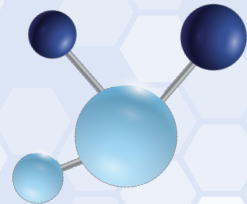




The Modulatory Effects of Estradiol and Progesterone on Exercise Metabolism & Fueling in Female Athletes

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Thesis Presentation for BS in Health Sciences
Franklin University Switzerland
May 2026





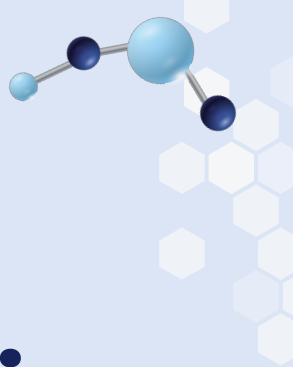
Objective of the Thesis

To create a proper fueling protocol for female athletes, focusing on the influence of ovarian hormones and baseline sex differences have on macronutrient metabolism and energy needs.



Only 32% of sports science studies include female athletes.





**14% of sports science studies
take hormone levels into
consideration.**





6% of sports science research studies are done exclusively on women.





**0.5-1% of studies use
gold-standard methodologies
to confirm hormone levels.**



Data Collection

Exclusively collected data from scientific papers, journal articles and studies.

Synthesized data from over 180 papers in reputable journals such as *Sports Medicine*, *JISSN*, *Applied Physiology*, *Journal of Clinical Endocrinology & Metabolism*, *Medicine & Science in Sports & Exercise*.

Specifically researched applied hormonal effects across the menstrual cycle and after menopause.

*Estradiol = E2
Progesterone = P4

Chapter Breakdown

01

**Overview of Female
Endocrinology**

02

**Ovarian Hormone*
Modulation of Carbohydrate
Metabolism**

03

**Ovarian Hormone
Modulation of Lipid
Metabolism**

04

**Ovarian Hormone
Modulation of Protein
Metabolism**

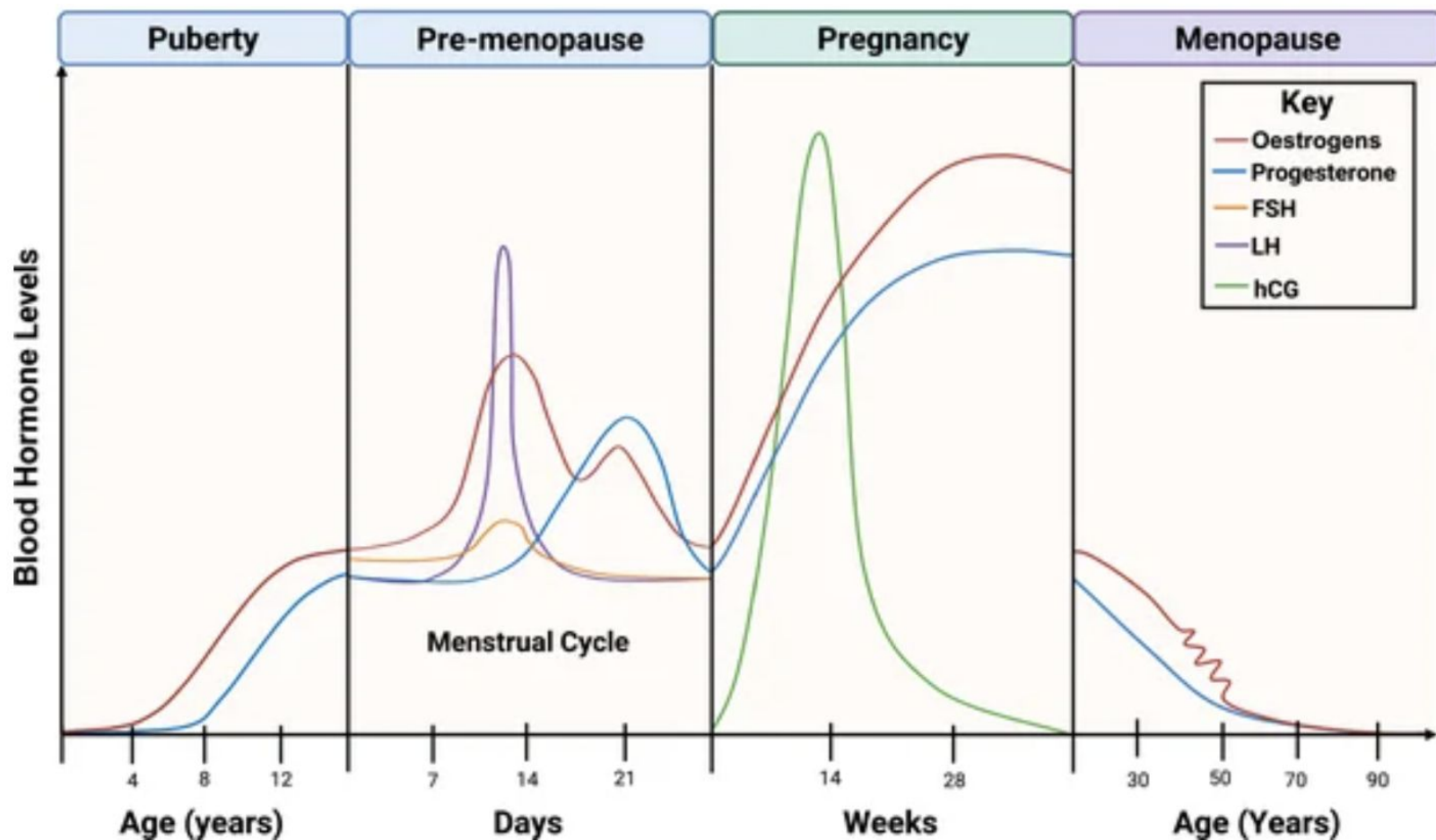
05

**Substrate
Utilization in
Female Athletes**

06

**Fueling Protocol for
Female Athletes**

Hormone Levels in Females Across the Lifespan



E2 & P4 Effects on Carbohydrate Metabolism

Estradiol (E2)

Increases GLUT4 mediated glucose-uptake ↑
Enhances insulin sensitivity ↑
Downregulates hepatic gluconeogenesis ↓
Decreases total carbohydrate oxidation ↓
Sparses glycogen usage ↓

Progesterone (P4)

Reduces GLUT4 mediated glucose-uptake ↓
Decreases insulin sensitivity ↓
Upregulates hepatic gluconeogenesis ↑
Increases total carbohydrate oxidation ↑
Increases glycogen usage ↑

E2 & P4 Effects on Lipid Metabolism

Estradiol (E2)

Increases lipolytic signalling ↑

Increases fat oxidation at rest & exercise ↑

Decreases adipocyte hypertrophy ↓

Suppresses hepatic lipogenesis ↓

Prevents visceral fat accumulation ×

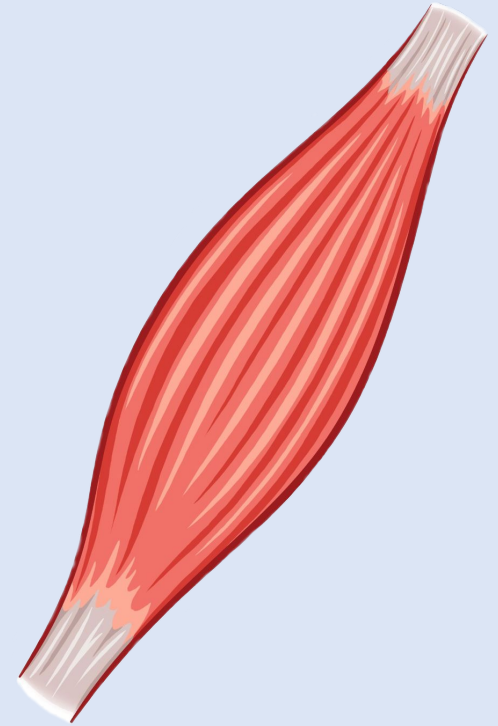
Progesterone (P4)

Blunts lipolysis during exercise ↓

Decreases lipid oxidation during exercise ↓

E2 & P4 Effects on Protein Metabolism

- Muscle growth and maintenance is a product of protein metabolism.
- E2 slightly enhances muscle mass, performance, quality and repair capabilities
- Progesterone is marginally catabolic, increasing muscle breakdown.
- Overall, these effects do not largely affect muscle growth and quality.



E2:P4 Ratio Importance

- Estradiol and Progesterone exhibit antagonistic effects.
- Estradiol shifts substrate utilization towards higher amounts of fat oxidation, and lower amounts of carbohydrate oxidation.
- When Progesterone is present alongside Estradiol, the effects are largely canceled out.

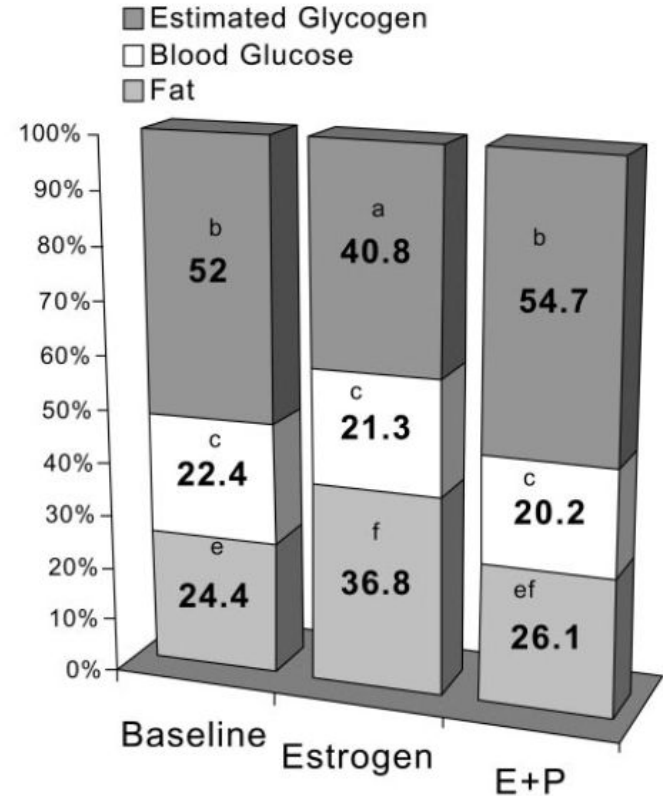
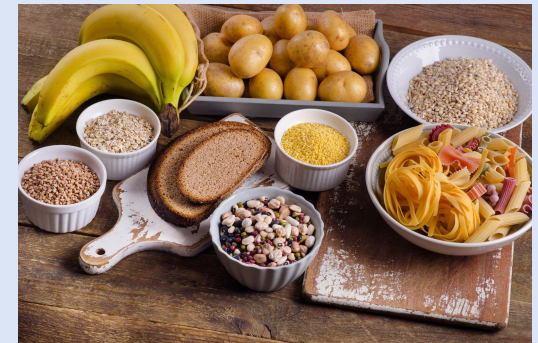
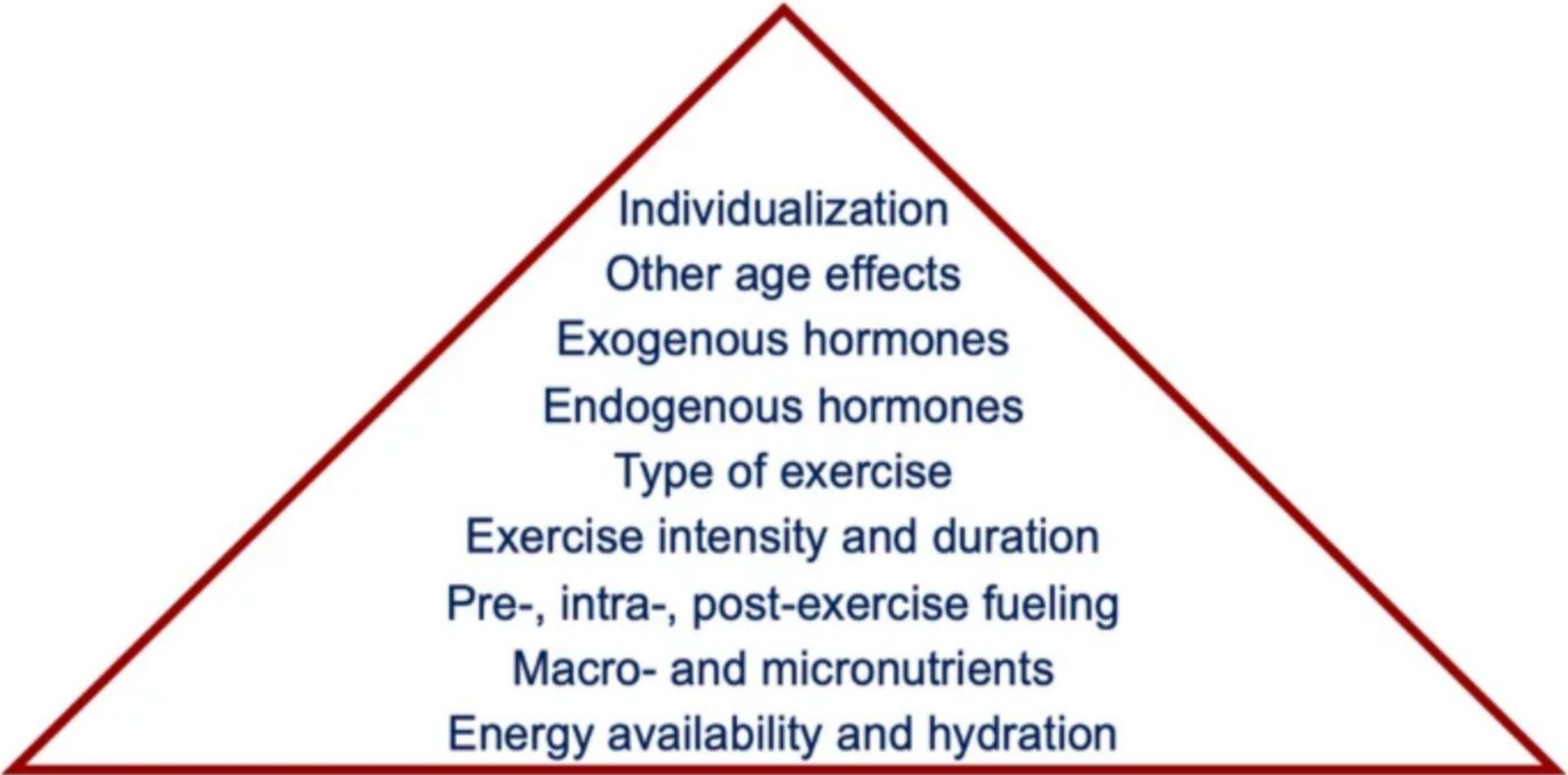


Fig. 4. Summary of average fuel utilization in the 3 treatment conditions during steady-state exercise. %Contribution to total energy expenditure is shown inside each bar. Conditions that do not share a superscript are significantly different from each other.

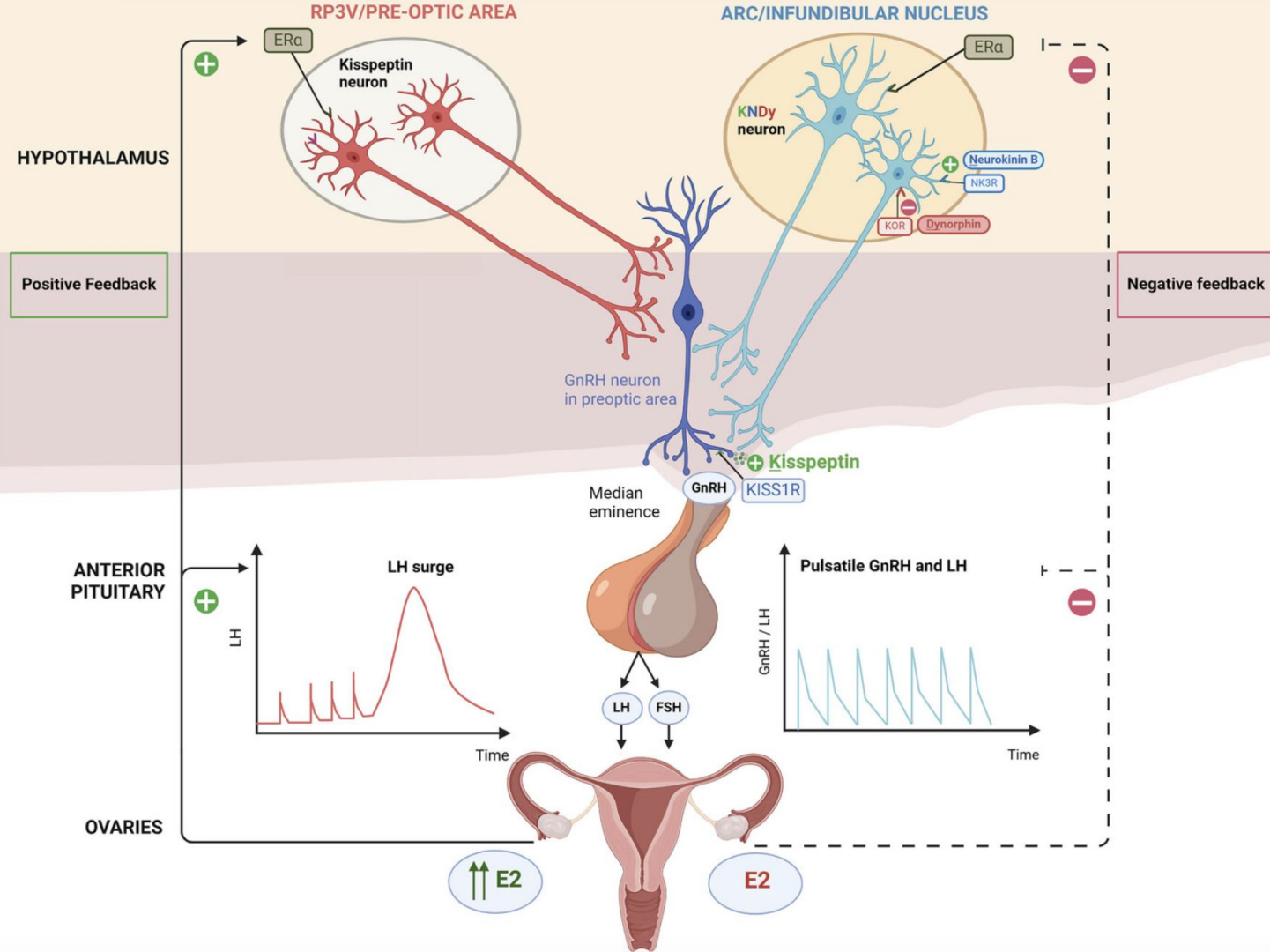
How do this impact fueling protocols?

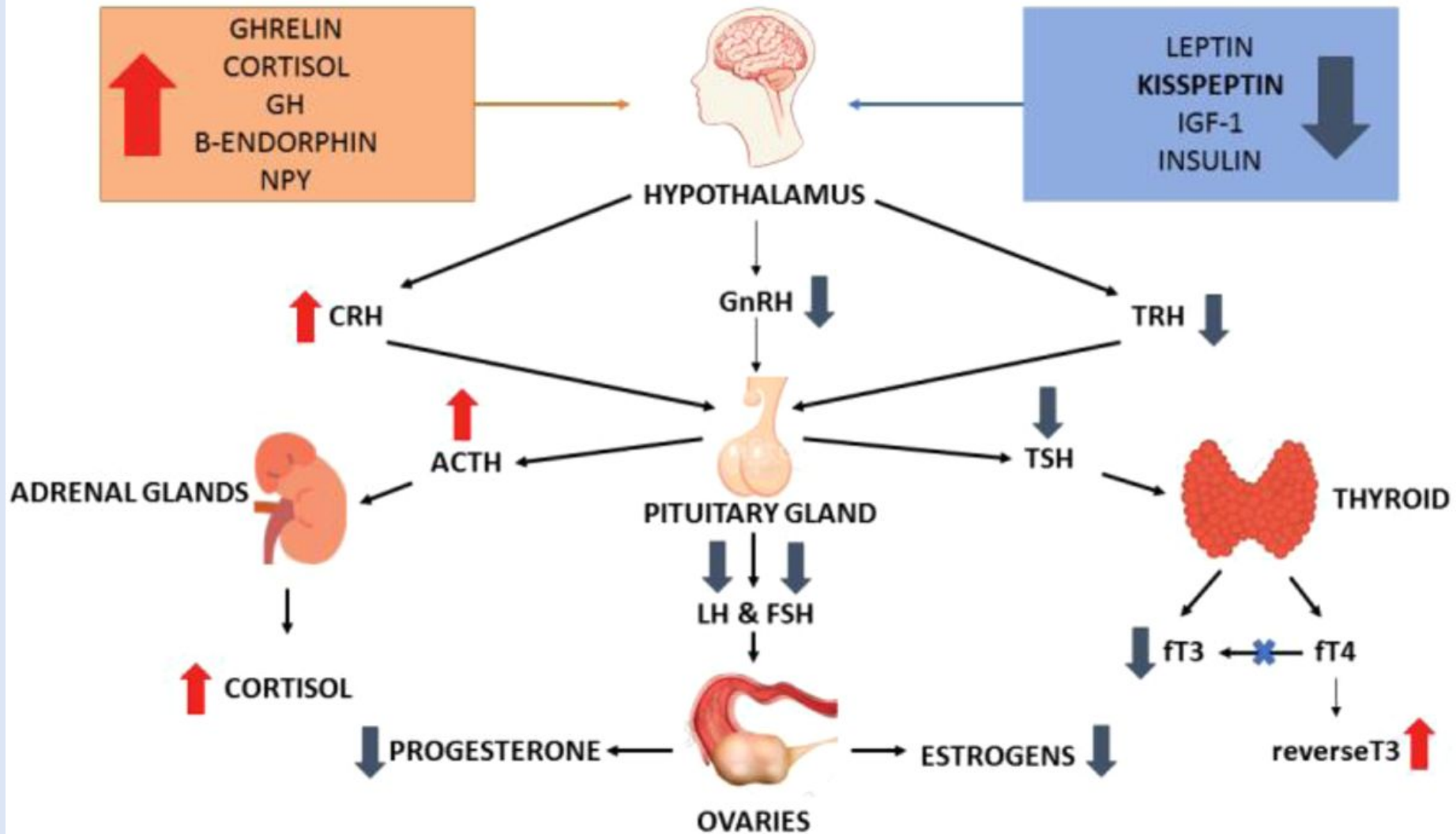
- Carbohydrate and protein intake become even more important!
- Female athletes have to rely more on exogenous carb sources while training.
- Progesterone increases importance of protein intake.
- However, **energy availability** is the most important factor.





Individualization
Other age effects
Exogenous hormones
Endogenous hormones
Type of exercise
Exercise intensity and duration
Pre-, intra-, post-exercise fueling
Macro- and micronutrients
Energy availability and hydration





Fueling Protocol

- The main priority for fueling to adequate energy intake with a net zero, or net positive energy balance.
- This is achieved by ≥ 45 kcal per kg of fat free mass every day.
- Carbohydrate intake should be between 5–12 g/kg/day.
- Protein intake should be between 1.3–2.2 g/kg/day.
- Fat intake should be between 20–30% of daily calories.

Fueling Model for Female Athletes

ENERGY AVAILABILITY ≥ 45 kcal / kg of FFM / day Adequate energy intake \geq expenditure; prevention of LEA/REDS <i>Maintains HPG axis signalling, metabolic homeostasis, and physiological function</i>			
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	Carbohydrates	Protein	Fat
Daily intake	5-12 g/kg/day 55-75% daily calories	1.3-2.2 g/kg/day 10-35% daily calories	20-30% daily calories
Pre-training	~30g	0.32-0.38 g/kg \leq 1 hr pre-exercise	No specific timing requirement; supports overall energy repletion
During training	30g-90g/hour (depending on duration and intensity)	Not a primary fuel substrate; no specific intake recommendation	No specific intake recommendation
Post-training	1.0-1.2 g/kg/hour during the first 4 hours post-exercise	0.32-0.38 g/kg \leq 1 hr post-exercise	No specific timing requirement; supports overall energy balance and repletion
Endocrine-specific modulation	Increased reliance on exogenous carbohydrate due to altered endogenous glucose production (E2-mediated)	Increased protein requirements in hypoestrogenic states and during P4-dominant phases due to increased protein catabolism	Critical for maintaining energy availability, steroid hormone synthesis, and preventing LEA/REDS
Scientific reasoning	<i>Maintains glycogen availability, supports high-intensity exercise, and delays fatigue.</i>	<i>Stimulates muscle protein synthesis, supports tissue repair, and offsets exercise-induced catabolism.</i>	<i>Supports steroid hormone synthesis, cellular function, nutrient absorption, and long-term energy balance.</i>

Macronutrient strategies in female athletes are modestly modulated by hormonal status but remain fundamentally governed by energy availability.

What does like look like in practice?

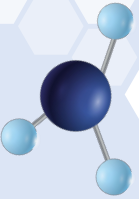
- Weight: 57 kg
- Fat Free Mass: ~46 kg
- Weekly running amount: 50-60 km
- Strength training sessions: 3-4x per week
- Various other sports (skiing, hiking, mountaineering, etc.)



- **Minimum daily intake: 2,000 kcal**
- **~3,000 kcal per day (more on long run days)**
- **~400-600 g of carbs**
- **~120 g of protein**
- **~40-60 g of fat**

This applies to so much more...

Women across the world are under-represented in science, and not taught about their physiology. The health ramifications are more present than ever.



Thank you!

Any Questions?

