy deficiency
- Decreased appetite
- Impaired metabolic efficiency
- Increased energy expenditure
- Dysregulation of growth hormone/ IGF 1 axis

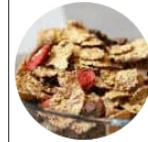
(Ferritin level < 20)

MYFOODDATA

## Top 10 Foods Highest in Iron

18mg of Iron = 100% of the Daily Value (%DV)

### 1 Fortified Cereals



**109% DV** (19.6mg)  
per 3/4 cup

113 calories

### 2 Beef (Skirt Steak)



**52% DV** (9.3mg)  
per 6oz steak

456 calories

### 3 Shellfish (Oysters)



**43% DV** (7.8mg)  
per 3oz serving

139 calories

### 4 Dried Fruit (Apricots)



**42% DV** (7.5mg)  
per cup

381 calories

### 5 Large White Beans



**37% DV** (6.6mg)  
per cup

249 calories

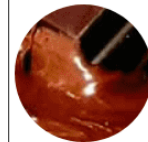
### 6 Spinach



**36% DV** (6.4mg)  
per cup cooked

41 calories

### 7 Baking Chocolate (Unsweetened)



**28% DV** (5mg)  
per 1oz square

186 calories

### 8 Quinoa



**15% DV** (2.8mg)  
per cup

222 calories

### 9 White Button Mushrooms



**15% DV** (2.7mg)  
per cup cooked

44 calories

### 10 Squash and Pumpkin Seeds



**14% DV** (2.5mg)  
per 1oz handful

159 calories

# IRON DEFICIENCY

- Poor dietary intake
- Mechanical hemolysis
- Intestinal bleeding
- Sweating
- Menses





# IRON DEFICIENCY

- Signs and Symptoms
  - Nausea
  - Frequent infection
  - Pale appearance
  - Shortness of breath during exercise
  - Decreased performance
  - Fatigue
  - Weakness
  - Lack of energy
  - Exhaustion



# IRON DEFICIENCY

- NCAA Division I athletes (2002-2014):
  - n- 2749
  - Collected ferritin and Hgb
    - N- 1059 females
      - Iron deficiency- 30.9%
      - Iron deficiency anemia- 2.2%
    - N- 411 males
      - Iron deficiency- 2.9%
      - Iron deficiency anemia- 1.2%



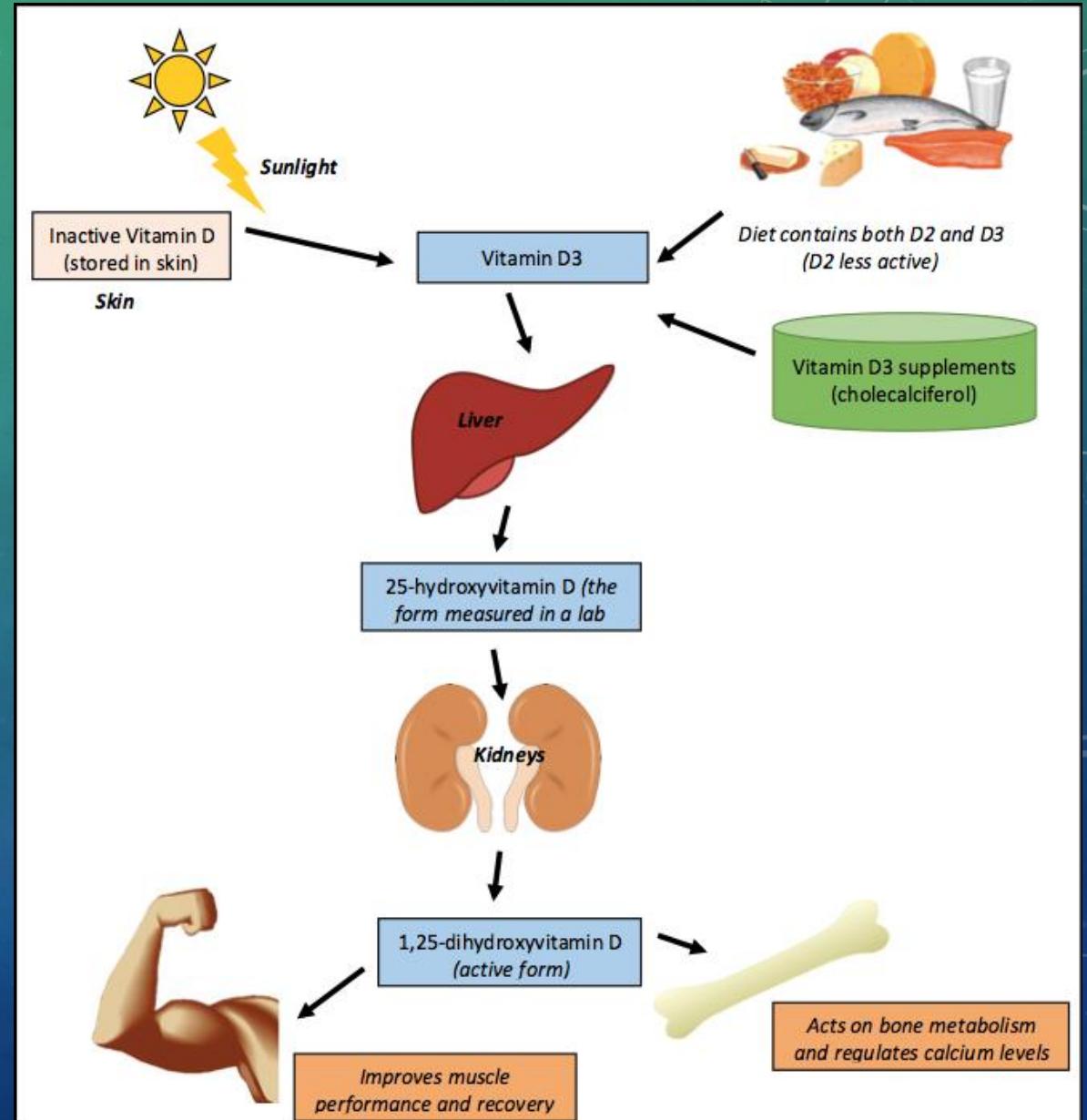
# VITAMIN D DEFICIENCY

- Skeletal muscle repair
- Skeletal muscle function ?
- Immune function
  - Role in regulating activation of immune cells
  - Immunomodulatory effect on T/B lymphocytes in acquired immunity
  - Helps dampen excessive inflammation/ tissue damage

\*General/ athletic/ military

Correlation between low vitamin D and increased URI's

- Bone health





# VITAMIN D DEFICIENCY

- Correlated with:
- Increased risk of stress fractures
- Higher incident of muscle strains of lower extremity
- Increased frequency of URI's
- Supplementation resulted in increased vertical jump



# VITAMIN D DEFICIENCY/ INSUFFICIENCY

- 36- 57 % of general population
- 56 % of athletes
  - Meta analysis of 2313 athletes
  - 23 studies
    - Forrest K.Y., Stuhldreher W.L. Prevalence and correlates of vitamin D deficiency in US adults. *Nutr. Res.* 2011;31:48–54. doi: 10.1016/j.nutres.2010.12.001

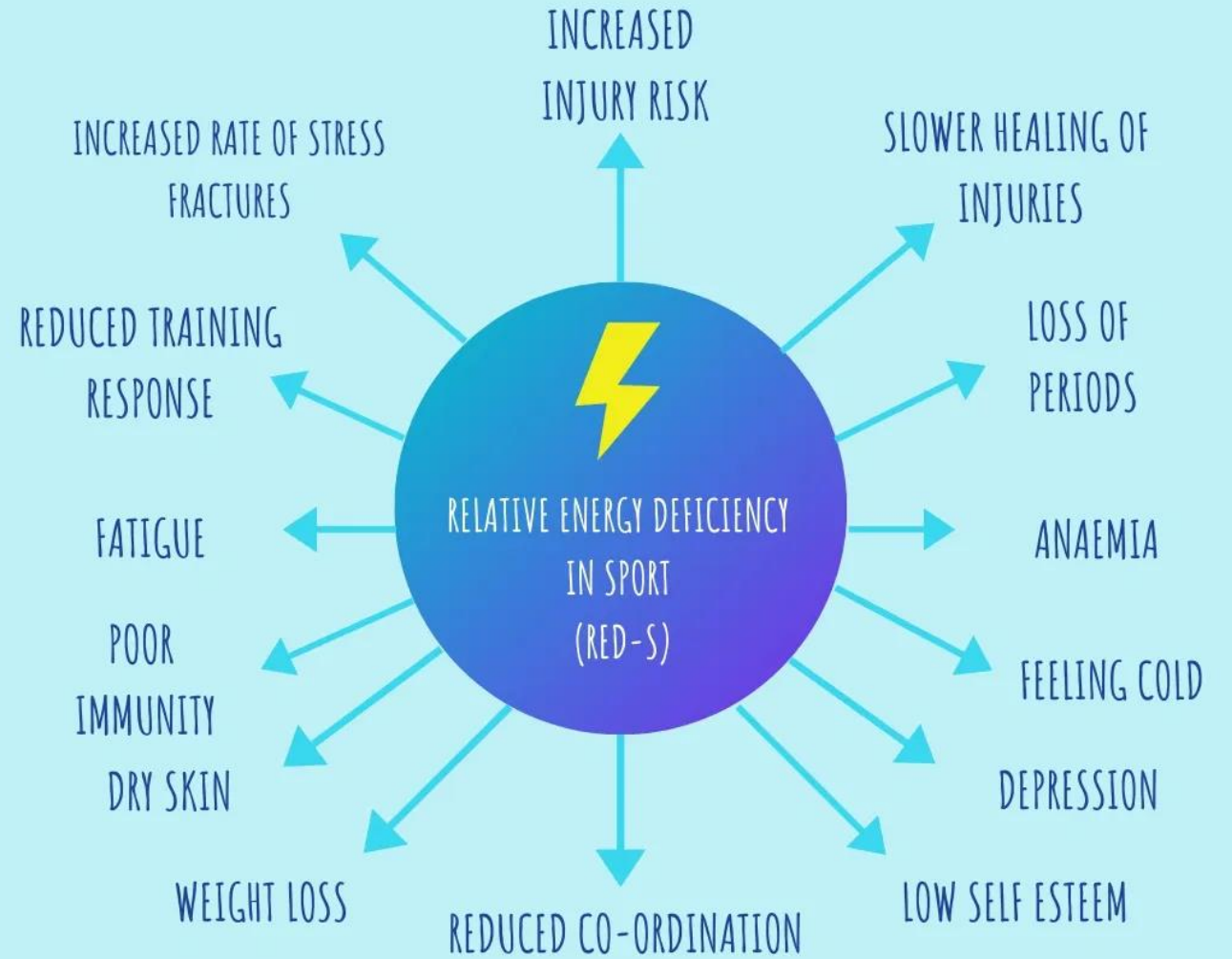


# TREATMENT TEAM





# SIGNS AND SYMPTOMS



# DIAGNOSIS: MEDICAL HISTORY

- Constitutional symptoms: fatigue, weakness, insomnia, etc
- Infections-: recurrent URI's
- GI issues: constipation, diarrhea
- Hair loss, cold intolerance
- Menstrual history
- Libido
- Stress fractures or recurrent MSK injuries
- Mental health issues: depression, anxiety, moody, change in behavior





# DIAGNOSIS: SPORTS HISTORY

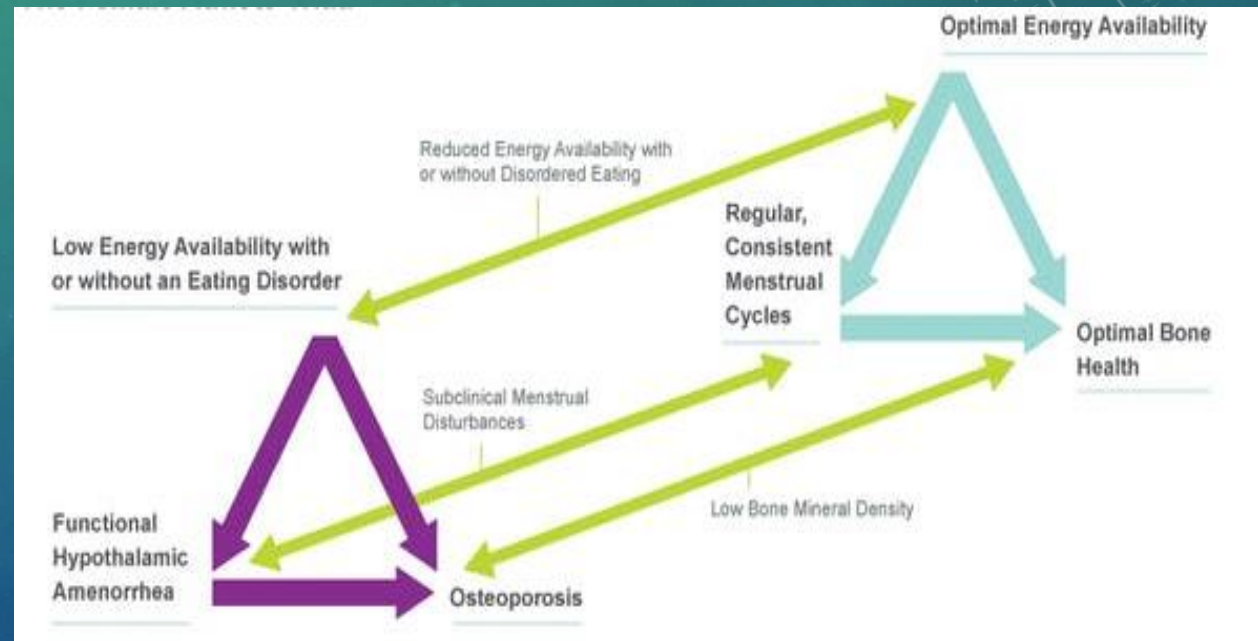
- Type of Sport- ? High risk sport
- Level- recreational vs highly competitive
- Training program- training hours, phase, changes
- Performance status- ? decreased





# DIAGNOSIS: NUTRITION/ DIET

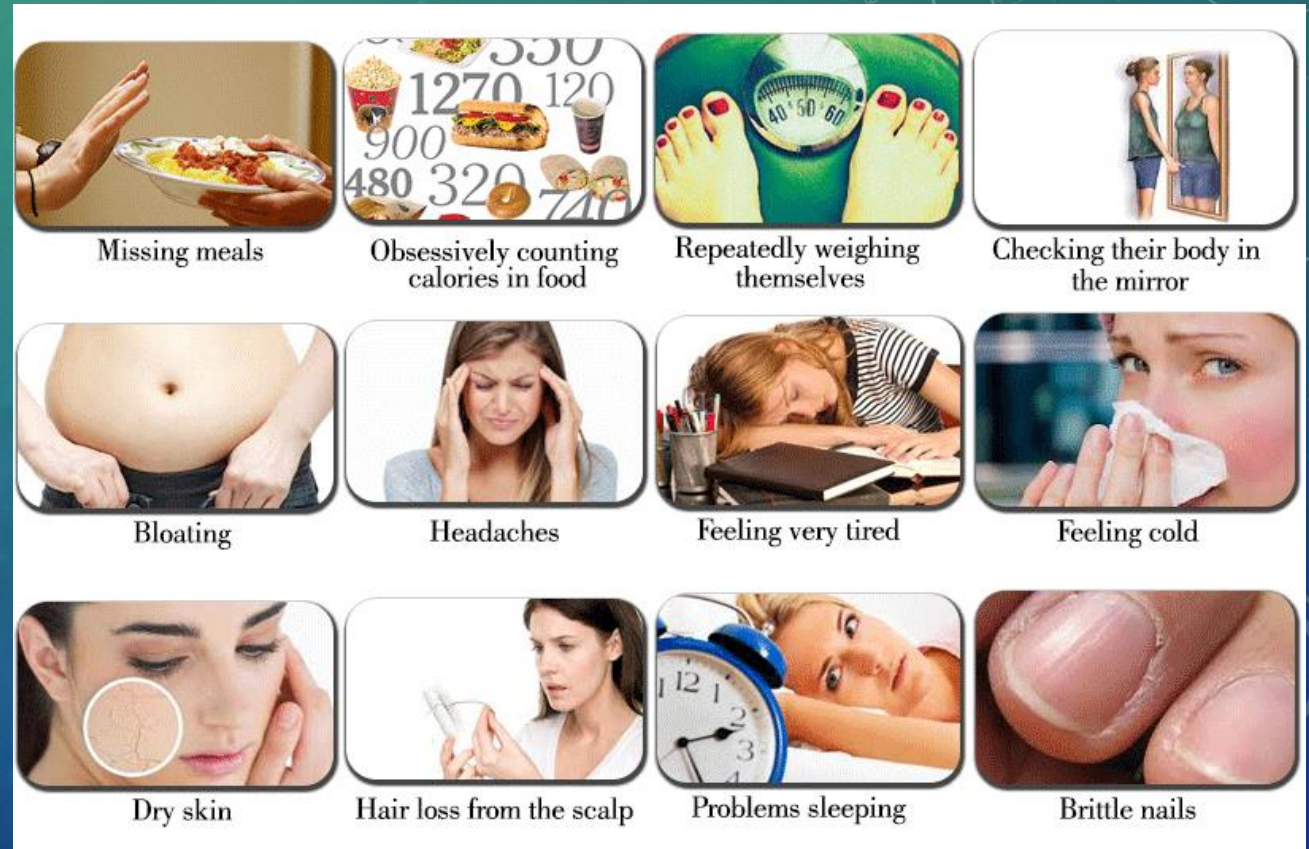
- Eating pattern
- Amounts
- Food avoidance
- Weighing habits
- Weight changes
- Weight goals



>45 kcal/kg fat free mass per day- optimal energy availability

# DIAGNOSIS: PHYSICAL EXAM

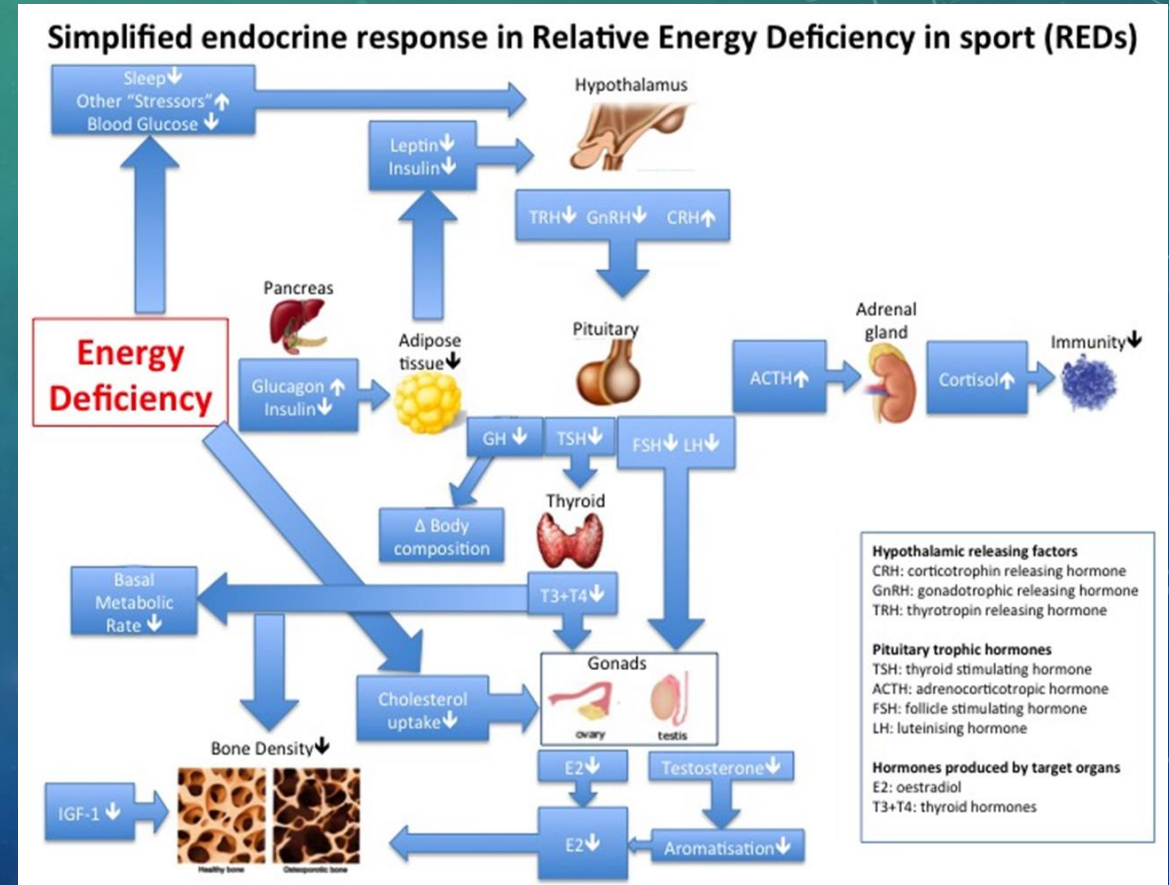
- Height, Weight: low BMI
- Heart Rate: bradycardia
- Blood pressure: low BP or orthostatic hypotension
- Eating disorder clues:
  - Dry skin, thinning hair, parotid gland enlargement, dental caries, callous on knuckles, red eyes.





# DIAGNOSIS: BLOOD TEST

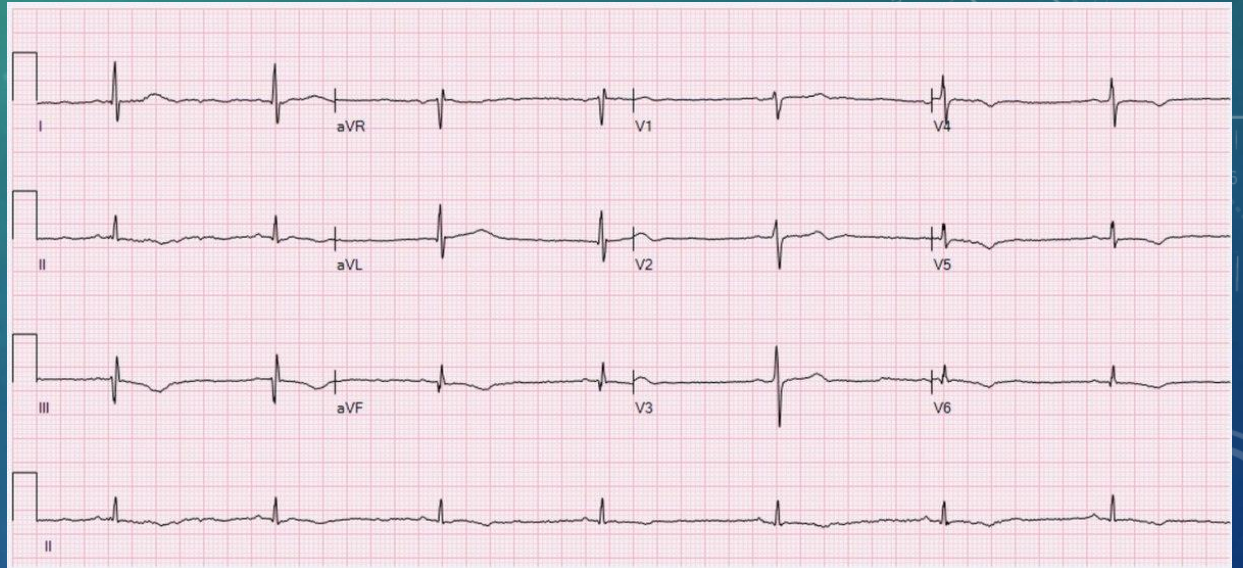
- CBC
- Comprehensive Metabolic Panel
- Iron studies
- Vitamin D
- B12
- Folic acid
- Lipid profile
- Amylase
- Cortisol
- IGF- I, GH
- Thyroid profile
- Reproductive sex hormones sex hormones
- Leptin, Ghrelin





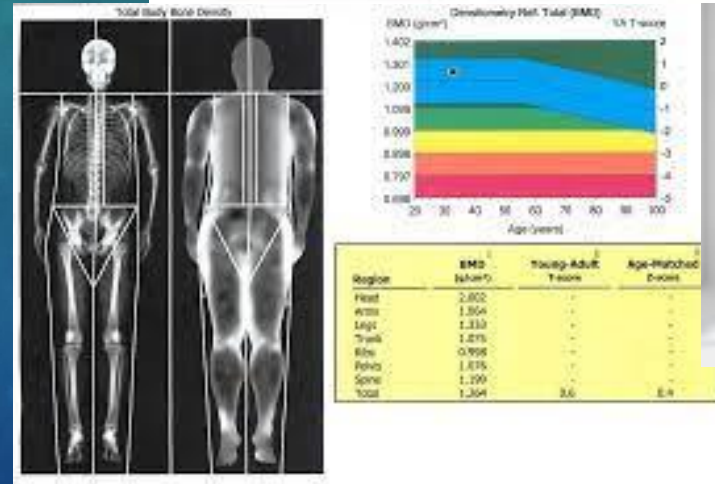
# DIAGNOSIS: ECG

- Sinus bradycardia
- Low voltage
- Prolonged QT
- Arrhythmias



# DIAGNOSIS: OTHER TESTS

- Resting Metabolic Rate (RMR)
- Bone Density (DEXA)
- Body Fat Composition



# DIAGNOSIS- DIFFERENTIAL

- Amenorrhea of other etiologies
- Stress fractures
- GI issues
- Viral illness
- Insomnia
- Vitamin/ mineral deficiencies
- Anemia
- Insomnia
- Mental conditions
- Training errors





# TREATMENT: GOAL

- Achieve optimal energy availability for health and performance
- Allow training and performance at a safe and appropriate level



# TREATMENT CONTRACT

- Include treatment team members.
- Required appointments with treatment team at designated intervals.
- Daily meal plans.
- Adapted training plan.
- If underweight: weight gain expectations with designated time frame.
- Regular weigh-in schedule.



# TREATMENT: ATHLETE'S ROLE

- How have you been feeling?
- How well do you sleep?
- What is your energy level like?
- How many stress fractures/ injuries have you had?
- How often do you get sick?
- How much training have you missed from injury/illness?
- How have your race times / performance been?
- How's your mood? Libido?
- Are you aware that amenorrhea leads to increased risk of stress fractures?





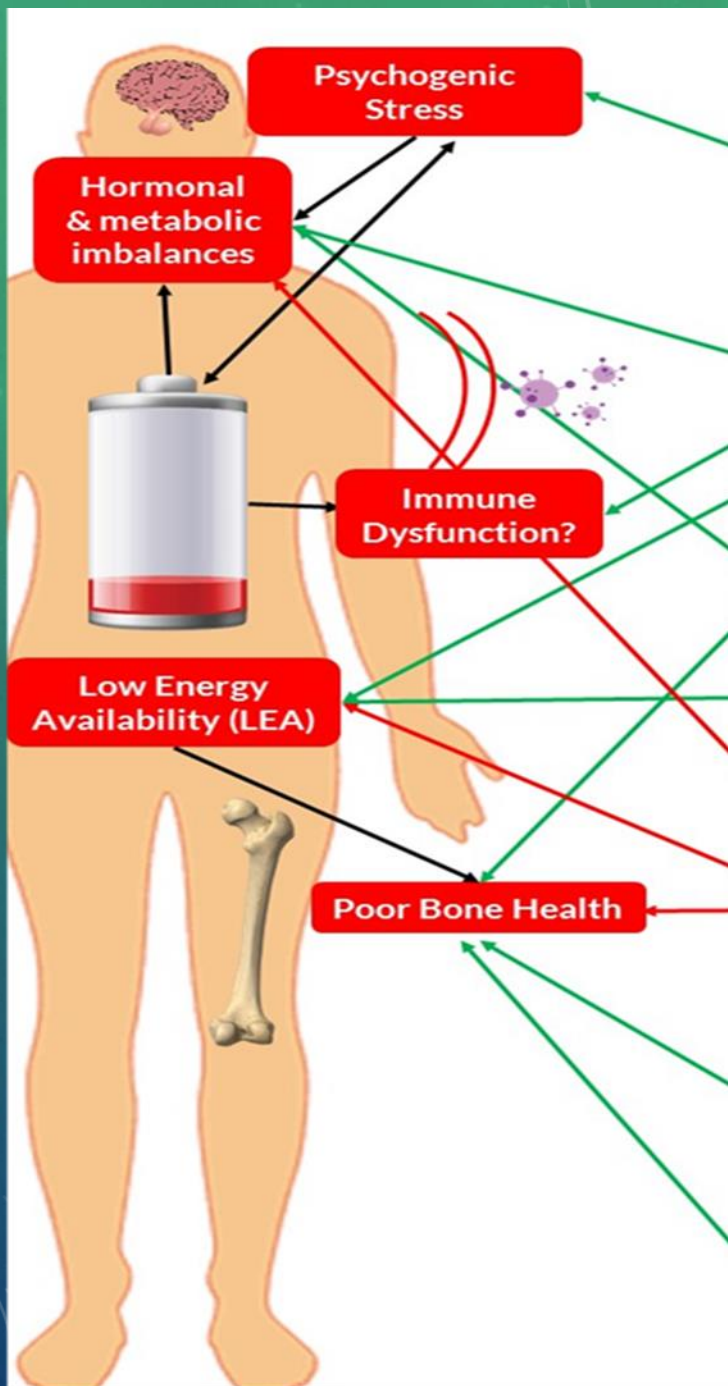
TREATMENT

Correct Energy Deficit!









### Fibre Intake

↑ satiety → ↓ energy intake → ↑ risk of LEA  
 ↓ estradiol and luteinizing hormone (LH) → ↑ risk of anovulation  
 ↓ reabsorption of calcium → affect bone health  
 Prescribe low fibre, high energy dense foods for athletes with RED-S

### Bone-Building Micronutrients

Ensure adequate intake of calcium, protein, magnesium, phosphorus, vitamin D, potassium & fluoride

### Mechanical Stress

Inclusion of strength or resistance training → ↑ bone mineral density  
 Especially in sport with relatively low impact force and low amount of bone loading such as cycling



## Recovery of Bone Mineral Density

## Recovery of Menstrual Status

## Recovery of Energy Status

**PROCESS: Days or Weeks**

**OUTCOMES:**

↑ Energy status will stimulate anabolic hormones (IGF-1) and bone formation

↑ Energy status will reverse energy conservation adaptations

**PROCESS: Months**

**OUTCOMES:**

↑ Reproductive hormones

↑ Estrogen exerts an anti-resorptive effect on bone

**PROCESS: Years**

**OUTCOMES:**

↑ Estrogen continues to inhibit bone resorption

↑ Energy status will stimulate anabolic hormones (IGF-1) and bone formation

# RETURN TO PLAY



HIGH RISK: NO START RED LIGHT	MODERATE RISK: CAUTION YELLOW LIGHT	LOW RISK: GREEN LIGHT
<p><i>Anorexia nervosa and other serious eating disorders</i></p> <p><i>Other serious medical (psychological and physiological) conditions related to low energy availability</i></p> <p><i>Extreme weight loss techniques leading to dehydration-induced haemodynamic instability and other life-threatening conditions.</i></p>	<p><i>Prolonged abnormally low percentage body fat measured by DXA or anthropometry using ISAK or non-ISAK approaches</i></p> <p><i>Substantial weight loss (5-10% body mass in 1 month)</i></p> <p><i>Attenuation of expected growth and development in adolescent athlete</i></p>	<p><i>Healthy eating habits with appropriate energy availability</i></p>
	<p><i>Abnormal menstrual cycle: FHA &gt;6 months</i></p> <p><i>Menarche &gt;16 yrs</i></p> <p><i>Abnormal hormonal profile in males</i></p>	<p><i>Normal hormonal and metabolic function</i></p>
	<p><i>Reduced BMD (either from last measurement or Z-score &lt;-1 SD).</i></p> <p><i>History of one or more stress fractures associated with hormonal /menstrual dysfunction and/or LEA</i></p>	<p><i>Healthy BMD as expected for sport, age and ethnicity</i></p> <p><i>Healthy musculoskeletal system</i></p>
	<p><i>Athletes with physical/psychological complications related to LEA/disordered eating;</i></p> <ul style="list-style-type: none"> <li><i>- ECG abnormalities</i></li> <li><i>- Laboratory abnormalities</i></li> </ul> <p><i>Prolonged relative energy deficiency</i></p> <p><i>Disordered eating behaviour negatively affecting other team members</i></p> <p><i>Lack of progress in treatment and/or non-compliance</i></p>	



# RETURN TO PLAY

<b>HIGH RISK RED LIGHT</b>	<b>MODERATE RISK YELLOW LIGHT</b>	<b>LOW RISK GREEN LIGHT</b>
<i>No competition</i> <i>No training</i> <i>Use of written contract</i>	<i>May train as long as he/she is following the treatment plan</i> <i>May compete once medically cleared under supervision</i>	<i>Full sport participation</i>

# TREATMENT

- Ongoing monitoring is necessary!



# PREVENTION

- Priority for sports medicine professionals, sports organizations, coaches, athletes, parents.
- Education
- Recognition
- Change





# RESOURCES

- **#TrainBrave**

- Raise awareness about RED-S
- Forum for coaches and athletes
- Source of information
- United Kingdom

- **Runyourcycle.com**

- Female athletes, parents and coaches

