Teacher Guide

Practical science exploring the mind and body in motion

Ages 11–19

www.getinthezone.org.uk
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www.getinthezone.org.uk
Welcome to the In the Zone experiments for secondary schools

In the Zone is the Wellcome Trust’s major UK-wide initiative inspired by the London 2012 Olympic and Paralympic Games. It provides a fun, free and fascinating way to discover how our bodies work during sport, activity, movement and rest.

In the Zone has the London 2012 Inspire Mark and is part of Get Set+, the official London 2012 education programme, run by LOCOG, the London Organising Committee of the Olympic Games.

To be a top sportsperson you need to be in the zone both mentally and physically. When I competed at the Olympics I had a huge team around me; including top scientists who helped me to understand how I could perform to be the very best that I could be.

This In the Zone kit has been designed to inspire children to get in the zone and find out more about how their bodies work. I hope you enjoy using it in your school.

Sir Steve Redgrave CBE
In the Zone Ambassador and five times Olympic Gold Medallist

What are the major elements of In the Zone?

• Free science investigation kits for schools
A box of physiology-related experiments delivered to every UK school, supported by exciting scientific equipment and teaching resources, containing everything you need, including this Teacher guide, to teach practical investigations.

• Touring exhibition
Engaging people of all ages with the science of our amazing human bodies relating to sport and movement. The In the Zone exhibition will tour the UK over summer 2012. Check www.getinthezone.org.uk for tour dates.

How are the In the Zone experiments organised?

The In the Zone experiments for 11–19 year olds are divided into three age ranges:

1  Ages 11–14 – On your marks... get set... breathe
Students use lung volume bags, peak flow meters and pulse oximeters to explore how their lungs work. They will collect and compare results in order to find out how different activities affect their breathing.

2  Ages 14–16 – From strength to strength
Students carry out a range of experiments investigating their muscle size, strength and endurance. They will analyse their results to explore questions such as whether fatiguing one set of muscles impacts the performance of different muscles.

3  Ages 16–19 – I’ve got the power
In these experiments students investigate how their bodies use ATP for muscle contraction and movement. Using respirometers, pulse oximeters and blood pressure monitors they will explore the physiological effects of exercise on their bodies.
For each age range in this Teacher Guide you will find the following:

- **Introduction** by a scientist who will set the context for the experiments.
- **Lesson plans** giving you an at-a-glance overview of the lessons and the experiments and what you will need to run them.
- **Teacher sheets** followed by **student sheets** containing the experimental protocol for each experiment.
- **Technician notes** covering all the experiments for the age range.

**What other resources are in the kit box?**

The box contains exciting scientific equipment you will need to run the experiments. (See page 6 for a list of kit supplied and what to do if you need to order more of any item.) You may need a few other pieces of equipment such as stopclocks but these should be readily available in your school. They are indicated on the teacher sheets for each experiment and technician notes for each age range.

All the equipment in the kit box is labelled so that you know which experiment each piece of kit is for.

You may notice that two items of kit (pulse oximeter, and tape measures) need to be used in experiments in more than one age range so some coordination is required between teachers planning these experiments.

In the box you will also find:

- **Laminated Knowledge Cards**, one set for each age range. These cards give context to the lesson and can be used as stimulus material with your students.

- **Curriculum Matching Charts** The In the Zone kit box has been delivered to all schools in England, Northern Ireland, Scotland and Wales. We have provided full curriculum references to each of these countries’ curricula on a separate curriculum guide, so that you can see how the experiments fit into your teaching plans and schemes of work.
What resources are on the In the Zone website?

The In the Zone website is packed full of extra resources to help you run the experiments successfully and engage your students in a memorable experience: www.getinthezone.org.uk.

On the website you will find:

- ‘Live Data Zone’ where students can upload data they have gathered from the experiments, to allow them to interrogate and analyse the data, and to let them compare their results to other students’ across the UK.
- **PowerPoints** to use as front-of-class stimulus material during the lessons, including photos, and ideas for starters and plenaries.
- **Photos** and information on the different experts, scientists and sportspeople who are referred to throughout the resources.
- **Editable Word files** of the teacher and student sheets contained in this guide, so you can customise them to suit the needs of your classes.
- **PDFs** of the Knowledge Cards.
- **Editable certificates** as rewards for student effort/performance.
- **Further links** and support, to help your teaching.

**Sharing and reusing the resources**

In the Zone resources are, unless otherwise stated, licenced under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 UK:England And Wales License. **This means that you can copy, share and adapt the materials as much as you like, as long as it is not for commercial use. When adapting lessons, however, please carry out your own risk assessments.**

Where material is owned by a third party, e.g. some photographs, certain restrictions may apply that you have to comply with. In particular, where a copyright line is included on a photograph you must not modify, adapt, or remove that photo from its context.

**How are the experiments linked to contemporary science?**

In the Zone gives students a real taste of scientific investigation. Each age range is introduced by a different physiologist who will explain the importance of understanding how our bodies work. They will show how the experiments relate to real-life scientific experiments and investigations being carried out by scientists and sports scientists. The materials also feature other experts including sportspeople, sports psychologists and trainers. These experts will show students how the experiments not only help them understand how their bodies work but also how they relate to the real world of sport training and performance.

**How do the experiments fit into my lessons?**

Many of the experiments require students to take part in physical/sporting activities. You may like to work with your PE department to run the activities, as many could be carried out in the gym or outside as well as in the science classroom. Working with your PE department will allow you to share running the experiments and students will be able to reinforce their learning in both their PE and science lessons.

As the students will be working in groups, some may prefer to take measurements or time the activities, plot graphs, etc., rather than take part in the physical/sporting activities themselves.
The resources are very flexible and can be adapted to fit in with your own particular school and students. Ultimately you can decide how many experiments you wish to run during any given lesson, but it is envisaged that each suite of experiments would last for three one-hour lessons:

- **Lesson 1**: introduction to In the Zone and whole class doing Experiment A.
- **Lesson 2**: a carousel of experiments B-D.
- **Lesson 3**: upload of data to the website, evaluation of results and extension questions.

**How can my students compare their results with other students’ results from across the UK?**

Students can upload their results to the interactive ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk). This is a real ‘How Science Works’ experience for your students, allowing them to interrogate national UK data, find patterns and explore hypotheses. Of course, as with any scientific research, the need for standardisation is crucial, so students should follow the experimental protocols as closely as possible to ensure reliability of the data.

**How do I differentiate the experiments for my students?**

All primary learning objectives have been set so as to be accessible by all students. Within each class, if there are keen, interested or gifted and talented students there are opportunities to extend the activity. They can use the extension questions in Lesson 3, explore links to contemporary science or find out about current research that is taking place in sports physiology, sports psychology and engineering that link with the experiments. These ideas are given in the PowerPoints on the In the Zone website (www.getinthezone.org.uk).

**How can I link the experiments to sport and use the resources post-2012?**

Links to the London 2012 Olympic and Paralympic Games are included in the PowerPoints and laminated Knowledge Cards. You can add more depending on the interests of your students and news about London 2012. The kit can also be used in the context of other sporting activities all year round, as well as non-sport activities like dance and yoga, so it should be possible to keep the interest of the less sports-inclined students and to ensure that the experiments and the kit remain relevant beyond 2012.

**What about the safety of the experiments?**

All the experiments have been safety checked but the responsibility for how they are run rests with your school. You must carry out a risk assessment before running any of the experiments. Please read the safety notes on pages 7–9 and 114 and on the individual teacher sheets before you start the experiments. Chemical safety sheets for the hazardous substances used in the investigations are available on the In the Zone website. Further safety information can be found at www.cleapss.org.uk and www.sserc.org.uk.

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**Measuring blood pressure.**

**Measuring peak flow.**

www.getinthezone.org.uk
# Kit box list

Please use the checklist at the top of the kit box to check that all items are present. If any item of kit or printed material is missing, please contact Pearson Customer Services, Telephone number +44 (0) 845 313 6666 or email inthezone@pearson.com. If you wish to order more of a particular item, please contact Scientific and Chemical Supplies Ltd quoting the catalogue details below for the kit (Tel: 01902 402402, email customerservices@scichem.com; website www.scichem.com).

<table>
<thead>
<tr>
<th>Kit name</th>
<th>Quantity in the kit box</th>
<th>Experiment</th>
<th>SciChem catalogue no.</th>
<th>Quantity available for reorder</th>
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<td>2</td>
<td>11–14 Experiment B</td>
<td>YHP400010</td>
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<tr>
<td></td>
<td></td>
<td>16–19 Experiments B and D</td>
<td></td>
<td></td>
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<td>YHP090010</td>
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<td>Lung Volume Bags</td>
<td>4</td>
<td>11–14 Experiment D</td>
<td>YHP174010</td>
<td>4</td>
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<td>100 disposable mouthpieces for Lung Volume Bags</td>
<td>100</td>
<td>11–14 Experiments C and D</td>
<td>YHP094010</td>
<td>100</td>
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<tr>
<td>and Peak Flow Meter</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 Elastic Bands</td>
<td>1</td>
<td>11–14 Experiment D</td>
<td>EMZ120010</td>
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<tr>
<td></td>
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<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td>14–16 Experiments A, B, C and D</td>
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<td></td>
<td></td>
<td>16–19 Experiment B</td>
<td></td>
<td></td>
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<td>14–16 Experiment C</td>
<td>CA050</td>
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<td>lengths of hard tubing</td>
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<td></td>
<td>TPC020020</td>
<td>30 m</td>
</tr>
<tr>
<td>lengths of flexible tubing</td>
<td>6</td>
<td></td>
<td>RTS 030130</td>
<td>20</td>
</tr>
<tr>
<td>bungs</td>
<td>6</td>
<td></td>
<td></td>
<td>Not available for reorder</td>
</tr>
<tr>
<td>2-litre plastic bottle</td>
<td>1</td>
<td>16–19 Experiment C</td>
<td>$00418</td>
<td>(drinks bottles can be used)</td>
</tr>
<tr>
<td>one-way valves</td>
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<tr>
<td>Bromothymol Blue (solid 5 gram in plastic container)</td>
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<td>16–19 Experiment C</td>
<td>BR130</td>
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<td>1</td>
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</table>

www.getinthezone.org.uk
How to use the equipment in the box

These instructions are supplied as a summary – please refer to the detailed manufacturers’ instructions supplied with the individual pieces of kit. We advise that you read the separate sheet of general safety information on page 114 of this guide.

Pulse Oximeter

The pulse oximeter allows you to measure both percentage oxygen saturation in arterial blood and pulse rate.

- Do not use the oximeter in the presence of flammable mixtures.
- Avoid contact with water or extreme moisture, avoid storing where there is high dust content or chemicals, and shield from external light sources.
- The oximeter should be handled with care to avoid shocks and falls.
- When the oximeter is in use, ensure that the batteries have sufficient capacity.

- Don’t use pointed objects such as pens or nails to press the buttons, as permanent damage may be caused.
- Any nail varnish including clear should be removed as it may distort the values given.

Battery installation

- Push the battery cover, the blue panel on the underneath of the pulse oximeter, horizontally away from the white section.
- Install the two AAA cells with polarities correct, otherwise damage might occur.
- Batteries should be removed if the oximeter won’t be used for some time.
- Don’t use lithium cells, as they may damage the oximeter.
- Don’t mix different types of cell, e.g. zinc chloride and alkaline.

Operation

- Press the white function button on the front panel for about 1 second and then release it to turn the pulse oximeter on. The oximeter automatically switches off when there is no signal for more than 3 seconds.
- Press the top of the pulse oximeter where it is labelled PUSH and insert one finger fully into the opposite end before releasing the end marked PUSH. The nail surface must be inserted so it is upward.

Measuring blood oxygen level and pulse rate.

- Put your lower arm and hand on a flat surface and wait for the readings on the pulse oximeter to become steady. You should wait approximately 10 seconds before taking any reading. Keep still during this time.
Peak Flow Meter
The peak flow meter measures peak flow – the maximum speed of air that a person can generate through a forced exhalation.

Operation
• The mouthpieces are for single person use only, so each student must use their own marked mouthpiece.
• Students should stand to take their readings.
• The pointer should be moved to the end of the slot nearest to the mouthpiece, below the 60 l/min mark, before students take their readings.
• The peak flow meter should be held so that fingers are clear of the pointer and slot.
• To measure peak flow students should take a deep breath in, place the peak flow meter in their mouth holding it horizontally, and close their lips around the mouthpiece. They should then blow as hard and as fast as possible into the peak flow meter.
• Students should note the number on the scale indicated by the pointer.
• After taking the reading, students should return the pointer to the starting position and repeat the procedure twice more.

Measuring peak flow.

Lung Volume Bag
The lung volume bag measures the capacity of the lungs (tidal volume and vital capacity).

Assembly
• The mouthpieces are for single person use only, so each student must use their own marked mouthpiece.
• Although disposable mouthpieces are being used any student with a cold should either not do their measurement or take their measurements after all the other students.
• Students should insert their mouthpiece halfway through the opening of the volume bag and secure it with a rubber band, twisting it four times.
• While sitting, students should hold the bag on their knee and press a paper towel against it to force the air out of the bag. They should start with the sealed end and push the air out toward the mouthpiece.

Assembling the lung volume bag.
Measuring tidal volume

Expiratory tidal volume is the volume of air that is moved during one inhalation and exhalation when breathing normally.

- Students should take a normal breath in through their nose and take a normal breath out into the lung volume bag mouthpiece. Students should practise this technique before starting the measurement. For the measurement it is recommended that students do this for five complete breaths in order to get a measurable amount of air in total. Students with a particularly large tidal volume may fill the bag with five breaths so the number should be adjusted accordingly for such students. Likewise those students who have a particularly small tidal volume may need to complete 10 breaths into the bag.

- Once students have finished breathing into the bag they should hold the bag at the top, close to the mouthpiece and twist it around so that none of the air can escape.

Measuring vital capacity

Vital capacity is the size of your lungs – the maximum amount of air that you can exhale after breathing in the maximum amount of air you can.

- Students should remove all the air from the lung volume bag by sliding the paper towel along its length from the sealed end towards the mouthpiece.

- Students should breathe in the largest breath possible and breathe out as much air as possible into the lung volume bag through their mouthpiece.

- Once students have finished breathing into the bag they should hold the bag at the top, close to the mouthpiece, and twist it around so that none of the air can escape.

- While sitting, hold the bag on the knee and slide a paper towel along the bag to push all the air to the end and measure the volume of air it contains. (The bag has litre and 1/10 litre graduations.)

- Students can remove all the air from the lung volume bag by sliding the paper towel along its length from the sealed end towards the mouthpiece.
**Respirometer Kit**

The respirometer kit can be used to measure the amount of carbon dioxide in exhaled air, at rest, and after exercise.

**WARNING:** Students must take great care that they only breathe out into the respirometer and do not breathe in to avoid ingesting the bromothymol blue solution.

In the kit box you will find equipment for the respirometer kit:
- 1 x 2-litre plastic bottle
- 6 x bungs
- 6 x lengths of hard tubing
- 6 x lengths of flexible PVC tubing
- 6 x one-way valves
- 5 mg of bromothymol blue
- 100 ml of 0.1 M sodium hydroxide solution
- 6 x pipettes

For more than one station in the carousel of experiments, you will need to supply up to 5 x 2-litre plastic bottles. Make up the bungs with the hard and plastic tubing and non-return valve inserted as in the respirometer kit assembled for you in the kit box.

See the Technician notes on page 107 for how to make up the bromothymol blue indicator solution.

Carbon dioxide is acidic and will gradually turn the bromothymol blue/sodium hydroxide solution from blue to green at neutral, then yellow. If a known amount of sodium hydroxide is added before any carbon dioxide then you can get an estimation of how much carbon dioxide is breathed out because 2 moles of sodium hydroxide are required to neutralise 1 mole of carbon dioxide.

\[
\text{CO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}
\]

Have two test tubes containing bromothymol blue solution for students to use for colour comparisons. If you then add a drop of a weak acid to one tube, they can see the colour change from blue to green at pH 7. They will be looking for the green colour, to show when the carbon dioxide in their breath has neutralised the sodium hydroxide added to the indicator solution. Students can also refer to the indicator charts supplied in the kit box. The charts are for universal indicator but both indicators change to green at pH 7.

You will need enough bromothymol blue solution to refill the respirometers three times (at 500 cm³) per group, and enough 0.1 M sodium hydroxide solution to add 5 cm³ to each respirometer of bromothymol blue per group.

*Respirometer kit.*

*Using a pipette to measure the volume of sodium hydroxide solution.*
Blood Pressure Monitor

The blood pressure monitor measures systolic and diastolic blood pressure as well as pulse rate. The systolic blood pressure is the maximum blood pressure during a heart beat and the diastolic blood pressure is the minimum blood pressure during a heart beat. Pulse rate is the number of heart beats per minute.

WARNING: Great care must be taken not to overinflate the cuff as this could cause pain and/or injury (burst blood capillaries).

Please refer to the manufacturer’s instructions.

Battery installation

- Remove battery cover on the underneath of the monitor by gently pulling up the battery cover panel.
- Place 1 AA (1.5 volt) cell in the compartment with positive (+) and negative (−) terminals matching those indicated in the compartment.
- Replace cover by sliding it into the compartment and gently pressing into place.
- Rechargeable batteries will not work with this monitor.

Cuff size and position

- Using the correct cuff size is important for an accurate reading. The correct cuff size is printed on the fastening of the cuff with markings to show when a smaller or a larger cuff is needed. The cuff size provided will be suitable for most 16–19 year olds.
- Students should remove constricting clothing and place the cuff on the bare left arm.
- Students should sit comfortably with their left arm resting on a flat surface so that the centre of their upper arm is at the same height as their heart.
- They should lay their left arm on the table, palm up, and thread the cuff end through the metal loop, smooth side against the arm. Then they should position the tube offcentre toward the inner side of the arm in line with the little finger.
- Students should pull the end of the cuff to tighten it, fold back the extra material, and fasten securely. The cuff should be snug but not too tight. They should be able to insert two fingers between the cuff and their arm.

Operation

- Students should relax for at least 5 minutes before taking a reading.
- Students should not cross their legs and should keep their feet flat on the floor during measurement.
- When the cuff is in the correct position press the START button (blue/grey button in the bottom right corner of the monitor). Students’ average blood pressure reading will appear with the number of measurements stored in memory and a flashing Λ symbol, indicating that the monitor is ready for measurement.
- If the V symbol is displayed continuously, the cuff has some air trapped in it. Press the exhaust valve button until the Λ symbol is displayed. You may have to press on the cuff while holding the exhaust valve to release all the air in the cuff.
- When the Λ symbol is displayed flashing, begin cuff inflation by squeezing the inflator bulb repeatedly and continuously until the Λ symbol disappears, this may take a few seconds.
- Stop squeezing the inflator bulb when the Λ symbol disappears or until cuff pressure reaches about 30 mm Hg to 40 mm Hg above expected systolic pressure.
- When the correct pressurisation has been reached, the automatic exhaust mechanism will gradually reduce the pressure in the cuff. Sit quietly during measurement. The ‘heart’ symbol will blink with your pulse beat.
- If students wish to stop inflation at any time, they should press the exhaust valve to release the pressure in the cuff.
- After students see the measurement results displayed on the screen, they should press the exhaust valve to release the excess air from the cuff.
- If students move their arm before pressing the exhaust valve, the result on the screen will be deleted.
- The monitor shuts off automatically in about 30 seconds. Students can also press the START button (blue/grey button in the bottom right corner of the monitor) to shut off the monitor.
- Allow at least 5 minutes between measurements on the same student.
How does exercise affect my breathing?

On your marks… get set… breathe is a group of experiments all about breathing and lung function.

Hi, I’m Professor Alison McConnell from Brunel University’s Centre for Sports Medicine and Human Performance. We all know that breathing is vital for everyday life but these experiments will allow your students to explore their own lungs and breathing, as well as gain some insights into how breathing can affect sporting performance. They will measure their own breathing rate, peak flow, expiratory tidal volume, vital capacity, and arterial oxygen saturation, as well as pulse rate, using exciting scientific equipment. In my job, I study breathing in athletes, and I have researched the effects that breathing training can have on sporting performance.

Training breathing

Since ancient times, sports performers have exercised their muscles by lifting weights to help them to jump higher, run or swim faster, and throw further. Because breathing muscles are active all the time, it was always assumed that these muscles were at the peak of fitness. However, in the last 10 years athletes have found that training their breathing muscles also helps to improve their performance.

One of my research studies found that after 6 weeks of breathing muscle training, cyclists were able to improve the time it took to cycle 40 km by more than 2 minutes (4.6%)\(^1\). In competitive terms this is a huge advantage, so it’s worthwhile finding out more about our breathing and how it changes with exercise.

Asthma

One reason that some students may already know about their breathing is if they have asthma. They may not, however, know that asthma is more common in athletes than in ordinary people\(^2\). The reason for this is not fully understood, but it may be due to the amount of vigorous breathing that athletes undertake in training and competition. Asthma can be controlled extremely well with medication and is no barrier to performing well in sports.

Two of the fastest marathon runners of all time both have asthma: Paula Radcliffe and Haile Gebrselassie.
Breathing and sport

Breathing is also important in sports such as archery where precision is crucial. Any type of movement, including the act of breathing in and out, can affect an archer’s aim and can mean the difference between a winning and a losing shot. Archers practise ‘Zen breathing’ where they learn slow and deep breathing. Archers breathe in and take aim, then release the arrow. They hold their breath to steady their body as they do this and then let out their breath.

Consider how much harder this breath control is for athletes competing in the sport of biathlon. They must ski at full speed for prolonged periods, and must then shoot a rifle at a tiny target, trying hard to control their breathing as they do so! Another activity where breathing can have a negative impact on performance is dance. In dance, the breathing muscles are involved in both breathing and movements of the upper body. This means that the dance movements can interfere with breathing and vice versa, so dancers must control their breathing so that it is coordinated with their movements.

I hope that you and your students enjoy the ‘On your marks... get set... breathe’ resources. Don’t forget you can upload some of the students’ own results to the In the Zone website at www.getinthezone.org.uk. I look forward to seeing your results. Show your students the 11–14 Knowledge Card to show them the link between the experiments and contemporary science.

---


**Resources**

**From the kit box:**
- 2 pulse oximeters
- 2 peak flow meters
- 4 lung volume bags
- disposable mouthpieces
- elastic bands
- tape measures
- Teacher Guide
- Knowledge Cards.

**From the school:**
- stopclocks
- paper towels

**optional:**
- metronome or pop music and music player
- running track/field
- skipping ropes
- stadiometer.

**From the website**

www.getinthezone.org.uk
- ‘Live Data Zone’ section of the website for upload and interrogation of data
- PowerPoint for the lesson
- editable Word files of teacher and student sheets and lesson plans
- editable certificates for student effort/performance.

**Learning objectives**

At the end of the lessons, students will be able to:
- measure breathing rate, pulse rate, lung volume, expiratory tidal volume, peak flow and blood oxygen level, and describe how these change following various physical activities
- describe the role of the respiratory system in physical activity
- explain how sportsmen and women, and the professionals they work with, use science to help them improve their performance
- critically analyse and evaluate evidence from observations and experiments
- plan and carry out practical and investigative activities, both individually or in groups.

**Teaching strategies**

- Professor Alison McConnell from Brunel University’s Centre for Sports Medicine and Human Performance is our expert physiologist for the 11–14 experiments. Students will measure important physiological indicators, like those physiologists use in their work to explore how taking part in physical activity alters breathing.
- The In the Zone website (www.getinthezone.org.uk) has a PowerPoint for the investigation giving structure for these lessons, with photos, starter ideas, some background science and data collection tables.
- You can use the teacher and student sheets supplied in this Teacher Guide (or the editable versions on the website) to run the experiments.
- The laminated Knowledge Cards supplied are stimulus material for students to use in the lessons, giving context and linking to real-life scientists and experiments as well as covering some of the science upon which the experiments are based. They could be used as jumping off points for discussion and exploration of the ideas or background for students at each station in the carousel of experiments.
- Students can upload some of the data they collect to the ‘Live Data Zone’ section of the In the Zone website and compare their results to those of other students across the UK.
- The investigation is designed to take three lessons but is flexible so can be run in more or fewer lessons depending on the sizes of your classes/groups.

**Getting in the zone**

During training and as part of preparing and carrying out sports activities, sportsmen and women get ‘in the zone’; breathing can play a huge role in this. Professor Alison McConnell has carried out research on training breathing muscles and how such training can improve sporting performance. See her Introduction to the 11–14 experiments on page 12.

**Through the door activity**

Show video clips of different athletes:
- a world class 100 m sprint final, e.g. Usain Bolt
- an endurance swimmer during and after a race
- athletes who are performing in the throwing events such as the shot put or javelin.

There are links to suitable clips in the PowerPoints. Ask students to compare the breathing of these different athletes after their events using the videos you have shown.
Suggested starter activities (~5–10 minutes)

Ask students how many breaths they think they take in a minute. Then ask them to hold their breath and time how long they can hold it for (stopclocks are needed). They should only do this once and should hold their nose as well as close their mouths. Some students may have some ‘sneaky’ breaths in through their nose but most will not be able to hold their breath for more than a minute. You can then tell them that the breath-holding World Record is from a Swiss free-diver who held his breath underwater for 19 minutes and 21 seconds! Care must be taken with this activity. If students begin to feel faint they must stop immediately.

Experiments

The experiments can be carried out in the science classroom and there is an opportunity for collaboration with your PE department and use of their facilities.

Lesson 1 – Experiment A – Students measure their resting breathing rate. Once they have learned how to do this (in Part 1) they investigate how different types of physical activity affect their breathing rate (in Part 2).

Lesson 2 – ‘carousel’ of activities – Experiments B–D (two stations for each experiment)

Experiment B – Students measure their blood oxygen level and pulse rate (both using a pulse oximeter) before and after exercise and see how long they take to get back to resting level.

Experiment C – Students make a prediction about how peak flow may change with height and then measure their sitting and standing height and peak flow using a peak flow meter.

Experiment D – Students measure their lung volumes and then their expiratory tidal volumes before and after exercise to see if there is any change.

See the Teacher sheets, Technician notes and Student sheets for details of the protocols for the experiments. See the 11–14 student Knowledge Card for background and context to the lessons.

Lesson 3 – During this lesson data from Experiments C and D can be uploaded to the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk). Your students will then be able to evaluate their results and analyse data from other schools all across the UK.

Suggested plenary activities (~5–10 minutes)

Students either work in pairs or individually to select an Olympic or Paralympic event, or an activity that involves movement, e.g. dance. Each student or pair of students talks to the whole class about how they think breathing rate is affected after the participant has performed the event or activity. This allows the students to apply the knowledge gained from the experiments and demonstrate their understanding of the respiratory requirements of a selected sport.

Learning outcomes

All students will be able to: Most students will be able to: Some students will be able to:

• measure their breathing rate, blood oxygen level, pulse rate and lung volume and describe how different types of activity have an effect on each of them • explain why breathing is important in sport and why different sports have different effects on the respiratory system • explain why breathing rate and pulse rate increase in line with the energy requirements of different types of activity

• interpret data collected from the experiments to describe how physical activity has affected their respiratory system. • explain how data collected from the experiments shows how physical activity has affected their respiratory system • analyse data collected from the experiments to assess how physical activity affects their respiratory system.

• describe the relationship between peak flow and height.

Homework suggestions

1 Design part of a training programme for an Olympic athlete to assess how their breathing is affected by different types of training.

2 Ask students to carry out research to find out:

• how asthma affects breathing rate at rest and during exercise
• how taking part in sports can improve lung function
• how ‘Zen breathing’ can help performances in some sports and activities.

3 Evaluate the ‘Live Data Zone’ on the In the Zone website (www.getinthezone.org.uk) to find out how their results compare to the national data.

Cross-curricular links

• PE – respiratory system
• Maths – averages – working out the mean, volumes

Keywords

breathing rate, exhalation, inhalation, O₂, peak flow, vital capacity, tidal volume, inspiratory muscules
Lesson 1

How is my breathing rate affected by exercise?

Student notes for this experiment are on page 20.

Aim
In Part 1, students will learn how to measure their resting breathing rate. In Part 2, they will make a prediction about how different types of activity affect their breathing rate and carry out an experiment to test it.

Equipment

From your school
- stopclock
- metronome or music
- running track or field
- skipping ropes

Safety
- Identify students with asthma so they can have their inhaler close at hand and use it if required.
- Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
- Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
- Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to over-exertion and possible fainting or injury.
- Ensure students carry out the activities in a suitable place, clear of any obstruction.

Running the experiment

Part 1: What is my resting breathing rate?

1 Students should have been seated for at least 5 minutes before taking their breathing rates to ensure that they are at, or close to, resting levels. During this time you could carry out the suggested starter activity given in the lesson plan. You may also wish to elicit students’ understanding of the term breathing rate.

2 Explain to students that breathing rate is the number of breaths taken in 1 minute. A breath is one inhalation and one exhalation. Ensure all students understand what an inhalation and exhalation means.

3 Using a stopclock, ask all students to count how many breaths they take in 30 seconds and record their result. It would be good if they did this in pairs with a partner counting the breathing rate so that students are not as conscious of their own breathing rate. Remind them to breathe normally.
To make it easier for those counting, you might like to ask the student breathing to put their hand on their chest so that their breathing is more visible.

Students should repeat this process two more times.

Ask students to work out their average resting breathing rate. Breathing rates should be presented as whole numbers.

Ask students to record their average resting breathing rate in a central class record and work out a class average.

Part 2: How do different activities affect my breathing rate?

1. Students will start the experiment by making a prediction about what they think will happen to their breathing rate after having taken part in physical activities.

2. Decide which activities the students will carry out, or they may wish to come up with some ideas themselves. They need to have at least three activities available. Ideally the activities should be different types to ensure some difference in breathing rate.

3. Students should do warm-up exercises and stretches before they begin the activities. Suggested warm-up exercises are walking on the spot and then raising it up to a gentle jog on the spot, followed by stretches for the quadriceps, hamstrings, and calves (see diagram on page 57).

4. They will need to perform each activity for 1 minute. Make sure that everyone performs each activity at the same level. There are some activity suggestions below and an outline of the equipment you will need for each one.

Suggestions for classroom-based activities

The table below gives some suggestions for activities that the students can do. The second table of suggestions can also be used if you have the equipment available. The key idea is that students carry out a few different types of activity. Students may also have suggestions for activities themselves.

All activities should be carried out continuously for a period of 1 minute. You should do a warm-up activity with your students before they start exercising.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumping on the spot</td>
<td>Metronome or music to help keep time</td>
</tr>
<tr>
<td>Jumping jacks</td>
<td>Metronome or music to help keep time</td>
</tr>
<tr>
<td>Jogging on the spot</td>
<td>Metronome or music to help keep time</td>
</tr>
<tr>
<td>Lunges</td>
<td>None</td>
</tr>
<tr>
<td>Ski squat</td>
<td>Wall to lean against</td>
</tr>
<tr>
<td>Press-ups</td>
<td>None</td>
</tr>
</tbody>
</table>

If you are using music to help the students to keep time, you may like to allow them to pick their own music or give them a selection to choose from. You will need to ensure that the music has an upbeat tempo such as pop or dance music.
Suggested classroom-based activities.

- **Jumping on the Spot**
  - Back straight
  - Hands on hips
  - Feet hip-width apart
  - Toes facing forwards

- **Jumping Jacks (Star Jumps)**
  - Stomach pulled in
  - Back straight
  - Back heel off floor

- **Jogging on the Spot**
  - Knee bent at no more than 90° and brought towards ground

- **Lunges**
  - Back heel off floor
  - Knee bent at no more than 90° and brought towards ground
  - Lean against wall
  - Hands against wall
  - Feet hip-width apart
  - Toes facing forwards

- **Ski Squats**
  - Lean against wall
  - Knees bent to 90°
  - Hands against wall
  - Lean against wall

- **Press-Ups**
  - Arms straight
  - Elbows at 90°
  - Toes touching the ground

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Ages 11–14
Suggestions for activities using sport facilities

All activities should be carried out continuously for a period of 1 minute.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise to music, e.g. aerobics, step aerobics, Zumba®</td>
<td>Music, DVD</td>
</tr>
<tr>
<td>Skipping</td>
<td>Skipping rope</td>
</tr>
</tbody>
</table>

5 Students each find a partner to work with. They take it in turns to take part in the activity. If one student is not able to or does not wish to participate, they can be responsible for timekeeping and data collection. The number of pairs doing each activity at a time will depend on the equipment you have available for each activity.

6 Students take part in a selected activity for 1 minute. If necessary, their partner times the activity and tells them when to stop.

7 Once the exerciser has completed the activity, they measure their breathing rate for 30 seconds while their partner times them and records the results.

8 The exerciser has 10 seconds break from counting and then continues to count their breathing rate for each 30 seconds after the completion of the activity, with a 10 second break between each count. They should do this five more times. Their partner times them and records the results.

9 Students swap over and repeat the activities or move onto step 10.

10 Students should ensure that they spend 5 minutes recovering from the activity. You may wish to suggest that students who feel that they are less fit could do the exercises that are of a lower intensity first to ensure they complete as many activities as possible.

11 Students move on to the next activity and repeat the process until at least three activities have been completed. Ideally these would be different types of activity to ensure some difference in breathing rate.

Expected results

It would usually be expected that the fitter the student, the faster their breathing rate will return to resting levels. However, students should be made aware that this is only one measure of fitness and therefore what appear to be anomalies could occur.

Next lessons

In Lesson 2 you will be running a carousel of three experiments (B–D), all on breathing, with two stations for each experiment. Lesson 3 will give students the opportunity to analyse and evaluate all the data they have collected. This is also when they will be able to upload the data from Experiments C and D into the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk) and analyse and interrogate national data from UK schools.
On your marks... get set... breathe

How is my breathing rate affected by exercise?

Part 1: What is my resting breathing rate?

Prediction
My resting breathing rate is _______ breaths per minute.

Obtaining the evidence
1. Sit quietly for at least five minutes.
2. One breath is counted when you have breathed in and out once. You are able to control your breathing rate to some extent, so try to breathe as normally as you can during the experiment.
3. Start your stopclock as soon as you are about to take a breath in then count how many breaths you take in 30 seconds. Multiply this number by two to get your resting breathing rate (number of breaths per minute). Record your results in the table below.
4. Repeat the measurement two more times with a 30 second break after each count, and record your results.

Presenting the results

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Number of breaths in 30 seconds</th>
<th>Number of breaths in one minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average resting breathing rate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part 2: How do different types of activity affect my breathing rate?

Prediction
What will happen to your breathing rate after you have taken part in physical activities?

My breathing rate would ______________ immediately after taking part in physical activities. It would then ______________. The type of activity that will have the biggest effect on my breathing rate is ______________.
Obtaining the evidence

5 You should be in pairs. Your teacher will tell you how to do some warm-up exercises before starting the physical activities. The exerciser does the activity for one minute. The time-keeper makes sure the exerciser is doing the activity correctly and safely and tells them when one minute is up.

6 After one minute the exerciser sits down and takes their breathing rate. The time-keeper times 30 seconds and records the number of breaths in 30 seconds. The exerciser must then rest for 30 seconds.

7 Continue recording breathing rate five more times. The exerciser takes the breathing rate for a 30 second period. The exerciser then rests for 30 seconds before taking the next reading.

8 The time-keeper and exerciser swap roles.

9 Repeat for all of the different activities.

Presenting the evidence

<table>
<thead>
<tr>
<th>Activity</th>
<th>Breathing rate per minute (number of breaths in 30 seconds × 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediately after activity</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Each interval is 30 seconds.
Lesson 2 uses a carousel approach to further investigate breathing and lung function: blood O$_2$ concentration level, pulse rate, peak flow, and lung volumes. The carousel comprises Experiments B, C and D (Teacher Guide pages 22–24, 26–27, and 30–31). Experiment D forms part of an exciting national data-collecting exercise that your students can take part in. Students will need to carefully carry out the investigation to ensure standardisation with data collected from other classes and schools so that when they analyse the national data their results are more reliable. Students should do warm-up exercises and stretches before they begin the carousel activities. Suggested warm-up exercises are walking on the spot and then raising it up to a gentle jog on the spot, followed by stretches for the quadriceps, hamstrings, and calves (see page 57).

Do my blood oxygen level and pulse rate change after exercise?

The student notes for this experiment are on page 25.

**Aim**

Students will investigate how the blood oxygen concentration level and pulse rate are affected by different activities.

**Equipment**

<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• pulse oximeter</td>
<td>• stopclocks</td>
</tr>
<tr>
<td></td>
<td>optional:</td>
</tr>
<tr>
<td></td>
<td>• running track/field</td>
</tr>
<tr>
<td></td>
<td>• skipping rope</td>
</tr>
<tr>
<td></td>
<td>• metronome or music</td>
</tr>
</tbody>
</table>

**Safety**

- Identify any students with asthma so they can have their inhaler close at hand and use it if required.
- Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
- Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
- Be aware of any student with any blood oxygen abnormality who may be distressed by having to take part in the pulse oximeter activity.
- Ensure students carry out the activities in a suitable place, clear of any obstruction.
Running the experiment

1. Students decide in their groups who will take part in the activities and who will time the activities and record the data.

2. Students who are going to take part in the activities each measure the resting level of O₂ in their blood and their pulse rate using the pulse oximeter. See the Student sheet for the protocol for obtaining evidence.

3. The pulse oximeter is opened by pushing down on one end (please refer to the ‘How to use the equipment in the box’ section on page 7 of this guide). Students insert one finger into the oximeter. They must wait at least 10 seconds before taking the blood oxygen concentration levels and pulse rate readings.

4. Students will need to perform their selected activity for 1 minute. Make sure that everyone performs the activity at the same intensity.

Suggestions for classroom-based activities

The table below gives some suggestions for activities that the students can do. The second table of suggestions can also be used if you have the equipment available. The key idea is that students carry out a few different types of activity. Students may also have suggestions for activities themselves.

These activities should all be carried out continuously for a period of 1 minute.

<table>
<thead>
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<tr>
<td>Jogging on the spot</td>
<td>Metronome or music to help keep time</td>
</tr>
<tr>
<td>Lunges</td>
<td>None</td>
</tr>
<tr>
<td>Ski squats</td>
<td>Wall to lean against</td>
</tr>
<tr>
<td>Press-ups</td>
<td>None</td>
</tr>
</tbody>
</table>

Suggestions for activities using sport facilities

These activities should all be carried out continuously for a period of 1 minute.

<table>
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<tr>
<th>Activity</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise to music, e.g. aerobics, step aerobics, Zumba®</td>
<td>Music DVD</td>
</tr>
<tr>
<td>Skipping</td>
<td>Skipping rope</td>
</tr>
</tbody>
</table>

5. Students must not wear the pulse oximeter whilst exercising. They must ensure that they have access to a pulse oximeter immediately after finishing their exercise. Immediately after the timed exercise, students take their blood oxygen concentration levels and pulse rates again.
Expected results

**Blood oxygen concentration** is a measure of the amount of oxygen carried in the blood. More specifically it measures the percentage of haemoglobin binding sites in the bloodstream that are occupied by oxygen. The pulse oximeter measures the arterial blood oxygen concentration using red and infrared light that is emitted by the pulse oximeter when a finger is inserted into it. The pulse oximeter is able to give an oxygen concentration reading using the absorption of this red and infrared light by the finger. Oxyhaemoglobin and deoxyhaemoglobin in the arteries absorb red and infrared waves very differently and so a ratio can be calculated from the absorption rates.

The normal expected range is between 95 and 100%. Blood oxygen concentration does not often change even when the body is taking part in strenuous exercising. This is because the body responds to exercise by taking more oxygen into the lungs by increasing the breathing rate. Oxygen is transported around the body more quickly with an increased heart rate which means that the volume of blood reaching the target (muscles) increases and hence more oxygen is delivered. Consequently blood oxygen concentrations are unaltered.

In athletes during exercise, and in individuals with some respiratory illnesses, oxygen saturation levels can fall to around 90%. In athletes this decrease is because their muscles are more efficient at taking oxygen from the blood and using it to help produce energy.

The average **resting pulse rate** for a child aged 11–14 is 70–100 beats per minute (bpm). Pulse rate will usually decrease as the child gets older because their heart will get bigger and therefore be able to pump out more blood each time it beats. Children who take part in aerobic types of exercise will also usually have a lower resting heart rate compared to their counterparts. This is because the exercise that they take part in trains their heart to make it stronger so that it can pump out more blood during each beat.

On your marks… get set… breathe

Do my blood oxygen level and pulse rate change after exercise?
On your marks… get set… breathe

Do my blood oxygen level and pulse rate change after exercise?

Prediction
My pulse rate will _________________________ and my blood oxygen level will _________________________ after taking part in exercise.

Obtaining the evidence
1. In your groups, decide who will take part in the activities and who will be time-keeper and record the data.
2. Students who will take part in the activities should measure their resting blood oxygen level and pulse rate using the pulse oximeter.
3. Open the pulse oximeter by pushing down on one end. Insert the middle finger into the oximeter and press the small button. Rest your hand on a table and keep still. Wait 10 seconds and then take your blood oxygen level and pulse rate readings.
4. Write your blood oxygen level and pulse rate readings in the table below.
5. Take part in the exercise activity for 1 minute. The time-keeper times this period.
6. Immediately after the timed exercise, take your blood oxygen level and pulse rate again using the pulse oximeter (use the instructions given in Step 3).

Presenting the results

<table>
<thead>
<tr>
<th>Student A</th>
<th>Blood oxygen level (%)</th>
<th>Pulse rate (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference between before exercise and after exercise readings</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Aim
Peak flow is a measure of the maximum velocity of air that a person can generate through a forced exhalation. In this experiment students will measure their height and their own peak flow and determine if there is a relationship between the two. Students can then go on to explore a hypothesis of their own choice to find out if there are any relationships between peak flow and types of sport, e.g. swimming.

Equipment
<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 2 peak flow meters</td>
<td>optional:</td>
</tr>
<tr>
<td>• disposable mouthpieces</td>
<td>• stadiometer</td>
</tr>
<tr>
<td>• tape measures</td>
<td></td>
</tr>
</tbody>
</table>

Safety
• Students should have a break between each peak flow test.
• Identify any students with asthma: they may not wish to participate or may wish to use their inhaler before they take part in the peak-flow measurement.
• Identify any student with heart/lung problems; they should be allowed to decline to take part in the peak-flow measurement.
• Ensure disposable mouthpieces are not shared, although they may be re-used by individual students.
• Students attempting to outdo each other in peak flow rates may become faint or suffer headaches; discourage such competition.
• Ensure students carry out the activities in a suitable place, clear of any obstruction.

Running the experiment
1 Students will use a stadiometer or tape measure to measure their standing and sitting heights. A stadiometer is a medical device for measuring height. The sliding horizontal headpiece will allow students to measure height more accurately. To do this they will need access to a wall. When students measure their height, they should do this without shoes and with a ruler or other flat object to level the top of their head. They should take a deep breath in, breathe out, relax and stand tall without going on tiptoes. You could ask three students to measure a fourth student’s height without taking the precautions above to illustrate the variation in readings they will obtain. Refer to the diagram on the Student sheet. Students will not need to repeat this if they have already done it for Experiment C.

2 Students will then measure their peak flow using the peak flow meter (please refer to the ‘How to use the equipment in the box’ section on page 7 of this guide). Each student must use their own disposable mouthpiece.
when using the peak flow meter. Students must throw their mouthpiece away at the end of the experiment.

3 When students are taking their peak flow readings the following important instructions must be followed:
   • The pointer on the peak flow meter should be set to the end of the meter (below the 60 mark) before students blow into it.
   • Students must stand up.
   • Students should hold the peak flow meter so that their fingers are clear of the scale and slot.
   • They should hold the meter horizontally when blowing into it.

4 See the Student sheet on pages 28–29 for the protocol for obtaining evidence.

5 Students take three readings and work out their average peak flow.

6 Students can then write their results on the whiteboard or a record sheet.

Expected results
Peak flow in this age group will be mainly dependent upon height. The peak flow of taller students is likely to be greater than those of other students. Peak flow is also likely to be higher in those who take part in regular exercise. Students with asthma are likely to have a lower peak flow and may be used to measuring their peak flow. In adults peak flow varies with height, age and sex.

Live Data Zone
Your students can enter their peak flow and heights from this experiment, together with data from Experiment D, into the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk). See Teacher notes on page 35 for 11–14 Lesson 3.
What is the relationship between peak flow and height?

**Prediction**
Peak flow is a measure of the maximum speed of air during a forced exhalation (breath out). How might peak flow vary with the height of a person? I predict that peak flow will increase/decrease/stay the same with height. Cross out the incorrect answers.

**Obtaining the evidence**
1. Using a stadiometer or tape measure, record your sitting and standing height. A stadiometer is a medical device for measuring height. The sliding horizontal headpiece will allow you to measure height more accurately. If you have already completed Experiment D you will not need to do this again.

Measuring standing and sitting height.

2. Each person writes their name on a mouthpiece, being careful not to press too hard on it so that you don’t change the shape of it. You must throw your mouthpiece away at the end of the experiment.

3. When it is your turn, put your mouthpiece on the peak flow meter, then set the pointer to the bottom of the scale (below the 60 mark).

4. Stand up and ensure that your fingers are clear of the scale and slot.

5. Take a deep breath and then place the peak flow meter in your mouth, making sure that you are holding the peak flow meter horizontally.
6 Close your lips tightly around the mouthpiece, then blow as hard and as fast as you can.

7 Record the number on the scale that the pointer reaches.

8 Rest for at least 1 minute and then repeat steps 3–7. Take another rest for at least 1 minute and repeat steps 3–7 again.

9 Return the pointer to the bottom and remove the mouthpiece. The next person in the group carries out steps 3–7 to take their peak flow measurement.

10 Repeat the process so that everyone in the group measures their peak flow three times to increase the reliability of your results.

11 Write your results in the table below.

Presenting the results

My standing height is ________________. My sitting height is ________________.

<table>
<thead>
<tr>
<th>Peak flow reading (l/min)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement 1</td>
<td></td>
</tr>
<tr>
<td>Measurement 2</td>
<td></td>
</tr>
<tr>
<td>Measurement 3</td>
<td></td>
</tr>
<tr>
<td>Average peak flow</td>
<td></td>
</tr>
</tbody>
</table>
How is expiratory tidal volume affected by exercising?

The student notes for this experiment are on pages 32–34.

Aim
In this experiment students will measure their vital capacity (the size of their lungs). They will also measure their expiratory tidal volume before and after exercising for 1 minute (the volume of air that is moved between inhaling and exhaling). Students will also be able to determine whether there is a relationship between vital capacity and height.

Equipment

<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 4 lung volume bags</td>
<td>• stopclocks</td>
</tr>
<tr>
<td>• disposable mouthpieces</td>
<td>• paper towels</td>
</tr>
<tr>
<td>• tape measures</td>
<td>• optional:</td>
</tr>
<tr>
<td>• elastic bands</td>
<td>• metronome or music to keep time</td>
</tr>
</tbody>
</table>

Safety
• Identify students with asthma so they can have their inhaler close at hand and use it if required.
• Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
• Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
• Ensure students carry out the activities in a suitable place, clear of any obstruction.
• The lung volume bags must be filled with disinfectant solution and left for at least 10 minutes before being rinsed out for use by the next student.

Running the experiment
1 Students will use a tape measure or stadiometer to measure and record their sitting and standing height – they will not need to repeat this if they have already done it for Experiment C.
2 Each student must use their own mouthpiece when using the lung volume bags (please refer to the ‘How to use the equipment in the box’ section on page 8 of this guide). They can use the same one as in Experiment C if they have already completed that experiment. Students should write their name or initials on the inside of the tube. Mouthpieces should be thrown away at the end of the experiment.
3 Students will use the lung volume bags to obtain measurements for their vital capacity and their expiratory tidal volume.

4 You might like to show students the lung volume bags first and ask them to make a prediction of their vital capacity.

5 See the Student sheet on pages 32–34 for the protocol for obtaining lung volume using the equipment provided. In addition you should be aware that:
   a) The lung volume bag must be airtight when set up. Following the protocol given on the Student sheet should achieve this.
   b) Students must ensure that the bag is entirely empty of air before taking their measurements.
   c) Students must be standing to carry out the test.
   d) Gardening wire can be used to secure the mouthpiece to the lung volume bags by students who are allergic to latex.

6 See the Student sheet on pages 33–34 for the protocol for obtaining expiratory tidal volume using the lung volume bags provided. In addition you should be aware that:
   a) Students must ensure that the lung volume kit is assembled with their own mouthpiece and that any air has been emptied out of the bag before they start taking measurements.
   b) Students must breathe as normally as possible during the experiment. They should practise the technique of breathing in through their nose and out through their mouth before attempting to measure their expiratory tidal volume using the lung volume bag.
   c) Remind students to hold the bag to prevent any air escaping once they have completed their breaths into it.

7 Students who either fill the lung volume bag or don’t breathe in a measurable amount of air may need to change the number of breaths they take into the bag and adjust their calculations accordingly.

8 As an alternative to disinfecting each lung volume bag before reuse, each student could breathe into their own large plastic bag, e.g. food or bin liner bag. The bag should be connected, by their own mouthpiece using elastic bands (or gardening wire if students are allergic to latex) to the lung volume bag. The air can then be squeezed out of the plastic bag into the lung volume bag and the the volume measured.

**Expected results**

Vital capacity is usually related to the size of a person. Therefore, the taller the student, the larger their vital capacity will be and vice versa.

Expiratory tidal volume will be greater in students who have been exercising at a high intensity. This is because they will have been breathing more air in as their inspiratory tidal volume in order to supply their working muscles with oxygen. When they stop exercising they will be breathing out greater quantities of carbon dioxide compared to students who have been exercising at a lower intensity.

**National data upload**

Your students can enter their lung volume results from this experiment, together with data from Experiment C, into the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk). See Teacher notes on page 35 for 11–14 Lesson 3.
On your marks... get set... breathe

How is expiratory tidal volume affected by exercising?

Predictions

Vital capacity is the size of your lungs – the maximum amount of air that you can exhale after breathing in the maximum amount of air you can. In litres, how much of the lung volume bag do you think you will be able to fill?

I will be able to fill _________________________________________________________

Expiratory tidal volume is the volume of air that is moved during one inhalation and exhalation when breathing normally. Do you think expiratory tidal volume is affected by exercise? If so, how? Write your prediction below.

Prediction ___________________________________________________________

Obtaining the evidence

1  Using a stadiometer or tape measure, record your sitting and standing height. You will not need to do this again if you have already completed Experiment C.

2  Measure the size of your lungs (your vital capacity) using the lung volume bags.
   a  Each person writes their name on the inside of the mouthpiece. Be careful not to press too hard on it so that you don’t change the shape of it. You must throw your mouthpiece away at the end of the experiment.
b Assemble the lung volume kit by inserting your disposable mouthpiece into the end of the lung volume bag. Fold the bag neatly around the holder to ensure it is airtight.

c Loop a rubber band three times around the folded part of the bag to securely fasten the bag to the mouthpiece.

d To take a measurement, ensure that the bag is entirely empty of air by flattening it against your leg with a paper towel and pulling it through with the other hand.

**Using the lung volume bag.**

e Stand up straight and take a deep breath in. Then blow as much air as possible into the bag in one continuous blow. Keep blowing until no more air comes out.

f Measure the volume by grasping the bag just below the mouthpiece. Twist it to trap the air and then push the air downwards. Put the bag on your knee with a paper towel on top. Use the paper towel to push the air to the bottom of the bag until the bag becomes stiff.

g Measure the volume of air blown into the bag – this is your vital capacity. Record your results (remember, the volume measured here is for one breath).

3 Measure your expiratory tidal volume at rest – this is the volume of air that is moved between inhaling and exhaling when at rest.

a Make sure the lung volume bag is assembled with your own disposable mouthpiece and all air has been emptied out of the bag.
b Practise breathing out through your mouth and then in through your nose. The breathing should be as normal as possible.


c Once you are able to comfortably breathe as explained in step b above, breathe out five ‘normal’ breaths into the lung volume bag.

d Measure the volume of air in the bag – this is the expiratory tidal volume for five breaths. Divide this volume by five to give the expiratory tidal volume for one breath.

4 Do jumping jacks to either a metronome or music continuously for 1 minute.

5 Repeat step 3 to record your expiratory tidal volume after exercise. Measure this volume and record your results.

Presenting the evidence
My sitting height is ________________ My standing height is ________________

<table>
<thead>
<tr>
<th></th>
<th>Volume</th>
<th>Volume of one breath</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital capacity (one long continuous blow into the bag)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expiratory tidal volume before exercise (5 breaths out into the bag)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expiratory tidal volume after exercise (5 breaths out into the bag)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lesson 3 can be used to allow your students to:

- Upload the data from Experiments C and D to the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk). They can then compare their results to students’ data from across the UK.
- Analyse, evaluate and consider the data collected from this group of experiments.

More details can be found on the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk).

Enter data from Experiment C

- peak flow
- height and sitting height.
From Experiment D

- vital capacity
- height and sitting height (depending on the order in which they do the experiments).

In order to be able to accurately compare their results to other students across the UK, your students will also need to enter the data listed below:
- age
- gender
- asthmatic or not (optional)
- school postcode
- class, e.g. 7C (optional)
- school year
- physical activity level, in minutes of exercise per week
- type of sport(s) played regularly
- how fit they think they are in relation to their class.

The Student sheet on page 37 provides a series of questions analysing and evaluating Experiments A–D. Answers are on pages 109–13. Alternatively, you may wish to analyse and evaluate the experiments through a more open-ended approach. Examples of this might be asking students to:

- Write a report for the coach of an Olympic or Paralympic athlete, outlining the findings of your research and how it might inform their training programme. Your report must include the results from your experiments and link these with the body’s response to exercise. You should try to include information about class and national data where you have it.

- Find an image of three different types of sport or activity. Label each image to illustrate how the person’s respiratory system changes during the exercise. You should relate these changes to evidence from your experiments.

- Choose three different types of sport or activity. Write a commentary through the event to describe how the respiratory system responds to the exercise. You should relate these changes to evidence from your experiments.

There are opportunities to extend the materials further in the accompanying PowerPoint available from the In the Zone website (www.getinthezone.org.uk). You may also wish to explore further with your students the links to contemporary science and sports science – again, the PowerPoint will help with this as well as the Knowledge Cards provided in the kit box.

If you would like to reward any of your students for effort or achievement in these experiments, then the In the Zone website (www.getinthezone.org.uk) has In the Zone Reward Certificates that you can download and customise for your students.
On your marks... get set... breathe

What is the effect of sport and exercise on my body?

These experiments have given you the chance to explore how your body reacts to different sports and physical activities. Complete the activities below to find out just how much you know about how breathing affects sporting performance.

**Experiment A – part 1**
1. Compare your average resting breathing rate to: the whole class and the class average.
2. If you have access to the internet you could also research the resting breathing rate of different types of sportspeople, wind instrument musicians, an average adult and a baby.

**Experiment A – part 2**
Complete the analysis below to describe and compare your breathing rate results after exercise with your class results and the class average. Fill in:

a. the missing values using your own results and the class results
b. the other missing words using the appropriate words in the box below.

My prediction was ___________. My breathing rate ___________ after I had taken part in exercise. This is because my body had to work harder to supply ___________ to my muscles. All the activities changed my breathing rate by ___________ amount. The exercise that increased my breathing rate the most was ___________ ( _____ breaths per minute). The exercise that increased my breathing rate the least was ___________ ( ___ breaths per minute).

My breathing rate took ___________ minutes to return to my resting breathing rate. This was ___________ than the class average. My breathing rate took ___________ time to return to my resting rate than others because I am ___________ than them.
Experiment B
Complete the table below to compare and explain oxygen levels and pulse rate before and after exercise.

<table>
<thead>
<tr>
<th>Resting level (before exercise)</th>
<th>After exercise</th>
<th>Reason for any change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your group average oxygen level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse rate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Experiment C

1. a Mark on the peak flow meter what your average peak flow measurement is and label it.
   b Use the data collected to work out the class average peak flow. Mark this measure on the peak flow meter above and label it.
   c Use the In the Zone website to find out what the national data collected show for average peak flow. Mark this on the peak flow meter and label it.

3. Describe how your average peak flow measurement compares to the other people in your group and the national data.

__________________________________________________________________
__________________________________________________________________

4. Suggest why there are differences in peak flow measurements in your group and nationally.

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

5. Was your prediction correct? How did peak flow vary with the height of a person? Cross out the incorrect answers.
   Peak flow increased/decreased/stayed the same as height increased.

6. Look at each of the sports on the next page. Suggest how the peak flow of the people who take part in each of the sports might compare to your own.

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
Experiment D

Tick whether the statements below are true or false. Correct those that are false.

1. Expiratory tidal volume increases after taking part in exercise.

2. Expiratory tidal volume is greater after high intensity exercise as more air is taken in to supply the working muscles with oxygen.

3. Taller people have a smaller vital capacity.

4. Males have a smaller vital capacity than females.

5. People who take part in lots of sport have higher vital capacities than people who do little exercise.

How does exercise affect my breathing?

Look at the results from all four of the experiments that you have carried out. Consider your own results, your class results and national data if you have this available to you.

1. List the changes that you measured in your body when you exercised. State how each of these measurements changed.

2. Use the list of changes that you have made above to describe and explain how your body responds to exercise.
Lesson 1

Experiment A: How is my breathing rate affected by exercise?
Each group will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>• 1 stopclock</td>
<td></td>
</tr>
<tr>
<td>• metronome or music</td>
<td>optional – to help keep time</td>
</tr>
<tr>
<td>• running track/field</td>
<td>optional</td>
</tr>
<tr>
<td>• 1 skipping rope</td>
<td>optional</td>
</tr>
</tbody>
</table>

Lesson 2 – Carousel of experiments
The tables below show the equipment required for one station for each experiment within the carousel. Depending upon the equipment available to each class and the number of students in the class, you may wish to provide more stations for one or more of the carousel experiments. The kit box contains 2 pulse oximeters, 2 peak flow meters and 4 lung volume bags.

Experiment B: Do my blood oxygen level and pulse rate change after exercise?
Each carousel station will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From kit box</td>
<td>requires 2 × AAA cells. Do not use lithium cells and avoid mixing different types, e.g. zinc chloride and alkaline refer to page 7 ‘How to use the equipment in the box’ in this guide for instructions</td>
</tr>
<tr>
<td>• 1 pulse oximeter</td>
<td></td>
</tr>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>• 1 stopclock</td>
<td></td>
</tr>
<tr>
<td>• metronome or music</td>
<td>optional – to help keep time</td>
</tr>
<tr>
<td>• running track/field</td>
<td>optional</td>
</tr>
<tr>
<td>• 1 skipping rope</td>
<td>optional</td>
</tr>
</tbody>
</table>
Experiments A–D

Experiment C: What is the relationship between peak flow and height?

Each carousel station will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>From kit box</strong></td>
<td></td>
</tr>
<tr>
<td>• 1 peak flow meter</td>
<td>refer to page 7 ‘How to use the equipment in the box’ in this guide for instructions</td>
</tr>
<tr>
<td>• disposable mouthpieces (1 per student)</td>
<td>to fit peak flow meters and lung volume bags students must write their name on their own and only use it for Experiment C</td>
</tr>
<tr>
<td>• 1 tape measure</td>
<td>stadiometers could be used for measuring standing height instead</td>
</tr>
<tr>
<td><strong>From school</strong></td>
<td></td>
</tr>
<tr>
<td>stadiometer</td>
<td>optional – tape measures could be used instead</td>
</tr>
</tbody>
</table>

Experiment D: How is expiratory tidal volume affected by exercising?

Each carousel station will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>From kit box</strong></td>
<td></td>
</tr>
<tr>
<td>• 1 lung volume bag</td>
<td>refer to page 7 ‘How to use the equipment in the box’ in this guide for instructions must be filled with 1% Virkon, and left for at least 10 minutes before it is rinsed out and reused by a different student</td>
</tr>
<tr>
<td>• disposable mouthpieces (1 per student)</td>
<td>to fit peak flow meters and lung volume bags students must write their name on their own mouthpiece and throw it away after use for Experiment D</td>
</tr>
<tr>
<td>• 1 tape measure</td>
<td>stadiometers could be used for measuring standing height instead</td>
</tr>
<tr>
<td>• elastic bands</td>
<td>gardening wire could be used to secure the lung volume bag to the disposable mouthpieces so that people with latex allergies are not affected</td>
</tr>
<tr>
<td><strong>From school</strong></td>
<td></td>
</tr>
<tr>
<td>• 1 stopclock</td>
<td></td>
</tr>
<tr>
<td>• stadiometer</td>
<td>optional – tape measures could be used instead</td>
</tr>
<tr>
<td>• paper towels</td>
<td></td>
</tr>
<tr>
<td>• metronome or music</td>
<td>optional – to help keep time</td>
</tr>
</tbody>
</table>
How do muscles affect sporting performance?

‘From strength to strength’ is a group of experiments all about muscle strength and endurance.

My name is Steve Ingham and I am the Head of Physiology for the English Institute of Sport. In this set of experiments your students will be exploring the body’s muscles, their function, and what happens when they do exercise. Specifically they will be investigating skeletal muscles – the ones that move the skeleton’s bones about. The ideas that your students will be exploring are ones that confront me on a daily basis – when my team and I are helping athletes find their best event, work out their strengths and weaknesses, develop their training plans, or work out how best to deliver their performance on the day.

As a team we also bring in ideas to help muscles get better at performing, so that an athlete is able to achieve more power, fatigue less, or just cope with the feelings of tired muscles. When our team of sports scientists are able to use their understanding of the human body and how it responds to exercise to good effect, we can really help athletes go faster, be stronger, go higher, and so push forward the boundaries of human achievements. And that is why I love this work!

Muscle type

Skeletal muscle makes up about 40% of the body’s mass, and men have a bit more skeletal muscle than women because they have more of the hormone testosterone. A human is generally a mix of ‘fast’ powerful muscle fibres and ‘slow’ endurance muscle fibres.

www.getinthezone.org.uk
The blend of fibre types is mostly set by genetics, but it can change slightly with different types of training. Athletes who are involved in very physical sports tend to have extremes of muscle fibre mixtures or amounts, i.e. they might have lots of slow-twitch fibres or lots of fast-twitch fibres or their muscles tend to be particularly small or big. Recent research led by Keith Baar\(^1\) from the University of Dundee has showed that if an athlete does a bit of endurance and a bit of strength work then they won’t improve their fitness as much as if they did their strength and endurance training separately (with at least an hour between). This shows that the muscle cells must be given time to respond and adapt to the stimulus of the training in order to maximise the improvements.

**Muscles and sport**

Students will be finding out about the muscles’ ability to generate force – for example, do they need big muscles to be strong enough to either move objects (like throwing the hammer) or move their own body mass about (like a high jumper or gymnast)? Students will also be thinking about whether their own blend of muscles is better at short, powerful efforts or long-duration, low-intensity efforts – like the sprinters Usain Bolt or Sir Chris Hoy at the power end of the spectrum, Mo Farah or Paula Radcliffe at the endurance end, or indeed the best of both worlds in the middle distance athletes like Kelly Holmes or Michael Rimmer, who are powerful but have a great engine too. Everyone knows what it is like when the muscles get tired; they ache and scream out to you to stop when the exercise gets tough. This is all about how muscles fatigue and students will be exploring whole body exercise and small muscle actions, and looking at the difference in what causes them to slow down.

I hope that you and your students find the ‘From strength to strength’ resources exciting to explore. The 14–16 Knowledge Card has lots of information about how important muscles are. You can upload some of the students’ own results to the In the Zone website at www.getinthezone.org.uk and contribute to capturing national data. I look forward to seeing your results.


www.getinthezone.org.uk
From strength to strength

How do muscles affect sporting performance?

Resources

From the kit box:
- tape measures
- chalk dust
- Teacher Guide
- Knowledge Card.

From the school:
- stopclocks
- bottles of sand for weight.

From the website www.getinthezone.org.uk
- ‘Live Data Zone’ section for upload and interrogation of data
- PowerPoint for the lesson
- editable Word files of teacher and student sheets and lesson plans
- editable certificates for student effort/performance.

Learning objectives

At the end of the lessons, students will be able to:
- understand that continuous or rapidly repeated contraction of muscle results in fatigue
- explain that different types of muscle fibre have a significant effect on sporting ability
- state that muscle size is related to muscle strength
- work accurately and safely, individually and with others, when collecting first-hand data
- interpret data relating to the effects of exercise on the human body.

Teaching strategies

- Steve Ingham, Head of Physiology for the English Institute of Sport, is our expert physiologist for the 14–16 experiments. He works with athletes to help their muscles perform better: achieve more power, fatigue less and cope with the feelings of tired muscles. Students will measure important physiological indicators, similar to those physiologists use in their work, to explore how muscle strength and endurance affect physical and sporting activity.
- The In the Zone website (www.getinthezone.org.uk) has a PowerPoint for the investigation giving structure for these lessons, with photos, starter ideas, some background science and data collection tables.
- You can use the teacher and student sheets supplied in this Teacher Guide (or the editable versions on the website) to run the experiments.
- The laminated Knowledge Cards supplied are stimulus material for students to use in the lessons, giving context and linking to real-life scientists and experiments as well as covering some of the science upon which the experiments are based. They could be used as jumping off points for discussion and exploration of the ideas or background for students at each station in the carousel of experiments.
- Students can upload some of the data they collect to the ‘Live Data Zone’ section of the In the Zone website and compare their results to those of other students across the UK.
- The investigation is designed to take three lessons but is flexible so can be run in more or fewer lessons depending on the sizes of your classes/groups.

Getting in the zone

During training and as part of the preparation and execution of sports activities, sportsmen and women get ‘in the zone’. Every sport requires some form of movement and it is our muscles that make this movement happen. Therefore, all sportspeople will ‘zone in’ and undertake specific forms of training to maximise their muscles’ performance for their selected sport. Many sportspeople will then get ‘in the zone’ prior to competition and remain focused to ensure that their muscles and mind are ready to perform at their best.

Through the door activity

Show video clips of different sportspeople taking part in a range of different sports or physical activities:
- long-distance running events
- horse riders
- weightlifting
- swimming
- sprinting
- dancers.

There are links to suitable clips in the PowerPoints. Ask students to look at the physique and muscles of each sportsperson and think about how it will affect their sporting performance.
Suggested starter activities (~5–10 minutes)

Ask students to make a list of five words that they think will be important in answering the question ‘How do muscles affect sporting performance?’ Suggest that students move their own arms and legs to see the movement of the muscles. Give students a few minutes to work in pairs to produce a combined list.

Revisit the video footage from the ‘Through the door’ activity again or show one of the others listed. Following this, ask students to look at their list again and ask them if they still think that these five words are important in answering the question or if they think there are others that are more important.

Experiments

The experiments can be carried out in the science classroom but there is an opportunity for collaboration with your PE department and use of their facilities.

Lesson 1 – Experiment A – Students measure the circumference of their upper arm, then carry out some strength tests to see if there is a relationship between muscle size and muscle strength.

Lesson 2 – ‘carousel’ of activities – Experiments B–D (two stations for each experiment)

Experiment B – Students will carry out an upper body muscular strength test (straight leg press-up) and a lower body strength test (squat) to find out if there is a difference in the number of repetitions they can manage to do in 1 minute. They will also measure their sitting and standing height.

Experiment C – Students investigate the relationship between power and endurance. They collect and analyse results from an anaerobic power test (vertical jump test) and a muscular endurance test (lunges) to find out more about the difference in properties of muscle fibres.

Experiment D – Students investigate how fatiguing one set of muscles affects how a different set of muscles performs. They will do a standard broad jump test, then bicep curls until their arm is fatigued, then the broad jump test again.

See the Teacher sheets, Technician notes and Student sheets for details of the protocols for the experiments. See the 14–16 student Knowledge Card for background and context to the lessons.

Lesson 3 – During this lesson data from Experiment B can be uploaded to the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk). Your students will then be able to evaluate their results and analyse data from other schools all across the UK.

Suggested plenary activities (~5–10 minutes)

Students can work in pairs and select a sportsperson of their choice. They present to the rest of the group why the sportsperson has their specific muscle size and what type of muscle fibre they think the person has in order to help them with their sporting performance. Students can also discuss how fatigue can affect sporting performance.

Learning outcomes

<table>
<thead>
<tr>
<th>All students will be able to:</th>
<th>Most students will be able to:</th>
<th>Some students will be able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• carry out a test to measure muscle power</td>
<td>• interpret the results of tests carried out to measure muscle power</td>
<td>• analyse the results of tests carried out to measure muscle power and relate your findings to musculature and the sports athletes take part in</td>
</tr>
<tr>
<td>• state that muscle size is related to muscle strength</td>
<td>• interpret results from tests that explore muscle fatigue</td>
<td>• analyse results from tests that explore muscle fatigue.</td>
</tr>
<tr>
<td>• describe the effects of fatigue on sports performance.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Homework suggestions

1. Research why some athletes enter more than one athletic event. Report back on the reasons for this and relate them to muscle use.
2. The heart is a muscle but it doesn’t have a rest throughout our life. Why do other muscles have to stop for a rest? Research and report back.
3. Evaluate the ‘Live Data Zone’ on the In the Zone website (www.getinthezone.org.uk) to find out how their results compare to the national data collected.

Cross-curricular links

PE – muscle function
Maths – data analysis, averages

Keywords

muscle fibre types, muscular endurance, power, fatigue
From strength to strength

Lesson 1

Does the size of muscles affect performance in different activities?

The student notes for this experiment are on page 49.

Aim
Students investigate whether there is a relationship between muscle size and sports performance.

Equipment

<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• tape measures</td>
<td>• stopclocks</td>
</tr>
<tr>
<td></td>
<td>• 1 l bottles of sand</td>
</tr>
<tr>
<td></td>
<td>optional:</td>
</tr>
<tr>
<td></td>
<td>• multi-gym, dumbbells</td>
</tr>
<tr>
<td></td>
<td>• sturdy box at about knee height</td>
</tr>
</tbody>
</table>

Safety

• Identify students with asthma so they can have their inhaler close at hand and use it if required.
• Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
• Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
• If PE activities and equipment e.g. multi-gym, weights are used, it is essential to use the expertise, advice, and supervision of trained PE staff.
• Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to over-exertion and possible fainting or injury.
• Ensure students carry out the activities in a suitable place, clear of any obstruction.

Running the experiment

1 Students work in same-sex pairs. Students could carry out the work in a group of three.
2 Students take it in turns to measure the size of their upper arm in millimetres with a tape measure. They measure around the upper arm at the largest point when the biceps are contracted; the arm should be bent at 90 degrees. Then they take a second measurement of the upper arm at the same point when the arm is hanging at the side of the body and the biceps are relaxed. Students must ensure that the tape measure is level all the way round the arm and that it does not squeeze the skin.
3 One student in the pair takes part in different activities (as many as time allows) but must complete some warm-up exercises and stretches first. Suggested warm-up exercises are walking on the spot and then raising it up to a gentle jog on the spot, followed by stretches for the quadriceps, hamstrings, and calves (see page 57). The other student counts the number of repetitions of each activity in 2 minutes. See the Student sheet for the protocol for obtaining evidence.
4 They record results and then swap roles.
Suggestions for classroom-based activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicep curls</td>
<td>Bottles of sand</td>
</tr>
<tr>
<td>Triceps dips</td>
<td>Sturdy box at about knee height, or chair seat</td>
</tr>
</tbody>
</table>

Suggested classroom-based activities: bicep curls and triceps dips.

Suggestions for activities using sport facilities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest presses</td>
<td>Dumbbells</td>
</tr>
<tr>
<td>Triceps extensions</td>
<td>Dumbbells or fixed weights</td>
</tr>
<tr>
<td>Pull-ups</td>
<td>Pull-up bar</td>
</tr>
</tbody>
</table>

www.getinthezone.org.uk
Suggested activities using sports facilities: chest presses, triceps extensions, pull-ups.

There is an opportunity to have a class discussion on whether there is a relationship between muscle size and number of repetitions performed in the selected activities. During any discussion, height and maturation status of students will need to be taken into account.

Expected results

It would be expected that students with larger biceps would be able to perform more repetitions of the activities in 2 minutes compared to students with smaller-sized arm muscles. This is because larger muscles are able to produce more force and therefore will not tire as easily as smaller muscles. Some students may have larger biceps due to excess body fat rather than large muscles size and therefore they may not perform as well as expected in the activities.

Next lessons

In Lesson 2 you will be running a carousel of three experiments (B–D), on upper and lower body strength, power and endurance and fatigue, with two stations for each experiment. Lesson 3 will give students the opportunity to analyse and evaluate all the data they have collected. This is also when they will be able to upload the data from Experiments C and D into the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk) and analyse and interrogate national data from UK schools.
From strength to strength

Does the size of muscles affect performance in different activities?

Prediction
Can people with larger muscles do more repetitions of an activity? Make a prediction.

Obtaining the evidence

1. Find a partner who is the same sex as you.
2. Using the tape measure, take it in turns to measure the size of each other's upper arm. Measure around the upper arm at the largest point when the biceps are contracted; the arm should be bent at 90 degrees. Ensure that the tape measure is level all the way around the arm and does not squeeze the skin. Record your results in the table on the next sheet. Take two repeat measurements and then work out the average.
3. Take a second measurement at the same point as in step 2 but this time make your arm hang at the side of the body so the biceps are relaxed. Record this measurement below. Take two repeat measurements and then work out the average.
4. The exerciser takes part in a selected activity for 2 minutes. The time-keeper starts the stopclock and keeps count of the number of repetitions completed in 2 minutes. The diagrams below show you the different exercises to do.
5. Record your results in the table below.
6. Now swap roles so that the other person in the pair takes part in the activity and the partner records the time and number of repetitions completed in 2 minutes.
7. Take part in different activities and repeat steps 3 to 5.
8. Write your results in the table on the next page.
### Presenting the results

#### Arm measurement, biceps contracted (mm)

<table>
<thead>
<tr>
<th>Measurement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement 1</td>
<td></td>
</tr>
<tr>
<td>Measurement 2</td>
<td></td>
</tr>
<tr>
<td>Measurement 3</td>
<td></td>
</tr>
<tr>
<td>Average measurement, biceps contracted (mm)</td>
<td></td>
</tr>
</tbody>
</table>

#### Arm measurement, biceps relaxed (mm)

<table>
<thead>
<tr>
<th>Measurement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement 1</td>
<td></td>
</tr>
<tr>
<td>Measurement 2</td>
<td></td>
</tr>
<tr>
<td>Measurement 3</td>
<td></td>
</tr>
<tr>
<td>Average measurement, biceps relaxed (mm)</td>
<td></td>
</tr>
</tbody>
</table>

**Difference in arm measurements:**
contracted measurement – relaxed measurement

<table>
<thead>
<tr>
<th>Activity</th>
<th>Number of repetitions in 2 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

www.getinthezone.org.uk
Lesson 2 uses a carousel approach to collect further data relating to muscles and physical activity; upper and lower body strength, power and endurance and fatigue. The carousel comprises Experiments B, C and D of the group. If you wish to take part in the data capture exercise then Experiment B should be closely monitored in order to ensure that students carry out the investigation correctly to ensure standardisation with other data collected from other classes and schools. Students should do warm-up exercises and stretches before they begin the carousel activities. Suggested warm-up exercises are walking on the spot and then raising it up to a gentle jog on the spot, followed by stretches for the quadriceps, hamstrings, and calves.

Is there a relationship between upper and lower body strength?

The student notes for this experiment are on page 53.

Aim
Students will carry out an upper body muscular strength test (straight leg press-up or if they are unable to do this a bent leg press-up) and a lower body strength test (squat) to find out if there is a difference in the number of repetitions they can manage to do in 1 minute.

Equipment

<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• tape measures</td>
<td>• stopclocks</td>
</tr>
<tr>
<td>optional:</td>
<td>• stadiometer</td>
</tr>
</tbody>
</table>

Safety

- Identify students with asthma so they can have their inhaler close at hand and use it if required.
- Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
- Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
- Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to over-exertion and possible fainting or injury.
- Ensure students carry out the activities in a suitable place, clear of any obstruction.

Running the experiment

1 Students work in small groups carrying out straight-leg press-ups and squats to find out if there is a difference in the number of repetitions they can manage to do in 1 minute. For each test, especially the straight-leg press-up test, it is not expected that every student will be able to continue exercising for the full duration of 1 minute. During the 1 minute time frame students can stop and rest at any point and then continue the press-ups or squats when they feel ready – however, the stopclock continues to run during these rest periods and the total number of press-ups or squats completed in the timed period of 1 minute is recorded.
2 If students are unable to complete a single straight-leg press-up, the bent-leg press-up technique can be used. It is recommended that where possible the straight-leg position should be used in order to produce meaningful comparisons of the upper body and lower body test results, and for the national data collected in the ‘Live Data Zone’.

3 One or more students in the group can take part in the selected activities. Each person exercising will need to have one person counting the number of repetitions and timekeeping. If time permits, students can swap over so every student gets to take part in the activity.

4 See the Student sheet on page 53 for the protocol for obtaining evidence.

5 Students measure their sitting and standing height. When doing this they should be without shoes and with a ruler or other flat object to level the top of their head. They should take a deep breath in, breathe out, relax and stand tall without going on tiptoes.

**Expected results**

Most people will have stronger lower body muscles compared to upper body muscles, as we use our lower body muscles more in everyday life to walk and run. Our upper body muscles are not usually stressed regularly unless you take part in specific activities, such as swimming, which exercise these upper body muscles. Our lower body muscles are much bigger than our upper body muscles, which also helps to explain how muscle size is related to muscle strength; this is investigated in other experiments.

A short person may have an advantage when doing press-ups compared to a tall person of the same weight and percentage of muscle mass. This is because taller people tend to have longer legs than short people, so the moment of their weight about the fulcrum (where their feet touch the ground) is greater because their centre of gravity is closer to their hands, making the press-up harder. However, a taller person with similar musculature to a shorter person has a greater volume of muscle to compensate for this disadvantage. Arm length is also a factor – how close you are to the ground. In rowing, greater sitting height is an advantage due to the greater stroke length.

**Live Data Zone**

Your students can enter and compare their results from this experiment into the ‘Live Data Zone’ of the In the Zone website (www.getinthezone.org.uk); see the Teacher notes on page 64 for 14–16 Lesson 3.
From strength to strength

Is there a relationship between upper and lower body strength?

Prediction
Can people who can do more press-ups also do more squats? Make a prediction.

Measuring standing and sitting height.

Obtaining the evidence

1. Using a stadiometer or tape measure, record your sitting and standing height.
2. Work in pairs or small groups. One or more students in the group should do press-ups. For each person exercising, you will need to have someone counting the repetitions and timekeeping.

Upper body activity – press-ups

3. The exerciser does the press-ups for 1 minute and completes as many repetitions as they can. The time-keeper times the 1-minute period and counts the number of repetitions completed.
Straight-leg position press-up

- The exerciser lies on the ground with their hands by their shoulders.
- Their toes should be touching the ground.
- They should push up from the ground with their arms so that the arms are straight.
- The press-up is then performed by lowering the body until the elbows are at 90 degrees and then extending the arms. This counts as one press-up.

Bent leg position press-up – this should only be used where one straight leg press-up cannot be performed

- Practise the press-up technique. You should be on all fours with your knees bent and your arms shoulder-width apart. Bend your elbows to bring your head towards the ground.
- Push up on your hands and straighten your elbows to push yourself up from the ground – this counts as one press-up.

---

<table>
<thead>
<tr>
<th>START</th>
<th>FINISH</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Start position" /></td>
<td><img src="image2" alt="Finish position" /></td>
</tr>
</tbody>
</table>

- The time-keeper starts the stopclock and the exerciser repeats the press-ups as quickly as possible but at a steady rate.
- The time-keeper must check that the person doing the press-ups is doing it properly, including keeping their back straight as they move towards the floor. The movement must be continuous with no rest during the single press-up. However, students may need to rest for a few seconds before starting the next press-up. The repetition can only be counted if the movement is done exactly as shown.
- The time-keeper must count the number of repetitions completed in 1 minute.
- Swap over, so that the time-keeper now does the press-ups and the exerciser records the time and number of repetitions.
Lower body activity – squats

8 The exerciser does squats for 1 minute and does as many repetitions as they can. If it has not been 5 minutes since you carried out the press-ups then you must wait to start the squats. During this time list sports which require good upper body strength and which need good lower body strength. The time-keeper times the 1-minute period and counts the number of squats completed.

Squats.

a Practise the squat technique. Your back should be straight, stomach pulled in and feet hip-width apart with toes facing forwards and your arms out straight in front of you.
b Bend your knees, pushing your bottom backwards and away as if you were going to sit down and keeping your feet flat on the ground.
c Make sure your knees bend to 90 degrees but no further.
d Straighten your knees and bring your bottom and hips forwards so that you are in a standing position.
e Start the stopclock and repeat the squatting process as quickly as you can but at a steady rate.
f The time-keeper must check that the exerciser is doing the squat properly as shown in the diagram. The repetition can only be counted if the full range of movement for the squat is done. The time-keeper must count the number of repetitions completed in 1 minute.

Presenting the results

My standing height is _____________   My sitting height is _______________

<table>
<thead>
<tr>
<th>Activity</th>
<th>Number of repetitions (in 60 seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper body activity, press-ups</td>
<td></td>
</tr>
<tr>
<td>Lower body activity, squats</td>
<td></td>
</tr>
</tbody>
</table>
Are people who are good at power sports also good at endurance sports?

The student notes for this experiment are on page 58.

**Aim**
Students investigate the relationship between power and endurance. They collect and analyse results from an anaerobic power test (vertical jump test) and a muscular endurance test (lunges) to try to find out more about the difference in properties of muscle fibres.

**Equipment**

<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• tape measures</td>
<td>• stopclocks</td>
</tr>
<tr>
<td>• powdered chalk</td>
<td>• metronome</td>
</tr>
<tr>
<td>optional:</td>
<td>• access to a vertical (electronic) jump board</td>
</tr>
</tbody>
</table>

**Safety**

- Identify students with asthma so they can have their inhaler close at hand and use it if required.
- Chalk dust is an irritant so students should quickly wash it off their hands, and try not to inhale it. See the chemical safety sheets available on the In the Zone website.
- Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
- Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
- If PE equipment e.g. vertical jump board is used it is essential to use the expertise, advice, and supervision of trained PE staff.
- Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to overexertion and possible fainting or injury.
- Ensure students carry out the activities in a suitable place, clear of any obstruction.

**Running the experiment**

1 Working in small groups, one or more students in the group can take part in the physical activities. Students will take part in two tests. The vertical jump test will test their muscle power, while the lunges will test their muscular endurance. They carry out the lunges until they can do no more. For each person taking the test, the group will need to have one person taking measurements and recording the results of each test.

2 Before any tests are carried out, students should take part in a gentle warm-up. The warm-up should raise their pulse, such as walking on the spot and then raising it up to a gentle jog on the spot, followed by stretches for the:
- hamstrings
- calves
- quadriceps.
Stretches for quadriceps, hamstrings, and calves.

3 You can use a vertical jump board for the vertical jump test if your school has one. We have assumed that there is no access to a vertical jump board on the Student sheet.

4 See the Student sheet on page 58 for the protocol for obtaining evidence in the power test (vertical jump test) and the muscular endurance test (lunges).

5 Jumpers should not swing their arms or squat before making their jump.

6 Encourage students to practise the lunge technique, ensuring that their back is straight, their stomach is pulled in, their feet are hip-width apart with their toes facing forwards, and their hands are on their hips to start. They must take a large step forward with one leg and bend their knee no more than 90 degrees. The heel of the back foot should be off the floor.

7 Students may find it easier to keep a steady rate for the lunges if they have access to a metronome.

8 Students should compare the results from the two different tests.

9 The prediction students are asked to make does not ask them to take into account the fitness of participants. You may wish to discuss with students the effect fitness may have on the result.

Expected results

Students who are good at the vertical jump test would not necessarily be good at the endurance test. This happens because people who are good at the vertical jump test will have a high percentage of fast-twitch muscles, whereas those who are good at endurance tests will have a high percentage of slow-twitch muscle fibres. Students who participate in sports, or a combination of sports that require both power and endurance, may perform well in both tests.
From strength to strength

Are people who are good at power sports also good at endurance sports?

Prediction
Can people who can jump higher also perform lunges for a longer time? Write a prediction for this investigation.

Obtaining the evidence
1. Work in small groups. One or more students in your group will need to take part in the selected activities. At least one of you will need to observe the test and record the data.
2. The time-keeper is responsible for measuring the distance jumped for the vertical jump (power test). They should also record the length of time and how many lunges have been performed in the endurance test.
3. Carry out the vertical jump test.

Preparing for the vertical jump test.
a Keep your feet together and flat on the ground. If you are right-handed, stand with your right hand next to the wall, and if you are left-handed, stand with your left hand next to the wall.

b Mark your fingers with chalk dust and reach up as high as you can with the hand closest to the wall. Do not jump. Chalk dust is an irritant so wash it off your hands quickly after step g, and try not to inhale it.

c The time-keeper should measure the height of the chalk mark on the wall where the top of the jumper’s hand reached up to. This is the standing reach height. Record the results in the table on the next page.

d The jumper should mark their fingers with chalk dust again and take a step away from the wall.

e The jumper should jump up as high as possible and touch the wall with their fingertips at the highest point of the jump. The chalk from their fingers should leave a mark on the wall – this is the jump height. Jumpers should not swing their arms or squat before making their jump. One dip of the arms and knees is permitted.

f The time-keeper should use the tape measure to record the jump height. Subtract the jump height from the standing reach height to give the jump distance. The measurements should be recorded in the table on the next page.

g Repeat the test two more times. Leave a short break of around 1 minute between jumps. The best distance of the three is recorded as the score for the test.

4 Carry out the muscular endurance test – lunges.

a Practise the lunge technique. Make sure that your back is straight and your stomach is pulled in.

b Your feet should be hip-width apart with your toes facing forwards and your hands on your hips.

c Take a long step forward with one leg. Bend your front knee at an angle of 90 degrees or less and bring your back knee towards the ground. Your back heel should be off the floor.

d Push off the front leg and come back to the starting position to complete one repetition.

e Repeat this process stepping forward on your other leg.

f Start the stopclock and repeat the lunge process at a steady rate until you can do no more. A metronome will help you to keep a steady rate.
The time-keeper must check that the exerciser is exercising properly and completing the full range of movement for the activity. The repetition can only be included in the count if this is the case. The time-keeper must count the number of repetitions completed and the length of time that the participant continued exercising for until they can do no more. They must be stopped if they are no longer doing the lunges correctly.

**Presenting the results**

**Power test (vertical jump test)**

<table>
<thead>
<tr>
<th></th>
<th>Attempt 1</th>
<th>Attempt 2</th>
<th>Attempt 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing height with arm extended (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jump height (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jump distance (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jump score (best distance)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Muscular endurance test (lunges)**

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lunges completed</td>
</tr>
<tr>
<td>Length of time exercising (min)</td>
</tr>
</tbody>
</table>

5 Record your results on a class sheet.
The student notes for this experiment are on page 62.

Aim
Students investigate how fatiguing one set of muscles affects how a different set of muscles performs. They will then have the opportunity to analyse and evaluate the results and relate them to athletes being able to take part in more than one event in a competition.

Equipment

<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>tape measures</td>
<td>1 litre bottles of sand</td>
</tr>
<tr>
<td></td>
<td>optional: dumbbells</td>
</tr>
</tbody>
</table>

Safety
- Identify students with asthma so they can have their inhaler close at hand and use it if required.
- Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
- Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
- If PE activities and equipment e.g. multi-gym, weights are used, it is essential to use the expertise, advice, and supervision of trained PE staff.
- Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to overexertion and possible fainting or injury.
- Ensure students carry out the activities in a suitable place, clear of any obstruction.

Running the experiment
1. Students work in small groups. One or more students in the group can take part in the exercises, each of which uses a different set of muscles: bicep curls and standing broad jump (also known as the standing long jump).
2. Students do standing broad jumps, which measures the strength in their legs. They then fatigue the muscles in their arms by doing bicep curls and carry out the standing broad jump test again to see if fatiguing the muscles in their arms has had any effect on their leg muscle strength result.
3. It is not expected that every student will be able to continue exercising for the full duration of 2 minutes.
4. See the Student sheet on page 62 for the protocol for obtaining evidence.

Expected results
There should not be a difference in the standing broad jump test results after the arm endurance exercise. The experiment is to show that the effects of fatigue are localised to the muscles involved in the activity.
**From strength to strength**

What is muscle fatigue and is it localised?

**Prediction**

Does fatiguing one set of muscles affect the performance of another set of muscles? Write a prediction.

---

**Obtaining the evidence**

1. Work in small groups. One or more of you in the group takes part in the selected activities and one of you will need to act as an observer.

2. The test observer is responsible for making sure the tests are carried out properly and results are recorded accurately.

3. Take part in the standing broad jump test.

---

**Standing broad jump test.**

- **a** Stand behind a marked line on the ground with feet hip-width distance apart.
- **b** Jump, taking off on two feet, swinging the arms and bending the knees to help you to jump as far as you can.
- **c** Land on two feet without falling backwards. The distance between the starting position and landing position is measured. Record your result.

4. Repeat this test two more times with at least a 2-minute break between each attempt.

5. Do bicep curls for a period of 2 minutes.
**Bicep curls.**

6. Repeat the broad jump test process and record the results.

**Presenting results**

<table>
<thead>
<tr>
<th></th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before bicep curl exercise</strong></td>
<td></td>
</tr>
<tr>
<td>Attempt 1</td>
<td></td>
</tr>
<tr>
<td>Attempt 2</td>
<td></td>
</tr>
<tr>
<td>Attempt 3</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td><strong>After bicep curl exercise</strong></td>
<td></td>
</tr>
<tr>
<td>Attempt 1</td>
<td></td>
</tr>
<tr>
<td>Attempt 2</td>
<td></td>
</tr>
<tr>
<td>Attempt 3</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
</tr>
</tbody>
</table>

Make sure you keep your back straight and elbow close to your body when you are performing curls.
Lesson 3 could be used to allow your students to:

- Upload the data from Experiment B to the ‘Live Data Zone’ of the In the Zone website (www.getinthezone.org.uk). They can then compare their results to students’ data from across the UK.

- Analyse, evaluate and consider the data collected from this group of experiments.

More details can be found on the In the Zone website (www.getinthezone.org.uk):

Enter data from Experiment B:

- number of press-ups in 1 minute
- number of squats in 1 minute
- height and sitting height.

In order to be able to accurately compare their results to other students across the UK, your students will also need to enter the data listed below:

- age
- gender
- asthmatic or not (optional)
- school postcode
- school year
- class, e.g. 10A (optional)
- physical activity level, in minutes of exercise per week
- type of sport(s) played regularly
- how fit they think they are in relation to their class.

The Student sheet on pages 65–67 provides a series of activities analysing and evaluating Experiments A–D. Answers are on pages 109–13. Alternatively, you may wish to analyse and evaluate the experiments through a more open-ended approach. Examples of this might be:

- Write a report for the coach of an Olympic or Paralympic athlete, outlining the findings of your research and how it might inform their training programme. You should try to include information about class and national data where you have it. Higher tier students may wish to consider a decathlete or a heptathlete as this will involve looking at several different disciplines.

- Find an image of three different types of sport or activity. Label each image to illustrate how the person’s musculature reflects the sport they take part in. You should relate these features to evidence from your experiments.

There are opportunities to extend the materials further in the accompanying PowerPoint available from the In the Zone website. You may also wish to explore further with your students the links to contemporary science and sports science – the Knowledge Card will help with this.

If you would like to reward any of your students for effort or achievement in these experiments, then the In the Zone website has In the Zone Reward Certificates that you can customise.
What is the effect of sport and exercise on my body?

These experiments have given you the chance to explore how your body reacts to different sports and physical challenges. Complete the activities below to find out how much you know about how muscles affect sporting performance.

Experiment A

1. a Complete the table below to summarise what your own and class results show about the relationship between the number of repetitions performed in upper body strength activities and the size of the upper arm when the biceps are contracted.

<table>
<thead>
<tr>
<th>Relationship between number of repetitions and upper arm size</th>
<th>Evidence from your own data</th>
<th>Evidence from class data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


b Does gender have an effect on this relationship? Use evidence to support your answer.

___________________________________________________________________________
___________________________________________________________________________

2. a Sort the sports into two groups: participants tend to have large upper arm muscles, and participants tend to have smaller upper arm muscles.

100 m sprint   canoeing  cycling  dancing  decathlon  diving  football
               gymnastics  javelin  judo  rowing  shot put  swimming  table tennis

<table>
<thead>
<tr>
<th>Large upper arm muscles</th>
<th>Smaller upper arm muscles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b Complete these sentences in your own words, using a connecting word such as and, because, but, however, so, such as, therefore.

i Canoeists have large upper body muscles...

ii Cyclists have large lower body muscles...
Experiment B

Read the statements below and decide, using the results from your own experiment and the national data collected, which are true and which are false. Correct those that are false.

1. There is a difference between the number of repetitions completed for the upper and lower body activities. 

2. The results show that most people have stronger lower body muscles compared to upper body muscles.

3. Most people have stronger upper body muscles because we use our lower body muscles in everyday life to walk and run.

4. Our upper body muscles are not usually as strong as our lower body muscles, unless we take part in specific activities, such as swimming, which exercise the lower body muscles.

5. People who play sports that require good upper body strength (such as tennis or swimming) can do more squats in one minute than people who play sports that require good lower body strength (such as running or rugby).

6. The national data shows that generally females have greater upper body strength than males.

Experiment C

1. a Write the results in the spaces.

<table>
<thead>
<tr>
<th>For the person who can jump the highest</th>
<th>Class data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power test:</td>
<td>Jump score (best distance)</td>
</tr>
<tr>
<td>Muscular endurance test:</td>
<td>Number of lunges completed</td>
</tr>
<tr>
<td></td>
<td>Length of time exercising (min)</td>
</tr>
</tbody>
</table>
**For the person who can lunge for the longest time**

<table>
<thead>
<tr>
<th>Class data</th>
<th>Power test: Jump score (best distance)</th>
<th>Muscular endurance test:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number of lunges completed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length of time exercising (min)</td>
</tr>
</tbody>
</table>

**b** Can people who can jump higher also perform lunges for longer?

_________________________________________________________________________

2 Explain your answer. ______________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

**3** Tick the boxes next to the sports to show which sportspeople you would expect to do well in the vertical jump test and in the lunges.
List any other sports that people play regularly and the test(s) that they were good at.

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Experiment D
Read the text below.
My standing broad jump result was very similar before and after performing the bicep curls. Before the bicep curls it was ________________ and after the bicep curls it was ________________. These results agreed with my prediction. The results show that fatigue in one set of muscles does have an effect on the performance of another set of muscles.

a Change anything that is incorrect and fill in the missing information.

b Underline in blue anything that describes the results from the experiment.

c Circle in red a conclusion explaining what these results show.
How do muscles affect sporting performance?

Look at the results from all four of the experiments that you have carried out. Consider your own results, your class results, and the national data if you have this available to you.

1. Draw lines to match the sports to the correct sentences explaining how different sports require different musculature of the athlete.

<table>
<thead>
<tr>
<th>Sport</th>
<th>Sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rowing</td>
<td>High lower body strength required to move fast</td>
</tr>
<tr>
<td>Dancing</td>
<td>High lower body strength required to control own body weight while standing on toes or when crouching down (squatting)</td>
</tr>
<tr>
<td>Swimming</td>
<td>High lower body strength required to produce large force and to raise body weight up steep climbs</td>
</tr>
<tr>
<td>100 m sprint</td>
<td>High upper body strength required to produce large force with each arm stroke, and large length</td>
</tr>
<tr>
<td>Shot put</td>
<td>High lower body strength required to move fast and maintain crouch position (squatting)</td>
</tr>
<tr>
<td>Judo</td>
<td>High lower body strength required to produce large force against a resisting force</td>
</tr>
<tr>
<td>Long-distance cycling</td>
<td>High upper body strength required to lift and throw large weights</td>
</tr>
<tr>
<td>Table tennis</td>
<td>High upper body strength required to grip and to pull hard</td>
</tr>
</tbody>
</table>

2. Choose two of the sports in the table and for each sport, suggest which two of the following factors are most important, and why:

- lower body endurance,
- upper body endurance,
- lower body power,
- upper body power

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
Lesson 1

Experiment A: Does the size of muscles affect performance in different activities?

Each group will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From kit box</td>
<td></td>
</tr>
<tr>
<td>• 1 tape measure</td>
<td></td>
</tr>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>• 1 stopclock</td>
<td></td>
</tr>
<tr>
<td>• 2 1-litre bottles of sand</td>
<td>for weights</td>
</tr>
<tr>
<td>• multi-gym, dumbbells</td>
<td>optional</td>
</tr>
<tr>
<td>• sturdy box at about knee height</td>
<td>optional</td>
</tr>
</tbody>
</table>

Lesson 2 – Carousel of experiments

The tables below show the equipment required for one station for each experiment within the carousel. Depending upon the equipment available to each class and the number of students in the class, you may wish to provide more stations for one or more of the carousel experiments – you will need additional tape measures as there is only 1 in the kit box.

Experiment B: Is there a relationship between upper and lower body strength?

Each carousel station will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From kit box</td>
<td></td>
</tr>
<tr>
<td>• 1 tape measure</td>
<td></td>
</tr>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>• stopclock</td>
<td></td>
</tr>
<tr>
<td>• stadiometer</td>
<td>optional</td>
</tr>
</tbody>
</table>
Experiment C: Are people who are good at power sports also good at endurance sports?

Each carousel station will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From kit box</td>
<td></td>
</tr>
<tr>
<td>• 1 tape measure</td>
<td></td>
</tr>
<tr>
<td>• powdered chalk</td>
<td>irritant: wash off hands quickly after use and do not inhale it</td>
</tr>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>• 1 stopclock</td>
<td></td>
</tr>
<tr>
<td>• metronome</td>
<td>optional</td>
</tr>
<tr>
<td>• access to a vertical jump board</td>
<td>optional</td>
</tr>
</tbody>
</table>

Experiment D: What is muscle fatigue and is it localised?

Each carousel station will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From kit box</td>
<td></td>
</tr>
<tr>
<td>• 1 tape measure</td>
<td></td>
</tr>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>• stopclock</td>
<td></td>
</tr>
<tr>
<td>• 2 1-litre bottles of sand</td>
<td>for weights</td>
</tr>
<tr>
<td>• dumbbells</td>
<td>optional</td>
</tr>
</tbody>
</table>
How does the body respond to changing energy needs?

‘I’ve got the power’ is a group of experiments all about what limits our performance during exercise and how we release the energy that we require to move our bodies during different types of exercise.

My name is Dr Valerie Gladwell and I am a Senior Lecturer in Physiology at the University of Essex. I teach undergraduates who are taking a Sport and Exercise degree all about how the body works at rest, during exercise, and following training. My research involves exploring how the cardiovascular system responds following exercise. I am also passionate about the effect physical activity can have on health. The concepts that your students will be investigating are questions that I ask during my research studies in order to gain an understanding of how the body responds to different types of exercise, the recovery from exercise, and how this can relate to improvements in performance and health.

In these experiments, your students will collect and consider data relating to VO₂max, blood pressure, pulse rate during and in recovery from exercise, and also carbon dioxide production. They will relate these measurements to how the whole body responds to movement before looking at how the same principles are applied by sports scientists and trainers to help athletes improve their performance.

How can we improve performance?

Performance is dependent on providing the energy required to contract our muscles to move our bodies. Apart from very short-duration exercise (less than 10 seconds), this is dependent on: getting air into the lungs; the blood collecting oxygen from the lungs; the heart pumping blood around the body; the blood capillary network around muscles taking oxygen to and removing carbon dioxide from the muscles; and the uptake of oxygen from the blood into muscle tissue and the mitochondria. Training can improve most of these things. All athletes want to know how fit they are and how to improve their training.

Fitness: VO₂max

The volume of oxygen that you use while exercising at your highest level can be used as a measure of fitness. This is known as VO₂max. VO₂max is the maximum amount of oxygen you can use in 1 minute and usually takes into account your body mass. The higher the VO₂max value, the fitter a person is. Measuring VO₂max requires specialised equipment to measure the oxygen uptake. However, it can be predicted in other ways, without even pushing your body to the max! One way is to measure heart rate during exercise or in recovery from exercise and to use equations or tables to estimate your VO₂max and your fitness level based on the results.

www.getinthezone.org.uk
Heart rate during exercise and in recovery from exercise

Heart rate is a really important but very easy measurement to take during exercise and can be used to determine VO2max and fitness. Furthermore, heart rate recovery from exercise can be used as a marker of fitness and health. The faster it falls after a certain intensity of exercise is performed, the fitter you are.

Athletes such as runners, triathletes, cyclists, and cross-country skiers monitor their heart rate during competition to check that they are not racing too hard. It is also used in training to determine how hard to train and also during recovery from exercise. Athletes and their coaches also monitor resting heart rate (before they get out of bed in the morning) to ensure that they are not overtraining.

During exercise, the heart not only contracts quicker (i.e. the increased heart rate you can measure) but it also contracts more forcefully and pushes out more blood on each contraction (increasing stroke volume). Both the increase in heart rate and the increase in stroke volume cause the cardiac output (measured in litres of blood per minute) to increase. This enables more oxygen to get to the muscles and more carbon dioxide and lactate to be removed to try to meet the demands of the muscles during exercise.

Blood pressure during exercise and in recovery from exercise

The heart cannot work alone and requires changes to occur in the blood vessels. The resistance in the blood vessels can be reduced, allowing more blood to reach the muscles that are active. If there are enough muscles that are active during exercise, the diastolic blood pressure (minimum blood pressure during a heart beat) may decrease. On the other hand, if contraction of the muscle is sustained or particularly forceful, diastolic blood pressure may increase. The increase in systolic blood pressure (maximum blood pressure during a heart beat) during exercise occurs as a result of the increased force of contraction of the left ventricle, which pushes out more blood with each beat (increased stroke volume).

So all in all, the increase in stroke volume and heart rate and the potential decrease in resistance in the blood vessels allow more oxygen to get to the muscles that require it. However, during very high-intensity activity the muscles work more anaerobically, as the oxygen demands of the muscles cannot be met.

How do we provide the energy needed for movement?

You may think that muscle cells are respiring either aerobically or anaerobically at any one time, but in fact both types of respiration can be going on simultaneously. Different types of movement generally use both ways of releasing energy, rather than purely one or the other. Most types of exercise use different proportions of the immediate, short-term or long-term energy systems:

- **Immediate energy system** – **alactic anaerobic respiration**. Explosive, strength and power events such as sprints use this system. It uses stored energy supplies but there is a limited amount available in muscle cells.
- **Short-term energy system** – **lactic anaerobic respiration**. Lactic acid is produced as a by-product of this system. At one time lactic acid was thought of as a waste product but in fact it can be used itself as fuel for aerobic respiration.
- **Long-term energy system** – **aerobic respiration**. Endurance events such as marathons use mainly aerobic respiration. It requires oxygen to get to the muscles for the energy to be released.
Carbon dioxide concentration during exercise

More carbon dioxide is produced during exercise than at rest, irrespective of whether the exercise is aerobic or anaerobic. In aerobic exercise glucose is combined with oxygen to produce carbon dioxide and water:

\[
glucose + oxygen \rightarrow carbon\ dioxide + water
\]

\[
C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O
\]

In anaerobic respiration, lactate in the blood is buffered by sodium hydrogen carbonate, which makes sodium lactate and carbonic acid. This in turn produces carbon dioxide and water.

\[
lactate + sodium\ hydrogen\ carbonate \rightarrow sodium\ lactate + carbonic\ acid
\]

\[
carbonic\ acid \rightarrow water + carbon\ dioxide
\]

In the laboratory, scientists can measure oxygen uptake and carbon dioxide production. Usually when carbon dioxide production is greater than oxygen consumption it suggests that the athlete is mainly producing energy anaerobically. Scientists can use this information to design training programmes that have the right balance of aerobic and anaerobic exercise, depending upon the event they are training for.
In the training zone

Many athletes and coaches have devised complicated training plans to encompass all parts of fitness, from stamina and endurance to speed, strength, and power. The type of training sportspeople do will depend upon the event they are training for. Sprinters need to focus on power and strength but need a good aerobic base.

For long-duration endurance athletes the main training is stamina and endurance so their bodies are able to produce their energy aerobically and can deal with lactate more efficiently (increasing the exercise intensity at which lactate accumulates – OBLA). They also incorporate strength training to help improve their performance. Many sports, however, are not one or the other and require high levels of fitness mixed with speed and strength (e.g. rugby).

I hope that you and your students find the ‘I’ve got the power’ resources inspiring and that they help your investigation into how the body responds to movement and exercise. The 16–19 Knowledge Card will help your students understand the role of respiration in exercise. You can use the ‘Live Data Zone’ on the In the Zone website (www.getinthezone.org.uk) to upload some of your results, compare them to results from students across the UK, and contribute to capturing national data. I look forward to seeing your results.


Lesson Plan

I’ve got the power

How does the body respond to changing energy needs?

Resources

From the kit box:
- 1 respirometer kit: 1 plastic 2-litre bottle, 6 bungs, 6 flexible tubes, 6 hard tubes, one-way valve
- bromothymol blue indicator solution
- 0.1 M sodium hydroxide solution
- 6 pipettes
- 2 pulse oximeters
- 1 digital blood pressure monitor
- Teacher Guide
- Knowledge Cards.

From the school:
- 5 clean, plastic 2-litre cola-type bottles
- stopclocks
- test tube rack
- 500 cm³ measuring cylinder
- gym benches or sturdy boxes (height 0.25–0.3 m)
- 2 test tubes
- safety goggles
- skipping rope
- video clip of Zumba® or CD of fast dance music
- metronome
- bathroom scales
- ruler
- tape measure/stadiometer.

From the website

www.getinthezone.org.uk
- ‘Live Data Zone’ section of the website for upload and interrogation of data
- PowerPoint for the lesson
- editable Word files of teacher and student sheets and lesson plans
- editable certificates for student effort/performance.

Learning objectives

At the end of the lessons, students will be able to:
- describe the roles of aerobic and anaerobic energy systems in the body
- measure the power they generate during exercise
- estimate aerobic fitness and VO₂ max
- record and graph the data obtained to see if there is any correlation between power generated and hours per week of activity
- outline the importance of scientific research in informing training and coaching programmes.

Teaching strategies

- Dr Valerie Gladwell from the University of Essex is our expert physiologist for the 16–19 experiments. Students will carry out investigations to find out the effect of exercise on amount of CO₂ in respired air, VO₂ max, pulse rate, and blood pressure, and explore what fitness is.
- The In the Zone website (www.getinthezone.org.uk) has a PowerPoint for the investigation giving structure for these lessons, with photos, starter ideas, some background science, and data collection tables.
- You can use the teacher and student sheets supplied in this Teacher Guide (or the editable versions on the website) to run the experiments.
- The laminated Knowledge Cards supplied are stimulus material for students to use in the lessons, giving context and linking to real-life scientists and experiments as well as covering some of the science upon which the experiments are based. They could be used as jumping off points for discussion and exploration of the ideas or background for students at each station in the carousel of experiments.
- Students can upload some of the data they collect to the ‘Live Data Zone’ section of the In the Zone website and compare their results to those of other students across the UK.
- The investigations are designed to take three lessons but this is flexible so can be run in more or fewer lessons depending on the sizes of your classes/groups.

Getting in the zone

Elite athletes and sportspeople need competence, strength, stamina, and endurance, and will have undergone regular training and coaching to improve their performance. Their aerobic and anaerobic energy systems need to be well balanced and all types of athletes train aerobically to increase their anaerobic threshold.

Sportspeople will ‘zone in’ and undertake specific forms of training to maximise their performance. They then get ‘in the zone’ prior to competition and remain focused to ensure that they are ready to perform at their best.

Through the door activity

Show various short video clips of parts of sports/activities, e.g. sprint, golf swing, tennis serve, weightlifting, javelin throw, swimming, cycling, downhill skiing, or high jump. There are links to suitable clips in the PowerPoints. Ask students to identify the activity in each video and say whether they think it is a strength/power event, a sustained power event, an anaerobic endurance event, or an aerobic endurance event. Ask them to write their answers down so that they can revisit them following the investigation.
Lesson Plan

I've got the power

How does the body respond to changing energy needs?

Lesson Plan

Ask students to write down what they think the following terms mean: endurance, strength, work, power, and energy. Ask students to discuss the definitions in pairs and then extend this to a whole-class discussion.

Suggested starter activities (~5–10 minutes)

Ask students to contribute to a class list of:

a how the body responds to different intensities of exercise
b how understanding how the body responds to exercise can help improve training programmes for different sports.

Return to the final list at the end of the investigation.

Experiments

The experiments can be carried out in the science classroom and there is an opportunity for collaboration with your PE department and use of their facilities. No student should feel under pressure to take part, for example if they are sensitive about their fitness levels or weight.

Lesson 1 – Experiment A – Students compare the power their leg muscles generate when they do step exercises at different levels of intensity.

Lesson 2 – ‘carousel’ of activities – Experiments B–D (two stations for each experiment)

Experiment B – Students explore what aerobic fitness is using a step test and measuring heart rate. This data will be used in Lesson 3 to calculate VO\textsubscript{2}max.

Experiment C – Students use respirometers to measure what happens to the volume of carbon dioxide in their breath before and after aerobic and anaerobic exercise.

Experiment D – Students use a blood pressure monitor and a pulse oximeter to measure their pulse rate and blood pressure before and after aerobic and anaerobic exercise.

See the Teacher sheets, Technician notes and Student sheets for details of the protocols for the experiments. See the 16–19 student Knowledge Card for background and context to the lessons.

Lesson 3 – During this lesson data from Experiment B can be uploaded to the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk). Your students will then be able to evaluate their results and analyse data for students from other schools all across the UK. It will also be an opportunity to discuss aspects of the scientific method such as reliability, validity, and correlation. Students also calculate their VO\textsubscript{2}max from their data generated in Experiment B.

Suggested plenary activities (~5–10 minutes)

Revisit the video clips of parts of sports/activities from the ‘Through the door’ activity from Lesson 1. Ask students to look again at their classification of each sport/activity: strength/power event; sustained power event; anaerobic endurance event; or aerobic endurance event. Ask them to identify any sports/activities that they would now change the classification of and give reasons for their change.

Revisit the class list from the starter of:

a how the body responds to different intensities of exercise
b how understanding how the body responds to exercise can help improve training programmes for different sports.

Discuss any changes that students think should be made to the list and ask them to create a list of five key principles for a training programme for a named sport.

Learning outcomes

All students will be able to:

- record and graph data on the physiological changes that occur when exercising at different intensities
- describe the roles of aerobic and anaerobic respiration and the cardiovascular system in various sports and activities.

Most students will be able to:

- analyse data on the physiological changes that occur when exercising and explain these changes in terms of meeting the extra needs of muscle tissue
- explain how measuring physiological changes that occur when exercising can inform training programmes devised for athletes.

Some students will be able to:

- evaluate the data on physiological changes when exercising
- devise ways of using such data to inform the development of training programmes for athletes
- explain why the aerobic and anaerobic energy systems have to be well balanced for athletes to achieve their full potential.

Homework suggestions

1 Devise part of a training programme for top athletes in school.
2 Research the challenges for athletes of performing in hot climates.
3 Evaluate the ‘Live Data Zone’ on the In the Zone website (www.getinthezone.org.uk) to find out how their results compare to the national data collected.

Cross-curricular links

Chemistry – moles, pH indicators
Physics – power and work
PE – fitness testing, aerobic and anaerobic energy systems

Keywords

aerobic fitness, aerobic respiration, anaerobic capacity, anaerobic respiration, anaerobic threshold, ATP, endurance, fatigue, glycogen, lactic acid, power, stamina, strength, VO\textsubscript{2}max, work

www.getinthezone.org.uk

Ages

16–19
I’ve got the power

Lesson 1

How much power do my muscles generate?

The student notes for this experiment are on page 80.

Aim
Students will investigate the power their leg muscles generate when they do step exercises. Using their results they will estimate how much work the body does during step exercises at different intensities. This will start to get the students to discuss how energy is provided to muscle cells to allow them to contract and be able to perform work, and to consider the different energy systems (aerobic and anaerobic) that produce the required ATP that is used as the body’s universal energy currency.

Equipment

<table>
<thead>
<tr>
<th>From your school</th>
<th>optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>stopclocks</td>
<td>• metronome</td>
</tr>
<tr>
<td>gym bench/ aerobic step/sturdy box/stair, of height 0.25–0.3 m</td>
<td>• music</td>
</tr>
<tr>
<td>bathroom scales</td>
<td>• tally counter</td>
</tr>
<tr>
<td>metre ruler</td>
<td></td>
</tr>
</tbody>
</table>

Safety

- If anyone begins the activity and starts to feel unwell they should stop immediately.
- Identify students with asthma so they can have their inhaler close at hand and use it if required.
- Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
- Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
- Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to overexertion and possible fainting or injury.
- Ensure students carry out the activities in a suitable place, clear of any obstruction.

Running the experiment

1. In the previous lesson ask students to measure their body mass in kg at home and bring this data with them to this lesson. They should measure their clothed mass, as they will be lifting their clothed weight during the experiment. Some may forget to measure their mass so have a set of bathroom scales available if possible – this will also ensure that measurements are standardised. No student should feel under pressure to take part, particularly if they are sensitive about their weight, and there is no need to share their mass in kg with the rest of the class.

2. Students ought to be reminded of the difference between mass and weight and of the units for both work and power.

3. Students will be counting how many times they can go up and down a step in 1 minute. They will need to measure the height of the step that they use. Ensure that they measure the height of the step, bench, or stair in metres rather than centimetres. If you have steps of different height, allow students shorter than e.g. 1.5 m to work on the lower steps to ensure they can step safely on and off the step. If using stairs, students should use a handrail.
4 You could liaise with your PE department to ensure that there is enough space and equipment. Students should work in pairs. See the Student sheet on page 80 for the protocol for obtaining evidence.

5 Students should practise the step exercise prior to starting the actual test to enable them to get the correct rhythm. Students may find it easier to keep the steady rate if they have access to a metronome, which is set at 120 beats per minute (4 clicks = one step cycle). Ensure students step onto the step with one foot, followed by the other foot, and then step down from the step with one foot followed by the other. This whole cycle is one step. They can choose which foot to lead with and this can be changed during the test if they wish.

6 Emphasise the need for time to rest and recover following the exercise before moving on to the next measurement.

7 The PowerPoint presentation on the In the Zone website includes a tool for recording class results.

8 Discussion should be around how the energy is generated, the energy systems (aerobic or anaerobic) at different rates of stepping, and how we get the oxygen required for energy release to the muscles that require it. This can also encompass a brief discussion about ability to generate greater power and different fitness levels.

**Expected results**

In each case:
- the distance moved is the height of the step provided, in metres
- the force (weight) is each student’s body mass in kg multiplied by 9.8 ms⁻² (acceleration due to gravity) to give the value in newtons (N)
- total work done is force × distance × number of steps in 1 minute, and the unit is joules (J).
- power (the amount of energy transferred each second) is total work done (J)/time taken (s), and the unit is watts (W).

Hence:
- total work done will vary from student to student depending on their mass, the step height used, and how many steps they do per minute
- work done will vary for each student at each different activity level, depending on how many steps they do per minute at each level of intensity.

For example, for a person of mass 70 kg, their weight is 70 × 9.8 = 686 N
If the step is 0.3 m high then for one step the work done is 686 × 0.3 = 205.8 J
For 30 steps in 1 minute:
their total work done is 205.8 × 30 = 6174 J
their power is \( \frac{6174 \text{ J}}{60 \text{ seconds}} = 102.9 \text{ W} \)

For 60 steps in 1 minute:
their total work done is 205.8 × 60 = 12348 J
their power is \( \frac{12348 \text{ J}}{60 \text{ seconds}} = 205.8 \text{ W} \)

- the small amount of work done descending the step, as well as the slight forward and backward movement of the body with each step, is ignored.

**Next lessons**

In Lesson 2 you will be running a carousel of three experiments (B–D) on aerobic fitness, and CO₂ exhaled, pulse rate, and blood pressure before and after exercise. There are two stations for each experiment. Lesson 3 will give students the opportunity to analyse and evaluate all the data they have collected, calculating VO₂max as a measure of fitness, for example. This is also when they will be able to upload the data from Experiment D to the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk) and analyse and evaluate national data from UK schools.
I’ve got the power

How much power do my muscles generate?

Prediction
How much power, in watts, do you think you can generate by doing stepping exercises for 1 minute? How do you think the power generated by your leg muscles will change if you double your rate of stepping?

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

Obtaining the evidence

1. Use bathroom scales to measure your body mass in kg if you haven’t brought this information with you to the lesson. You do not have to share this data with the class.

2. Work in pairs. Measure the height of your step, bench, or stair in metres. Record your results in Table 1.

3. Practise stepping onto and down from the step. Step onto the step with one foot, followed by the other foot, and then step down from the step with one foot followed by the other. This whole cycle is one step. You can choose which foot to lead with and this can be changed during the test if you wish.

4. One of you acts as time-keeper. The other partner steps on and off the step approximately once every 2 seconds. Count how many steps you do in 1 minute. Record your results in Table 2.

5. Swap roles. This will allow the exerciser to rest and recover.

6. Repeat stages 4 and 5. This time, step approximately once every second. Record your results in Table 2.

7. Repeat stages 4 and 5 but this time step on and off the step as fast as you can. Record your results in Table 2.

Presenting your results
Use the notes on the next page to help you complete the tables using the results you have collected.

Table 1

<table>
<thead>
<tr>
<th>Body mass (kg)</th>
<th>Force (N)</th>
<th>Height of one step (m)</th>
<th>Work done for one step (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Calculation 1</strong></td>
<td></td>
<td><strong>Calculation 2</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Calculation 1: Force
Convert body mass (kg) to weight (N) by multiplying your mass by 9.8 \text{ ms}^{-2} \text{ (the acceleration due to gravity). This tells you your body weight in newtons (N), which is the force you are stepping against.}

\text{Body mass (kg)} \times 9.8 \text{ (ms}^{-2}) = \text{force (N)}

Calculation 2: Work done
To calculate the work done for one step:

\text{Work done} = \text{force (from calculation 1)} \times \text{distance moved (height of step) in m}

The units for work done are newtons \times \text{metres (Nm), which is the same as joules (J).}

This only gives the work done for one step. Note that no external work is done when stepping down.

Table 2
<table>
<thead>
<tr>
<th>Step test</th>
<th>Actual number (S) of steps in 60 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (approx. 1 step every 2 seconds)</td>
<td></td>
</tr>
<tr>
<td>2 (approx. 1 step every 1 second)</td>
<td></td>
</tr>
<tr>
<td>3 (as many steps as possible)</td>
<td></td>
</tr>
</tbody>
</table>

You will use the data in Tables 1 and 2 later, to calculate the total work done and your power for each rate of stepping.
I’ve got the power

Lesson 2

Lesson 2 uses a carousel approach to further investigate the body’s response to exercise: CO₂ exhaled, pulse rate, and blood pressure are all measured and from the measurements VO₂max is estimated (in Lesson 3). The carousel comprises Experiments B, C, and D. Experiment D forms part of an exciting national data-collecting experiment that your students can take part in using the ‘Live Data Zone’ section of the In the Zone website.

Students will need to carefully carry out the investigation to ensure standardisation with data collected from other classes and schools, so that when they analyse the national data their results are more reliable. Instructions for using the pulse oximeter and blood pressure monitor are given on pages 7–9 of this guide.

Be aware of any student with any blood oxygen abnormality who may be distressed by having to take part in the pulse oximeter activity. Students should do warm-up exercises and stretches before they begin the carousel activities. Suggested warm-up exercises are walking on the spot and then raising it up to a gentle jog on the spot, followed by stretches for the quadriceps, hamstrings, and calves (see diagram on page 57).

What does being fit mean?

Student notes for this experiment are on page 85.

Aim

Students will explore what aerobic fitness is and how they can measure their own aerobic fitness using a step test. The step test involves measuring the heart rate after a period of exercise and gives an indication of aerobic fitness based on previous studies where the aerobic fitness values have been calculated and placed in normative tables. They will also use the data from the experiments to estimate VO₂max as a measure of fitness (in Lesson 3). No student should feel under pressure to take part, for example if they are sensitive about their fitness level.

Equipment

<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1 pulse oximeter</td>
<td>• stopclock</td>
</tr>
<tr>
<td>• tape measure</td>
<td>• gym bench/step stool/sturdy box/stair of height 0.25–0.3 m</td>
</tr>
<tr>
<td></td>
<td>optional:</td>
</tr>
<tr>
<td></td>
<td>• stadiometer</td>
</tr>
<tr>
<td></td>
<td>• metronome</td>
</tr>
</tbody>
</table>

Safety

• If anyone begins the activity and starts to feel unwell they should stop immediately.
• Identify students with asthma so they can have their inhaler close at hand and use it if required.
• Ensure students are dressed appropriately for the activities – for classroom-based activities, normal school uniform with sensible shoes will be fine. Trainers are required for some of the aerobic activities.
• Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to overexertion and possible fainting or injury.

Ensure students carry out the activities in a suitable place, clear of any obstruction. If using stairs, students should use a handrail.

Running the experiment

1. The step test can take place in the classroom or outside. You could liaise with your PE department to ensure that there is enough space and equipment.

2. Test the pulse oximeter before the lesson and familiarise yourself with it so you can show students how to use it.

3. Students will use a stadiometer or tape measure to measure their standing and sitting heights. A stadiometer is a medical device for measuring height. The sliding horizontal headpiece will allow students to measure height more accurately.

To collect accurate height measurements they will need access to a wall. When students measure their height, they should do this without shoes and with a ruler or other flat object to ensure that the measurement on the wall is to the top of their head. They should take a deep breath in, breathe out, relax, and stand tall without going on tiptoes.

You could ask three students to measure a fourth student’s height separately without taking the precautions above to illustrate the variation in readings they will obtain.

4. See the Student sheet on page 85 for the protocol for obtaining evidence. Students may find it easier to keep the steady rate if they have access to a metronome. For a step rate of 30/minute set the metronome at 120 beats per minute (4 clicks = one step cycle). There are also online metronomes and free metronome apps.

5. The pulse oximeter is used for two things during this experiment: the heart rate and the percentage oxygen saturation in arterial blood. Students must not wear the pulse oximeter whilst exercising. They must ensure that they have access to a pulse oximeter immediately after finishing their exercise.

If you don’t have enough pulse oximeters, you could get the students to calculate their heart rate in beats per minute by counting the number of beats in 15 seconds at the end of each minute of exercise. Ideally, however, all data submitted to the ‘Live Data Zone’ should be collected using the same equipment, i.e. pulse oximeter.

Expected results

The pulse oximeter measures the percentage oxygen saturation in arterial blood and pulse rate.

Pulse rate

Pulse rate increases with exercise, and may rise to 160–180 beats per minute following the step test. Resting heart rate is likely to be between 60 and 100 beats per minute, depending on the fitness of the individual and if they have consumed caffeine or smoked cigarettes. It can take up to 10 minutes for the pulse rate to return to resting value after hard exercise, although very fit individuals may have recovered at the end of 3 minutes.

Blood oxygen saturation

The percentage oxygen saturation in arterial blood, usually around 97–99%, may not change during exercise.
Students may realise that as the arterial blood delivers more oxygen to tissues, the blood returning to the heart and then going to the lungs will be more deoxygenated than when at rest. This gives a steeper concentration gradient across the alveoli walls in the lungs and more oxygen diffuses into the blood.

The increased demand for oxygen by muscle tissues during exercise is met by increased heart rate, increased stroke volume, and the lowering of the haemoglobin’s affinity for oxygen so that oxygen is given up more readily to respiring tissues.

During exercise, arterial blood delivers oxygen to muscles. The haemoglobin’s affinity for oxygen is lowered and so in the muscles, the oxygen is given up more readily to the respiring tissues (dissociation curve shifts to the right). Therefore, venous blood leaving the muscle tissues may have less oxygen than when at rest. However, this oximeter measures only oxygen levels in arterial blood. After prolonged exercise more oxygen may be extracted from the air in the alveoli, but this may not happen with short periods of exercise.

The oximeter is used when athletes train/compete at higher altitudes, to check their levels of arterial oxygen, as before acclimatisation, this baseline level is likely to be lower than normal.

Some research shows that in about 50% of trained athletes, their arterial oxygen saturation levels actually fall during exercise. This may be due to inadequate increases in their pulmonary ventilation (breathing rate and depth), but so far the evidence is inconclusive.

**Fitness levels and VO\(_2\)max**

The normative values for the fitness index are from the Harvard step test, which used an original bench height of 40–50 cm. For gym benches (usually 22 cm), students will be exercising at a lower intensity so we have found that they will over-estimate their fitness levels – this could be discussed. The equation also assumes students keep to the 30 steps per minute rate and full five minutes.

Typical values for VO\(_2\)max (estimated in Lesson 3) are given in the Student sheet for Lesson 3. These values are affected by gender, genetics, and age, as well as cardiovascular fitness. There is a way of directly measuring VO\(_2\)max in a lab using gas analysis, but that is not available to us. Students estimate their rate of oxygen consumption during the step test and should consider how well it might correlate with actual VO\(_2\)max (it is an indirect method; they are also not exercising at maximum possible intensity). They should also appreciate that the formula used does not consider body mass, and that height and mass may both affect how well people can carry out the stepping task. Total oxygen consumed can be found by multiplying the value in ml kg\(^{-1}\) min\(^{-1}\) by body mass in kg.

In Lesson 3, students will evaluate whether height or sitting height affects the calculation for VO\(_2\)max, for students of the same age, gender, and general fitness. Since the step is the same for students of all heights, taller people or people with long lower limbs use less energy to to step a fixed height. This means they will not have to work so hard, their heart rate will be lower, and VO\(_2\)max is underestimated.
I’ve got the power

What does being fit mean?

**Prediction**
Discuss what is meant by fitness and how might we measure it.

Write a prediction about how exercise will affect pulse rate and arterial (blood) oxygen saturation level.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

**Obtaining evidence using the step test**
In this experiment you will estimate your fitness level by measuring your heart rate and arterial oxygen saturation levels before and after aerobic exercise.
Using a stadiometer or tape measure, record your sitting and standing height.

Measuring standing and sitting height.

1. Sit down and relax. Place the pulse oximeter on your finger and switch it on. Wait for at least 10 seconds before taking any readings.
2. Measure your resting pulse rate (heart rate) and record it in beats per minute. Repeat twice more and find your mean resting pulse rate.
3. Record your resting arterial (blood) oxygen saturation level. Remove the pulse oximeter.

Measuring blood oxygen level and pulse rate.
4. Step up onto the stool/box/stair as follows:
   - step up with one foot
   - place both feet on the stool
   - step down with the first foot
   - place both feet on the floor.

Performing the step-up exercise.

Each cycle begins and ends with both feet on the floor. Practise the pace so that you complete one cycle in about 2 seconds, i.e. 30 steps/minute.
Establish the rhythm, then stop and rest for a minute. This was your warm-up.
5 Now step on and off the step at the pace you have practised for 5 minutes without stopping or until you are so fatigued you cannot maintain the pace of 30 steps per minute. Sit on a chair at the end of the task.

6 Immediately after you end the stepping task, place the pulse oximeter back on your finger and record the result for pulse rate and arterial (blood) oxygen saturation level.

7 After finishing the exercise, rest for 1 minute and then take your pulse rate. At the same time, record your arterial oxygen saturation level.

8 Repeat this 2 and 3 minutes after exercise.

9 Enter your results in the table below. You will use these in Lesson 3 to estimate your fitness level using your heart rate measurements and measurements of your cardiovascular system’s recovery from exercise, and to estimate your rate of oxygen consumption during exercise.

**Presenting your results**

Complete the table below to show your results. Also record your standing and sitting height.

Standing height __________

Sitting height __________

<table>
<thead>
<tr>
<th>Time after exercise (minutes)</th>
<th>Pulse rate (beats per minute)</th>
<th>Oxygen saturation level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
I’ve got the power
Lesson 2 (continued)

Does the level of carbon dioxide in my breath change after exercise?

Aim
Students will explore what happens to the level of carbon dioxide in their breath following exercise. They will use a respirometer with bromothymol blue to measure how much carbon dioxide is in their breath at rest and after doing 2 minutes of exercise.

Equipment

<table>
<thead>
<tr>
<th>From the kit box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1 respirometer pack (1 plastic 2-litre bottle, 6 bungs, 6 pieces of plastic tubing, 6 pieces of flexible tubing, one-way valve)</td>
<td>• stopclock</td>
</tr>
<tr>
<td>• bromothymol blue indicator solution, prepared as per the Technician notes on page 107</td>
<td>• 5 empty, washed, plastic 2-litre cola-type drink bottles</td>
</tr>
<tr>
<td>• 0.1M sodium hydroxide solution</td>
<td>• 2 test tubes</td>
</tr>
<tr>
<td>• 6 pipettes</td>
<td>• test tube rack</td>
</tr>
<tr>
<td>• indicator charts</td>
<td>• 500cm³ measuring cylinder</td>
</tr>
<tr>
<td></td>
<td>• safety goggles</td>
</tr>
<tr>
<td></td>
<td>optional:</td>
</tr>
<tr>
<td></td>
<td>• skipping rope</td>
</tr>
<tr>
<td></td>
<td>• video clip of Zumba® or CD of fast dance music</td>
</tr>
<tr>
<td></td>
<td>• gym bench/step stool/sturdy box/stair of height 0.25–0.3m</td>
</tr>
</tbody>
</table>

Safety
• If anyone begins the activity and starts to feel unwell they should stop immediately.
• Any student (such as those with heart/lung problems) not able to take part in school PE/games lessons may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
• Identify students with asthma so they can have their inhaler close at hand and use it if required.
• Teachers who have not used a respirometer before will need training by an experienced colleague and should familiarise themselves with how it works.
• 0.1M sodium hydroxide solution is a skin irritant and is extremely hazardous to the eyes. Technicians should add a label to the sodium hydroxide, before students are given it to use, that it is an irritant. See the chemical safety sheets available on the In the Zone website.
• Bromothymol blue is low hazard but skin contact should be avoided. See the chemical safety sheets available on the In the Zone website.
• Make sure it is clear that students only breathe out into the apparatus and not breathe in via the tube. The non-return valve must be fitted to ensure that the students cannot breathe in the solution by accident.
• Students should wear safety goggles at all times.
• Ensure students carry out the activities in a suitable place, clear of any obstruction.
• Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to over-exertion and possible fainting or injury.

www.getinthezone.org.uk

Ages 16–19
Running the experiment

1. Assemble the respirometer as shown in the diagram below. Practise using the respirometer so that you are familiar with it and can help students use it if necessary.

2. The flexible plastic tubing should be disinfected or sterilised before and after each use.

3. Carbon dioxide is acidic and will gradually turn the bromothymol blue solution from blue to green. If a known amount in moles of sodium hydroxide is added before any carbon dioxide then you can get an estimation of how much carbon dioxide is in one breath (from calculation 2 on the next page), because two moles of sodium hydroxide are required to neutralise one mole of carbon dioxide.

   \[ \text{CO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} \]

4. Have two test tubes containing bromothymol blue solution for students to use for colour comparisons. If you then add a drop of a weak acid (such as lemon juice or vinegar) to one tube, they can see the colour change from blue to green at pH 7 and to yellowy-green at pH 6. They will be looking for the green colour to show when the carbon dioxide in their breath has neutralised the sodium hydroxide added to the indicator solution. Students can also refer to the indicator charts supplied in the kit box. The charts are for universal indicator but both indicators change to green at pH 7.

5. You will need enough bromothymol blue solution to refill the respirometers three times (at 500 cm³ each time) per group. See the Technician notes on page 107.

6. Students will use pipettes to add 5 cm³ of 0.1 M sodium hydroxide solution to the bromothymol blue solution in the respirometer. This will turn it blue. It will take 0.01 g or 5.0 cm³ of carbon dioxide to neutralise the indicator/sodium hydroxide solution.

7. Students should practise breathing in through their nose and out through their mouth. While they are seated and relaxed, they breathe out into the respirometer containing the 500 cm³ bromothymol blue solution and 5 cm³ 0.1 M sodium hydroxide solution. They should use normal breaths and should not increase the volume of air they breathe out at each breath.

8. Students will be measuring the carbon dioxide given out before exercise, after low-intensity aerobic exercise such as steps, and after more high-intensity anaerobic exercise such as squats, which must be deep and performed as fast as possible.

9. See the Student sheet on page 91 for the method for obtaining evidence.

Expected results

It should take more breaths to neutralise the solution at rest than after aerobic exercise (since more CO₂ is produced when exercising aerobically than at rest). The same is true for anaerobic exercise. However, students’ comparisons of aerobic and anaerobic exercise may differ and this could be discussed. The percentage of carbon dioxide in the breath is likely...
to increase with increasing exercise intensity, however the volume of expired air (in this case volume in one breath) may also change. Furthermore, for anaerobic exercise there may be a delay in increased carbon dioxide production as lactate is buffered in the blood and then carbon dioxide is produced. Another factor is whether students exercising at high intensity actually reach the anaerobic threshold.

During anaerobic respiration, hydrogen ions are formed from the dissociation of lactic acid. In the blood this is buffered by sodium hydrogen carbonate to give sodium lactate and carbonic acid, which produces carbon dioxide and water:

\[
\text{Lactate: } \text{H}^+ + \text{NaHCO}_3 \rightarrow \text{Na lactate} + \text{H}_2\text{CO}_3
\]

\[
\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2
\]

To calculate how much carbon dioxide is required to neutralise the solution:

Amount of NaOH in solution = 0.1 mol dm\(^{-3}\)  \times 0.005 dm\(^3\) (i.e. 5 cm\(^3\) of sodium hydroxide solution in respirometer)  

= 0.0005 moles

1 mole of CO\(_2\) neutralises 2 moles of NaOH (CO\(_2\) + 2NaOH \rightarrow Na_2CO_3 + H\(_2\)O)

Therefore:

number of moles of CO\(_2\) = \frac{0.0005}{2} = 0.00025 moles

1 mole of CO\(_2\) occupies 22.4 litres, so 0.00025 moles occupy 5.6 cm\(^3\). This is the volume of carbon dioxide required to neutralise the sodium hydroxide added to the respirometer.

So, the volume of carbon dioxide in each breath = \frac{5.6\text{cm}^3}{\text{total number of breaths}}

where students count the total number of breaths required to change the colour of the indicator from blue to green (i.e. to neutralise the sodium hydroxide solution). Results would be expected to be similar to those shown below, shown for 5 breaths in a period of 25 seconds. Students calculate these values in Lesson 3: Teacher sheet page 99, Student sheet page 101.

**Calculation 1: Breathing rate**

Breaths per minute = \frac{\text{total number of breaths (N)}}{\text{time to neutralise solution in s}} \times 60

= 5/25 \times 60 = 12

**Calculation 2: Volume of carbon dioxide in one breath**

To neutralise the solution it takes 5.6 cm\(^3\) of carbon dioxide.

Carbon dioxide in one breath = \frac{5.6 \text{ cm}^3}{\text{total number of breaths}}

= \frac{5.6 \text{ cm}^3}{5}

= 1.12 \text{ cm}^3

**Calculation 3: Volume of carbon dioxide in 1 minute**

Volume of carbon dioxide in 1 minute = breathing rate \times \text{volume of carbon dioxide in each breath}

= 12 \times 1.12 \text{ cm}^3 = 13.44 \text{ cm}^3
I’ve got the power

Does the level of carbon dioxide in my breath change after exercise?

What happens to our breathing when we exercise? Why might the volume of carbon dioxide we produce change after exercise? Predict how the number of breaths it takes to neutralise an alkaline solution before exercise will compare to the number of breaths it takes to neutralise the same solution after exercise.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Obtaining the evidence

1 Work in pairs or small groups. Wearing safety goggles, use a pipette to add 5 cm$^3$ of 0.1 M sodium hydroxide solution to the respirometer containing bromothymol blue solution. 0.1 M sodium hydroxide solution causes skin and eye irritation and should be handled with care. Then press the bung with the tubing in it into the neck of the bottle making sure the hard tubing reaches into the liquid. The others will act as time-keepers and look for the colour change.

2 One person should practise breathing in through your nose and out through their mouth.

3 While seated and relaxed, breathe out through your mouth into the respirometer containing the bromothymol blue solution and sodium hydroxide. Do not breathe in the bromothymol blue/sodium hydroxide solution from the bottle. Use normal breaths. Do not increase the volume of air you breathe out at each breath. You need to breathe in through your nose and out through your mouth, as you practised in step 2.

Using the respirometer.

4 Count how many normal breaths it takes to change the colour of the bromothymol blue /sodium hydroxide solution from blue (pH $>7.6$) to green (indicating pH 7). Use your indicator chart as a guide to when it has reached pH 7. Also time how long it takes (in seconds) for this to happen using a stopwatch. Write your results in the table at the end of the next sheet.
5 Before you start the next exercise, another person in your group should replace the used bromothymol blue/sodium hydroxide solution in the respirometer with a fresh mixture of 500 cm³ of bromothymol blue and 5 cm³ of 0.1 M sodium hydroxide solution. They should wear safety goggles and avoid skin contact with the bromothymol blue solution and sodium hydroxide solution.

6 Get someone to time you while you do at least 1 minute of high-intensity anaerobic exercise such as squats. Do them as quickly as possible.

7 When you have finished exercising breathe out into a respirometer containing the fresh bromothymol blue and sodium hydroxide. Count how many breaths it takes for the colour to change to indicate pH 7. Time how long it takes for this to happen (in seconds). Write your results in the table below.

8 Wait at least 3 minutes, preferably longer, for your cardiovascular system to recover. While this is happening, someone else in your group should replace the used bromothymol blue solution in the respirometer with 500 cm³ of bromothymol blue and 5 cm³ 0.1 M sodium hydroxide solution. Now do 2 minutes of more gentle aerobic exercise. You may want to skip, dance/Zumba®, or do the step exercise.

9 Repeat stage 7 and record the results in the table below.

Presenting the results

Complete the table below with your results.

<table>
<thead>
<tr>
<th>Level of activity and type of exercise</th>
<th>At rest</th>
<th>Exercise 1</th>
<th>Exercise 2 (if time)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Activity _______</td>
<td>Activity _______</td>
<td></td>
</tr>
<tr>
<td>Number of breaths (N) needed to neutralise indicator /sodium hydroxide solution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time taken for this number of breaths (seconds)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
I’ve got the power
Lesson 2 (continued)

What happens to my heart rate and blood pressure when I exercise?

Aim
Students use the digital blood pressure monitor to measure their blood pressure and a pulse oximeter to measure their heart rate. They make their measurements at rest and immediately after two types of exercise (anaerobic then aerobic). They follow the cardiovascular system’s recovery from the different types of exercise. It is important that students coming to the experiment after one of the other carousel experiments allow their pulse and blood pressure to recover before measuring their resting blood pressure. They ought to rest for at least 5 minutes and preferably 15 minutes.

After making a prediction about how they expect their systolic blood pressure to change with anaerobic and aerobic exercise, they gather data to test their prediction. No student should feel under pressure to take part, for example if they are sensitive about their fitness or ability to do press-ups.

Equipment

<table>
<thead>
<tr>
<th>From the box</th>
<th>From your school</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1 blood pressure monitor</td>
<td>• stopclock</td>
</tr>
<tr>
<td>optional:</td>
<td></td>
</tr>
<tr>
<td>• 1 pulse oximeter</td>
<td></td>
</tr>
</tbody>
</table>

Safety

• If anyone begins the activity and starts to feel unwell they should stop immediately.
• Identify students with asthma so they can have their inhaler close at hand and use it if required.
• Identify any student (such as those with heart/lung problems) not able to take part in school PE/games lessons. They may need to be excused from taking part in the physical part of this activity but can take on a time-keeper or data recording role.
• If you have not used a blood pressure measuring instrument before, ask to be shown how to use one by an experienced colleague. Also refer to the ‘How to use the equipment in the box’ section on page 9 of this guide. The amount of inflation and the period of inflation must be carefully controlled. Students will need close supervision if using it themselves and any student with a known blood pressure or heart problem should not take part in the activity. Students should not measure their blood pressure more often than at 5 minute intervals.
• Ensure students carry out the activities in a suitable place, clear of any obstruction.
• Healthy competition is encouraged but be aware of and discourage excessive competition between students as it can lead to over-exertion and possible fainting or injury.

Running the experiment

1 Before the lesson, try out the blood pressure monitor and familiarise yourself with it. Students may need help with using it so that they ensure that the cuff is of the correct tightness around the arm and do not overinflate the cuff. It is most important that the air hose is in the correct position in the crook of the arm, where the artery is.
2 The measurement is complete when the buzzer sounds and the systolic and diastolic blood pressure readings and pulse rate are displayed. Sometimes during the test the blood pressure isn’t found and the Λ symbol is displayed. When this happens the cuff needs to be reinflated until the buzzer sounds.

3 In order to ensure that the blood pressure is measured as soon as the participant has finished the exercise, the student measuring the blood pressure needs to get the cuff on to the participant’s arm and inflated as quickly as possible. The participant could exercise with the cuff loosely in place and the air pipe tucked in, so at the end of the exercise period they just need to plug the air pipe into the monitor box. Care should be taken that this does not become loose and cause injury, as well as affecting the test by having to stop exercising to reposition the pipe or cuff.

4 Students will take pulse rate and blood pressure measurements at rest and after two different types of exercise: star jumps and press-ups. See the Student sheet on page 96 for the protocol for obtaining evidence. Note, it is easier to use the pulse oximeter to measure pulse rate every minute in the recovery period after exercise.

Expected results

Heart rate
Heart rate is likely to be between 160 and 170 beats per minute following the star jumps (aerobic exercise), rising to 180–190 beats per minute following the press-ups (anaerobic exercise). Resting heart rate is likely to be between 60 and 100 beats per minute, depending on the fitness of the individual and if they have consumed caffeine or smoked cigarettes. Recovery time for both pulse rate and blood pressure is usually around 10 minutes, but varies according to the individual’s fitness and degree of exertion.

The heart responds to the extra energy demands of the body with an increase in the rate of contraction (heart rate) and a rise in the volume of blood forced out of the heart during each ventricular contraction (stroke volume). The increase in heart rate and stroke volume causes the cardiac output to increase, allowing more oxygen to be carried to the muscles.

Blood pressure
Systolic pressure, the maximum pressure during a heart beat, is also likely to increase. Diastolic pressure, the minimum pressure during a heart beat, may not increase very much or may even fall during the lower intensity activity and may remain low following the exercise. A typical value for a young adult’s diastolic pressure before exercise is 70–80 mm Hg and after exercise is 70–80 mm Hg (the same). A typical value for systolic pressure before exercise is 100–120 mm Hg and after exercise is c.200 mm Hg. Both diastolic and systolic blood pressure increase with height and increase with smoking and amount of tension. Children and young people have higher blood pressure than adults.

Students should understand that the increase in systolic blood pressure during exercise occurs as a result of the increased force of contraction of the muscles pushing out more blood with each beat (stroke volume). The increase in stroke volume and heart rate and a potential decrease in resistance in the blood vessels allow more oxygen to get to the muscles that require it. During very high-intensity activity, the muscles also respire anaerobically as the extra oxygen demands of the muscles cannot be met. The high rate and force of contraction of the muscles can decrease the flow of the blood in the muscles and increase resistance in the blood vessels, resulting in an increase in diastolic blood pressure if enough muscles are contracting. During exercise, systolic blood pressure increases with sometimes an increase in diastolic blood pressure during very intense anaerobic exercise. After exercise, systolic and diastolic blood pressure both tend to fall rapidly, as both heart contractions and muscle contractions are no longer occurring.
Live Data Zone

Your students can enter their results from this experiment into the ‘Live Data Zone’ of the In the Zone website (www.getinthezone.org.uk); see the Teacher notes on page 99 for 16–19 Lesson 3.
I’ve got the power

What happens to my heart rate and blood pressure when I exercise?

What happens to the heart rate and blood pressure following exercise? Write a prediction and plan how you can collect data to test your prediction.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Obtaining the evidence

1 Practise using the blood pressure monitor. One person will have their blood pressure measured and another will need to operate the blood pressure monitor. The person having their blood pressure measured needs to be comfortably seated and relaxed. Their left arm should be resting on a table/lab bench and their shirt sleeve should be rolled up so the cuff can be fitted around the arm, fairly tightly, just above the elbow. The air hose should be positioned in the crook of their arm, slightly towards the body.

2 Connect the air pipe to the monitor and press the start button.

3 When the Λ symbol starts to flash and you hear the buzzer start to inflate the cuff by squeezing the rubber bulb. The cuff will feel very tight. Do not overinflate the cuff.

4 When the Λ symbol disappears from the screen, stop squeezing the bulb.

5 The cuff automatically deflates slowly while the measurement is in progress and the buzzer sounds and the heart symbol blinks with each pulse beat.

6 When the measurement is complete the buzzer sounds and your systolic blood pressure, diastolic blood pressure, and pulse rate will be displayed.

7 Record the measurements shown on the blood pressure monitor in the table on the next sheet. It is important not to measure your blood pressure more often than at five minute intervals, so wait three minutes between having your blood pressure measured and starting the star jumps.
8. Now do your star jumps, working as hard as you can, for exactly 2 minutes.

9. Immediately after you have stopped, sit down and your partner should use the monitor to measure your blood pressure and pulse rate. Record them in the table.

10. Use the pulse oximeter to measure your pulse rate every minute until it has returned to your resting level. Take the blood pressure measurement every 5 minutes and try to estimate how long it takes for this to return to your resting blood pressure.

11. Now do your press-up activity for 1 minute or as long as you can manage. Press-ups should be done on your knees making sure you bend your arms at the elbow. Get your partner to place their hand on the floor, edge on; your shoulder should touch their hand during each press-up.

12. Repeat stages 9 and 10.

13. Press the exhaust valve button to completely release the air from the cuff and switch off the monitor.

Presenting your results

Blood pressure should be written as the systolic pressure over the diastolic pressure, e.g. 140/90 mm Hg.

My resting blood pressure is __________ mm Hg.

My resting heart rate is _______________ beats per minute (bpm).

My first exercise was (e.g. star jumps) ____________________________.

My second exercise was (e.g. press-ups) ____________________________.
<table>
<thead>
<tr>
<th>Time after exercise (minutes)</th>
<th>First exercise</th>
<th>Second exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blood pressure (mm Hg)</td>
<td>Pulse (heart) rate (bpm)</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note, you will only be measuring blood pressure immediately after exercise and then every fifth minute. You may need to add extra rows for recording pulse rate, depending on the time taken for pulse rate to recover.
Lesson 3 can be used to allow your students to:

Part 1: Upload the data from Experiment D to the ‘Live Data Zone’ section of the In the Zone website (www.getinthezone.org.uk). They can then compare their results to students’ data from across the UK.

Part 2: Analyse, evaluate and consider the data collected from this group of experiments.

Part 1: More details can be found on the ‘Live Data Zone’ section of the In the Zone website:

The Live Data Zone for ages 11-19 experiments.

Enter data from Experiment D

- resting pulse rate
- pulse rate immediately after 2 minutes of aerobic exercise
- pulse rate at 1 minute intervals until recovery is complete.

www.getinthezone.org.uk
In order to be able to accurately compare their results to other students across the UK, your students will also need to enter the data listed below:

- age
- gender
- asthmatic or not (optional)
- school postcode
- school year
- class, e.g. 13C (optional)
- physical activity level, in minutes of exercise per week
- type of sport(s) played regularly
- how fit they think they are in relation to their class.

**Part 2**

The Student sheet on pages 101–105 provides a series of questions analysing and evaluating their results from Experiments A–D. Answers are on pages 109–13. Alternatively, you may wish to analyse and evaluate the experiments through a more open-ended approach. Examples of this might be asking students to:

- Write a report for the coach of an Olympic or Paralympic athlete, outlining the findings of your research and how it might inform their training programme. Your report must include the results from your experiments and link these with the body’s response to exercise. You should try to include information about class data and national data where you have this.

- Find an image of three different types of sport or activity. Label each image to illustrate how the person’s cardiovascular system changes during the exercise. You should relate these changes to evidence from your experiments.

- Choose three different types of sport or activity. Write a commentary through the event to describe how the cardiovascular system responds to the exercise. You should relate these changes to evidence from your experiments.

The Take it Further part of the In the Zone website and the accompanying PowerPoint suggest opportunities to extend the materials further (www.getinthezone.org.uk). You may also wish to explore further with your students the links to contemporary science and sports science – again, the PowerPoint will help with this, as well as the Knowledge Cards provided in the kit box.

If you would like to reward any of your students for effort or achievement in these experiments, then the In the Zone website (www.getinthezone.org.uk) has In the Zone Reward Certificates that you can download and customise for your students.
How does the body respond to changing energy needs and what are the implications for sports training programmes?

These experiments have given you the chance to explore how your body reacts to different sports and physical challenges. Complete the analysis and evaluation below to find out just how much you know about how the body responds to changing energy needs and how this has implications for training programmes for sportspeople.

**Experiment A: I've got the power**

Use the values you have already calculated from your results from the stepping exercises to complete Table 3 below. The instructions below the table will help you with your calculations.

The quantity of work done per step will always stay the same if the height of the step stays the same and the person doing the task is the same. What happens if you alter the rate of stepping?

**Table 3 – Calculating total work done and power**

<table>
<thead>
<tr>
<th>Total number of steps in 60 s (S)</th>
<th>Total work done (S × work for one step) (J)</th>
<th>Power (total work/60) (watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Calculation 3</strong></td>
<td><strong>Calculation 4</strong></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Calculation 3: Total work done**

Calculate the total work done for the steps completed in 1 minute (S). This can be done using the results from your experiments and the calculations you have already done.

Total work done = number of steps in 1 minute × work for one step (in Joules, J)

**Calculation 4: Power**

\[
\text{Power in watts (W)} = \frac{\text{total work done in J (from calculation 3)}}{\text{time you spent exercising in seconds}} \\
= \frac{\text{total work (J)}}{60} \text{ W}
\]

1. Compare your power values and total work done values with those of your partner.
2. Find the mean power and the mean work done for the whole class at the different intensity levels. How do your values compare to the mean values?
3. How does the power and total work done vary within the class? Suggest what factors affect the power generated and the total work done.
4. Which factors may affect the values you got in the final exercise, at the highest intensity?
5. Who was able to generate the greatest power? Suggest why.

6. What other changes did you notice in your body while you did this experiment? For example, did you feel warmer, did your face look red, did you breathe faster, did your legs begin to ache? Suggest why these changes happened. Was it the same for all three intensity levels of exercise? Did the all-out effort feel different from the other tasks? Why might this be?

7. How was your body able to provide the energy it needed to move your muscles during the stepping task? Do you think the energy in all stages of the stepping task was obtained in the same way, or do you think different energy systems were used?

**Experiment B: What does being fit mean?**

1. Fitness levels can be compared by using your heart rate at 1 minute after aerobic exercise. In Experiment B, what was your heart rate at 1 minute after exercise? Look up this value in this table to compare your fitness rating with the ratings for 18–25 year olds.

<table>
<thead>
<tr>
<th>Male (beats per min)</th>
<th>Female (beats per min)</th>
<th>Fitness rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;79</td>
<td>&lt;85</td>
<td>Excellent</td>
</tr>
<tr>
<td>79–89</td>
<td>85–98</td>
<td>Good</td>
</tr>
<tr>
<td>90–99</td>
<td>99–108</td>
<td>Above average</td>
</tr>
<tr>
<td>100–105</td>
<td>109–117</td>
<td>Average</td>
</tr>
<tr>
<td>&gt;106</td>
<td>&gt;118</td>
<td>Below average</td>
</tr>
</tbody>
</table>

2. A better estimation of your fitness level can be calculated by taking into account the recovery of your heart rate over the 3 minutes following exercise by using the following formula. Work out your score using the data you collected from Experiment B and compare it with the ratings below*.

\[
\text{Fitness score} = \frac{30000}{HR_1 + HR_2 + HR_3}
\]

<table>
<thead>
<tr>
<th>Fitness score</th>
<th>Excellent</th>
<th>Above average</th>
<th>Average</th>
<th>Below average</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>&gt;90</td>
<td>80–90</td>
<td>65–79</td>
<td>55–64</td>
<td>&lt;55</td>
</tr>
<tr>
<td>Female</td>
<td>&gt;86</td>
<td>76–86</td>
<td>61–75</td>
<td>50–60</td>
<td>&lt;50</td>
</tr>
</tbody>
</table>

*These values are for 16-year-olds.

3. Another common way that athletes talk about fitness levels is by calculating the maximum rate at which their bodies absorb and use oxygen. This is known as their VO2max. This can then be compared against tables for people of the same age and gender as yourself. The test you did within this experiment is a sub-maximal test (i.e. you are unlikely to have exercised as hard as you could) but you can calculate the rate at which you used oxygen during the stepping task. From this you can calculate an approximation of your maximum rate of oxygen uptake (i.e. the maximum amount of oxygen you could use in your body to do an activity).
Background information for VO₂ max calculation

During your stepping task there are two components that need to be taken into account to calculate the rate at which you used oxygen. You have backwards/forwards (horizontal) movement and you also have an upward/downward (vertical) movement. These both need to be taken into account when calculating the rate at which oxygen is consumed. The full equation is:

\[
VO_2 (\text{ml kg}^{-1}\text{min}^{-1}) = [f \times 0.2] + [f \times h (\text{m}) \times 1.8 \times 1.33] + 3.5 \text{ml kg}^{-1}\text{min}^{-1}
\]

where
- \( f \) = steps per minute (30 steps per minute in Experiment B)
- \( h \) = height of the step

0.2 ml kg\(^{-1}\) min\(^{-1}\) = work done for the horizontal movement
1.8 ml kg\(^{-1}\) min\(^{-1}\) = work done for upward movement

A factor of 1.33 is used for the vertical movement because you need to include oxygen used when stepping down, which takes 0.33 of the energy of stepping up (1 + 0.33 = 1.33).
3.5 ml kg\(^{-1}\) min\(^{-1}\) is the rate at which we consume oxygen at rest, so this is added too.

Worked example

For example, for stepping using a bench height of 0.3 m at a rate of 30 steps per minute:

\[
VO_2 = (30 \times 0.4) + (30 \times 0.4 \times 1.8 \times 1.33) + 3.5
\]

= 34 ml kg\(^{-1}\) min\(^{-1}\)

a Use the formula to work out your rate of oxygen consumption during exercise in Experiment B.

b Next, you need to find out how hard you worked. This is calculated by knowing your heart rate at the end of the task. Then calculate this as a percentage of your maximum heart rate. An approximation for maximum heart rate is 220 – age.

\[
\% \text{ of maximum heart rate} = \frac{\text{heart rate at end of task}}{\text{maximum heart rate}} \times 100
\]

c Finally, calculate the rate at which you would have consumed oxygen if you had been working at maximum heart rate:

\[
\text{maximum rate of O}_2 \text{ consumption} = \frac{\text{rate of O}_2 \text{ consumption during exercise}}{\% \text{ of maximum heart rate}}
\]

and compare it with the values of VO₂max below*.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Excellent</th>
<th>Above average</th>
<th>Average</th>
<th>Below average</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>&gt;60</td>
<td>47–60</td>
<td>42–46</td>
<td>37–41</td>
<td>&lt;37</td>
</tr>
<tr>
<td>Female</td>
<td>&gt;56</td>
<td>42–56</td>
<td>38–41</td>
<td>33–37</td>
<td>&lt;32</td>
</tr>
</tbody>
</table>

*These values are for 18–25-year-olds.
4 What happens to your heart rate and arterial oxygen saturation level following exercise?

5 Compare the different ways you have calculated aerobic fitness. What do you think are good ways of assessing aerobic fitness? Explain your answer.

6 Do you feel that you exercised as hard as you could in the stepping task? How would this affect the VO$_2$max that you calculated?

7 Look at the class data for VO$_2$max and standing or sitting height, for students of the same gender and perceived fitness. Do you think standing or sitting height affects the calculation for VO$_2$max?

8 What other ways can you think of that could be used to assess your fitness levels?

9 Why is measuring fitness levels important for athletes and for health?

10 Why does training improve fitness levels? What does it alter inside your body?

**Experiment C: Does carbon dioxide increase in my breath after exercise?**

Fill in the table below using your results from Experiment C and draw a graph of your data. Think about which type of graph is most appropriate and which data you need to plot. Think about which exercise was aerobic and which was anaerobic.

<table>
<thead>
<tr>
<th>Level of activity and type of exercise</th>
<th>At rest</th>
<th>Exercise 1</th>
<th>Exercise 2 (if time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of breaths (N) needed to neutralise indicator / sodium hydroxide solution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time for number of breaths in seconds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breathing rate (calculation 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of carbon dioxide in each breath = 5.6/N (cm$^3$) (calculation 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of carbon dioxide breathed out in 1 minute = (5.6/N) × BR (cm$^3$) (calculation 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Calculation 1: Breathing rate**

Breaths per minute = \[ \frac{\text{total number of breaths (N)}}{\text{time to neutralise solution in seconds}} \times 60 \]

**Calculation 2: Volume of carbon dioxide in one breath**

To neutralise the solution it takes 5.6 cm$^3$ of carbon dioxide.

Volume of carbon dioxide in one breath = \[ \frac{5.6}{\text{total number of breaths}} \text{ cm}^3 \]
Calculation 3: Volume of carbon dioxide in 1 minute

Volume of carbon dioxide in 1 minute = number of breaths per minute × volume of carbon dioxide in each breath

1. Discuss the change in the volume of carbon dioxide breathed out per minute after exercise compared to being at rest. Is this what you expected?

2. Explain why the volume of carbon dioxide in the breath changes.

3. Does the type of exercise alter the change in volume of carbon dioxide breathed out? What happens if it is really intense exercise, e.g. anaerobic exercise where energy is released in respiration without using oxygen? What happens if it is more gentle exercise, e.g. aerobic exercise where energy is released in respiration using oxygen? Do we produce the same volume of carbon dioxide in each breath?

4. What are the possible sources of error in this investigation and how could they be reduced? How else could carbon dioxide production be measured?

5. Why might it be important for physiologists working with top athletes to measure oxygen consumption as well as carbon dioxide production?

Experiment D: What happens to my heart rate and blood pressure when I exercise?

1. How long did it take in each case for your heart rate and blood pressure to return to normal after exercise? Suggest reasons for any differences.

2. Estimate how long it took in each case for your blood pressure to return to normal. What are the limitations of this method in terms of finding exactly how long blood pressure takes to return to normal?

3. Why does it take a while for your heart rate and blood pressure to return to normal?

4. Plot your data on a graph.

5. Suggest why an athlete who has been pedalling hard on an exercise bike feels dizzy and faint if she suddenly stops pedalling, rather than slowly doing a ‘cool-down’ before getting off the bike.

6. All athletes and sportspeople need to be in good health. Why do you think a resting blood pressure of around 110–120/70–80 mm Hg is an indicator of good cardiovascular health?

7. When we stop exercising, heart rate and blood pressure do not immediately return to their resting levels. What may alter how quickly heart rate returns to baseline?

How does the body respond to changing energy needs?

1. What were the differences in the body’s response to aerobic and anaerobic exercise?

2. Which sporting events use a) aerobic and b) anaerobic respiration systems?

3. How would you train for a) aerobic and b) anaerobic events?

4. Look at the data on the ‘Live Data Zone’ on the In the Zone website. How do your results compare to students’ results across the UK? How do you think that the results of athletes such as those Dr Valerie Gladwell works with would compare to your results?

5. What exercise did you find hardest out of all the ones you took part in? Suggest why.
I’ve got the power

How does the body respond to changing energy needs?

Lesson 1

Experiment A: How much power do my muscles generate?
Each group will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>1 stopclock</td>
<td></td>
</tr>
<tr>
<td>1 gym bench/aerobic step/sturdy box/stair</td>
<td>height 0.25–0.3 m</td>
</tr>
<tr>
<td>bathroom scales</td>
<td>in case students forget to measure their mass at home</td>
</tr>
<tr>
<td>1 ruler, metre</td>
<td>to measure step height</td>
</tr>
<tr>
<td>metronome</td>
<td>optional – to help keep time</td>
</tr>
<tr>
<td>music</td>
<td>optional – to help keep time</td>
</tr>
<tr>
<td>tally counter</td>
<td>optional – to keep a tally of repetitions completed</td>
</tr>
</tbody>
</table>

Lesson 2 – Carousel of experiments

The tables below show the equipment required for one station for each experiment within the carousel. Depending upon the equipment available to each class and the number of students in the class, you may wish to provide more stations for one or more of the carousel experiments.

Experiment B: What does being fit mean?
Each carousel workstation will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From kit box</td>
<td></td>
</tr>
<tr>
<td>1 pulse oximeter</td>
<td>requires 2 × AAA cells. Do not use lithium cells and avoid mixing different types, e.g. zinc chloride and alkaline refer to page 7 ‘How to use the equipment in the box’ in this guide for instructions</td>
</tr>
<tr>
<td>1 tape measure</td>
<td>stadiometers could be used for measuring standing height instead</td>
</tr>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>1 stopclock</td>
<td></td>
</tr>
<tr>
<td>1 gym bench/aerobic step/sturdy box/stair</td>
<td>height 0.25–0.3 m, and higher if possible</td>
</tr>
<tr>
<td>stadiometer</td>
<td>optional – tape measures could be used instead</td>
</tr>
<tr>
<td>metronome</td>
<td>optional – to help keep time</td>
</tr>
</tbody>
</table>
Experiment C: Does carbon dioxide increase in my breath after exercise?

Each carousel workstation will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>From kit box</strong></td>
<td></td>
</tr>
<tr>
<td>1 respirometer pack (1 plastic 2-litre bottle, bung, piece of plastic tubing, piece of flexible tubing, one-way valve)</td>
<td>refer to the diagram on page 89 of this guide for assembly instructions one piece of flexible tubing in the kit box has the valve fitted for extra stations, the flexible tubing will need to be cut in half (2 × 12.5 cm lengths) and rejoined with the valve in the middle of them; the ends screw in</td>
</tr>
<tr>
<td>bromothymol blue indicator solution (low hazard)</td>
<td>5g provided in kit as a solid prepare a stock solution of 0.1% bromothymol blue: • 0.3g bromothymol blue dissolved in 150 ml deionised water. • To obtain 1 litre of working solution, dilute 30 ml of stock solution to 1000 ml with deionised water. • The solution may appear blue or green depending on the pH of the stock water. To adjust the colour to just green (neutral) add 0.1 M sodium hydroxide drop wise but do not add to excess. • Each group will require 1500 cm³ of working solution. The quantity of stock solution above will produce 10 litres of working solution, enough for six groups.</td>
</tr>
<tr>
<td>0.1 M sodium hydroxide solution</td>
<td>each group needs less than 20 cm³ add a label to each bottle, before giving to students to use, indicating that it is an irritant</td>
</tr>
<tr>
<td>1 indicator chart</td>
<td>for colour comparison of bromothymol blue</td>
</tr>
<tr>
<td>pipette, 3 ml</td>
<td>for measuring the volume of sodium hydroxide solution added (5 cm³ is required, so students will have to refill the pipette)</td>
</tr>
<tr>
<td><strong>From school</strong></td>
<td></td>
</tr>
<tr>
<td>1 stopclock</td>
<td></td>
</tr>
<tr>
<td>safety goggles (1 per student)</td>
<td></td>
</tr>
<tr>
<td>disinfectant or sterilising solution</td>
<td>to sterilise flexible tubing before and after each use disinfectant must always be freshly prepared prior to use and must be active against viruses e.g. chlorine-based such as a diluted bleach solution or a persulphate compound such as Virkon™ tubes should remain in the disinfectant for 24 hours and well rinsed prior to next use</td>
</tr>
<tr>
<td>2 test tubes</td>
<td></td>
</tr>
<tr>
<td>1 test tube rack</td>
<td></td>
</tr>
<tr>
<td>1 measuring cylinder</td>
<td>to measure out 500 cm³ of bromothymol blue solution</td>
</tr>
</tbody>
</table>
I’ve got the power

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>empty, washed, 2 litre plastic bottle</td>
<td>the kit box includes 1 plastic 2-litre bottle; depending on how many stations you set up for Experiment C you will need more cola-type drink bottles</td>
</tr>
<tr>
<td>1 skipping rope</td>
<td>optional</td>
</tr>
<tr>
<td>1 gym bench/aerobic step/step stool/sturdy box/Chair</td>
<td>height 0.25–0.3 m, optional</td>
</tr>
<tr>
<td>video clip of Zumba® or CD of fast dance music</td>
<td>optional</td>
</tr>
</tbody>
</table>

Experiment D: What happens to my heart rate and blood pressure when I exercise?

Each carousel workstation will need:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>From kit box</td>
<td></td>
</tr>
<tr>
<td>1 pulse oximeter</td>
<td>requires 2 × AAA cells. Do not use lithium cells; avoid mixing different types, e.g. zinc chloride and alkaline refer to page 7 ‘How to use the equipment in the box’ in this guide for instructions</td>
</tr>
<tr>
<td>1 blood pressure monitor</td>
<td>requires 1 × AA 1.5 V cell refer to page 10–11 ‘How to use the equipment in the box’ in this guide for instructions</td>
</tr>
<tr>
<td>From school</td>
<td></td>
</tr>
<tr>
<td>1 stopclock</td>
<td></td>
</tr>
</tbody>
</table>
Answers

11–14
Lesson 3 pages 37–39

Experiment A
1 Student’s own answers. 1 correct comment comparing their own resting breathing rate to: the whole class (1 mark); the class average (1 mark); national average as on the In the Zone website (1 mark).
2 1 mark for each correct resting rate given up to a maximum of 4 marks, e.g. average adult 12–20 breaths per minute; athletes 10–15 breaths per minute; newborn babies 30–60 breaths per minute; wind musician 6–12 breaths per minute.
3 1 mark for each correct answer.
My prediction was (correct or incorrect). My breathing rate (increased) after I had taken part in exercise. This is because my body had to work harder to supply (oxygen) to my muscles. All the activities changed my breathing rate by (a different) amount. The exercise that increased my breathing rate the most was (from student’s results) (from student’s results) breaths per minute). The exercise that increased my breathing rate the least was (from student’s results) (from student’s results) breaths per minute).
My breathing rate took (from student’s results) minutes to return to my resting breathing rate. This was (higher or lower) than the class average and (higher or lower) than the average time nationally. My breathing rate took (less or more) time to return to my resting rate than others because I am (fitter or less fit) than them.

Experiment B
1 1 mark for each correct reason.
Student’s own answers in columns 1 and 2.
Your group and national average oxygen level – should have remained the same or very nearly the same as when not exercising because the body takes in more oxygen by increasing the breathing rate and so oxygen is transported around the body more quickly.
Pulse rate – increases after exercise because blood must be pumped around the body more quickly to transport the increased oxygen that the muscles need during exercise.

Experiment C
1 a correctly marked and labelled peak flow reading (1 mark)
b correctly calculated class average peak flow (1 mark)
c correctly marked and labelled national average peak flow reading (1 mark).
2 Student’s own answers. 1 correct comment comparing their own average peak flow measurement with; their group (1 mark); the national average (1 mark).
3 1 mark for a sensible suggestion of why there are differences in peak flow e.g. asthmatic/non-asthmatic; regularly takes part in sport/does limited amount of sport; different heights/age (peak flow increases until full growth); gender (independent of height, boys tend to have larger chests and so larger lungs).
4 increased (1 mark)
5 Regular (competitive) swimmers generally have higher peak flows than people who do not regularly swim (competitively). Gymnasts and high jumpers are also likely to have higher peak flows than people who don’t exercise. (Any aerobic exercise increases lung strength so that the breath can be expelled faster.)

Experiment D
1 True 2 True 3 False. Taller people tend to have a larger vital capacity that shorter people. 4 False. Males tend to have higher vital capacities than females. 5 True.

How does breathing affect sporting performance?
1 1 mark for each correct measurement and change with exercise: breathing rate increases with exercise; blood oxygen level stayed the same with exercise; pulse rate increases with exercise; tidal volume increases with exercise.
2 Breathing rate increases because more oxygen must be taken in to supply the exercising muscles (1 mark). Pulse rate also increases because the heart must contract faster so that blood and the oxygen it carries can be transported to the muscles more quickly (1 mark). Blood oxygen level remains the same because although more oxygen is required this need is met by the increased breathing rate and pulse rate (1 mark). Expiratory tidal volume increases during and after exercise – increasing the volume of air for each breath supplies working muscles with more oxygen and since more carbon dioxide will have been produced this needs to be got rid of (1 mark).

14–16
Lesson 3 pages 65–67

Experiment A
1 a Student’s own answers. 1 correct comment describing the relationship, e.g. people with bigger bicep muscles can do more reps of upper body strength exercises (1 mark); 1 correct comment describing evidence from their own data, e.g. Sonja had bigger bicep muscles, and could do more press-ups/bicep curl reps than me (1 mark); 1 correct comment describing evidence from class data with some indication of ordering of the data, e.g. the top 5 people in the class for bicep size were also the top 5 for number of reps of press-ups/bicep curl (1 mark).
b Student’s own answers. 1 correct comment describing the effect of gender in class data, e.g. the relationship is true for both genders, however, all the boys except two had bigger biceps than the girls, and all the boys except three could do more reps than the girls. So males generally have bigger upper arm muscles and greater upper body strength than females (1 mark).
2 a Large upper arm muscles: canoeing, decathlon,
gymnastics (e.g. horizontal bar, parallel bar, rings), javelin, rowing, shot put, swimming (1 mark each).

Smaller upper arm muscles: 100 m sprint, cycling, dancing, diving, football, gymnastics (for artistic/rhythmic events), judo, table tennis (mainly leg muscles) (1 mark each).

b i Student’s own answers. 1 correct comment, e.g. such as biceps, triceps, back, and shoulders; however they will generally not have large lower body muscles; because they have trained those muscles (arms and shoulders) that are important for their sport; because they need high upper body strength; so they can produce more force with each arm stroke and make fast movements by contracting muscles quickly; therefore they will be able to make fast, strong arm movements needed in their sport (1 mark).

b ii Student's own answers. 1 correct comment, e.g. such as thighs, calves, and hamstrings; however they will generally not have large upper body muscles; because they have trained those muscles (legs) that are important for their sport; because they need high lower body strength (1 mark).

Experiment B

1 True 2 True 3 False. Most people have stronger lower body muscles because we use our lower body muscles in everyday life to walk and run. 4 False. ... such as swimming, which exercise the upper body muscles.

5 False. People who play sports that require good upper body strength (such as tennis or swimming) can do more press-ups in one minute than people who play sports that require good lower body strength (such as running or rugby).

6 The national data shows that generally males have greater upper body strength than females.

Experiment C

1 a Student’s own answers. Correctly calculated class average jump score and number of lunges completed (1 mark).

b Student’s own answers. 1 correct comment using class data to describe that is likely to be false (1 mark).

2 1 correct comment explaining that people who are good at the vertical jump test will have a high percentage of slow-twitch muscle fibres; which is needed for the endurance test (lunges).

3 Student’s own answers. e.g. (1 mark for each match with a correct reason)

- football
- swimming
- hockey
- tennis
- sprinting
- long distance running
- judo
- skating
- cycling
- rugby
- dancing
- netball

good at lunges (i.e. endurance)
good at lunges (i.e. endurance)
good at lunges (i.e. endurance)
good at lunges (i.e. endurance)
good at vertical jumps (i.e. power)
good at vertical jumps (i.e. power)
good at vertical jumps (i.e. power)
good at vertical jumps (i.e. power)
good at vertical jumps (i.e. power)
good at vertical jumps (i.e. power)

Experiment D

1 mark for each correct answer.

My standing broad jump result was (very similar) before and after performing the bicep curls. Before the bicep curls it was (from student’s results) and after the bicep curls it was (from student’s results). These results (agreed/did not agree) with my prediction. The results show that fatigue in one set of muscles (does not) have an effect on another set of muscles. (Note however that there will probably be some cases where students do get a difference.)

1 1 mark for each correct answer.

[100 m sprint] High lower body strength required to move fast

[dancing] High lower body strength required to control own body weight while standing on toes or when crouching down (squatting)

[cycling] High lower body strength required to produce large force and to raise body weight up steep climbs

[rowing] High upper body strength required to produce large force with each arm stroke, and large stroke length

[table tennis] High lower body strength required to produce large force against a resisting force

[shot put] High upper body strength required to lift and throw large weights

[judo] High upper body strength required to grip and to pull hard

2 Student’s own answers. 1 mark for each correct observation for each sport (up to 4 marks). For example, Dancing: lower body power needed for vertical jumps (1 mark); lower body endurance needed for repeated squats/crouches over an hour’s performance (1 mark); Judo: lower body power upwards from squat (1 mark) and muscular endurance for fights of 5-10 minutes (1 mark).

16-19

Lesson 3 pages 101-105

Experiment A

1 Subjective – depends on students’ own data

2 Depends on their data – teacher can check that students have substituted values correctly in the appropriate equation.

3 Factors affecting power generated and work done: strength of people’s muscles; flexibility of their joints; stamina and endurance – how long they can do the exercise before tiring; cardiovascular fitness; body composition (muscle-to-fat ratio); how much exercise you do on a regular basis each week; type of exercise you do; genetics – e.g. proportion of slow or fast-twitch muscle fibres; whether hungry or not; previous consumption of alcohol/caffeine; whether on any medication; asthmatic or not; general health (e.g. having a cold).

4 Tiredness, as muscles fatigue due to lactic acid from anaerobic respiration.

5 Probably males as they generally have more muscle;
people with high muscle-to-fat ratio; slim people; people who exercise regularly.

6 (i) Feel warm, as when muscles need to contract their cells need to increase the rate of respiration to make more ATP. Some energy released from glucose is released as heat. This is carried away from muscle cells, in blood, to be dissipated.

(ii) Hence, students may look red-faced or red-skinned in other parts of their body due to vasodilation, when more blood flows near the skin surface to lose heat by radiation.

(iii) They may also sweat, as this is a method of cooling down – water in sweat on the skin evaporates, taking latent heat from the skin.

(iv) The increased rate of respiration produces more carbon dioxide. This enters the blood and flows through an area of the brain (medulla) where the lowered pH is detected. The medulla sends impulses (via the autonomic nervous system) to the (phrenic) nerve supplying the diaphragm to increase the rate and depth of breathing. This flushes out the extra carbon dioxide and brings in more air and hence more oxygen.

(v) Legs may begin to ache as muscles fatigue. This may be due to lactic acid from anaerobic respiration and may also be a result of the brain ‘informing’ muscles that they are fatigued. These effects may become more severe as intensity of exercise builds up, although at some point, athletes get a ‘second wind’ and as toxic by-products are dealt with and extra oxygen is supplied to muscles to meet demand, the task seems easier/lighter.

7 The muscles of your legs need ATP to contract. In the first 2–3 seconds of exercise, this extra ATP is supplied from stored ATP in muscle cells. The ATP is hydrolysed, releasing energy. Another compound stored in muscle, creatine phosphate, can also be broken down to produce ATP. However, these stores are rapidly used up. For about the next 75 seconds (up to 1.5 minutes into the exercise) it is mainly anaerobic respiration that provides the energy. Anaerobic respiration takes place in the cytoplasm of the muscle cells and partially breaks down many molecules of glucose per minute to release energy to make ATP and lactic acid. At the same time as all of these systems are operating, aerobic respiration also goes on in muscle cells, but at first this is not sufficient to meet the muscles’ demands for energy. After about 2 minutes, when heart rate and breathing rate have increased, the aerobic system provides most of the energy. Lactic acid produced during anaerobic respiration can enter the mitochondria of muscle cells and be directly used in aerobic respiration. Pyruvate from glycolysis, the breakdown of glycogen/glucose in the cytoplasm of muscle cells, also enters mitochondria and is further oxidised. Much ATP is produced.

**Experiment B**

1, 2 and 3: Depends on students’ own data – teacher can check they have substituted data correctly in the formulae.

4 Heart rate should increase after exercise. Arterial oxygen saturation level probably will not change. Heart rate will increase as the brain sends more nerve impulses, via the autonomic nervous system, to the sino atrial node of the heart. This has the effect of delivering more oxygenated blood to the skeletal muscles more quickly and of removing carbon dioxide and lactic acid from muscle cells more quickly. The lowered pH of muscle tissue (due to increased carbon dioxide or lactic acid from the increased rate of respiration) and the increased temperature of muscle tissue (due to increased heat released from the increased rate of respiration) shift the oxygen dissociation curve to the right. This lowers the affinity of haemoglobin for oxygen so that oxygen dissociates from haemoglobin more readily in the muscles. The venous blood leaving the muscles may therefore contain less oxygen then when we are at rest, but the pulse oximeter measures arterial oxygen levels. At normal altitudes, these levels are always likely to be high.

5 They need to see if they get similar ratings from the three different methods. VO₂ max is likely to be more accurate (nearer to the true value) than the other two methods, but these are perhaps easier and quicker. All three methods are a good way of estimating an athlete’s aerobic fitness, as exercise needs muscle contraction, which needs ATP, which is generated by respiration; aerobic respiration needs oxygen, which is delivered by the cardiovascular system to muscles. Hence, any indirect measure of the body’s increased use of oxygen or increased efficiency of circulation is a good way of assessing an athlete’s fitness/ effectiveness of a training programme.

Students could note that a direct measurement of oxygen consumption (and hence an accurate measurement of VO₂ max) is only possible if athletes run on a treadmill or cycle on an exercise bike in a lab while having their oxygen consumption and carbon dioxide production measured by gas analysis, for example using a Douglas bag.

Students could consider what factors are likely to alter the results they get from each fitness test, such as tiredness; whether hungry or not; previous consumption of alcohol/ caffeine; whether on any medication; asthmatic or not; general health (e.g. having a cold); also age and genetics.

6 They probably did not exercise as hard as they could, which is why they scale their rate of oxygen consumption during exercise by the percentage of their maximum heart rate. In sports physiology labs athletes usually exercise to exhaustion, but this is more time consuming, not pleasant, and could be dangerous in this experiment as we do not know the fitness levels of students.

If the rate of stepping or the height of the bench had been increased, students’ heart rate would have increased further and they would be working nearer their maximum rate of oxygen consumption (VO₂ max), but probably still sub-maximal.

7 The step is the same size for students of all heights, so taller people or people with long lower limbs use less energy to step a fixed height. This means they will not have to work so hard, their heart rate will be lower, and VO₂ max is underestimated.
There are many ways of measuring fitness. For aerobic fitness:

- resting heart rate – someone who has good cardiovascular fitness has a high stroke volume so at rest, to achieve normal cardiac output, they have a low resting pulse rate. However, some people who are not fit have bradycardia – an abnormally slow heart rhythm.
- recovery time – shorter time taken for pulse rate to return to normal after exercise indicates good cardiovascular fitness.
- resting blood pressure – if within the 110–120/70–80 mm Hg, indicates good cardiovascular health.
- VO₂ max is the most accurate way to estimate cardiovascular fitness. It measures how well the heart and lungs deliver oxygen to muscles and how well the muscles use the oxygen. However, to do this properly requires exercise to exhaustion (such as the bleep test).

Other ways of measuring fitness include:

- strength – many athletes are assessed on how much weight they can lift, to indicate the strength of their arm muscles. Press-ups, sit-ups, and vertical jumps also indicate muscle strength.
- power – a vertical jump can indicate the explosive power of leg muscles.
- flexibility – head turning can assess flexibility of the neck. Sitting on the floor with legs flat out in front of you, then stretching arms and fingertips towards your toes also assesses flexibility.
- endurance – repeating an exercise, such as press-ups or pull-ups, to see how long it takes before you tire.
- size – waist-to-hip ratio can indicate fat distribution of the body. Muscle size can also be measured – e.g. biceps and/or thigh circumference.
- bone density can indicate strength
- BMI (body mass index) or just body mass. This is a rough guide as it does not give an indication of muscle-to-fat ratio, so a very muscular athlete could appear to be overweight. Skin callipers can indicate percentage body fat, but some people appear thin but have fat stored around their internal organs rather than subcutaneously. Body fat composition can be assessed by Bioelectrical Impedance Analysis – a low level electric current is passed through the body and its impedance is measured. However, subjects need to be at a particular level of hydration so must not eat or drink 4 hours before the test and must not drink alcohol or take diuretics for 48 hours before the test.

In all of these tests, age needs to be taken into consideration.

Most athletes/sportspeople in training take some of the above measurements at intervals to monitor how effective their training programme is and to see if they are improving. Some of these measurements are also important as health indicators for the general population. For example, resting blood pressure (high values indicate a risk of heart disease or stoke), resting pulse rate (high values indicate a risk of heart attack due to the heart working harder all the time), BMI/body mass (extra weight puts a strain on the heart, joints, and back), bone density (if too low it indicates risk of osteoporosis), flexibility (we all need, for example, to bend to pick things up, turn heads when driving to see traffic), waist/hip ratio (being apple-shaped is more of a risk for heart disease than being pear-shaped as being apple-shaped increases risk of diabetes), endurance (being able to walk briskly for 12 minutes as age increases improves wellbeing and can help prevent back pain).

Training increases cardiovascular fitness. It increases heart size with thickening of the left ventricle wall, so its contraction is more powerful. It increases stroke volume and cardiac output, and reduces resting heart rate and resting blood pressure. It increases tidal volume, vital capacity, and the rate at which maximum uptake of oxygen is reached.

Training strengthens other muscles and increases their power – it leads to increased size of muscle fibres; increased number and size of mitochondria; increase in glycogen and fat stored in muscles; increased quantities of respiratory enzymes; increased amount of myoglobin (an oxygen store) in muscles.

Training also improves utilisation of fat as a respiratory substrate, balance, coordination, and flexibility, and strength of ligaments, tendons, and bones.

**Experiment C**

1. Depends on students’ own data. It is likely that they will expect less carbon dioxide in their breath after the intense/an anaerobic exercise compared to the less intense/aerobic exercise, because they know that anaerobic respiration produces lactic acid and no carbon dioxide.

2. At rest there is some aerobic respiration going on in muscle cells. After aerobic exercise, the rate of aerobic respiration will increase so more glucose molecules will be respired per minute and more carbon dioxide will be produced. Some students may refer to where the carbon dioxide is produced (Krebs cycle).

3. A short burst of intense exercise will use the anaerobic system to boost ATP production, and this involves partial breakdown of glucose to pyruvate in the cytoplasm and then to lactate, which then diffuses into blood capillaries. No carbon dioxide is produced as an immediate result of this reaction. However, there is a reaction between sodium hydrogen carbonate in the blood and lactate to produce sodium lactate and carbonic acid, which then dissociates into water and carbon dioxide, which is carried in blood to the lungs to be breathed out. Although more carbon dioxide is produced during anaerobic exercise than at rest, there is a short delay before the carbon dioxide produced is breathed out. If the exercise is less intense and aerobic then the amount of carbon dioxide in breath will increase as explained in answer to question 2.

4. Measuring volume of sodium hydroxide solution: human error and systematic errors in the pipette. Errors in making up the 0.1 M solution of sodium hydroxide solution. Determining the end-point is subjective. This can be made easier by holding a white card behind the solution to judge colour change, but subjectivity would be removed.

www.getinthezone.org.uk
if colorimetry were to be used. Mistakes may be made in counting the number of breaths. Some electronic counting device would reduce this error. Students may also specify other valid sources of error. Other methods of measuring carbon dioxide could be to use a different indicator that is also sensitive to small amounts of carbon dioxide (hydrogen carbonate indicator solution), or to use a pH sensor/probe and data logger.

5 This would indicate more clearly whether aerobic respiration is increasing (as indicated by a greater rate of oxygen uptake). Scientists can use this information to design training programmes that have the right balance of aerobic and anaerobic exercise, depending upon the event they are training for. It could also tell us about the type of respiratory substrate being used – e.g. fat or protein as opposed to glucose, as the respiratory quotient could be calculated.

Experiment D

1 This depends on each student’s data. The expected difference between gentle (low-intensity), aerobic exercise and high-intensity anaerobic exercise is that they may fatigue more quickly with intense anaerobic exercise; their pulse rate may increase more than when doing less intense exercise; with longer-lasting, less intense aerobic exercise, they may get a ‘second wind’ and not feel fatigued. Recovery time after intense exercise may be longer than after less intense exercise.

2 It is not possible to measure blood pressure more often than once every 5 minutes, so the recovery time must be estimated by interpolating between measurements made every 5 minutes.

3 While the exercise was being carried out, the body may be in ‘oxygen deficit’. Muscle cells will have used stored oxygen from myoglobin and the haemoglobin in red blood cells will have delivered up more of its oxygen. There will be more carbon dioxide and lactic acid produced. If the heart rate stays high after exercise finishes, blood with the toxic by-products is carried away more quickly to the liver or lungs, to be breathed out (carbon dioxide) or recycled (lactic acid). The increased blood flow to muscles will also re-oxygenate the myoglobin. As a greater volume of blood per unit time is leaving the muscles and returning to the heart in the vena cava, this stretches the heart wall and causes it to contract more powerfully (Starling’s law), increasing systolic blood pressure.

4 Teacher to check they have plotted graph correctly

5 If the athlete stops pedalling suddenly, their systolic blood pressure may drop too quickly and not enough blood would reach the head/brain. A ‘cool down’ or ‘warm down’ as it is usually called (as it is not to do with body temperature dropping) means the systolic pressure returns to normal more slowly and the brain is not suddenly deprived of oxygen.

6 A blood pressure within this range indicates good blood flow/less resistance to blood flow in the arteries, which indicates lack of atheromatous plaque and a reduced risk of heart disease or stroke.

7 How quickly blood pressure returns to baseline may depend on the aerobic or cardiovascular fitness level of the individual. A short recovery time indicates good cardiovascular fitness. Good cardiovascular fitness may depend on the individual’s body mass or body mass index, the amount of exercise they do regularly, genetic makeup, diet (less fat, less salt), and whether or not they smoke or drink alcohol.

How does the body respond to changing energy needs?

1 This will be different perhaps for each of them. They may notice that their heart rate increases more when exercising lightly, to remove the lactic acid and to dissipate heat. They may feel warmer and fatigue more quickly when exercising anaerobically. Recovery time after intense exercise may be longer than after less intense exercise.

2 Aerobic: e.g. marathon running, any running of a distance more than 1500 m; swimming over a distance greater than 800 m; cycling; cross-country skiing. Anaerobic: e.g. shot put; javelin throw; high jump; long jump; discus throw, sprinting e.g. 100 m, 200 m.

3 Both require the anaerobic and aerobic systems to be ‘fine-tuned’, and both need strong muscles, bones, and tendons; flexibility; and good general health. So all training programmes will involve exercises like skipping, sit-ups, press-ups, possibly some swimming, and walking and running (varying amounts). Athletes also need to pay attention to their diet and habits (alcohol/tobacco) and they work with their trainers/coaches to develop the programme that suits their needs. They may work in different training zones – see Knowledge Card and PowerPoint slides. To train for aerobic events, athletes develop the aerobic system to enable their body to use oxygen and deal with lactate by long duration but low-intensity cardiovascular exercises such as long runs/skipping/cycling at 60–80% of maximum heart rate. To train for anaerobic events, athletes obviously train the specific muscles but also develop the anaerobic system to raise anaerobic (lactate) threshold by short duration, high-intensity (80–90% of maximum heart rate) exercises.

4 Depends on their data and how athletic individual students are.

5 Depends on their data and accept any sensible suggestion for reasons.
General safety information

We have attempted to ensure that all recognised hazards have been identified and appropriate strategies to reduce the risk to acceptable levels are suggested. Where possible, the proposed protocols are in accordance with commonly adopted model (general) risk assessments.

However, Wellcome Trust can take no responsibility for the safety of any activity that has been altered from the original printed version. **Before doing any practical activity, schools and colleges should always carry out their own risk assessment.** In particular, any local rules issued by your employer must be obeyed, regardless of what is recommended here. Where students are required to write their own risk assessments they must always be checked by the teacher and revised, as necessary, to cover any issues the students may have overlooked. The teacher should have the final control as to how practical work is conducted.

**Laboratory policy and practice**

It is assumed (unless the context dictates otherwise) that the following general precautions apply:

- Practical work is conducted in a properly equipped and maintained laboratory.
- Eye protection is worn by both students and teachers/lecturers whenever the risk assessment requires it.
- Other protective control equipment (e.g. safety screens, efficient fume cupboard to the standard of at least *Fume Cupboards in Schools*, Building Bulletin 88) is used when the risk assessment requires it.
- Long hair is tied back and ties, scarves, and cardigans are not allowed to hang freely.
- Containers of chemicals are clearly labelled with an appropriate name and any hazards. All chemicals are handled according to good laboratory practice.
- Eating, drinking, and chewing gum are not permitted in laboratories.
- Whenever students are themselves the subject of an investigation, they do not feel any under pressure to take part, and areas such as body measurements are dealt with sensitively.
- Electrical and other equipment is well maintained and subject to regular checks.
- Students at particular risk (for example asthmatics, those with allergies, and those with known disabilities) are identified by the teacher and catered for.
- Science staff have received appropriate training in the activities, including hazard identification and risk assessment.
- Students using a computer must take a break every 20 minutes and staff must ensure that any Internet use is supervised appropriately.

Various regulations, but especially the COSHH Regulations 1999 and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure is carried out, or hazardous chemicals are used or made, the employer must make a risk assessment. Guidance on managing health and safety in science, including risk assessment, can be found in *Topics in Safety* (3rd edition, ASE, 2001) and *Safeguards in the School Laboratory* (11th edition, ASE, 2006). *Materials of Living Origin – A Code of Practice for Scottish Schools* (SSERC, 2005) covers activities where pupils are subjects of experiment or investigation. For CLEAPSS members, detailed guidance is contained in their Science Publications CD-ROM. This includes the L196 guide, *Managing Risk Assessment in Science and Student Safety Sheets*, to teach students about risk assessment, together with many helpful examples of actual practical activities.

CLEAPSS members can find HazCard information relating to use of chemical substances, their safe disposal, and treatment of equipment between use at www.cleapss.org.uk.
In the Zone is the Wellcome Trust’s major UK initiative inspired by the London 2012 Olympic and Paralympic Games. It provides a fun, free and fascinating way to discover how our bodies work during sport, activity, movement and rest.

This Teacher Guide contains teacher and student sheets for three sets of In the Zone experiments for Secondary Schools. They are all supported by the exciting practical kit that you will find in the In the Zone box, and the In the Zone website where you can analyse results and download Word and PDF versions of this Guide.

On your marks... get set... breathe (ages 11–14)
How does exercise affect my breathing?
Students use lung volume bags, peak flow meters, and pulse oximeters to explore how their lungs work.

From strength to strength (ages 14–16)
How do muscles affect sporting performance?
Students carry out a range of experiments investigating muscle fatigue, upper and lower body strength, and whether people who are good at power sports are also good at endurance sports.

I’ve got the power (ages 16–19)
How does the body respond to changing energy needs and what are the implications for sports training programmes?
Students use respirometers, pulse oximeters, and a blood pressure monitor to explore the physiological effects of exercise on the body and aerobic and anaerobic respiration.
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