Exercise Physiology
- Preparation and Training Methods

Preparation and Training Methods

Exercise physiology is the response of the body's anatomy and physiology to exercise. It is primarily concerned with how training can be manipulated to maximise performance and maintain an active, healthy lifestyle

Training programmes are designed to meet the specific needs of an individual performer to make sure they can peak in performance at the correct time

Principles of Training (Mr Spov)

The rules that underpin training programme design to ensure safe and effective fitness adaptation

Moderation	Training must be appropriate for the performer to adapt while maintaining a healthy, balanced lifestyle
Reversibility	Training must be maintained to prevent deterioration in performance
Specificity	Training should be relevant and appropriate for the individual, sport, energy system, muscle fibre type and movement pattern
Progression	Training demand should gradually increase over time to ensure the performer adapts and improves
Overload	Training intensity should be above the performers comfort zone to place a stress on the body to force an adaptation
Variance	Training includes a range of exercises and activities to prevent boredom, maintain motivation and limit overuse injuries

FITT Principle

4 components can be manipulated to achieve overload, known as the FITT principle

Frequency	Intensity	Time	Type
How many session per week are performed?	How hard are the sessions, intervals or sets?	How long are the sessions, intervals or sets?	What is the method of training used?

Training Programme

A training programme needs to include test, warm – up and a cool - down

Test	Warm - Up	Cool - Down
Training intensity will be based upon results from an appropriate evaluation test, progression can be monitored by performing mid-programme tests and post-programme tests	Training sessions must begin with a warm-up, pulse-raising activity and mobility exercises will prepare the body for exercise and reduce the risk of injury	Training sessions must end with a cool-down, pulse-lowering activity and stretching will prepare the body for rest and reduces the risk of delayed onset muscle soreness

Periodisation

The organised division of training into blocks, each with a goal and time-frame, each training block is known as a cycle and has a specific goal and time-frame

Aim of Periodisation is to Ensure…

- A performer reaches their physiological peak at the correct time
- They avoid injury and burnout
- Training is structured to give realistic and achieve able goals

- Most athletes and coaches will plan training on a yearly basis for national championships and qualifying races. Each year will have 3 cycles to make training plans specific and achievable

3 Training Cycles

- Macro Cycle – Meso Cycle – Mirco Cycle

Macro - Cycle

A long-term training plan, typically over one year, to achieve a long-term goal

- This aims to achieve a long-term goal, such as a personal best at national championships

- A macro-cycle is broken down into several meso-cycles

Meso - Cycle

A mis-term training plan, typically 6 weeks to achieve a mid-term goal

- This aims to achieve a mid-term goal such as maintaining general fitness over a transition phase
- Each meso-cycle is broken down into several micro-cycles

Micro - Cycle

A short-term training plan, typically 1 week to achieve a short-term goal

- This aims to achieve a short-term goal, such as perfecting the sprint start technique
- Each micro-cycle is split up into a number of sessions, each focusing on a specific unit, such as skill-based practices or flexibility training
- The design of each cycle will depend on the phase of training a performer is in within their year

3 Main Sessions

- Preparatory Phase – Competitive Phase – Transition Phase

Preparatory Phase

The time of year when general sports-specific and skill-based fitness is the focus

Preparatory Phase 1

- During the off-season, general conditioning will be undertaken to develop a base to build on in pre-season, this will consist of aerobic training, mobility training and strength and conditioning

Preparatory Phase 2

- During the pre-season, progressive overload is the focus and intensity of training is increased, sport-specific fitness will be central
- As competition looms, the total training volume will reduce and competition-specific training will take over

Competitive Phase

The time of year to maintain the fitness developed in the preparatory phase, avoid injury and focus on strategies and tactics

Competitive Phase 3

- Training load reduces with periods of lower intensity and adequate rest days to maintain fitness while remaining injury free

Competitive Phase 4

- To achieve peak performance, a process known as tapering may be undertaken

Competitive Phase 3

- Strategies, tactics and game-play will be the focus, although endurance performers will still need high-intensity training to be competition ready

Competitive Phase 4

- 2-3 weeks prior to performance, training load is gradually reduced and relief increased to ensure a performer is fully recovered with maximal fuel stores, training intensity is maintained but volume decreased by 1/3

Tapering

Maintaining the intensity but decreasing the volume of training by 1/3 to prepare for competition

Transition Phase

The time of year for active rest and recuperation

Low – intensity aerobic work will be completed while receiving treatment for injuries
As the preparatory phase approaches training load will gradually increase again and the new year will commence

Aerobic Capacity

The ability to provide and sustain energy aerobically for long periods of time

VO_2 Max

The maximum volume of oxygen that can be taken in and used by the muscles per minute during exhaustive exercise

- A person's VO_2 max will determine endurance performance in sport and is measured in ml / kg / min. It is the expectation that elite athletes can train at 80-85% of their VO2 max

VO_2 Max Depends on

- How effectively an individual can inspire and expire
- How effective the transportation of the oxygen is from the lungs to where it is needed
- How well that oxygen is then used

Factors Affecting VO_2 Max …

- Training – Physiological Make Up – Gender - Age

Training

VO_2 max can be improved by up to 1—20% following a period of aerobic training
Aerobic training will cause long term adaptations to the body including increased respiratory efficiency, levels of haemoglobin and myoglobin

Physiological Make Up / Body Composition

VO_2 max decreases as the percentage of body fat increases
A larger lung capacity and stronger left ventricle will enable a bigger inspiration and increased Cardiac Output and Stroke Volume respectively
Capillarisation will increase the surface area available for gaseous exchange

Gender

A male endurance athlete will typically have a better VO_2 max of around 10 ml kg-1 min-1, this is because the average female is smaller than the average male

Females have a smaller left ventricle and therefore a lower stroke volume, a lower maximum cardiac output, a lower blood volume which results in a lower haemoglobin level and a lower tidal and ventilatory volumes

Age

As we get older our VO_2 max declines as our body systems become less efficient

Maximum heart rate drops by around 5-7 beats per minute per decade
An increase in peripheral resistance results in a decrease of maximal stroke volume
Blood pressure increases both at rest and during exercise
Less air is exchanged in the lungs due to a decline in vital capacity and an increase in residual air.

Aerobic Capacity – Methods of Evaluating

Direct Gas Analysis

An accurate method carried out under laboratory conditions
The athlete runs on a treadmill, to the point of exhaustion, the air that is expired is collected in a Douglas bag

The concentration of oxygen in the expired air is then compared with the percentage of oxygen that is in atmospheric air to see how much oxygen has been used

Advantages	Disadvantages
- Direct measurement of using valid and reliable data - Can control variables in a laboratory which makes it accurate	- Requires access to specialist and expensive equipment - It is a maximal test which require the athlete to work to exhaustion - Cannot be used with the elderly or those with respiratory diseases.

Multistage Fitness Test

The athlete performs a 20 m progressive shuttle run in time with a bleep, to the point of exhaustion. The level reached depends on the number of shuttle runs completed and VO2 max is ascertained from a standard results table

Advantages	Disadvantages
- Can measure large groups at anytime one time - Simple and cheap to administer - Published tables make it easy for comparison.	- Predictive measures are not 100% accurate - Limited by athlete's motivation.Not sport specific

Queen's College Step Test

Involves the athlete stepping up and down rhythmically on a box for 3 minutes, the recovery heart rate is then measured 15 seconds after exercise and used to predict VO_2 max

Advantages	Disadvantages
- Simple and cheap - Heart rate easily monitored - Sub-maximal test	- Predictive measurement only - Not sport specific - Short athletes may have a disadvantage

The Cooper 12 Minute Run

This requires the athlete to run as far as they can in 12 minutes and the distance covered is recorded and compared to a standardised table. In this test the performer runs to exhaustion

Advantages	Disadvantages
- Simple and cheap - Large groups can be catered for - Can administer own test.	- Predictive measurement only - Limited to subject's motivation - Not specific to a sport.

Aerobic Capacity – Training Methods

Continuous Training

This type of training involves a steady but regular pace at a moderate intensity (60-80% of max HR) which should last for at least 30 minutes

Activities can includes running, walking, swimming, rowing or cycling and is used by endurance performers. Many distance runner will cover up to 100 miles per week

High Intensity Interval Training

This type of training involves repeated bouts of high intensity effort followed by varied recovery times. These short, intense workouts will improve aerobic capacity

A typical HIIT session will include; Exercise intensity – 80-95% of max HR, 1:1 work to rest ratio

HIIT can be modified for different athletes of varying abilities
Cyclists and swimmers use it as a cross training method to add variance to a programme

Aerobic Capacity – Calculating Intensities

Maximum Heart Rate (MHR) = 220 – age

Then you need to work out a certain percentage of the maximum heart rate using the **Karvonen Principle**

Karvonen Principle

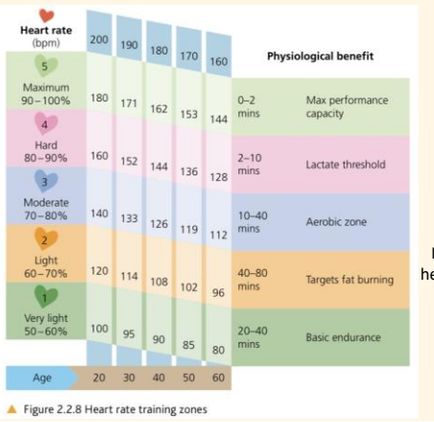

Figure 2.2.8 Heart rate training zones

The Karvonen Principle is more accurate than other methods as it takes into account performers age and resting HR (indicating their fitness level)

Karvonen Formula ;
training HR = resting HR + % (max HR – resting HR)

It is suggested a training intensity of 75% of maximum heart rate therefore a 25 year old (resting HR = 60bpm) should work at:

60 + 0.75 X (195-60) = 60 + 101 = 161 BPM

Physiological Adaptations

Aerobic exercise increases VO_2 max due to the following physiological changes that take place…

Cardiovascular System

- Cardiac hypertrophy – causes an increased maximum cardiac output (at rest) and stroke volume (at rest and during exercise) Decreased rest heart rate
- Increased elasticity of arterial walls – increased efficiency of vascular shunt (vasoconstriction and vasodilation of vessels)
- Increased blood volume and red blood cells count – lower blood viscosity which aids venous return and oxygen carrying capacity
- Increased capillarisation – increased gaseous exchange

Muscular – Skeletal System

- Increased slow oxidative muscle fibres – increase potential for aerobic energy production
- Increased density and size of mitochondria – increased ability to utilisation oxygen
- Increased stores of myoglobin – increased storage and transport of oxygen to the mitochondria
- Increased strength of connective tissue including cartilage – increased joint stability to decrease the risk of injury
- Increased stores of glycogen and triglycerides – increased availability of aerobic energy fuels

Respiratory System

- Stronger respiratory muscles – increases efficiency of breathing mechanics (increased maximum lung volume)
- Increased surface area of alveoli – increases gaseous exchange

Metabolic System

- Increased concentrations of oxidative enzymes – increased metabolism of glycogen
- Decreased fat mass – an increase in lean mass with increase metabolic rate and breakdown triglycerides more readily
- Increased insulin resistance – improved glucose tolerance

Strength Training

The ability to exert a large amount of force in a single maximum effort

Dynamic Strength

This type of strength involves movement used in events that take a long period of time to complete, it is associated with power

Static Strength

Takes place when the muscle length stays the same, it is used to stabilise the body

Explosive/Elastic Strength

This type of strength comes about when a burst of maximum effort is required

Maximum Strength

The greatest force that is possible in a single maximum contraction, this is shown with a 1 repetition maximum test

Strength Endurance

This is the ability to sustain strong repeated muscular contractions whilst withstanding the fatigue

Factors Affecting Strength

- Muscle Fibre Type – Cross Sectional Area – Age - Gender

Muscle Fibre Type	Cross Sectional Area
The greater the number of Fast Glycolytic and Fast Oxidative Glycolytic fibre types the greater the strength Large motor units recruit more fast twitch fibre with each contraction	The great the cross-sectional are the greater the strength The more force per square cm of muscle the stronger the force produced
Age	**Gender**
Strength development peaks around 20-30 years of age and then decreases with age This is due to a decreased efficiency in the neuromuscular system and testosterone count	Males generally have a higher strength than women due to higher testosterone levels

Strength Training – Methods of Evaluating

Grip Strength Dynamometer

Measures the strength of the performer hand grip strength in one action

Advantages	Disadvantages
- Simple and easy to measure - Cheap to administer - Produces reliable data to compare with others	- Only the muscles in the forearm are used - Test is not sport specific

One Repetition Maximum Test (1RM)

This test measures the maximum strength of various muscle Groups

- Athlete should attempt to perform one full repetition of the stated exercise at the highest possible weight
- Increase the weight until only 1 repetition is possible
- The weight should be recorded

Advantages	Disadvantages
- Easy procedure to follow - Equipment is accessible - Direct measurement of the muscle group is isolated	- Trial and error at manageable weight can cause fatigue - Good technic is essential - Potential for injury is high

Press Up or Sit Up Test

This test measures strength endurance where the individual continuously performs press ups or sit ups

- Athlete performs as many sit ups as possible to the point of exhaustion

Advantages	Disadvantages
- Large groups can complete the test at any one time - Simple and cheap equipment required - Valid test with normative values to compare to	- Good technique is a necessity - Can be limited by subjects motivation levels - Not sport specific

Vertical Jump Test

The performer must use power in the legs to generate height

Advantages	Disadvantages
- Simple and cheap equipment is needed - Test can be administered by the participant - Formula used to calculate power output	- Test not isolated to one muscle group - Only measure the explosive power in the legs

Strength Training – Training Methods

Training guidelines for maximum, explosive and endurance strength are below…

Strength Type	% OF 1 RM	Reps	Sets	Work : Rest ratio	Rest Time
Endurance	50 – 70 %	20 - 25	5 - 7	1:2	45s – 1m
Explosive	75 – 85 %	7 - 10	4 - 6	1:3	4 – 5 mins
Maximum	85 %+	1 - 5	2 - 4	1:5	5 mins +

Weight Training

This is a form of training that uses progressive resistance against a muscle group

Free weights can help to isolate the muscle and build strength and help posture and alignment.Free weights can be potentially dangerous and often a 'spotter' can be used to offer assistance

Plyometrics

This method of strength training involves a series of explosive exercise performed at speed

Plyometrics exercises cause the muscle to lengthen (eccentric action) before a maximal muscle shortening (concentric action)

Circuit

A series of exercise stations completed one after another working multiple muscle groups

Each station should work a different area of the body to avoid fatigue. Circuits are mainly associated with improving strength endurance but is easily adaptable.Circuit training can be made specific by using skills from your chosen sport

Physiological Adaptations

Muscle & Connective Tissues	Neural	Metabolic
• Muscle hypertrophy – this increase in muscle size will increase force of contractions • Muscle hyperplasia – increased number of muscle fibres Particularly increases in FG and FOG fibres • Increased strength of tendons and ligaments – this will increase joint stability	• Increased recruitment of motor units – this improved stimulation of motor neurones will increase contraction force • Increased effect of the stretch reflex – increases the force produced by the agonist	• Increased ATP, phosphocreatine and glycogen stores – increased capacity for rapid energy production • Increased buffering capacity – increased tolerance and removal of lactic acid, delayed OBLA • Increased muscle mass.

Flexibility Training

The range of movement at a joint

Also known as suppleness refers to the ability of the muscles to stretch and then return to their original position. It is important for athletes such as gymnasts but also for reducing the risk of muscles strains and injuries

Static Flexibility

The range of motion around a joint without movement it can be active or passive

This is stationary

Active Flexibility	Passive Flexibility
The performer works on one joint, pushing it beyond its point of resistance (lengthening the muscles)	The stretch occurs with the help of an external force, such as a partner, gravity or a wall

Dynamic Flexibility

Involves a range of motion around a joint with speed of movement
e.g a javelin throw

This is moving

Factors Affecting Flexibility

- Type of Joint – Length of Surrounding Connective Tissue – Age - Gender

Type of Joint	Length of Surrounding Connective Tissue
Ball and socket joints have a shape than allows a greater range of motion than others	The greater the length around the muscles, tendons and ligaments the greater the range of motion
Age	**Gender**
Younger individuals are more flexible than older people. The lost in connective tissue elasticity increases over time	Females are generally more flexible than males. This is due to higher levels of oestrogen and relaxin in the body. These are key to tissue elasticity

Flexibility Training – Methods of Evaluating

Sit and Reach Test

Measures the range of movement at the hips/torso

- Legs straight with feet touching the box
- Push marker as far as possible without bending your knees
- The hold must be held for at least 2 seconds

Advantages	Disadvantages
- Simple and easy to measure - Cheap to administer - Produces reliable data to compare with others through normative tables	- Only measures flexibility in the lower back and hamstring - Must be sufficiently warmed up or can be dangerous - Test is not sport specific

Goniometry

A goniometer is used to measure the range of motion of various joints around the body

- To measure the range of motion at a joint, the centre of
- The goniometer is positioned at a joint, and the arms of the goniometer are aligned to the bones
- The difference in joint angle is taken from starting position to full range position

Advantages	Disadvantages
- Simple and easy to measure - Accurate - All angles and joints are accessible and measurable	- Can be difficult to place accurately on some joints in the body - Training is required to get an accurate reading

Flexibility Training Methods

Flexibility should be involved in all training programmes as there are both health and performance related benefits

Static Stretching

Involves lengthening a joint and surrounding ligaments and muscles to a point of resistance and holding it for 15 – 30 seconds

There are 2 types of static stretching…

Active Stretching	Passive Stretching
The performer moves the joint into a position without any external force	The stretch occurs with the help of an external force, such as a partner, gravity or a wall

Isometric Stretching

This involves contracting the muscle isometrically (no movement) while holding a stretch position, this creates a greater stretch to the already extended muscle groups

It does carry a high risk of injury to the nature of the stretches

Ballistic Stretching

Involves performing a stretch with swinging or bouncing movements to push a body part even further

Proprioceptive Neuromuscular Facilitation (PNF)

Where the muscle is contracted isometrically for a period of at least 10 seconds, it is then relaxed and stretched again, usually going further subsequent times
The aim is to desensitise the stretch reflex to increase the range of motion

PNF stretching is often used in rehabilitation programmes, it must be performed by trained individuals or injury can occur

Dynamic Stretching

This stretch involves taking the joint through a full range of movement under full control, this includes walking lunges and side squats

This is more controlled than ballistic stretching and does not go to the extreme ends of a stretch and normally forms a part of a warm up

Flexibility Physiological Adaptations

Flexibility training can take up to 6 weeks to see results but will increase the body's ability to produce fast and powerful contractions

Muscle and Connective Tissues

- Increased elasticity – this will increase the potential for static and dynamic flexibility
- Increased joint resting length – muscle spindles adapt to the increased length and reduce the stretch reflex stimulus

Training and Lifestyle Diseases

Physical activity is essential to a healthy lifestyle and can prevent many diseases and conditions

Cardiovascular System : Coronary Heart Disease (CHD)

This is caused from atherosclerosis (a build up of fatty deposits that form on artery walls) It slowly narrows the lumen and reduces the ability of blood to flow easily through the vessels

As a result blood pressure builds up and the likelihood of blood clots are increased.CHD is a disease which can lead to heart attacks

Heart Attack

This is where a piece of fatty plaque can break away from the artery walls and block the coronary artery which results in it cutting off the oxygen supply to areas of the cardiac muscle

Stroke

A stroke is a blockage in celebral artery cutting off the blood supply to the brain or through a blood vessel bursting on the brain

A stroke is one of the largest causes of death in the UK

Sedentary Lifestyle

Leading a sedentary lifestyle can contribute to many preventable causes of death and a major risk factor for cardiovascular diseases

Regular physical exercise or training will:
- Reduce the levels of blood lipids and cholesterol
- Increase the proportion of High density lipoprotein (HDL) to LDL (bad cholesterol):

Good Cholesterol

This carries cholesterol away from arteries to the liver to be removed from the body
e.g. Fruits, Vegetables and Grains

Having good cholesterol is important as…

- Prevent the hardening and loss of elasticity of artery walls which slow the development of atherosclerosis
- Decrease blood thickness and prevent blood clots
- Improve blood flow around the heart
- Decrease body fat and manage weight which places less strain on the heart
- Improves the efficiency of the heart and lowers blood pressure.

Respiratory System

Respiratory disease affect the airways, lungs and alveoli causing breathings difficulties and even death

Asthma

When the airways are constricted due to inflammations

Symptoms include shortness of breath, wheezing and coughing caused by an irritant

Asthma can be induced by exercise when the air is cold and dry and is relieved via an inhaler
Sufficient warm ups and respiratory muscle training can also limit the effects of asthma

Chronic Obstructive Pulmonary Disease

This is the term for conditions where the airways become inflamed and narrow
e.g chronic bronchitis and emphysema

Over time the inflammation lead to mucus production, damage to the alveoli and bronchiole walls

Benefits of Exercise

Regular physical exercise or training will improve quality of life and can…

- Increase strength in the respiratory muscles
- Decrease the frequency of breathing making everyday task easier
- Increase strength of inspiratory muscles which increases air flow and reduce the chances of breathlessness
- Maintain lung tissue and the elasticity properties
- Increasing the surface area of alveoli maximising gaseous exchange.