

# Implications of Relative Energy Deficiency in Sport

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- I have no disclosures



# Objectives

- Provide overview of RED-S
- Describe relationship between hormones and bone health and associated injuries
- Discuss RED-S implications on other body systems
- Briefly highlight screening, treatment and recovery

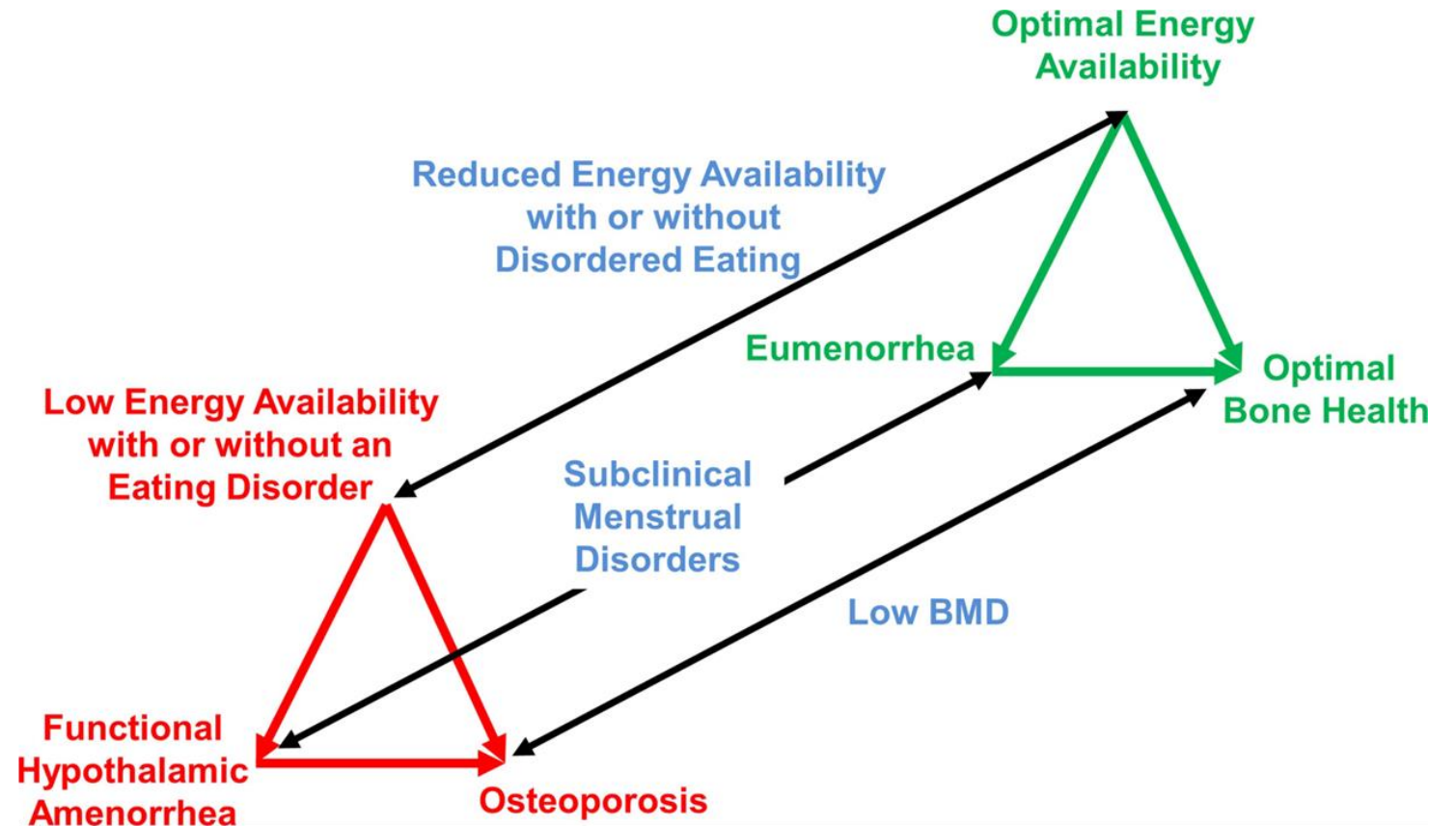


# Definitions and Overview

- Relative Energy Deficiency in Sport
  - Coined in 2014
  - Inclusive and all encompassing
  - Few studies on male athletes
  - Para athletes potentially even higher risk IOC Consensus Statement on RED-S 2023
  - Will use *Male* and *Female* in reference to physiologic sex assigned at birth
  - Epidemiology is difficult

# Female Athlete Triad

- Subset of RED-S
  - Energy Availability
  - Menstrual function
  - Bone Mineral Density



From ACSM Position Stand, MSSE 2007 and reaffirmed in 2014 FAT coalition statement

# Diminished Reproductive Function

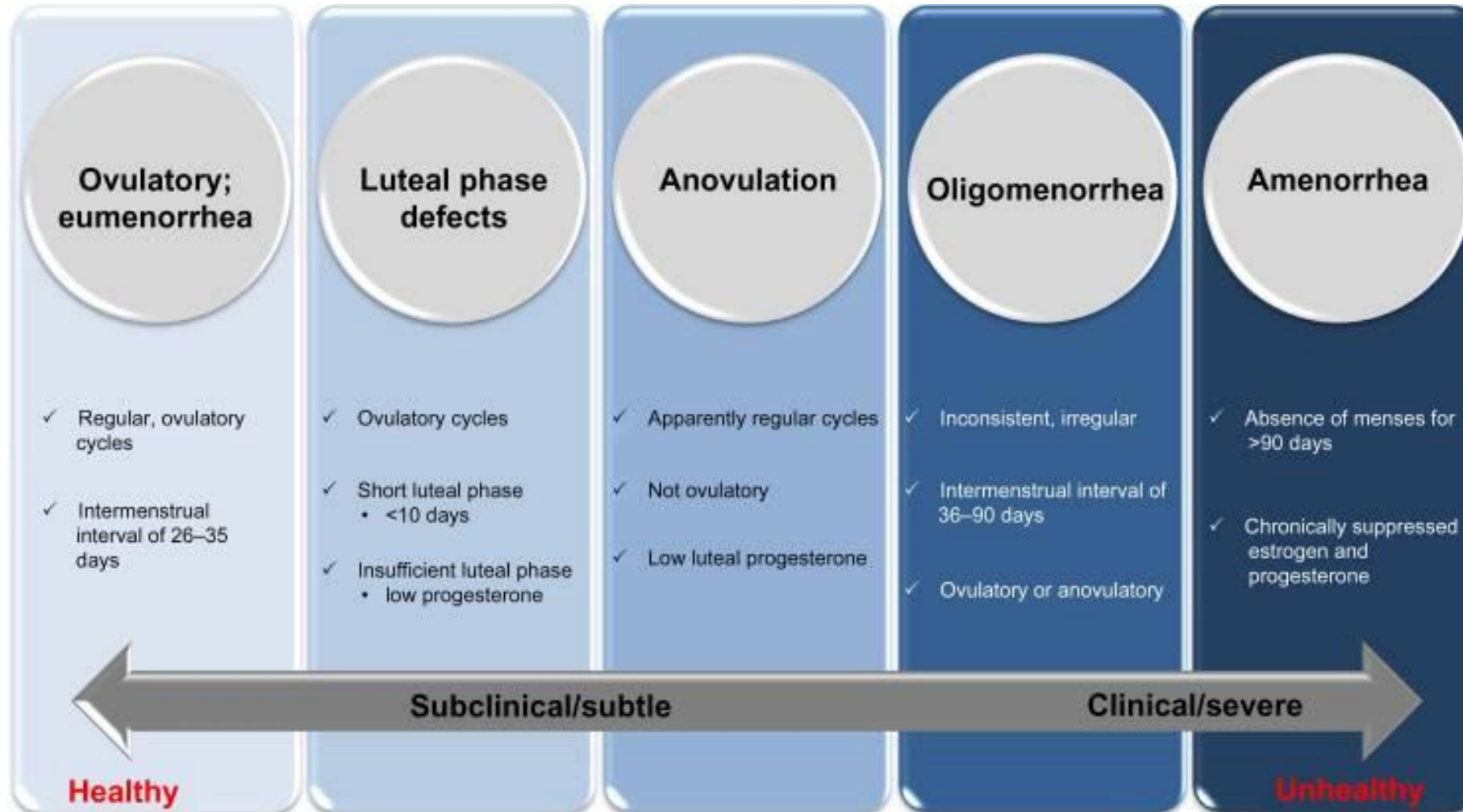
## *Female Athletes*

- Menstrual dysfunction Gibbs, Med Sci Sports Exerc 2013
- Reduced estrogen and progesterone VanHeest, Med Sci Sports Exerc 2014
- Altered LH pulsatility Ackerman et al, Clin Endocrin, 2013

## *Males Athletes*

- Sperm Abnormalities Souza, Int J Sports Med 1994
- Erectile Dysfunction Lundy, Nutrients, 2022
  
- Decreased Libido Souza, Int J Sports Med 1994
- Reduced Testosterone Keay et al, BJSM Open Sport Exerc Med 2018

# Range of Menstrual Dysfunction



# Estrogen and Bone Health



- Estrogen Barrack et al, Int J Sport Nutr Exerc Metab 2021
  - Protects skeleton from bone resorption
  - Stimulates bone formation
  - Lifelong exposure
- Bone Mineral Density Gibbs, Med Sci Sports Exerc 2014
  - Peaks in childhood and early adolescence
  - No threshold density
- Long periods of amenorrhea can cause irreversible risk





# Decreased Bone Health

- Loss of BMD/not enough gained Barrack et al, Int J Sport Nutr Exerc Metab 2021; Barry J Bone Miner Res 2008
- Lower Z scores Gibbs, Med Sci Sports Exerc 2014; Hilkens, Med Sci Sports Exerc, 2008
- Impaired bone strength and architecture Southmayd et al, Osteoporos Int, 2017; Greene et al, Int J Sports Med 2013
- Changes in bone remodeling Ackerman, Clin Endocrinol 2013; Murphy et al, Nutrients, 2021,
- Increased bone stress injuries\*

# Increased Risk of Stress Fractures-Males

- Elite runners had 4.5x risk of training absences due to bone injuries

Heikura, Int J Sports Nut Exerc Metab 2017

- Kuikman et al, Nutrients 2021
  - 276 male athletes – endurance, mixed sports, power sports
  - Disordered eating 2.4 x more likely to have had stress injury
  - More likely to have missed time from sport from overload injuries
- Kraus et al, Br J Sports Med, 2019
  - Collegiate middle and long distance runners
  - Low EA, Low BMI, Low BMD or prior BSI were at increased risk of stress fracture
  - Cumulative risk

# Increased Risk of Stress Fractures - Females

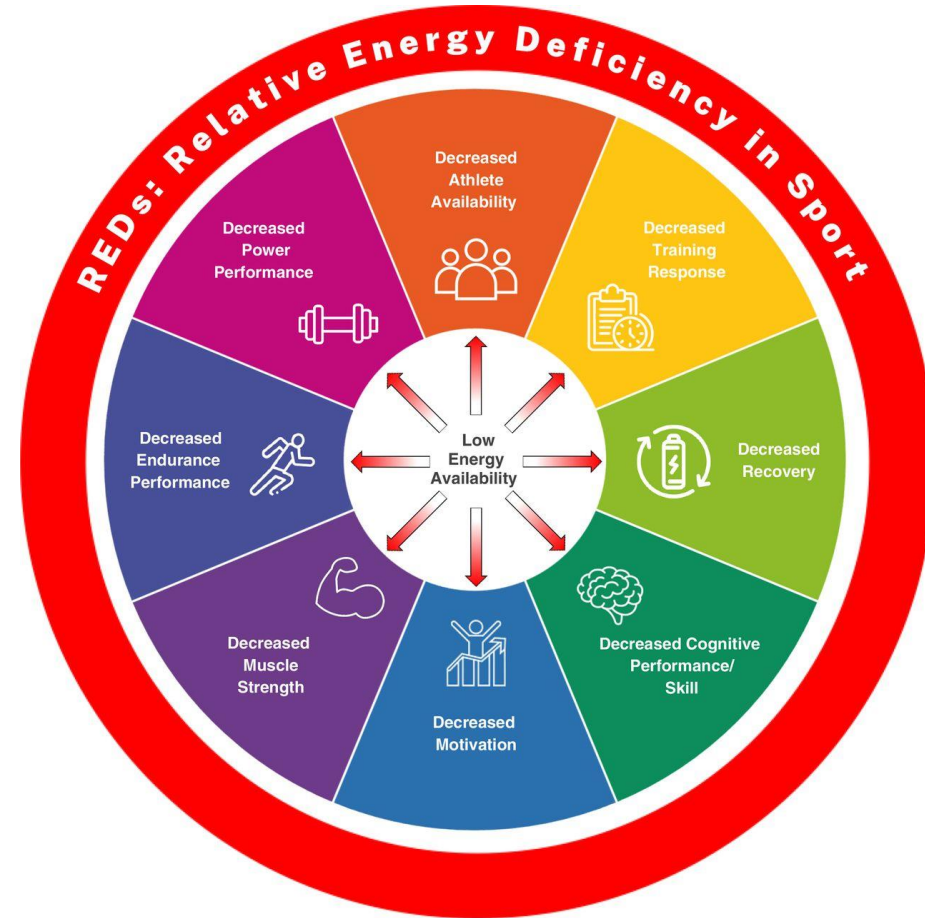
- ~2-4 x higher in athletes with menstrual dysfunction
- 11 x higher in service women
- 16% of active-duty Army women have had stress fracture
- Risk increased from 15-20% (one F.A.T risk factor) to 30-50% (with 2-3 risk factors) – Barrack 2014 AMSM
- Locations
  - Pelvic/sacral
  - Femoral neck/shaft
  - Tibial
  - Tarsal/Metatarsal

# Increased Injury Risk with low BMD and MD.

- Rauh, Nichols, Barrack, *JAT*, 2010
- 163 female athletes (age  $15.7 \pm 1.3$  years)
  - 8 sports, studied over 1 season
  - 62 overuse/chronic injuries, 28 acute
- Injured athletes
  - Had significantly higher scores on EDE-Q
  - Had significantly lower spine and total body BMD
  - More likely to have oligo/amenorrhea (3x injury risk compared to eumenorrheic athletes)
- “Major time loss” injury ( $\geq 22$  days out)
  - Increased risk with low BMD, disordered eating, or dietary restraint behavior



# Other Body System Implications



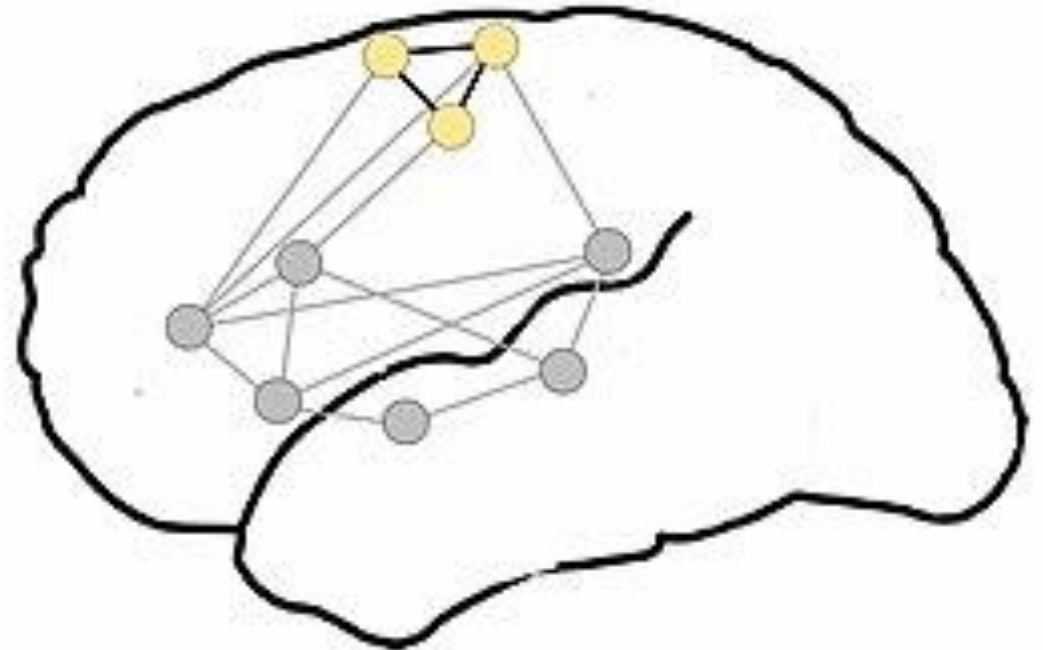
# Low Energy Availability creates a hypometabolic state.

- Reductions in
  - Insulin-like growth factor binding protein VanHeest et al, Med Sci Sports Exerc, 2014
  - RMR Mathisen, Scand J Med Sci Sports, 2020
  - Total T<sub>3</sub> Keikura, Int J Sport Nutr Exerc Metab 2018
  - Leptin Mathisen, Scand J Med Sci Sports, 2020
  - Insulin Papageorgiou et al, Bone 2014
  - Glucose Melin, Br J Sports Med, 2014
- Increased health risks
  - Further Weight loss
  - Dehydration
  - Organ Damage



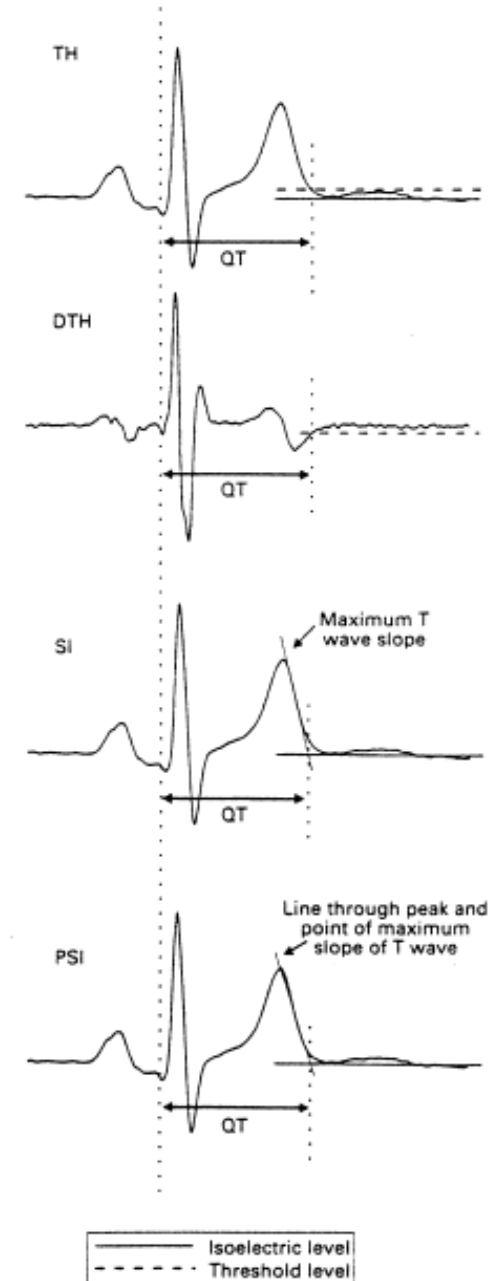
# Athlete Neurocognitive Implications

- Females
  - Reduced Memory Baskaran, Psych Res, 2017
  - Reduced spatial awareness Martin, Appl Physiol Nutr Metab 2021
  - Reduced executive functioning Baskaran, Psych Res, 2017
- Males and Females
  - Sleep disturbances Gillbanks, PLoS One, 2022; Pardue, Int J Sport Nutr Exerc Metab 2017



# Increased Cardiovascular Risk

- Endothelial Dysfunction Lanser, Zach, Hoch, *PM&R*, 2011, BMD Hoch et al. *CJSM* 2011
- Changes in Lipid Profile Rickenlund et al, *J Clin Endo Meta*, 2005
- Dysautonomia O'Connell et al, *Hypertension*, 2015
- Bradycardia
- Hypotension
- QT dispersion Galetta et al, *Pediatrics* 2002

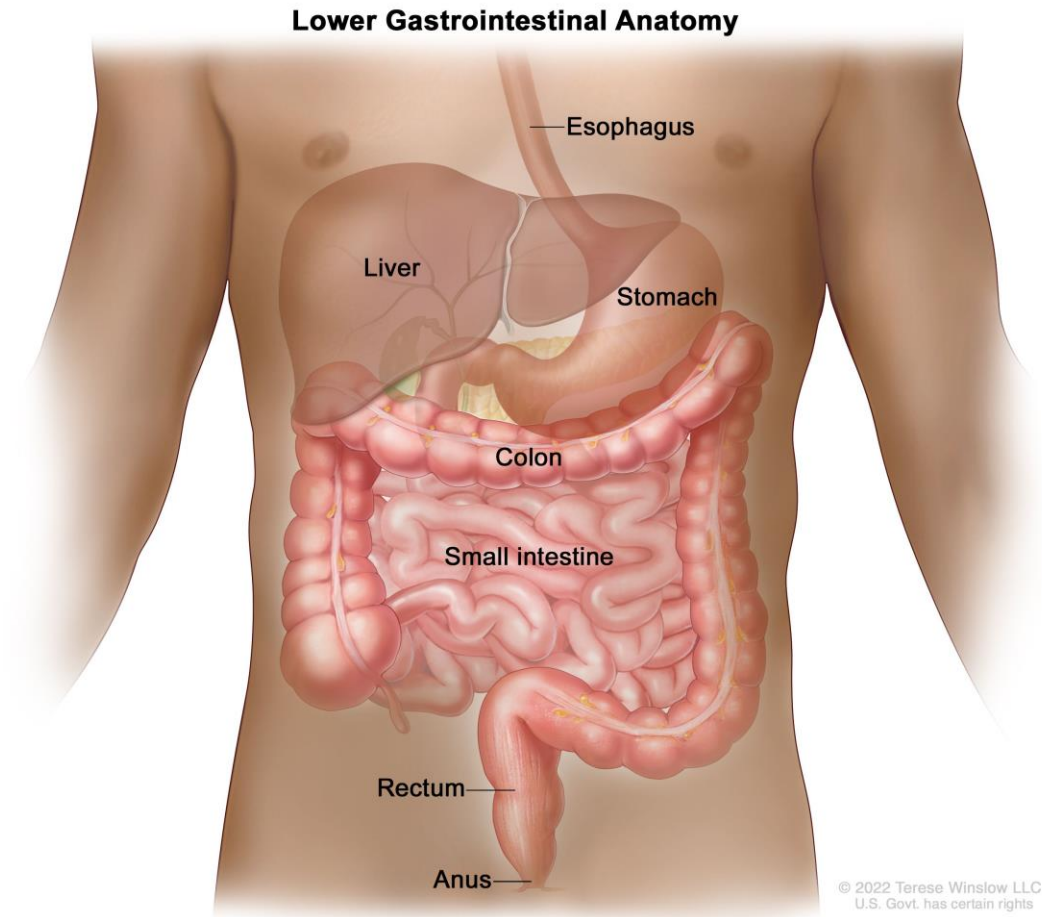




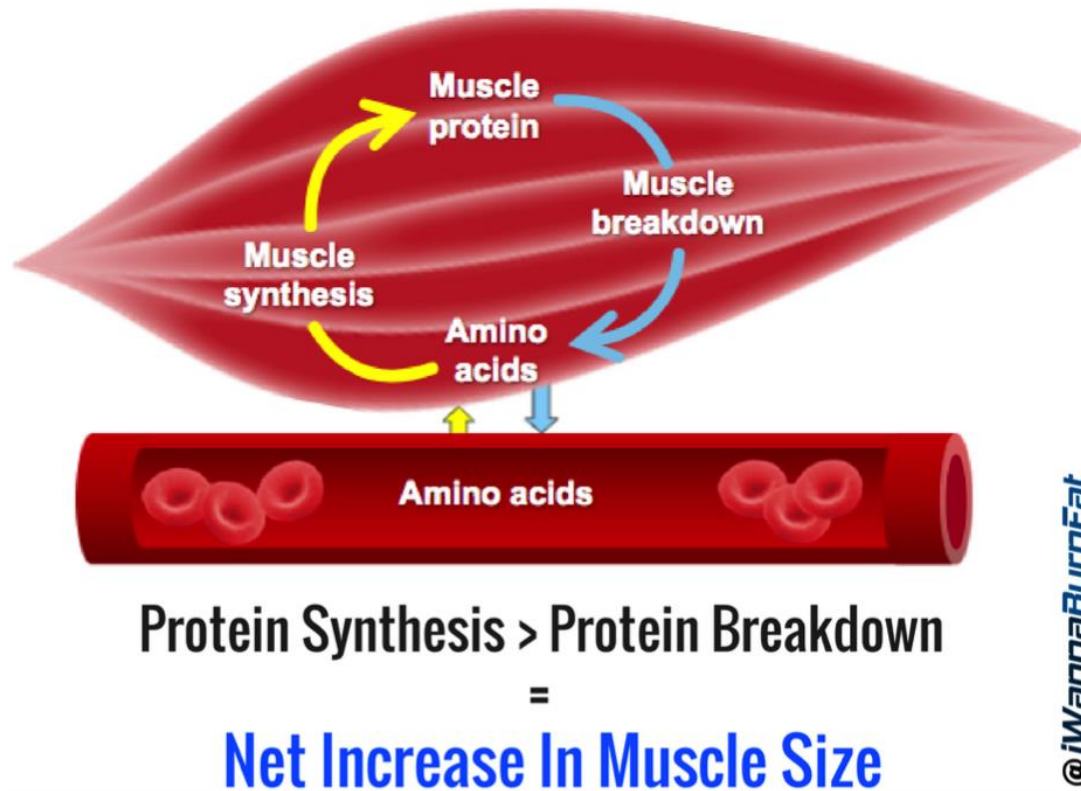
# Effects on Gastrointestinal Function Kuikman et al,

Nutrients 2021

- Abdominal Pain
- Cramps
- Bloating
- Changes in bowel movements



# Reduced Skeletal Muscle Function



@iWannaBurnFat

- Decreased muscle protein synthesis Areta et al, Am J Physiol Endocrinol Metab 2014
- Slowed glycogen restoration Costill et al, Med Sci Sports Exerc 1998; Tarnopolksy et al, J Appl Physiol 2001

# Hematologic Changes

## *Female Athletes*

- Low iron Finn et al, Med Sci Sports Exerc 2021

## *Male Athletes*

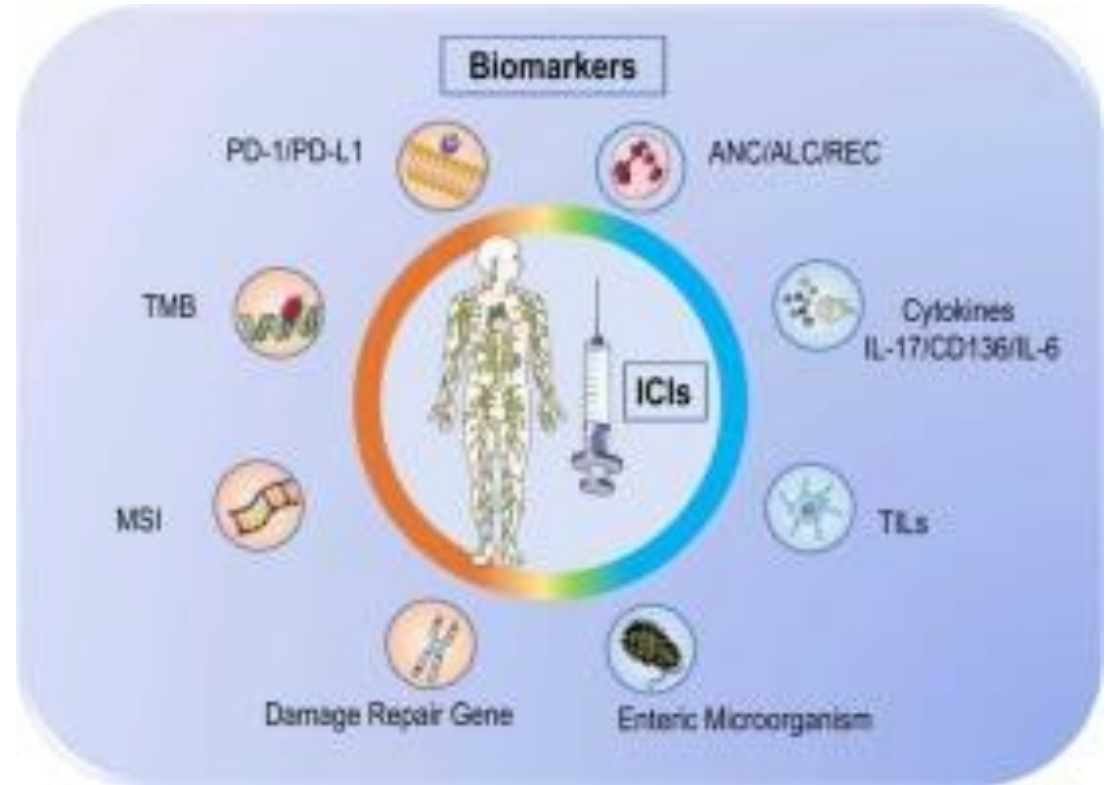
- Increased hepcidin Hennigar, Am J Clin Nutri 2021
- Reduced iron absorption Hennigar, Am J Clin Nutri 2021
- Reduced response to altitude training McLean, Br J Sports Med, 2013

- Lower hemoglobin Heikura, Int J Sports Physiol Perform 2018 ; Jurov, Eur J Appl Physiol 2022



# Impaired Immune Function









- Increased infection/illness susceptibility Bromley et al, Br J Sports Med 2018
- Changes in immune biomarkers Sarin et al, Front Immunol 2019; McGuire et al, Eur J Nutr 2023



# Psychologic Implications

Consensus statement

2023 International Olympic Committee's (IOC) consensus statement on Relative Energy Deficiency in Sport (REDs)

 Margo Mountjoy<sup>1, 2</sup>,  Kathryn E Ackerman<sup>3</sup>, David M Bailey<sup>4</sup>,  Louise M Burke<sup>5</sup>, Naama Constantini<sup>6</sup>,  Anthony C Hackney<sup>7</sup>,  Ida Aliisa Heikura<sup>8, 9</sup>, Anna Melin<sup>10</sup>,  Anne Marte Pensgaard<sup>11</sup>,  Trent Stellingwerff<sup>8, 9</sup>,  Jorunn Kaiander Sundgot-Borgen<sup>12</sup>,  Monica Klungland Torstveit<sup>13</sup>, Astrid Uhrenholdt Jacobsen<sup>14</sup>,  Evert Verhagen<sup>15</sup>, Richard Budgett<sup>16</sup>, Lars Engebretsen<sup>16</sup>, Uğur Erdener<sup>17, 18</sup>

- Short term with perceived “positive” results
- Disordered eating and Eating disorders
- Perfectionist tendencies
- Drive to be thin
- Self esteem
- Depression
- Anxiety



# What does this all mean for the athlete?

- Combination of decreased bone health, impaired muscle recovery, less healing and physical and mental reserve placed athletes at high risk for any muscle, skeletal injury or concussion and potential for irreversible changes
- Decreased sport performance and resiliency



# Other Important Concepts

- Screening is key but challenging
  - Ask at PPEs, yearly visits
  - If one component present, screen for others
  - May be normal weight, eumenorrheic, can be in ANY athlete
- Lab work typically normal
- Treatment is multidisciplinary
- Continued education is imperative



# Recovery takes days to years.

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



# Thank You!



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# History Questions

## Box 1 Triad Consensus Panel Screening Questions\*

- ▶ Have you ever had a menstrual period?
- ▶ How old were you when you had your first menstrual period?
- ▶ When was your most recent menstrual period?
- ▶ How many periods have you had in the past 12 months?
- ▶ Are you presently taking any female hormones (oestrogen, progesterone, birth control pills)?
- ▶ Do you worry about your weight?
- ▶ Are you trying to or has anyone recommended that you gain or lose weight?
- ▶ Are you on a special diet or do you avoid certain types of foods or food groups?
- ▶ Have you ever had an eating disorder?
- ▶ Have you ever had a stress fracture?
- ▶ Have you ever been told you have low bone density (osteopenia or osteoporosis)?

\*The Triad Consensus Panel recommends asking these screening questions at the time of the sport pre-participation evaluation.



# Risk Stratification

Risk Factors	Magnitude of Risk		
	Low Risk = 0 points each	Moderate Risk = 1 point each	High Risk = 2 points each
<i>Low EA with or without DE/ED</i>	<input type="checkbox"/> No dietary restriction	<input type="checkbox"/> Some dietary restriction‡; current/past history of DE;	<input type="checkbox"/> Meets DSM-V criteria for ED*
<i>Low BMI</i>	<input type="checkbox"/> BMI $\geq 18.5$ or $\geq 90\%$ EW** or weight stable	<input type="checkbox"/> BMI $17.5 < 18.5$ or $< 90\%$ EW or 5 to $< 10\%$ weight loss/month	<input type="checkbox"/> BMI $\leq 17.5$ or $< 85\%$ EW or $\geq 10\%$ weight loss/month
<i>Delayed Menarche</i>	<input type="checkbox"/> Menarche $< 15$ years	<input type="checkbox"/> Menarche 15 to $< 16$ years	<input type="checkbox"/> Menarche $\geq 16$ years
<i>Oligomenorrhea and/or Amenorrhea</i>	<input type="checkbox"/> $> 9$ menses in 12 months*	<input type="checkbox"/> 6-9 menses in 12 months*	<input type="checkbox"/> $< 6$ menses in 12 months*
<i>Low BMD</i>	<input type="checkbox"/> Z-score $\geq -1.0$	<input type="checkbox"/> Z-score $-1.0^{***} < -2.0$	<input type="checkbox"/> Z-score $\leq -2.0$
<i>Stress Reaction/Fracture</i>	<input type="checkbox"/> None	<input type="checkbox"/> 1	<input type="checkbox"/> $\geq 2$ ; $\geq 1$ high risk or of trabecular bone sites†
Cumulative Risk (total each column, then add for total score)	___ points +	___ points +	___ points = ___ Total Score

	Cumulative Risk Score*	Low Risk	Moderate Risk	High Risk
<i>Full Clearance</i>	0 – 1 point	<input type="checkbox"/>		
<i>Provisional/Limited Clearance</i>	2 – 5 points		<input type="checkbox"/> Provisional Clearance <input type="checkbox"/> Limited Clearance	
<i>Restricted from Training and Competition</i>	$\geq 6$ points			<input type="checkbox"/> Restricted from Training/ Competition-Provisional <input type="checkbox"/> Disqualified

