

An Introduction To Exercise Endocrinology

Paul Taylor

All images courtesy of Human Kinetics unless otherwise stated

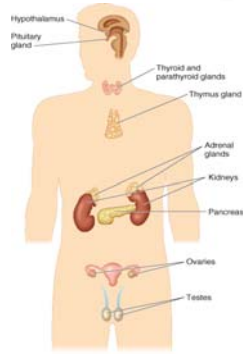
Topics To Be Covered

- The role of your endocrine system in maintaining body homeostasis during rest and physical activity
- The difference between steroid and nonsteroid hormones and their actions within the body
- The roles of hormones in regulating fat and carbohydrate metabolism
- How hormones help keep your fluid levels in check and prevent dehydration
- How hormones affect muscle mass
- Anabolic Steroids



Endocrine and Exocrine Functions

- Endocrine glands—ductless glands that secrete hormones directly into the blood
- Exocrine glands secrete their products into ducts (e.g. sweat glands)
- Pancreas has both functions: exocrine—digestive enzymes; endocrine—insulin and glucagon
- Other tissues
 - Neuroendocrine tissues
 - Adipose tissue
 - Other organs
 - Local hormones – autocrines & paracrines



Hormones

- Chemical messengers from endocrine glands that travel in the blood placing them in direct contact with all cells
 - Regulate metabolic functions of target cells
- Most are amino acid-based
 - Simple AA, peptides, proteins
- Hormones travel in the blood to their specific target organs
- Receptors are specific to hormones
 - Only the correct hormone will “fit” the correct receptor
 - Each cell has 2,000 to 10,000 specific receptors

Hormone Actions

- Alter cell activity
 - Response depends on the target cell type
- Will typically elicit one or more of the following
 - Alters plasma membrane permeability
 - Stimulates protein synthesis
 - Activates or deactivates enzymes (regulatory molecules)
 - Induces secretory activity
 - Stimulates mitosis

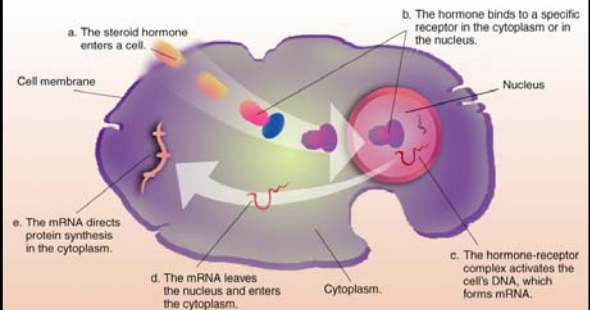
Steroid Hormones

- Lipid soluble
- Diffuse easily through cell membranes; receptors located within cell
- Synthesise protein via direct gene activation
- Chemical structure is derived from or is similar to cholesterol
- Secreted by:
 - Adrenal cortex (e.g., cortisol)
 - Ovaries (e.g., estrogen)
 - Testes (e.g., testosterone),
 - Placenta (e.g., estrogen)
- Eicosanoids (hormonelike chemicals)
 - Highly localised effects
 - Not true *circulating hormones*

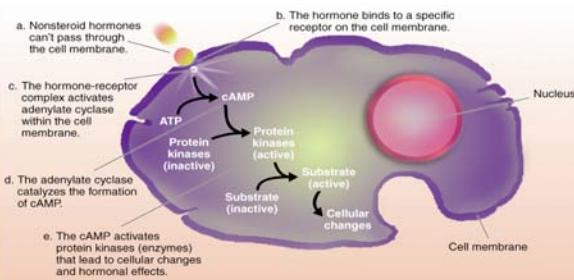
Nonsteroid hormones

- Nonlipid soluble
- Cannot easily diffuse through cell membranes; receptors located on cell membrane
- Bind to receptors on the cell membrane, which triggers a second messenger within the cell, which in turn triggers numerous cellular processes
- Two types:
 - Amino acid derivatives (e.g. adrenalin/epinephrine)
 - Protein or peptide hormones (e.g. insulin)

Action Of A steroid Hormone



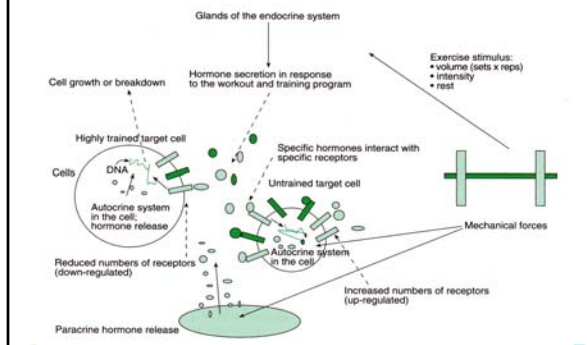
Action Of A Nonsteroid Hormone



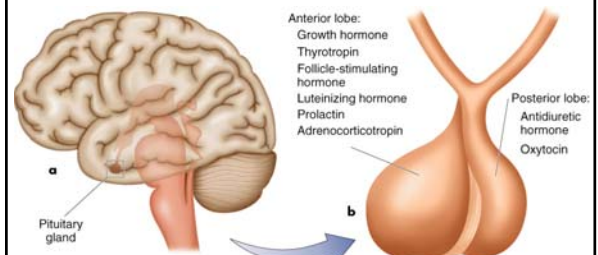
Control of Hormone Release

- Plasma levels of specific hormones fluctuate
- Secretion is regulated by a negative feedback system
- Cells can also alter their number of hormone receptors via down- or up-regulation to change sensitivity to that hormone
 - **Down-regulation**—Decrease in number of cell receptors; less hormone can bind to the cell and higher concentrations of the hormone remain in the blood plasma
 - **Up-regulation**—Increase in number of cell receptors; more hormone can bind to the cell and lower concentrations of the hormone remain in the blood plasma

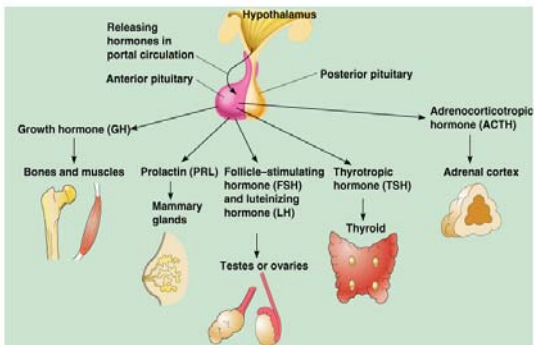
Hormonal Response To Resistance Training



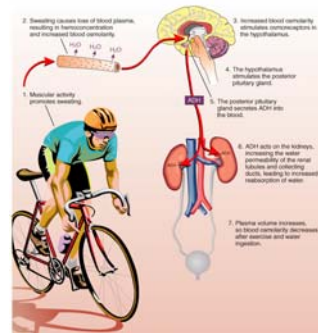
Pituitary Gland Hormones



Hormones Of The Anterior Pituitary Gland



ADH & Body Water



- Exercise promotes sweating
- Sweating causes loss of blood plasma
 - Haemoconcentration
 - Increased blood osmolarity
- Stimulates osmoreceptors in hypothalamus
- Hypothalamus stimulates posterior pituitary gland
- PPG secretes ADH into blood
- ADH acts on the kidneys
 - Increased reabsorption of water
- Plasma volume increases
 - Blood osmolarity decreases after exercise & water ingestion

Growth Hormone

- Secreted by Pituitary Gland
- Promotes muscle growth and hypertrophy by facilitating amino acid transport & protein synthesis
 - Liver, IGFs
- Directly stimulates fat metabolism (lipolysis)
 - Glycogen sparing
- Levels are elevated during aerobic exercise in proportion to exercise intensity
 - Lactate is key
 - Heavy resistance, high total work and short rest periods
- Post-exercise CHO & protein
- Increases gradually

Hormones of the Thyroid Gland

- **Triiodothyronine (T3) and Thyroxine (T4)**
 - Increase metabolic rate
 - Increase size and number of mitochondria in cells
 - Increase protein and enzyme synthesis
 - Promote rapid cellular uptake of glucose
 - Enhance glycolysis and glycogenesis
 - Increase FFA availability for oxidation
- **Calcitonin**
 - Decreases plasma calcium concentration
 - Acts primarily on bones and kidneys

Hormones of the Adrenal Medulla

- **Catecholamines**— epinephrine (adrenalin) and norepinephrine (noradrenalin)
 - Stimulated by sympathetic nervous system to prepare you for immediate action (fight or flight)
 - Increase rate and force of heart contraction, blood pressure, and respiration
 - Increase metabolic rate, glycogenolysis, and release of glucose and FFA into blood
 - Allow more blood to go to the skeletal muscles through vasodilation and vasoconstriction of specific vessels
- Work together to increase both duration of stimulation & force of contraction
- Quick response to strenuous exercise

Catecholamines cont'd..

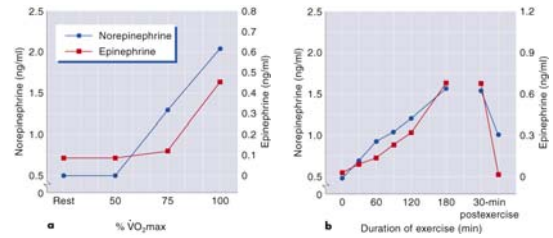
- Augment the secretion of other hormones (Tes)
- Metabolic changes peak 30 sec after adrenal stimulation
 - Response lasts several minutes
- High intensity, high volume workout with short rest causes prolonged catecholamine response
 - Bodybuilding workout
 - High-intensity interval CV training
- Adequate rest required for adrenals to recover
 - Otherwise Cortisol becomes chronically elevated

Hormones of the Adrenal Cortex



- **Mineralocorticoids**
 - Include aldosterone
 - Maintain electrolyte balance in extracellular fluids
- **Glucocorticoids**
 - Include cortisol
 - Maintain consistent plasma glucose levels between meals
- **Gonadocorticoids**
 - Include androgens (eg testosterone), estrogens, and progesterones
 - Released in addition to those released by reproductive organs but in lesser amounts

Catecholamine Responses To Exercise



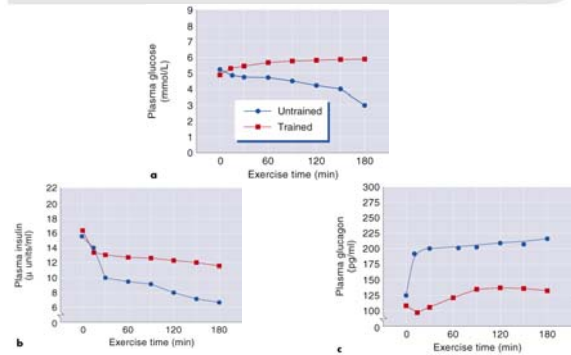
Hormones of the Pancreas



- **Regulation of blood glucose**
- **Insulin**
 - Secreted when plasma glucose levels are elevated (hyperglycemia)
- **Glucagon**
 - Secreted when plasma glucose concentrations are below normal (hypoglycemia)



Pancreatic Hormone Responses To training

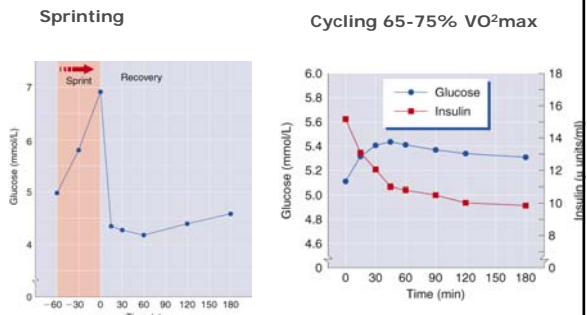


Hormones Increasing Glucose Metabolism

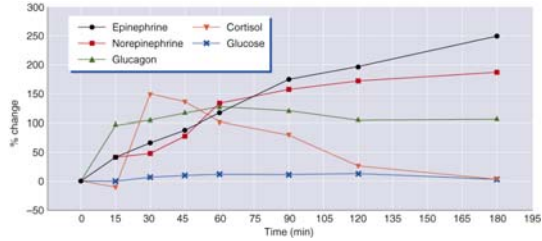


- Glucagon
- Adrenalin (Epinephrine)
- Noradrenalin (Norepinephrine)
- Cortisol
 - Glucagon, adrenalin, noradrenalin, and cortisol help promote glycogenolysis and gluconeogenesis, thus increasing plasma glucose levels when needed
 - Insulin facilitates glucose transport to the muscle fibers
 - Glucose levels decline during prolonged exercise, indicating that exercise facilitates insulin action so that less is required during exercise than at rest

Blood Glucose and Insulin Responses To Exercise



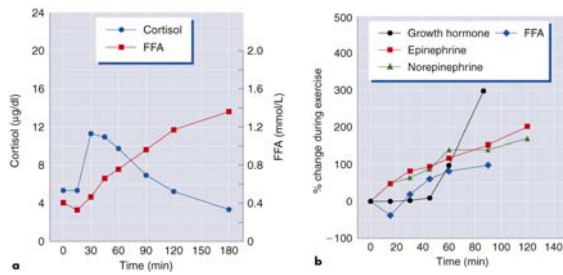
Hormonal responses To Cycling At 65-75% VO₂max



Hormones Increasing Fat Metabolism

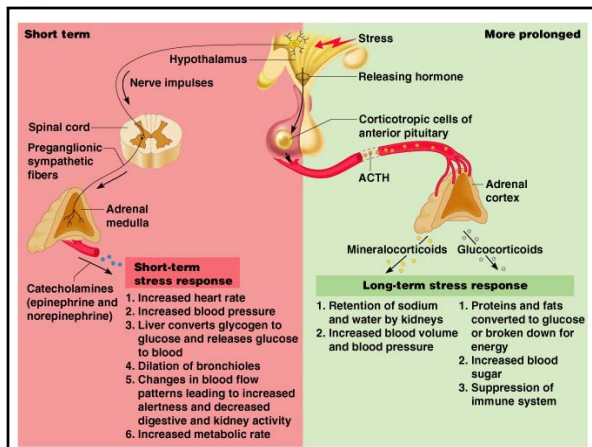
- Cortisol
- Growth Hormone
- Adrenalin (Epinephrine)
- Noradrenalin (Norepinephrine)
 - Cortisol accelerates lipolysis, releasing FFAs into the blood so they can be taken up by the cells and used for energy production
 - Levels peak and return to near normal levels during prolonged exercise.
 - Catecholamines and GH then take over cortisol's role in releasing FFAs into the blood

Hormonal & FFA Responses To Cycling At 65-75% VO₂max

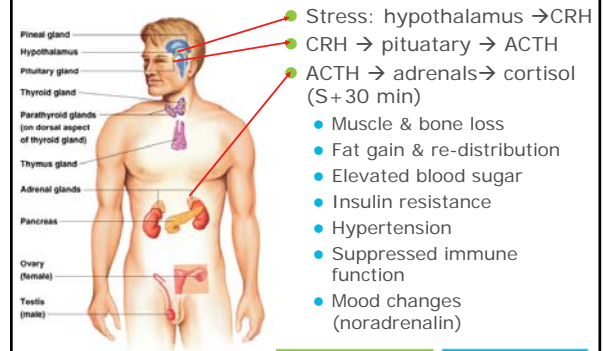


Cortisol

- Regulated by ACTH (anterior pituitary)
- Released by adrenal cortex
 - Response to stress, exercise, fractures, burns
 - Main function is to regulate blood glucose levels
- Increases in proportion to exercise intensity
- Most intense training causes greatest (catabolic response)
- Effects on muscle fibres:
 - Produces enzymes that break proteins into AA
 - Facilitates AA conversion into glucose
 - Inhibits protein synthesis (more in type II)
- Cellular damage initiates tissue remodelling
- Cortisol: Testosterone or Cortisol: DHEA ratio NB



Chronically Elevated Cortisol



Testosterone



- Steroid hormone secreted by the testes (& adrenals)
- Men have 15-20 times higher concentration
- Important anabolic hormone
 - Stimulates protein synthesis and muscle growth
 - Binds to DNA
- Indirect effects
 - Growth hormone stimulation
 - Secretion of neurotransmitters that affect structural proteins
- Produces aggressive behavioural responses

Increasing Testosterone Through Training



- Training time and volume NB
- Large muscle group exercises
- Squat, deadlift, power clean
- 85-95% 1-RM
- Moderate to high volume
- Short rest intervals
- Training maturity (2 years+)
- Can increase in males by up to 30% during maximal work
- No evidence of similar increases in women
 - Does have an impact

Anabolic Steroids



- Mimic effects of Testosterone
- Originally designed for muscle-wasting diseases
- Used in competition for decades
- Increase protein synthesis (mass) & enhance recovery (reduced muscle breakdown)
- Increase arousal, aggression & mental focus
- Injected or taken orally
- May be 'stacked'
- Increase muscle mass & strength, but not aerobic power

Anabolic Steroids – Side Effects



- Physical:
 - Acne, premature baldness, breast enlargement (males)
 - Masculinisation in females (voice, facial & body hair)
 - Tendon rupture
- Psychological:
 - Increased aggressiveness, 'Roid Rage'
- Reproductive:
 - Shrinking testes, reduced libido & sperm, impotence
 - Enlargement of clitoris
- Cardiovascular:
 - HDL/LDL , impaired glucose tolerance, hypertension, stroke, heart disease
- Liver
 - Tumors, cysts, jaundice

Introduction To Exercise Nutrition

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All graphs courtesy of Human Kinetics unless otherwise stated

Pre-Exercise Nutrition



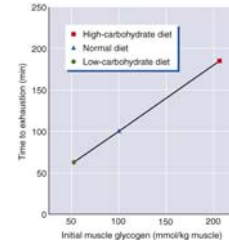
- The main goals of pre-exercise nutrition are to:
 - Maintain blood glucose levels
 - Help settle the stomach
 - Achieve adequate hydration
 - Top up stores of liver and muscle glycogen
 - Pacify the mind

Pre-Exercise Nutrition

- Need to allow adequate time for digestion:
 - 3 – 4 hrs for a large meal
 - 2 – 3 hrs for a small meal
 - 1 – 2 hrs for a liquid meal
 - <1 hr for a snack (depends on own tolerance)
- Food eaten 1 – 2 hrs before exercise should be high in CHO and of moderate GI
 - Foods high in fat and protein take longer to digest and may cause tiredness or nausea

Importance of Glycogen

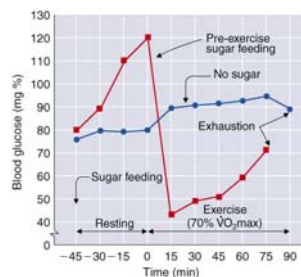
- Having adequate stores of glycogen delays time to exhaustion
- Very important for endurance events



Pre-ex glycogen & TTE

Pre-Exercise Nutrition

- In the hour before exercise be careful about consuming high GI CHO foods:
 - Transient hypoglycaemia



From Physiology of Sport and Exercise, Wilmore & Costill, 2004

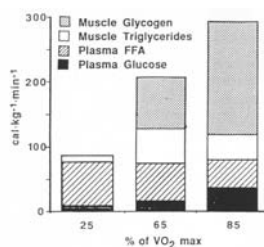
Pre-Exercise Nutrition

- Ability to tolerate food in stomach depends on the type and intensity of activity
- Pre-exercise protein ingestion can be effective for enhancing protein synthesis in response to weight training
 - Protein should be consumed in liquid form
- Eat familiar foods, especially before competition
- The pre-competition meal can ensure a normal blood glucose level and prevent hunger
- It should include 200 to 500 kcal of foods that are easily digestible and are eaten no less than 2 hours before competition



Nutrient Use During Exercise

Effect of exercise intensity

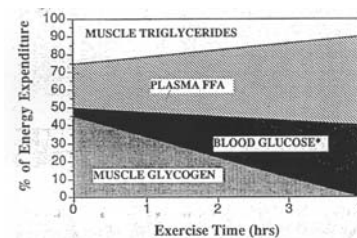


Romijn et al. Am J Physiol 265: E380-391, 1993.

- Fat oxidation:
 - Muscle triglycerides & FFA
- CHO oxidation:
 - Muscle glycogen & plasma glucose
- Effect of CHO feeding
 - Plasma glucose increases
 - Everything else spared
- Weight loss?
 - Substrates
 - Intensity
- CHO ingestion during exercise can improve work output and delay fatigue

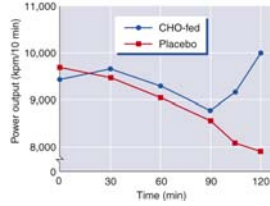
Nutrient Use During Exercise

Effect of exercise duration



CHO Ingestion During Exercise

- CHO ingestion during exercise can improve work output and delay fatigue
- 'Spare' muscle glycogen
- Only for moderate exercise >90 mins or High-intensity intermittent for 60 mins or more



CHO vs. Placebo - every 15 min during 2 hrs cycling

Fluid Intake During Exercise

- Water suitable for events < 60 mins in duration
- Fluid consumption should keep pace with sweat losses (aim to replace ~80% of body weight lost as fluid)
- Start drinking early to minimise dehydration and maintain gastric emptying
- Consume drinks at regular intervals (e.g. 150 to 250ml at 15- to 20-minute intervals)

Fluid Intake During Exercise

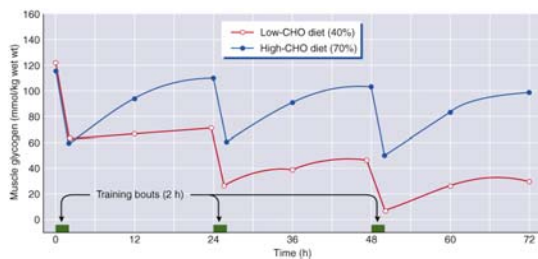
- Keep beverages cool to assist with temperature regulation
- The concentration of a sports drink may vary for different exercise situations (i.e. prolonged exercise in the cold may require a higher % CHO solution)
- Choose a sports drink that tastes appealing, especially when consumed in large quantities
- Fluid intake practices for competition should be well rehearsed during training

Post-Exercise Nutrition

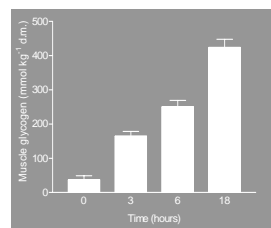
- **Endurance exercise:**
 - Primary concern is fluid and glycogen replacement
 - High GI CHO is preferred in first 2 hrs
 - Aim to consume 8 – 8.5 g/kg within first 24 hrs
- **Resistance exercise:**
 - Essential amino acids within 3 hrs
 - Liquid protein replacement with glucose ideal
 - Mixed CHO and protein meal
- Avoid alcohol because of its effects on hydration, protein and CHO metabolism and inflammation



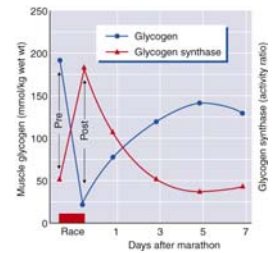
Carbohydrates and Glycogen



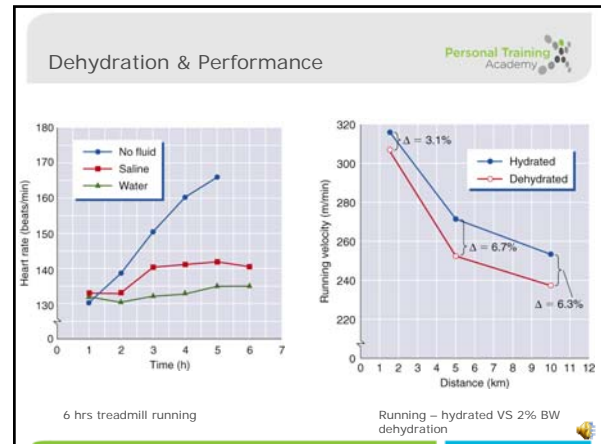
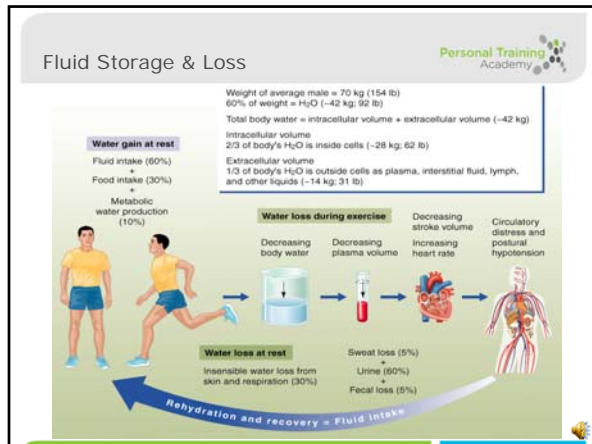
Glycogen Resynthesis



Kimber et al. J Physiol 548: 919-927, 2003.



From Physiology of Sport and Exercise. Wilmore & Costill, 1994



- ### Hydration & Exercise
- Personal Training Academy
- The need to replace body fluids is greater than the need to replace electrolytes
 - Our thirst mechanism does not match our hydration state, so it is best to consume more fluid than thirst dictates
 - Water intake during prolonged exercise reduces the risk of dehydration and optimizes performance
 - Drinking too much fluid can result in hyponatremia (low levels of plasma sodium), which can cause confusion, disorientation, and seizures
 - 1-2 litres/hour, depending on intensity and heat
 - Small amount of CHO (4-8%) and electrolytes