“If we could give every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health.”

Hippocrates (460 – 377 BC)
Learning Outcomes

1. Revise energy metabolism in relation to exercise including aerobic and anaerobic exercise
2. Understand the importance of carbohydrate in sport, how it affects performance outcomes and optimal intake before, during and post exercise
3. Discuss the advantages and disadvantages of carbohydrate loading on exercise outcome
4. Understand the importance of protein in sport and competition performance, its uses and optimal intake
5. Understand the importance of lipids in sport and competition performance, its uses and optimal intake
6. Discuss the burning of lipids for exercise and how intensity, duration and fitness can be manipulated to use lipids as fuel.
Learning Outcomes

7. Discuss the importance of hydration in sport, electrolytes and various types of sports drinks and the effects of alcohol on performance
8. Outline why immunity is poor in athletes and revise how immunity can be enhanced
9. Discuss the effect of specific nutrients in sports in relation to functional medicine and how they can aid performance and recovery.
10. Outline the difference between whey and casein based protein powders, their benefits and disadvantages.
11. Discuss the importance of flexibility and sports psychology in enhancing performance.
“Nutrition cannot substitute for raw talent, training, mental preparation or equipment, but bad nutrition can destroy performance.”

Stone Foundation, June 2005
Energy Production for Exercise

During exercise your body works harder to produce ATP so all physiological functions are kept optimal and performance level is sustained.

There are two forms of energy delivery systems:

ENERGY DELIVERY SYSTEMS

1) ANAEROBIC
   • Phosphate Energy System
   • Lactate Energy System
      (The Cori Cycle)

2) AEROBIC
ANAEROBIC ENERGY PRODUCTION

• Phosphate Energy System
  • Uses phosphocreatine as fuel (see following slide)
  • For bursts of speed up to 6 seconds duration (i.e. 20m sprint)
  • Produces no waste products
  • Recovery =
    50% by 30 seconds
    100% by 2 minutes

• Lactate Energy System
  • Uses stored muscle glycogen and serum glucose only
  • At 95% intensity lasts 30 seconds
  • At 60% intensity lasts 30 minutes
  • Produces lactic acid by product
  • Recovery =
    Takes 20min – 2hrs to fully remove lactic acid build up.
Phosphocreatine

- Creatine is produced in the liver from glycine, arginine, methionine. It is then transported to muscle cells where it combines with phosphate producing phosphocreatine (PC).
- PC is stored in the muscle cells so it can be quickly used for maximum energy bursts by breaking the phosphate + creatine bond and using phosphate to regenerate ADP producing ATP.
- Up to 120g of creatine can be stored in muscle cells. 60-70% as PC and 30-40% as free creatine.
- Free creatine is recycled into more PC or is converted into creatinine which is excreted in the urine.

Lactate Energy System
(Anaerobic Glycolytic System)

• Also called the Cori Cycle  (review Biochemistry notes)
• In the absence of oxygen, glucose conversion halts at pyruvate and excess is converted into lactate. This must then be reconverted into glucose via the liver.
Aerobic Energy Production

• In the presence of oxygen, energy is produced via glycolysis, Krebs cycle and Electron Transport Chain.
• Uses carbohydrates, lipids and protein as fuel
• Produces ATP + CO₂ + H₂O
• Used in exercise reaching 65% maximum effort
• Used in long distance events with moderate intensity
## Main Energy Systems Utilised in Different Exercise Intensity

<table>
<thead>
<tr>
<th>Type of Exercise</th>
<th>Main Energy System</th>
<th>Major Fuels Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum short bursts lasting less than 6 secs</td>
<td>ATP- PC system</td>
<td>ATP and PC</td>
</tr>
<tr>
<td>High intensity lasting up to 30 secs</td>
<td>ATP-PC Anaerobic glycolytic</td>
<td>ATP and PC Muscule glycogen</td>
</tr>
<tr>
<td>High intensity lasting up to 15 mins</td>
<td>Anaerobic glycolytic Aerobic</td>
<td>Muscle glycogen</td>
</tr>
<tr>
<td>Moderate-high intensity lasting 15-60 mins</td>
<td>Aerobic</td>
<td>Muscle glycogen, Adipose Tissue</td>
</tr>
<tr>
<td>Moderate-high intensity lasting 60-90 mins</td>
<td>Aerobic</td>
<td>Muscle glycogen, Liver glycogen, Blood glucose, intramuscular fat, Adipose Tissue</td>
</tr>
<tr>
<td>Moderate intensity lasting longer than 90 mins</td>
<td>Aerobic</td>
<td>Muscle glycogen, Liver glycogen, Blood glucose, intramuscular fat, Adipose Tissue</td>
</tr>
</tbody>
</table>

• Aerobic metabolism relies on optimally functioning cardiovascular and respiratory systems to deliver oxygen to active skeletal muscle. This is commonly measured as VO\textsubscript{2max} (maximum oxygen uptake).

• VO\textsubscript{2max} is measured by ml/kg bodyweight/minute.

• Resting VO\textsubscript{2max} is approximately 3-5ml/kg/min. Elite endurance athletes have been recorded with levels of up to 92ml/kg/min.

• The higher the uptake of oxygen the longer aerobic energy production is sustained.
Approximate Fuel Usage

Intensity - % $V_0^{2 \text{max}}$

- Low 25%: Fat 25%, CHO 75%
- Moderate 60%: Fat 52%, CHO 48%
- High 85%: Fat 20%, CHO 80%

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Calculating Calorie Intake

1. Estimate Basal Metabolic Rate (BMR)
   - Female: BMR = kg body weight x 22 calories
   - Male: BMR = kg body weight x 24 calories
2. Estimate Physical Activity Level (PAL)
   - Mostly inactive/sedentary = 1.2
   - Moderately active (2-3 x wk) = 1.4
   - Active (exercise hard more than 3 x wk) = 1.5
   - Very active (exercise hard daily) = 1.7
3. Multiply BMR x PAL = daily calorie intake
   i.e. 70kg x 22 = 1540 x 1.4 = 2156 calories daily
Carbohydrates & Sport

Carbohydrate as a fuel source is critical to performance and endurance:

• ↑ muscle and liver glycogen stores:
  = longer anaerobic & aerobic energy production
  = longer sustained performance
  = delayed exhaustion

• Depleted glycogen stores:
  = fatigue
  = ↓ performance
# Daily Carbohydrate Intake for Exercise Sustainability


<table>
<thead>
<tr>
<th>Activity level</th>
<th>Grams / kg / day</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5 hours / week</td>
<td>4-5</td>
</tr>
<tr>
<td>5-7 hours / week</td>
<td>5-6</td>
</tr>
<tr>
<td>1-2 hours / day</td>
<td>6-7</td>
</tr>
<tr>
<td>2-4 hours / day</td>
<td>7-8</td>
</tr>
<tr>
<td>More than 4 hours / day</td>
<td>8-10</td>
</tr>
</tbody>
</table>
Carbohydrate Calorie Calculation

• Take the amount of CHO per day
• Multiply this number by 4
  (4 calories per gram of carbohydrate)
• The final amount is the number of carbohydrate calories required per day

i.e. An athlete weighs 70 kg + trains 6 hours per week

Therefore:

- requires 5g carbohydrate per day
- \( 70 \times 5 = 350 \text{g of carbohydrate per day} \)
- \( 350 \text{g} \times 4 = 1400 \text{ calories of carbohydrate per day} \)
Carbohydrate Loading

• CHO loading began in 1967 by Scandinavian researchers Bergstrom and Hultman as a method of increasing performance by “super-loading” glycogen stores prior to competition.

• It is especially beneficial in endurance events lasting longer than 90 minutes i.e. marathons, long distance cycling.

• It can increase performance by 2-3% and delay exhaustion by 20%

• Glycogen depletion is not likely to affect performance in competitions lasting less than 90mins.

• Its is important that athletes practice CHO-loading regimes to find the type that best suits them so they are well rehearsed when using the program for a major competition.
Carbohydrate Loading

The original regime consisted of three phases:
1. Day 1 = Exhaustive prolonged exercise (depletes glycogen stores) + low-CHO diet
2. Day 2-3 = tapering of original exercise regime + low-CHO diet
3. Day 4-6 = tapering of original exercise regime + high-CHO diet
4. Day 7 = COMPETITION
Carbohydrate Loading  
- Original Regime –  


Positives

- Glycogen depletion stimulates glycogen synthetase activity which increases glycogen storage when glucose become available again.
- Higher glycogen stores means longer optimal performance.

Negatives

- The combination of exhaustive exercise and low-CHO diet means athletes become exhausted, irritable, tired.
- The exhaustive exercise interferes with exercise tapering.
- Some athletes still do not achieve above average glycogen stores.
Carbohydrate Loading
Modified Regime

• In 1981 Ohio State University in the US discovered a CHO-loading regime which reduced the negative side effects of the original program.
• This program meant the athlete could endurance train whilst on a normal diet, then taper exercise slowly over 5-6 days whilst maintaining moderate to high levels of CHO.

<table>
<thead>
<tr>
<th>Day</th>
<th>Exercise</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Endurance training</td>
<td>Normal Diet</td>
</tr>
<tr>
<td>2</td>
<td>Tapering exercise</td>
<td>Moderate CHO diet</td>
</tr>
<tr>
<td>3</td>
<td>Tapering exercise</td>
<td>Moderate CHO diet</td>
</tr>
<tr>
<td>4</td>
<td>Tapering exercise</td>
<td>Moderate CHO diet</td>
</tr>
<tr>
<td>5</td>
<td>Tapering exercise</td>
<td>High CHO diet</td>
</tr>
<tr>
<td>6</td>
<td>Tapering exercise</td>
<td>High CHO diet</td>
</tr>
<tr>
<td>7</td>
<td>COMPETITION</td>
<td></td>
</tr>
</tbody>
</table>

Carbohydrate Loading
1 Day Regime

- Recent research from the University of Western Australia concluded that high glycogen levels can be obtained by focusing high CHO loading on the last day before competition post 1x 3min intense exercise event i.e. a sustained sprint
- Positive results from this regime include:
  - training tapering is not interrupted
  - Athlete mood is sustained due to lack of depletion phase

<table>
<thead>
<tr>
<th>Day</th>
<th>Exercise</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tapering exercise</td>
<td>Normal Diet</td>
</tr>
<tr>
<td>2</td>
<td>Tapering exercise</td>
<td>Low CHO diet</td>
</tr>
<tr>
<td>3</td>
<td>Tapering exercise</td>
<td>Low CHO diet</td>
</tr>
<tr>
<td>4</td>
<td>Tapering exercise</td>
<td>Low CHO diet</td>
</tr>
<tr>
<td>5</td>
<td>Tapering exercise</td>
<td>High CHO diet</td>
</tr>
<tr>
<td>6</td>
<td>Tapering exercise</td>
<td>High CHO diet</td>
</tr>
<tr>
<td>7</td>
<td>Warm-up &amp; 3min high intensity exercise (sustained sprint)</td>
<td>High-CHO diet 10g/kg</td>
</tr>
<tr>
<td>8</td>
<td>COMPETITION</td>
<td></td>
</tr>
</tbody>
</table>

Who can benefit from CHO loading?

Carbohydrate loading DOES NOT increase power, strength, VO$_2$ max or maximum aerobic output, it simply enables an athlete to continue for longer at their maximum aerobic pace.

- Marathon runners
- Cross-country skiers
- Long distance swimmers - longer than 10 km 30 + km runs
- Triathletes > Olympic distance
- Football players / Rugby players
- Cycling time trials - longer distances
- Long distance kayak racing - longer than 10 km
- Orienteering

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When not to use CHO loading

EVENTS UNDER 2 HOURS!!!

• There is insufficient exercise to use the extra glycogen.
• Doubling glycogen stores will increase water and glycogen weight by about 2kg and create muscle tightness.

CHO loading is NOT recommended for the following:
• <10 km runs
• Down hill ski races
• Walking / hiking
• Most short swimming events
• Basketball / weightlifting
• Most track and field events
• Rowing

However in all these sports ensure adequate glycogen stores will be of great benefit!!!
Carbohydrate Loading
Choosing the Correct Carbohydrate

The correct CHO depends on when it is eaten.

1. Before exercise
2. During exercise
3. Post exercise
4. Between exercise sessions
Before Exercise

• 2.5g of CHO per kg bodyweight
• 2 - 4 hours before exercise – leave enough time for food to settle
• Use low GI CHOes such as:
  sweet potato, porridge, soy beans, chickpeas, baked beans, lentils, quinoa, brown rice, wild rice, corn, wholemeal pasta, vegetables.
• Pre-workout snacks (1-2hrs before): fresh fruit, dried fruit, fruit smoothies, protein shake, fruit bread.
• Timings must be practiced. Eat too close to exercise and stomach cramps, food fermentation and gas develop. Eat too far from exercise and hypoglycaemia results.
During Exercise
(lasting longer than 60mins + moderate-high intensity)

• 30-60g CHO per hour
• Begin CHO ingestion post 30mins exercise, top-up at regular intervals, before fatigue sets develops
• Use high GI foods such as:
  - Isotonic sports drinks or diluted juices (6g/100ml) Absorbed easily, quickly in the stomach and small intestine. They also provide fluid for hydration
  - Solid foods such as raisins, sultanas, bananas must be consumed with water. These will take longer to digest and be absorbed.
Post Exercise

- 1g CHO per kg bodyweight
- Up to 2 hours post exercise then every 2 hours
- First 45 minutes optimal for utilising glycogen synthetase
- Use high or low GI foods depending on exercise intensity and duration.
  - High GI directly post exercise and up to 2 hrs. i.e. isotonic sports drink, protein shake
  - Low GI thereafter (see previous slides)
- Combining protein and CHO post exercise has been shown to improve glycogen recovery as it stimulates greater insulin release and therefore greater muscle glucose and amino acid uptake.
- If eating is delayed by 2 hours, muscles don’t just decrease their insulin sensitivity but become almost insulin resistant. This can last up to 16 hours.

Between Exercise Sessions

• 5-10g CHO per kg bodyweight or 60% of calorie intake
• 4-6 meals/snacks over the course of the day
• Use only low GI foods
CHO Loading For Lean Mass

- Protocol: this protocol is designed to bulk up and limit fat gain.
- It is a shock program NOT TO BE REPEATED MORE THAN TWICE A YEAR.
- AT LEAST 2 GRAMS A DAY OF OMEGA 3 ARE COMPULSORY DUE TO THE LOW AMOUNT OF FAT CONSUMED.
- It is a 9 day program to be repeated 3 times and will require a final calorie load at the end of the cycle.
- Structure: Program (9 days)/ repeat/ repeat/ calories load)
CHO Loading For Lean Mass

• **Day 1 to 3 moderate carbs loading:**
  (body weight in kg X 2.5 = grams of carbs per day)
  (body weight in kg X 2.5 = grams of protein per day)
  10 grams of fats per day (10 almonds, 2 teaspoons of olive oil and so on)

• **Day 4 to 6 high carbs loading:**
  (body weight in kg X 3 = grams of carbs per day)
  (body weight in kg X 2 = grams of protein per day)
  10 grams of fats per day (10 almonds, 2 teaspoons of olive oil and so on)
CHO Loading For Lean Mass

• **Day 7 to 8 Carbs unloading:**
  
  (body weight in kg = grams of carbs per day)

  (body weight in kg $\times$ 2.5 = grams of protein per day)

  30 grams of fats (30 almonds, 2 tablespoons of olive oil)

• **Day 9 full unloading**

  30 grams of carbs per day

  (body weight in kg $\times$ 1.5= grams of protein per day)

  30 grams of fats (30 almonds, 2 tablespoons of olive oil)

• **REPEAT FROM DAY 1 TWICE**
CHO Loading For Lean Mass

- **Day 28:** once you have finished the cycle 3 times it’s time for a last calories loading to give your body a metabolic shock before going back to your normal diet.
- Calories loading rules:
  - You must eat at least 4000 calories during this day
  - You must keep your fat consumption high (especially good fatty acids)
  - You must eat at least 1 gram of protein for each kg of your body weight
- Enjoy this day, it is well deserved!!
CHO & Protein Supplementation  
(Post Exercise)

• Ideal ratio 4:1 / Carbohydrate:Protein

• Promotes the release of insulin thus stimulating muscle glycogen replacement

• Stimulates the transport of amino acids into muscle cells thus promoting protein synthesis and blunting cortisol levels

• Cortisol suppresses the rate of protein synthesis and stimulates protein catabolism (breakdown)
50 grams of carbohydrate with at least 10 grams of protein

- 200 g fruit flavoured yoghurt with 1 cup fruit salad
- 60 grams breakfast cereal with ½ cup milk
- Fruit smoothie/milk shake (250-350 ml)
- Liquid meal supplement (250-350 ml)
- Wholegrain sandwich with meat/cheese filling and 300 ml sports drink
- 250 g baked beans with 2 pieces of wholegrain toast
- 250 g baked potato with cottage cheese filling
- 2 crumpets with nut butter (thick spread)
- 5 oatcakes + 1 x 60g tub hummus
- 1 small banana + almond Bounce Ball
- 200g coconut yoghurt + cup of fruit salad + 10 almonds
- 1 avocado + 3 rice cakes + 2 tablespoons cashew nut butter
- 5 oatcakes + 2 boiled eggs
Protein & Exercise

• Why is protein important for athletes?

• What would happen if insufficient protein was available for the body?

• Make a list of 10 body functions that require protein
Protein & Exercise

• The RDA Daily protein requirements of 0.75g – 0.8g/kg is insufficient for both athletes and people who regularly exercise.

• Inappropriate protein consumption can reduce performance and hinder training and recovery.

• Exact protein requirements depend on the intensity and duration of exercise undertaken.
## Protein Requirements for Athletes


<table>
<thead>
<tr>
<th>Category</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate sports activity</td>
<td>1g of protein for every kg of body weight</td>
</tr>
<tr>
<td>Weight training athletes</td>
<td>1.2 - 1.6 grams</td>
</tr>
<tr>
<td>Endurance training athletes</td>
<td>1.2 - 1.6 grams</td>
</tr>
<tr>
<td>Adolescent and growing athletes</td>
<td>1.2 - 2.0 grams</td>
</tr>
<tr>
<td>Pregnant athletes</td>
<td>Add an extra 10 grams of protein per day above the RDA in the 2nd and 3rd trimesters</td>
</tr>
<tr>
<td>Breast feeding athletes</td>
<td>Add an extra 20 grams per day above the RDA</td>
</tr>
</tbody>
</table>
## Protein & Exercise


<table>
<thead>
<tr>
<th>Group</th>
<th>Protein intake (g/kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary men and women</td>
<td>0.8-1.0</td>
</tr>
<tr>
<td>Elite male endurance athletes</td>
<td>1.6</td>
</tr>
<tr>
<td>Moderate-intensity endurance athletes</td>
<td>1.2</td>
</tr>
<tr>
<td>(Exercising approximately four to five times per week for 45-60 min)</td>
<td></td>
</tr>
<tr>
<td>Recreational endurance athletes</td>
<td>0.8-1.0</td>
</tr>
<tr>
<td>(Exercising four to five times per week for 30 min at &lt;55% VO$_{2peak}$)</td>
<td></td>
</tr>
<tr>
<td>Football, power sports</td>
<td>1.4-1.7</td>
</tr>
<tr>
<td>Resistance athletes (early training)</td>
<td>1.5-1.7</td>
</tr>
<tr>
<td>Resistance athletes (steady state)</td>
<td>1.0-1.2</td>
</tr>
</tbody>
</table>
Protein & Endurance Training

• Protein will need to replace muscle damaged or broken down during training
• Post 60-90 minutes exercise the body begins to convert branch chain amino acids (BCAAs) into energy i.e.

Leucine → Alanine → Glucose (in liver)
Protein & Strength & Power Training

• Muscle is constantly damaged during training such as weight lifting.
• To replace muscle diet must be in “positive nitrogen balance”
• Research conducted by McMasters University Canada concluded that timing of protein intake is important. Positive protein uptake was recorded during post exercise recovery phase (best results within the first 1hr). They also found consuming CHO with protein enhanced recovery.
• How can an athlete minimise protein breakdown during training? (hint – see carbohydrates)

# How Much Protein?

(The following provides approximately 10g protein)

<table>
<thead>
<tr>
<th>Animal Foods</th>
<th>Plant Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 2 small eggs</td>
<td>• 4 slices (120 g) wholemeal bread</td>
</tr>
<tr>
<td>• 30 g (1.5 slices) cheese</td>
<td>• 3 cups (90 g) wholegrain cereal</td>
</tr>
<tr>
<td>• 70 g cottage cheese</td>
<td>• 2 cups (330 g) cooked pasta</td>
</tr>
<tr>
<td>• 1 cup (250 ml) low-fat milk</td>
<td>• 3 cups (400 g) cooked rice</td>
</tr>
<tr>
<td>• 35 g lean beef, lamb or pork (cooked weight)</td>
<td>• 3/4 cup (150 g) lentils or kidney beans</td>
</tr>
<tr>
<td>• 40 g lean chicken (cooked weight)</td>
<td>• 200 g baked beans</td>
</tr>
<tr>
<td>• 50 g grilled fish</td>
<td>• 120 g tofu</td>
</tr>
<tr>
<td>• 50 g canned tuna or salmon</td>
<td>• 60 g nuts or seeds</td>
</tr>
<tr>
<td>• 200 g reduced fat yoghurt</td>
<td>• 300 ml soy milk</td>
</tr>
</tbody>
</table>
Lipids & Sport

• In virtually every sport, the leanest athlete wins (except sumo wrestling).

• Excess fat in an athlete can be a distinct disadvantage to endurance, strength and speed.

• It is importance that athletes are never completely free from lipid stores…Why?

• What is the problem with a low-fat diet?
Measuring lipid stores
(See Assessment & Diagnostics Lecture)

• **Body Mass Index (BMI)**
  \[
  \frac{\text{kg}}{(\text{height in metres})^2} = \text{BMI} \\
  \frac{60}{(1.7\text{m})^2} = 21
  \]

What are the problems with using BMI in Sports?

• **Waist:Hip ratio**
  \[
  \text{waist cm/inches/ hip cm/inches} = \text{ratio} \\
  \text{women should be around 0.8} \\
  \text{men should be around 0.95} \\
  \text{i.e. woman with waist 66cm and hips of 91.5cm} \\
  = 66/91.5 = 0.72
  \]
Ideal Lipid % for Athletes

According to the University of Arizona, the ideal body fat percentage is:

- Female = 12-18%
- Male = 6-15%

This is sport depending. i.e. a male endurance runner can achieve optimal performance on 6% whilst a cyclist, gymnast or sprinter may perform better at 10%

- UK statistics recommend dietary fat intake for athletes should be between 20-33%

Omega 3 & Sport

• Increase delivery of oxygen and nutrients
• Higher cell membrane flexibility and therefore cell performance
• Improve release of growth hormone
• Improve recovery
• Enhance aerobic metabolism
• Increase energy and stamina
• Increase exercise duration and intensity
• Anti-inflammatory in action

Exercise for Burning Lipid Stores

Some athletes will need to reduce body lipid stores to improve performance:
• Delay eating 1hr post exercise = more lipid stores will be released and burnt (insulin levels kept low)
• Problem: compromise muscle glycogen re-storage.

Burning lipids during exercise depends on:
• Intensity and type of exercise
• Duration of exercise
• Fitness level
• Pre-exercise diet.
Intensity & Type of Exercise

- Anaerobic high intensity exercise = \uparrow muscle glycogen use
  e.g. sprinting, lifting heavy weights, bursts of energy in teams sports such as football
- Aerobic moderate intensity exercise = mixture muscle glycogen + lipids as a source of fuel
  e.g. steady jog or swim
- Aerobic low intensity exercise (less than 50% V02max) = lipids used as main fuel
  e.g. walking, yoga, pilates

Duration of Exercise

- Muscle glycogen is a limited supply of energy and will thus decrease with an increase in exercise duration.
- As muscle glycogen utilisation dips, lipid catabolism increases.
- Lipids cannot be utilised as energy without the presence of carbohydrates.

Fitness Level

Aerobic training increases:

- Fat-oxidising enzymes such as lipase. This will increase rate of lipids released from storage
- The number of capillaries supplying muscles. This increases lipid transport
- The number of mitochondria within the muscle cell. This increases lipid utilisation and ATP production.

Pre-exercise Diet

• A carbohydrate restricted diet = ↓ muscle & liver glycogen stores

• ↓ glycogen stores:
  = ↓ ATP production
  = ↓ V0₂max
  = ↓ maximum output power

• With low glycogen stores, the body reverts to using lipids & protein for energy.
Hydration

• Fluid loss reduces performance and endurance

• How much fluid can be lost?
  Depends on:
  - exercise intensity
  - exercise duration
  - environmental temperature & humidity
  - individual body composition & physiology
Hydration

• 1hr moderate exercise in average environmental conditions by the average athlete = 1L H₂O loss
• The amount of fluid loss can be obtained by weighing pre and post exercise.
  1kg body weight loss = 1L H₂O loss
• Many athletes (& non-athletes) suffer mild dehydration.
  Symptoms: sluggishness, fatigue, headache, anorexia, light headedness, nausea.
Reduced Water in the Body

1. Temperature homoeostasis compromised =
   – Blood moves to skin to dispel heat
   – ↑ Blood on skin surface = ↓ blood for working muscles

2. Disruption of chemical and physiological reactions

3. Mental function compromised

4. The less water available to the body, the less you sweat – compounds problem
Dangers of Dehydration

Loss of 1% of bodyweight =
- Thirst threshold
- Impaired performance
(pale straw coloured urine indicates athlete within 1% of hydration)

Loss of 2% of body weight =
- Strong thirst
- No appetite
- Blood volume decreases
- Body temperature rises
- Impaired performance (maximal capacity reduces by 10-20%)
Dangers of Dehydration

Loss of 3% bodyweight =
- Dry mouth
- Reduced appetite
- GIT discomfort
- Impaired water absorption

Loss of 4% bodyweight =
- Nausea
- Vomiting
- Diarrhoea
- Impaired performance (maximal capacity reduces by 20-30%)
Dangers of Dehydration

Loss of 5% bodyweight =
• Difficulty concentrating, decision making
• Headache
• Impatience
• Sleepiness (brain 76% water)
• Impaired performance (maximal capacity reduces by 30%)
• Heat exhaustion

Loss of 6-7% bodyweight =
• Likely collapse

Loss of 10% bodyweight =
• Circulatory collapse
• Heat stroke
Staying Hydrated

Before Exercise:

• Athlete must be well hydrated prior to exercise
• Monitor urinary colour and output
• Approx. 400-600ml in 2hrs before exercise
  - only water if exercising under 1hr
  - add sports drink if 1hr+
• Avoid hyponatraemia by not over drinking

Symptoms: dizziness, nausea, bloating, unconsciousness
THESE SYMPTOMS ARE SIMILAR TO DEHYDRATION!!!
Staying Hydrated

During Exercise:
- Start hydrating before feeling thirsty
- $\uparrow$ sweat = $\uparrow$ hydration
- Research has found performance capacity is retained when 80% of fluid lost through sweating is replaced.
- Drinking too much can cause hyponatraemia
- Intense exercise > 1hr = rehydration fluid must contain 8g sugar/100ml
- Exercising > 4hrs = 800ml intake per hour (or guide by thirst response).
- Make sure hydration fluids are easy to reach and readily available
- IOC recommends 20-60g carbohydrate/hour to delay fatigue and keep serum glucose levels optimal
- During hotter/more humid weather - $\uparrow$ hydration by diluting fluids

Staying Hydrated

Post Exercise:

• 1.2-1.5 x weight of fluid lost (or each kg lost) during exercise should be consumed post exercise.

• Drink at comfortable speed in divided doses

• If ↑ exercise duration = drink sports drink to avoid hyponatraemia
## Staying Hydrated

<table>
<thead>
<tr>
<th>Exercise Conditions</th>
<th>Drink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise lasting &lt;30mins</td>
<td>Nothing or water</td>
</tr>
<tr>
<td>Low-moderate intensity exercise lasting &lt;1hr</td>
<td>Water</td>
</tr>
<tr>
<td>High intensity exercise lasting &lt;1hr</td>
<td>Hypotonic or Isotonic Sports Drink</td>
</tr>
<tr>
<td>High intensity exercise lasting &gt;1hr</td>
<td>Hypotonic or Isotonic Sports Drink or glucose polymer drink</td>
</tr>
</tbody>
</table>

Sports Drinks

Two main types:

1. Fluids replacement drinks

2. Carbohydrate energy drinks
Fluid Replacement Drinks

- Contain diluted Na, K, Cl, Mg & glucose, sucrose, fructose or glucose polymer (maltodextrin)

- Manipulates Sodium-Glucose-Transporter in small intestine

- Can be hypotonic or isotonic
Carbohydrate Energy Drinks

- Delivers high amounts of CHO
- Contain more CHO per 100ml than fluids replacement drinks
- CHO in glucose polymer form
- Liquids - usually isotonic
- Powders – hypotonic or isotonic
Glucose Polymers

- Usually maltodextrins
- Links 10-15 simple sugar molecules together to provide increased CHO content for equivalent osmolality compared to solutions of simple sugars.
- Glucose polymers greatly reduce the number of particles in the solution / sports drink and thus facilitate the movement of glucose from the stomach into the small intestines for absorption.
- Virtually tasteless
Types of Sports Drinks

Hypotonic = sports water
• low osmolarity,
• ↓contents per 100ml fluid (approx 4g CHO & electrolytes/100ml)
• Absorbed faster than water

Isotonic = sports drink
• Identical osmolarity to body fluids
• 4-8g CHO & electrolytes/100ml
• Absorbed as fast or faster than water
• Try and replicate ideal combination of rehydration & refuelling

Hypertonic = soft drink
• ↑osmolarity than body fluids
• > 8g CHO & electrolytes/100ml
• Absorbed slower than water
Homemade Sports Drinks

| DIY SPORTS DRINKS |
|-------------------|-----------------|
| **Hypotonic**     | **Isotonic**    |
| 100ml fruit squash | 200ml fruit squash |
| 900ml water       | 800ml water     |
| 1-1.5g (1/4 tsp) salt | 1-1.5g (1/4 tsp) salt |
| 250ml fruit juice | 500ml fruit juice |
| 750ml water       | 500ml water     |
| 1-1.5g (1/4 tsp) salt | 1-1.5g (1/4 tsp) salt |

Dangerous Rehydration

1. Do not consume salt tablets. The stomach draws water out of body to dilute the salt, dehydrating further.

2. Avoid diet drinks – these contain no glucose and are usually low in Na.

3. Avoid caffeine containing drinks – although research has proven added lipid burning capabilities, additional strain on adrenals/NS is undesirable.
Alcohol & Sport

Alcohol reduces:
• Coordination
• Reaction time
• Balance
• Decision making & judgement
• Body temperature control
• Serum glucose levels
• Glycogen synthesis
• Inhibits tissue recovery

Alcohol increase:
• Urination ( & therefore dehydration)
• Injury & accidents

Alcohol & Sport

- Alcohol might be one of the reasons for not getting the results that you want in sports.
- Alcohol metabolism also interferes with protein synthesis

Read more:
The Immune System & Sport

- Excess training increases strain on body resources, tissue repair and recovery.
- Often ↓ immunity in athletes
- Could be due to:
  - nutrient restrictive diets
  - ↑ adrenaline and cortisol levels with excess exercise
  - ↓ nutrients vital for immune system function (A, E, C, Zn, Se, glutamine, adequate protein)
The Immune System & Sport

- Cortisol and adrenalin levels in the blood increase during exercise, thus inhibiting many important infection fighting immune cells.

- Glutamine and glucose levels in the blood both decrease as a result of strenuous exercise.

- The lower the blood glucose levels, the higher the cortisol levels.

- Ingesting glucose during exercise can limit the release of cortisol levels by up to 80% in comparison to water (Gleeson, 2001).

- Immune system suppression post exercise can last up to 72 hours (especially NK cells suppression) (Ivy, 2004).


• Not every athlete can sustain a nutritionally balanced diet. Travel, events, training times, work shifts can all get in the way.
• Nutrients can optimise physiological function, but are unlikely to enhance performance unless nutrient deficiencies are present.
• Nutrients can aid recovery rate post exercise
• Nutrient deficiencies are common in female athlete, especially on a calorie restricting diet
In 2002 60 female athletes tested were found dietary consumption of Ca, Fe, Zn were below recommended RDAs.

The University of Arizona (2002) found female hepathletes only received 67% of dietary nutrients RDAa. They also found vitamin E status to be virtually non-existent.

In 2001 RDAs in the diets of 58 swimmers were tested. Results showed 71% of males and 93% females did not meet RDAs for any of the antioxidant vitamins and minerals.

Specific Sports Nutrients

- Antioxidants
- Energy Metabolism Nutrients
- Magnesium, Calcium, Iron, Taurine, Carnitine
- Creatine monohydrate
- Glutamine
- Branched Chain Amino Acids
- Beta- Hydroxy Beta-methylbutyrate (HMB)
- Meal Replacements & Protein Drinks
Antioxidants

Antioxidants are crucial for post exercise recovery to mop up free radicals and regenerate tissue damage

Some vital functions of Antioxidants (in relation to Sports)

- **Vitamin C**: required for CT replacement, adrenaline formation, RBCs, mops up free radicals, rejuvenates Vit E, anti-viral, enhances Fe absorption
- **Vitamin E**: protects cell membranes & FAs, enhances T helper cell synthesis, improves blood flow, mops up free radicals, reduces inflammation
- **Vitamin A**: epithelial tissue regeneration and repair, lipid antioxidant, enhances phagocytes and antibody production, mucous membrane integrity, maintenance of myelin sheath.
- **Zinc**: DNA, RNA synthesis, every aspect of immunity, testosterone, insulin & growth hormones synthesis, reduces lactic acid levels, wound healing, lost in sweat.

Nutrients for Energy

Think back to Biochemistry & your Vitamins & Mineral Lectures…

Which nutrients are involved in Glycolysis, The Krebs Cycle & the Electron Transport Chain?

What could be the importance of the following in Sport?
- B1, B2, B3
- B6
- B5
- B9, B12
Magnesium

Magnesium:
• Relaxes nerve & muscle fibres
• Vasodilates blood vessels
• Co-factor for energy production & DNA protein synthesis
• Important in Ca homeostasis
• Important in temperature control
• A large amount of Mg lost in sweat and deficiency is common, especially in endurance athletes

What are you Mg deficiency signs and symptoms?

What dose would be beneficial in an athlete?

Calcium

Calcium:
• Required for nerve transmission
• Required for muscle contraction
• Regulates cell division
• Maintains electrolytes & buffers acidity in blood
• Important in bone, teeth structure & cell membrane permeability

What are your Ca deficiency signs and symptoms?

What dose would be beneficial in an athlete?

Iron

Iron is crucial for all athletes but especially female athletes. Why?

- Required for formation of haemoglobin and myoglobin ($O_2$ transport around the body & into muscle cells)

- Required by immune cells, bone homeostasis, DNA & nt synthesis, all aspects of growth.

Taurine

• Is an amino acid very abundant in muscle tissue.

• It increases hydration of cells and improving the uptake of electrolytes and of creatine. (Facilitates movement of C, K, Na, Mg ions in and out of cells)

• Regulates Na+K+ATPase pumps & Ca channels

• Stimulates insulin release & can act as an insulin mimicker, shunting glucose and amino acids into the muscle cells.

• It can enhance protein metabolism and is anti-catabolic. (Stimulates growth hormones synthesis)

• A very useful supplement for intense training athletes.

Acetyl-L-Carnitine

- The first step in the utilisation of fatty acids for energy (beta-oxidation) is their transport into the mitochondria. This requires carnitine.

- Once inside the mitochondria, fatty acids are split from carnitine and oxidised for energy.

- Also aids in gene replication, utilisation of ketones (brain function), use of ATP in cardiac muscle.

- Improves reflex speed, increases concentration and more muscle fibre stimulation.

Creatine

- A protein made from 3 amino acids: glycine, arginine, methionine
- Sources: herring, salmon, tuna, beef, wild game,
- Adequate vitamin E status may also be needed to optimise creatine uptake.
- Combines to form phosphocreatine
- Increases maximum capacity, strength, recovery, aids protein production and muscle hypertrophy, decreases muscle acidity

Creatine

- Improving strength, body composition, or short-duration, repetitive, high-intensity exercise.
- Stimulates muscle growth and increases muscle strength. Clinical studies have proven that supplemental creatine increases one-repetition maximum lifting strength in bodybuilders.
- May reduce neuromuscular fatigue and increases muscle strength and increases muscle mass in neuromuscular disease. It is also speculated to alleviate Alzheimer’s Disease, Amyotrophic Lateral Sclerosis and Parkinson’s Disease and it is presently undergoing investigation for the treatment of these conditions.

Creatine

• It is hypothesised that when muscle absorbs creatine, the creatine brings water intracellularly with it, so the muscle becomes more "hydrated."

• It is estimated muscle is approximately 70% water, so this process results in a larger, fuller muscle.

• Evidence suggests when a cell is well hydrated it may accelerate synthesis of new proteins and may also minimise protein degradation.

Research

• (2002) Australian Institute of Sport found enhanced sprint times in football players
• (2004) In Yugoslavia, football players supplemented with creatine showed enhanced sprint bursts, dribbling, and vertical jumps. There was no improvement in endurance.
• (1998) Elite kayakers improved performance with creatine supplementation

Cox (2002)
Ostojic (2004)
McNaughton (1998)
Glutamine

- Glutamine is the most abundant amino acid found in the muscles.
- Depleted with resistance training
- Important for the transport of nitrogen and carbon within the tissues.
- Shown to increase cell volume
- Insulin and glutamine together seem to work synergistically to enhance cellular hydration.
- Stimulates the synthesis of hepatic glycogen.
- Post exercise, greater availability of glutamine promotes muscle glycogen accumulation.
- An energy source for cell division.
- Precursor for the synthesis of amino acids and glutathione

Glutamine

Plasma levels of glutamine:
• Increase during prolonged, high-intensity exercise.
• Diminish significantly post exercise.
• Takes several hours of recovery before levels are restored to pre-exercise levels.

• If recovery between exercise bouts is inadequate, the acute effects of exercise can be cumulative.

• Over trained athletes appear to maintain low plasma glutamine levels for months or years.

Glutamine

• What other body systems benefit from glutamine supplementation?

• What would be a beneficial dosage range for both muscles and other body systems?
Branched Chain Amino Acids (BCAAs)

Leucine, isoleucine and valine

• Act as energy substrates and nitrogen donors and used in the formation of alanine, glutamine and aspartate.
• A large supply of BCAAs appear to have a sparing effect on muscle glycogen degradation during exercise.
• If high quality protein is consumed adequate amounts of BCAAs are supplied.
• Large doses of BCAAs competes with tryptophan, tyrosine and phenyalanine (aromatic amino acids) brain uptake which may lead to decreased neurotransmitter synthesis.

Beta-hydroxy-beta-methylbutyrate (HMB)

- HMB is anti-catabolic
- Decreases muscle protein turnover and may minimise protein degradation.
- Evidence HMB blocks protein catabolism. This is based on the ability to decrease urinary 3-methylhistidinedine (a marker of muscle breakdown) and to decrease plasma levels of creatine phosphokinase and lactic dehydrogenase.
- Facilitates muscle growth and increases muscle strength when combined with isotonic exercise (i.e. weight lifting).
HMB & Creatine

• When creatine and HMB are used together they may increase lean body mass possibly via different mechanisms.

• This beneficial effect could be due to the ability of HMB to inhibit the creatine phosphokinase enzyme that catalyses the breakdown of creatine phosphate, thus prolonging the effect of the supplemental creatine.

HMB

• Recommended dose for HMB is 3 g/day

• HMB has a short half-life of 2-3 hours, so split doses need to be taken throughout the day for the maximum therapeutic benefits

• As relatively high protein intake was reported in the study demonstrating HMB's efficacy. Whether the same results will occur with a low-protein diet is unknown, a similar protein intake of between 120 and 175 g/day for athletes supplementing their diets with HMB might produce best results.

Meal Replacements

- In the form of powders, bars, ready-made drinks

- Contain protein (usual whey or casein), CHO, vitamins and minerals.

- Won’t enhance performance, but will improve muscle recovery and growth.
Whey vs Casein

- Whey **transits** the stomach **quickly** and is rapidly absorbed from the human intestine.
- The beta-lactoglobulin component remains soluble in the stomach and empties rapidly as an intact protein needing further hydrolysis by pancreatic enzymes.
- Casein, on the other hand, transits the stomach slowly.
- Whey contains substantially more **cysteine** than casein. Cysteine availability is considered a rate-limiting step in glutathione synthesis.
- Whey may stimulate insulin-like-growth-factor-I production (improves muscle protein production)
- Casein contains higher levels of glutamine (c.20%)

Amino acid profiles of highest biological value proteins

<table>
<thead>
<tr>
<th>Glutathione production</th>
<th>Whey</th>
<th>Casein</th>
<th>Milk</th>
<th>Egg white</th>
<th>Soy</th>
<th>Beef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cysteine</td>
<td>2.45</td>
<td>0.4</td>
<td>0.94</td>
<td>2.24</td>
<td>1.3</td>
<td>1.12</td>
</tr>
<tr>
<td>Glutamate</td>
<td>18.99</td>
<td>20.9</td>
<td>20.9</td>
<td>11.74</td>
<td>21.64</td>
<td>15.0</td>
</tr>
<tr>
<td>Glycine</td>
<td>2.34</td>
<td>1.8</td>
<td>2.13</td>
<td>3.45</td>
<td>4.46</td>
<td>5.45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Branched Chain Amino Acids (BCAAs)</th>
<th>Whey</th>
<th>Casein</th>
<th>Milk</th>
<th>Egg white</th>
<th>Soy</th>
<th>Beef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leucine</td>
<td>11.82</td>
<td>9.1</td>
<td>9.8</td>
<td>8.12</td>
<td>8.41</td>
<td>7.9</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>6.19</td>
<td>4.6</td>
<td>6.5</td>
<td>5.44</td>
<td>5.27</td>
<td>4.5</td>
</tr>
<tr>
<td>Valine</td>
<td>6.37</td>
<td>5.7</td>
<td>6.68</td>
<td>7.43</td>
<td>5.08</td>
<td>4.86</td>
</tr>
</tbody>
</table>

*Metagenics Australia technical data. Undenatured whey protein isolate.*
Whey Protein / Lactalbumin

- Provides a balanced source of essential amino acids and peptides with a high protein efficiency ratio.

- Whey protein contains:
  - alpha-lactoglobulin, beta-lactoglobulin, bovine serum albumin.
  - immunoglobulins, enzymes, iron-binding proteins.
  - calcium, potassium, sodium, phosphorous.
  - vitamins A, C, B1, B2, B3, B5, B12, folic acid, and biotin.
  - sulphur containing amino acids - methionine and cysteine.
  - branched-chain amino acids - leucine, isoleucine and valine.
  - glutamine.
  - substrates for glutathione synthesis.

Protein Source Comparison

• This study was designed to compare the acute response of mixed muscle protein synthesis (MPS) to rapidly (i.e., whey hydrolysate and soy) and slowly (i.e., micellar casein) digested proteins both at rest and after resistance exercise.

• Conclusion: feeding-induced stimulation of MPS in young men is greater after whey hydrolysate or soy protein consumption than casein both at rest and after resistance exercise.

• Moreover, despite both being fast proteins, whey hydrolysate stimulated MPS to a greater degree than soy after resistance exercise. These differences may be related to how quickly the proteins are digested (i.e., fast vs. slow) or possibly to small differences in leucine content of each protein.

Amino acid intake is essential in preparing the athlete as much as possible to competition.

We know the benefits, but what are disadvantages of too high amino acid intake?

Which body systems could suffer from added protein in the diet?
Important!

There is always the possibility of supplement contamination with illegal substances!

Anabolic androgenic steroids and other illegal substances have been found in various supplements. The IOC tested 634 supplements in 2001 in Cologne Germany and found 15-19% were contaminated with enough illegal substances to fail a sports drug test.


Some illegal substances include:

- Ephedrine
- Strychnine
- Androstenedione
- Androstenediol
- Dehydrospiandrosterone (DHEA)
- 19-Norandrostenedione
- 19-Norandrostenediol

Enhancing Performance: Importance of Flexibility

• Flexibility is the ability to move a muscle through its full range of motion.

  – This involves the interrelationships among muscles, ligaments, tendons, and joints.

  – Range of motion is restricted by a lack of flexibility, and the performance of routine movement is hindered.
Flexibility

- When a muscle fibre is exercised with repetitious movement, it tightens and shortens.

- A shortened muscle fibre = less force of contraction

- Less force of contraction = reduced strength & less circulation (water/nutrients) reaching the working muscle.

- Stretching out muscle fibres post exercise will loosen the muscle fibres and bring them back to their original shape. This retains the optimal force of contraction of the muscle.
Flexibility

• EVERY exercise program requires stretching!! (regardless of how little exercise is completed)

• Yoga or Pilates exercises are excellent and will enhance performance, endurance and aid recovery of all athlete and exercise types.

• During 1 hour of exercise, a minimum of 10-15 mins of stretching is required. Make sure all muscles involved are stretched thoroughly.
Sports Psychology

Athletes require an enormous amount of psychological conditioning as well as physical.

DO NOT OVERLOOK THE IMPORTANCE OF MENTALLY PREPARING THE ATHLETE FOR COMPETITION!!

- Can aid control of the athletes state of mind under pressure & maintaining focus during extreme circumstances of uncertainty
- Can stabilise mood, concentration & improve sports performance
- Research shows that mental training, in addition to physical training, can improve results much more than physical training alone.

Sports Psychology

Four Commonly Used Techniques:

1. Arousal regulation
   - Maintaining optimal cognitive and physiological activation before and during performance. Can include breathing techniques or meditation to calm and focus the mind if anxiety is an issue or energising the athlete using music, routines or thought exercises. Helps the athlete remain present during performance.

2. Goal setting
   - Within a time-line or time frame, systematically planning ways to achieve goals. Goals need to be specific and obtainable (but not too easy or too difficult). Writing them down and repeating daily can help. Research suggests that goal setting in sport improves performance when compared to athletes with no set goals.

Sports Psychology

3. Imagery
• A powerful tool used to re-create or imagine the up-coming competition. Running through each stage of the competition (with successful outcomes) and involving all sense (touch, taste, hearing, sight, smell) can enhance performance & increase confidence research suggests.

4. Self-talk
• Thoughts or words used by athletes usually in their mind to direct attention to a specific timing or thing. During training specific words/sentences are used during desirable outcomes. These words are then repeated before or during competition to enhance performance. E.g. wording such as “hit” when a swimmer hits the pool wall during a turn around can focus the mind or repeating a positive phrase during each quarter of a football match helps the athlete remained focused and keeps their mind in the game.

Sports Psychology

Regardless of physical conditioning, an athlete will fail to perform optimally if they believe they are unable to.

Optimal physical conditioning is paramount, but mental preparation for competition is essential!
References

Useful Books

Useful Websites
• Australian Institute of Sport www.ausport.gov.au/ais
• British Nutrition Foundation www.nutrition.org.uk
• English Institute of Sport www.eis2win.co.uk/pages/default.aspx
• Gatorade Sports Science Institute www.gssiweb.com
• International Society of Sports Nutrition http://www.sportsnutritionsociety.org
• Runners World www.runnersworld.co.uk
• Sports Scientists www.sportsscientists.com
• Sports Cardiovascular and Wellness Nutrition http://www.scandpg.org/sports-nutrition/sports-nutrition-fact-sheets/
• NHS Choices http://www.nhs.uk/Livewell/Goodfood/Pages/Sport.aspx