Lecture 1: Carbohydrates

Nutritional Biochemistry: Carbohydrate

- KNOW:
  - CHO, muscle glycogen and performance
  - Types of CHO in the diet
  - CHO intake and health
  - Glycaemic Index (GI)
- **Carbohydrates** are comprised of carbon, hydrogen and oxygen – they provide glucose which is either utilised (fuel for skeletal muscle, CNS, retina) or stored as glycogen
- The primary role of CHO in the body is to provide energy – CHO is the **preferred fuel source** for CNS and also supports high intensity exercise – **glycogen** from starchy CHOs in diet gets stored in muscle and liver (more in muscle, but liver high after meal)
- 1 g of CHO = 4 kCal
- **Glycogen** + **glucose** are critical fuels for high intensity (>50% VO2 max) exercise – **McArdles patients are only able to exercise maximally at 50% that of others**
  - Fat is the main source of energy in low intensity, becomes less important and glycogen more important as you increase exercise intensity. Thus don't want low CHO diet for athletes as they won't be getting high glycogen levels.
  - Fat can only be burned in oxygen, so at high intensity exercise (anaerobic) when glycogen is lost, muscles lose ability → hitting a wall
- Fatigue during prolonged exercise has long been associated with glycogen depletion – **hypoglycaemia → associated with fatigue**
- **Hypoglycaemia** is generally prevented through involvement of endocrine system
- **Increased intensity of exercise – increase in glycogen used** as preferred fuel switches from fat to glycogen (used anaerobically)
- At very high intensity, you get fatigue in minutes
- Increased glycogen intake pre work → increased work you can do
- With 6kg of muscle (e.g. quads), there can be between 90 and 120g of glycogen stored. 2.6mL of water bound to each gram of glycogen – thus with 120g of glycogen, 312 mL of water is stored also → **carb loading increases glycogen, and thus increases water and increases weight, but the heaviness wears off**
- Ingestion of glucose, sucrose and fructose during exercise has been shown to result in higher oxidation rates than when glucose alone is consumed (take advantage of **different carriers**)
  - Carbs are important pre exercise, and then during exercise, athletes consume sugary sports drinks → more effective to use different saccharides, not just glucose
- Limitations to using exogenous CHO during exercise appear due to the rate of absorption – the transporters become saturated
- Max oxidation at consumption of 2.4g/min

CHO ingestion during exercise

- *How does it improve endurance exercise performance?*
- *Does it spare the use of muscle glycogen?*
  - In some cases yes, but only Type 1 slow twitch fibres

- The findings are equivocal – it seems the potential for sparing may be different for running and cycling
- If CHO ingestion does spare glycogen, insulin levels must be high (to promote glucose uptake into cells) – even then, sparing is thought to only occur Type I fibres
- However, CHO ingestion during exercise **does** prevent/delay hypoglycaemia (via sparing of liver glycogen use) and promotes increased CHO use late in exercise

- Some cells (brain nerve cells, retina, RBCs) are **totally dependent** on glucose for fuel – affected in hypoglycaemia ([glucose]<4mmol/L). Symptoms of hypoglycaemia occur in most people when blood glucose levels fall to below 3mmol/L.
    - They can't burn fat as no mitochondria (no aerobic metabolism), so can only use glucose, not produce it
- **Gluconeogenesis:** fructose and galactose are converted to glucose by the liver. In addition, glucose can be manufactured from lactate, pyruvate, glycerol and amino acids – **liver producing new glucose**
- Glucose is stored in liver + muscle cells as glycogen and can also be taken up by fat cells when in excess (stored as fat – as triglycerides). It cannot be converted back to glucose from fat
- 1hr of exercise results in a 50% reduction in liver glycogen
- 15 hours of starvation leads to depletion of liver glycogen, mainly to brain which is why you feel faint

- CHOs generally represent 40-45% of total daily energy intake –**half of calories consumed**
- For an athlete consuming 3000 calories/day, 55-60% from CHO would equate to 1650-1800 calories (400 and 450 grams a day)
- %'s need to be balanced against total energy intake when CHO needs of athletes are considered; athletes who consume large amounts of energy per day may meet their maximal rates of glycogen synthesis with CHO representing only 40% of total energy
- At least 100g (some say 300g) of CHO needs to be consumed daily, otherwise protein stores will be used for gluconeogenesis → breakdown muscle
- 60% of absorbable CHO is in the form of polysaccharides (mainly plant starches) – remainder is mostly sucrose and lactose
- Disaccharide and monosaccharide intake is much higher now than it's been previously as it's more refined (40% of absorbable CHO now vs 25% 100 years ago)
- Sucrose constitutes around 25% of diets in developed countries – it's from **fructose + glucose**
- Interest in fructose was initially related to its potential benefits for diabetics – it is sweet, has low GI and does not require insulin for transport into hepatic cells
    - **Fructose converted to glucose in liver → liver overloaded with fructose + get fat → fatty liver disease due to high fructose consumption**

High Fructose Corn Syrup (HFCS)

- HFCS is produced by processing corn starch to yield glucose, and then processing the glucose to produce a syrup with a higher percentage of fructose
- It was developed in the mid 1960s as an alternative to sucrose
- HFCS provides a high level of sweetness, maintains long-lasting moisturisation in baking products and extends shelf life of many foods and is cheap to produce – important to understand hepatic metabolism of fructose favours lipogenesis

- It's metabolised by liver and long term HFCS intake has been associated with increase in resting VLDL, hypertriglyceridemia, insulin resistance and weight gain → **overload liver with fructose**
- Some have implicated HFCS as a key factor in obesity epidemic – increased intake of HFCS in USA
- However, it cannot be established where or not the relationship is cause and effect
- Also, bear in mind that sucrose is 50% glucose and 50% fructose – so increase in sucrose intake already delivers high levels of fructose to the body.
- HFCS-55 = **42% glucose, 55% fructose + 3% other CHOs**
- HFCS-42 = **53% glucose, 42% fructose + 5% glucose polymers**
- There's a correlation between obesity and HFCS but don't know if it's the cause
- Monosaccharides include glucose, galactose and fructose (*glucose also called dextrose*)
    - Saccharide means sugar or sweet
- Disaccharides include sucrose (fructose + galactose), lactose (glucose and galactose) and maltose (glucose + glucose)
- Polysaccharides have three or more glucose molecules and include glycogen and cellulose
    - Glycogen from **animals** → can't get glycogen from plants
- Glucose polymers generally have 10 or more glucose molecules

Fibre

- Dietary fibre is **that portion of the diet not enzymatically digested by our digestive enzymes and doesn't contribute as a source of nourishment**
    - It's important for health, but NOT for athlete performance
- Fibre includes cellulose + hemicellulose from plant walls, pectins (ground substance of fruits) and gums (white portion of citrus). Most insoluble forms of fibre are cellulose and lignin while most soluble are pectins and gums. *Lignin technically not CHO*
- **Insoluble fibres** pass through entire GIT unmetabolized – **insoluble fibres drag stuff with it + helps get rid of waste, including carcinogens**. They don't lower cholesterol but are important for health of digestive system
- **Soluble fibres** can be metabolised in LI – get swelling as water. Gut bacteria partially break down soluble fibres in our gut and this results in the production of very short chain FAs (which are used by gut epithelial cells) – soluble fibres have been associated with modest decrease in blood cholesterol
- Fibres flattens blood glucose time curve and aids in glucose control – may also bind cholesterol and bile in gut and prevent its reabsorption
    - **Fibre slows absorption of glucose**, and is good because you don't want spikes in glucose.
    - Binding cholesterol decreases bad cholesterol levels circulating
- Also displaces fat intake in diet
- Current average intake of fibre is 15g a day but needs to increase to at least 25g/day for women, 35g a day for men
- **Glycaemic index** reflects the effect a particular food has upon rate and amount of increase in blood glucose concentration in response to an oral glucose load – baseline is 100
    - **High GI –** high blood glucose levels reached quickly
    - **Low GI –** low blood glucose levels and takes longer to reach → lower appearance of glucose in the blood, e.g. fibre rich foods

Sugar and Addiction

- Evolutionarily, sugar (honey, ripened fruit) provide a sensory and reward via neurotransmitters
- Sugar helped lay down fat for periods when food was going to be scarce
- In animals studies, sugar elicits similar neurotransmitter response to those that occur with cocaine – reward for sugar can surpass that of cocaine
- Associated with cravings, bingeing and withdrawal problems

Lecture 2: Fats

Nutritional Biochemistry: Fats

- We consume more than 30% (up to 40) of our daily energy as fat;
  - 1 g of fat = 9kCal of energy
- >15% of total energy intake in form of saturated + trans fats (often in processed food) – **bad fats**
- Major dietary source of fat is triglycerides (95%) with sterols and PLs making up other 5%
- Lipids used in body structures, as fuel and in transport – they are also central to production of some hormones. Hence, they are necessary and not all are bad
- Dietary fat provides fat-soluble vitamins (ADEK)

Saturated Fats

- Short, medium and long chain – they have a full quota of H ions
- Saturated fats associated with rise in plasma LDL concentrations
- Processed foods have high concentration of saturated fats + trans FAs
- *Coconut and palm oils are saturated fats – liquids at RT because short chain fats*

Monounsaturated Fats

- *E.g. oleic (18:1, n=9), eladic and euric (22:1, n=9)*
- Have a single double bond, and can thus take two H
- Foods with other significant monounsaturated fats include oil and avocados → good fats but high calorie amount

Nomenclature

- Number before colon = number of C atoms
- Number after colon = number of C=C bonds
- When double bond furthest from carboxyl group is 3 C from methyl end, belongs to n-3

Unsaturated (polyunsaturated) fats

- The less double bonds there are (i.e. more hydrogens), the harder the fat or oil generally is
- Linoleic (18:2; n-6) – found in vegetables – **omega 6**
- Linolenic (18:3; n-3) – found in some fish – **omega 3 → encouraged**
- Arachidonic (20:4; n-6) – vegetables
- **Linoleic + linolenic** are **essential fatty acids –** need to get from diet
  - They form key components in membranes and are involved in eicosanoid production – active metabolites that inhibit platelet adhesion and dilate blood vessels

- **EPA** (eicosapentaenoic acid) and **DHA** (decosahexaenoic acid) are omega 3 fatty acids found in cold water fish
    - **Cold water fish –** salmon, mackerel, herring, sardines, all contain high [EPA] – *EPA is an antifreeze for fish*
    - Fish get omega 3 from kelp and algae (thus omega 3 originates from plants) – fish farmed on grain have EPA levels not as high
    - **Flaxseed oil** also a good source of omega 3
- Omega 3 FAs influence and reduce clotting in blood
- VLDL production (+ thus cholesterol + TG concentrations) thought to be reduced by EPA
    - EPA may depress cholesterol production at liver + increase LDL receptor numbers

Trans Fats/FAs

- Partially hydrogenated fats or oils have been manufactured to have hydrogen added to some unfilled bonds – fat becomes more saturated and hardens, and this process can result in production of **trans fatty acid** → increased LDL (bad cholesterol)
- **Hydrogenation** of fats changes consistency of oil/fat – most common are **lard + margarine**
- Vegetable oil – may have started as mono or poly unsaturated but could have been purposely hydrogenated: monounsaturated to trans fats (more saturated)
- Trans FAs are **independent risk factor for CVD**
    - Increase LDL (bad cholesterol) and decrease HDL concentrations (good cholesterol)
    - Also trigger endothelial dysfunction, inflammation and promote insulin resistance
    - AEs on CV health worse than those associated with saturated fat intake

Cholesterol

- Sterol only found in animal products, and is not an essential nutrient (produced by liver)
- Also used in producing steroid hormones and Vit. D
- Oxidation of LDL cholesterol has been implicated in development of atherosclerosis + heart disease
- Atherosclerosis is associated with a poor diet over decades, and the build-up of plaque is also due to high blood glucose concentrations → spikes cause inflammation, which contributes to heart disease and blood vessel deterioration
- Could antioxidants consumed in diet reduce risk of heart disease? Vit E supplementation can reduce oxidation of LDL and slow the rate of atherosclerosis (theory is right but practice doesn't work)

Lecture 3: Proteins

Nutritional Biochemistry: Proteins

- Of the 20 AAs required by body, 9 have to be gained from diet
- AA and protein contribute to structure, transport, enzyme function, hormone production, immune function, acid-base balance, fluid balance and energy availability

Biological Value

- **Biological value** is a measure of the proportion of absorbed protein from a food which becomes incorporated into the proteins of the organism's body. It summarises how readily the broken down protein can be used in protein synthesis in organism's cells

Amino Acids + Peptides

- Most vegetable proteins (except soybeans) are short of at least two essential AAs
- Grains and nuts tend to be low in Lys and sometimes Trp
- Legumes tend to be deficient in sulphur AAs – baked beans lack Met and bread has Met but not Lys
- Cereals and legumes are good combination – corn and black beans give you the complete set
- **Dipeptide = 2 AAs**, Tri=3, **Polypeptide = 50-100 AAs**
- **Protein =** >100 AAs, with myosin having over 4500 AAs

Protein and AA Metabolism

- Unlike CHOs and fats, AAs contain nitrogen as well as C H and O
    - Once amino group is removed, remainder of molecule can be metabolised in TCA cycle
    - AA metabolism may contribute 5% of total energy used in prolonged exercise – these AAs generally taken from non-contractile proteins
- During extended exercise, it can promote AA use at the liver if hypoglycaemic when muscles run out of glycogen stores and have to use glucose from gluconeogenesis
- 5-10% of total energy in 2-3 hr event can be from AA (thus important towards the end of exercise when energy balance is offset)
- Most significant outcome of gluconeogenesis using AA is restoration of blood glucose, NOT as a fuel for muscles during exercise → it is used to protect functions such as **brain**

Glucose-Alanine Cycle

- Liver uses Ala and Gln for gluconeogenesis
- **Ala**: non-essential AA, synthesised at muscle, important for gluconeogenesis
    - **Pyruvate + Amino group → alanine**
- After 4 hr endurance exercise, Ala accounts for 45% of hepatic glucose output
- Nitrogen (remnant from AA is toxic → convert to urea, excrete via kidney)
- Ala entering liver has its NH2 group ripped off, and the remaining carbon skeleton used for energy
- Liver releases the glucose produced from alanine into the blood to be used by CNS, or it can also be taken up by exercising muscles