Research
Based
Curricula

Caffeine in Sport and Exercise: All in the Mind?

Key Stage 5 Sport and Exercise

2019

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For Pupils
Welcome

To get into the best universities, you must demonstrate that you are intellectually curious, and will make the most of the wonderful academic opportunities available to you.

One of the best ways of demonstrating this, is by going above and beyond what is taught in school and studying something that is not on the curriculum.

This resource will give you exactly such an opportunity. You will have something interesting to write about in your application to university, something interesting to talk about in a university interview, and open whole new areas of study you might be interested in!

You will develop valuable academic skills as you go, that we have marked out with gold badges (see the next page on university skills). As you work through the resource you can look out for these badges so that you can explain which skills you have developed and what you did to demonstrate them. Developing these skills will help you get university ready!

If you have any questions while you are using the resources in this pack, you can contact your teacher or email us directly at schools@access-ed.ngo.

Good luck with your journey to higher education!

For Pupils
University Skills

To complete this resource, you will have to demonstrate impressive academic skills. When universities are looking for new students, they will want young people who can study independently and go above and beyond the curriculum. All of these skills that you will see here will demonstrate your abilities as a university student – while you're still at school!

Every time you have to look something up, or write up a reference you are showing that you can work independently. Every time that you complete a challenging problem or write an answer to a difficult question, you might demonstrate your ability to think logically or build an argument. Every time that you evaluate the sources or data that you are presented with, you are showing that you can "dive deep" into an unfamiliar topic and learn from it.

Here are the skills that you will develop in this course:

independent research	your ability to work on your own and find answers online or in other books
creativity	your ability to create something original and express your ideas
problem solving	your ability to apply what you know to new problems
building an argument	your ability to logically express yourself
providing evidence	your ability to refer to sources that back up your opinions/ ideas
academic referencing	your ability to refer to what others have said in your answer, and credit them for their ideas
deep dive	your ability to go above and beyond the school curriculum to new areas of knowledge
source analysis	your ability to evaluate sources (e.g. for bias, origin, purpose)
data interpretation	your ability to discuss the implications of what the numbers show
active reading	your ability to engage with what you are reading by highlighting and annotating

For Teachers
RBC Guide

Programme Aims

The Research-Based Curriculum aims to support student attainment and university progression by providing classroom resources about cutting-edge research at local universities. The resources are designed to:

- ✓ promote intellectual curiosity through exposure to academic research
- ✓ stretch and challenge students to think deeply about content that may be beyond the confines of the curriculum
- ✓ develop core academic skills, including critical thinking, metacognition, and written and verbal communication
- ✓ inform students about how subjects are studied at university, and provide information, advice and guidance on pursuing subjects at undergraduate level

Content

The programme represents a unique collaboration between universities and schools. Trained by AccessEd, PhD Researchers use their subject expertise to create rich resources that help bring new discoveries and debates to students.

The Research-Based Curriculum offers ten modules suitable for either KS4 or KS5 study. The modules span a range of disciplines, including EBacc and A-level subjects, as well as degree subjects like biochemistry. Each module includes six hours of teaching content, supported by student packs, teacher notes and slides. All modules are available online and free of charge for teachers at select schools.

Delivery

Resources are designed to be used flexibly by teachers. The resources can be completed by students individually or in groups, in or out of the classroom.

For Teachers
RBC Guide

Here are five examples of delivery options:

Extra-Curricular Subject Enrichment Clubs

The resources can be completed in small groups (4-8 pupils) across a series of weekly lunch clubs or after-school clubs. Groups can reflect on their learning by presenting a talk or poster on the subject matter at the end of the course.

University Access Workshops

The resources can be used by students to explore subjects that they are interested in studying at university. This can inform their decision making with regards to university degree courses, and allow students to write more effective personal statements by including reflections on the Research-Based Curriculum.

Research Challenge

The resources can be used to ignite curiosity in new topics and encourage independent research. Schools could hold a research challenge across a class or year group to submit a piece of work based on the resources. Pupils could submit individually or in small groups, with a final celebration event.

Summer Project

Resource packs can function as 'transition' projects over the summer, serving as an introduction to the next level of study between KS3 and KS4, or KS4 and KS5. Students could present their reflections on the experience in a journal.

Evidence

The Research-Based Curricula programme builds on the University Learning in Schools programme (ULiS), which was successfully delivered and evaluated through the London Schools Excellence Fund in 2015. The project was designed in a collaboration between Achievement for All and The Brilliant Club, the latter of which is the sister organisation of AccessEd. ULiS resulted in the design and dissemination of 15 schemes of work based on PhD research for teachers and pupils at Key Stage 3. The project was evaluated by LKMCo. Overall, pupils made higher than expected progress and felt more engaged with the subject content. The full evaluation can be found here: ULiS Evaluation.

Questions?

For more information contact hello@access-ed.ngo

Introduction to Topic
The Placebo Effect

A placebo is a physiologically inactive intervention that is generally thought to have a neutral effect on sport and exercise performance. However, by manipulating beliefs and expectations, placebos can exert a positive outcome through physiologically and psychologically mediated mechanisms. Expectations are thought to have a direct relationship with the placebo effect. That is, if we are able to manipulate (or trick) somebody into believing they are receiving a beneficial intervention (think caffeinated coffee just before exercise) then they may well reap the same benefits as though they were consuming caffeinated coffee! This vastly depends on an individual's pre-existing expectations about caffeine and ultimately how well we have tricked them (even the smallest doubt can cause the placebo effect to be ineffective). Expectations may be mediated by verbal information or by visual methods like pretending to prepare a cup of caffeinated coffee in front of the person you are attempting to deceive.

So what benefit does the above have in the world of research? Well, aside from it being a huge bundle of fun, by exploring the placebo effect of caffeine we can make more robust conclusions about how active caffeine works, as at present the psychological effects of caffeine are largely unaddressed in most research. Additionally, active caffeine can sometimes cause negative health effects (like high blood pressure and irregular heart beat) in some individuals. Therefore, if we can research whether a similar benefit can be observed on sport and exercise following placebo consumption, then maybe placebos can act as a health friendly alternative for some individuals.

The topics within this pack will include:

Caffeine, Sources, Prevalence and Toxicity

Caffeine Associated Mechanisms of Action

Caffeine Use in Sport and Exercise

Caffeine and health concerns

Caffeine and the placebo effect

Caffeine placebos as an alternative to active caffeine?

Introduction to Topic
The Placebo Effect

Interestingly to date, lots of research has already observed caffeine placebos to improve sport and exercise performance comparably to active caffeine, however there is so much more to figure out (at present only 17 experimental studies have explored this phenomenon – and out of those, 13 observed a placebo effect of some sort).

In this resource pack, you will uncover where we source caffeine from and in which food/drink sources caffeine is most prominently included. You will then learn about caffeine's mechanisms of action, its potential benefits on sport and exercise performance, before considering some of the negative health implications associated with its use. Following on, you will discuss some exciting and recent research regarding the placebo effect and how mere expectation of caffeine consumption can improve sport and exercise performance whilst potentially reducing the negative health effects associated with biologically active caffeine.

Good luck!

Akbar Shabir

Introduction to Subject Sport and Exercise Science at University

The study of sport and exercise science relates to all aspects of human performance that can be developed to enhance both athletic enactment (individual or team orientated) and/or health states. Sport and exercise science comprises various sub-disciplines including nutrition and metabolism, sport and exercise psychology, strength and conditioning, anatomy and physiology, injury rehabilitation, performance analysis, biomechanics and many more. Consequently, sport and exercise science is considered an interdisciplinary study that allows students the opportunity to explore a vast array of career prospects.

Sports science is a relatively young discipline in the UK which gained popularity in the last quarter of the 20th century. I think the easiest way to explain the discipline of sport and exercise science is for you to imagine your favourite sports person or sports team (Manchester United is mine so I will go with that here). Manchester United will have a network of at least some (if not all) of the disciplines I have previously mentioned. These disciplines will then work in a mono, multi or interdisciplinary fashion and assess the athlete/team before any issues and/or areas for development are identified and worked on. The study of sport and exercise science is all about preparing the scientists of the future by enabling both creativity and criticality. To achieve this, students take part in a relatively equal share of class room based, theory driven sessions, and practical sessions comprising working in laboratory facilities whereby exciting and novel research is sought!

Introduction to Subject Sport and Exercise Science at University

If you want to learn more about the intricacies of the sciences that makes up successful sport and exercise performance then this degree is definitely for you! The skills outlined previously will set you up for a potentially fantastic and exciting career (if you have the effort and drive!). I have used the knowledge I attained since studying as an undergraduate and now a post-graduate student to help facilitate my own sports improvements across football and weightlifting, whilst also pursuing a career as a lecturer and researcher at the University of Derby.

Meet the PhD Researcher Akbar Shabir

After studying A levels in Biology, Business management and Economics, I arrived at De Montfort University to study business management and economics in September 2011. Optimistic to one day become an economist, I enjoyed learning about business and maths, however, my burning desire for sport and exercise made me think 'maybe I might be better suited to try something new'. Subsequently, I decided to embark on a new adventure in September 2012, this was studying sport and exercise science at the University of Derby. I graduated with a first class honours degree in July 2015 prior to starting my PhD in August 2016 (at the University of Derby). My PhD explores: expectation of oral caffeine consumption and its effects across sport and exercise performance.

My research specifically aims to investigate whether merely believing you have ingested caffeine can improve sport and exercise performance comparably versus consuming pharmacologically active caffeine! This is an important research area as it may encourage future research to account for caffeine's psychological influence (at present this is widely unaddressed) which may be as influential as caffeine pharmacology. Moreover, caffeine expectancies may also represent an alternative to caffeine pharmacology which would be particularly useful to individuals suffering from health concerns (e.g. high blood pressure, irregular heartbeat, anxiety etc.) that prohibit them from using caffeine.

A-Level Subjects	Biology, Business management, Economics
Undergraduate	Sport and Exercise Science
Postgraduate	Psychobiology

Glossary

Term	Definition
Placebo	An inert intervention that has no pre-existing physiological benefit.
Placebo effect	The experience of a positive benefit following administration of a placebo. Often associated with positive expectancies.
Nocebo effect	The experience of a negative effect following administration of a placebo. Often associated with negative expectancies.
Pharmacology	The branch of nutrition concerned with the physiological effects
Psychoactive	Typically a drug that effects the mind
β-endorphins	A neurotransmitter associated with making individuals feel good.
Neurotransmitter	A chemical substance which is released at the end of a nerve fibre by the arrival of a nerve impulse
Central nervous system	The complex of nerve tissues that controls the activities of the body. In humans it comprises the brain and spinal cord
Thermogenesis	To produce heat
Plasma	The colourless fluid part of blood
Neuromuscular transmission	The mechanism by which a nerve impulse causes the recruitment of motor units and initiates a muscular contraction
Motor unit	Made up of a bundle of muscle fibres and a motor neuron
CYP1A2	A gene associated with rates of caffeine metabolism

Glossary

Term	Definition
Homozygote	An individual having two identical alleles of a particular gene or genes
Caffeine half-life	The extent of time the effects of caffeine last for
Polymorphism	The presence of genetic variation within a population
Catecholamine	Any of a class of aromatic amines which includes a number of neurotransmitters such as endorphins, adrenaline and dopamine.
Catechol-O-methyl transferase	One of several enzymes that degrade catecholamines
Allele	Each of two or more alternative forms of a gene that arise by mutation and are found at the same place on a chromosome.
Decaffeinated coffee	Coffee which smells and even tastes like coffee, but does not contain the pharmacologically active substance caffeine
Quantitative analysis	A mathematical and statistical method of analysing data and/or predicting outcomes
Qualitative analysis	Exploratory research (e.g. interviews, questionnaires etc.) used to gain an understanding of underlying reasons, opinions, and motivations.

Resource One Overview

Topic

Caffeine, Sources, Prevalence and Toxicity

A-Level Modules

- Neuromuscular system
- Diet and nutrition and their effect on physical activity

Objectives

After completing this resource you should be able to discuss

- ✓ The chemical structure of caffeine
- ✓ Sources of caffeine consumption
- ✓ The prevalence of caffeine consumption across the general population
- ✓ Issues associated with caffeine toxicity

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading

Context

Caffeine is the most frequently consumed psychoactive substance in the world with approximately 90% of adults across Western civilisation consuming at least one caffeinated beverage or food source per day. Caffeine is found in the seeds, nuts or leaves of a number of plants native to Africa, East Asia and South America.

The most well recognised source of caffeine is the coffee bean, which is typically cultivated from Coffea Arabica and Coffea Canephora. However, some other sources of cultivation include the leaves of the tea plant, South American holly yerba mate and yaupon. Alternatively, caffeine is also commonly extracted from kola nuts and seeds from Amazonian maple guarana berries.

Once caffeine has been extracted it may be used as a preservative and/or flavouring for various food sources including milk chocolate, dark chocolate and ice cream/frozen yoghurt. Conversely, caffeine is more notably consumed in the form of coffee, but significant proportions are also found in tea and most soft drinks (e.g. coca cola, Pepsi, red bull and the diet labelled equivalents). To make these drinks, caffeine is extracted from its plant source via a process called infusion which typically involves steeping the plant product in hot water.

Resource One
Data Source

Table 1
Sources of caffeine

The table below provides an overview of common food/beverage sources and there corresponding caffeine content.

Product	Serving size	Approximate caffeine dosage (miligrams (mg))
Caffeine tablet	1 tablet	100 - 200
Dark chocolate (45 % cocoa)	1 bar (43 grams (g))	31
Milk chocolate (11% cocoa)	1 bar (43 g)	10
Percolated coffee	207 millilitres (ml)	80 - 135
Drip coffee	207 ml	115 - 175
Espresso coffee	45-60 ml	100
Decaffeinated coffee	207 ml	5
Tea	175 ml	22 - 75
Coca cola	One can	34
Diet Pepsi	One can	69
Red bull	One can	80
Hot chocolate	207 ml	9
Chocolate ice cream	Half cup	3

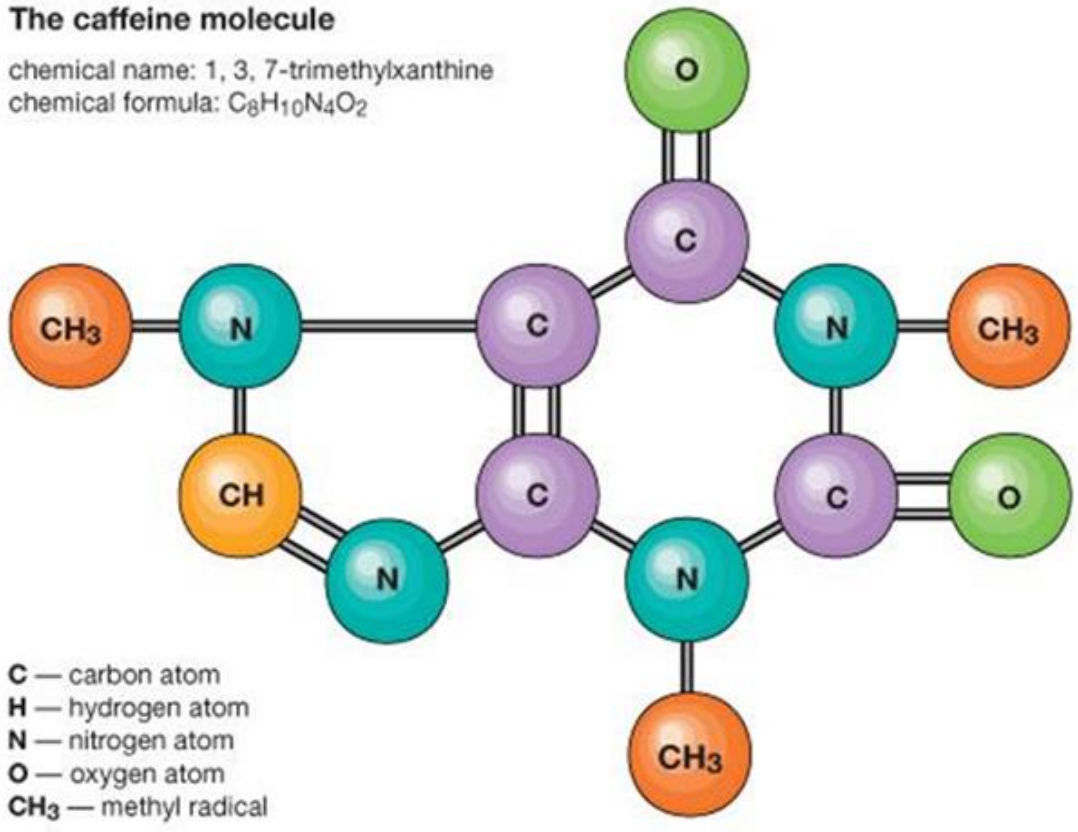
Caffeine is a central nervous stimulant of the methylxanthine class. The medical name, derived from its molecular structure, is 1,3,7-trimethylxanthine. However, other names include caffeine, theine, mateine, guaranine, or methyltheobromine. Caffeine is commonly consumed to prevent feelings of drowsiness, enhance perceptions of energy and wakefulness and for social/leisure purposes.

Caffeine is classified by the US food and drug administration as generally safe, yet caffeine can prove toxic at approximate dosages equivalent to 400 - 500 mg for adults. To put this into context an ordinary cup of homemade coffee contains 80 -175 mg of caffeine, therefore it would require a healthy adult to consume approximately 3 - 5 ordinary cups of coffee (within 12 hours) to reach such a toxic dose. The issue related to caffeine toxicity is probably of greater association with caffeine tablets/capsules which contain a large and refined dose of caffeine (and are significantly easier to consume versus 5 cups of coffee!).

Resource One
Data Source

Figure 1
Caffeine's chemical structure

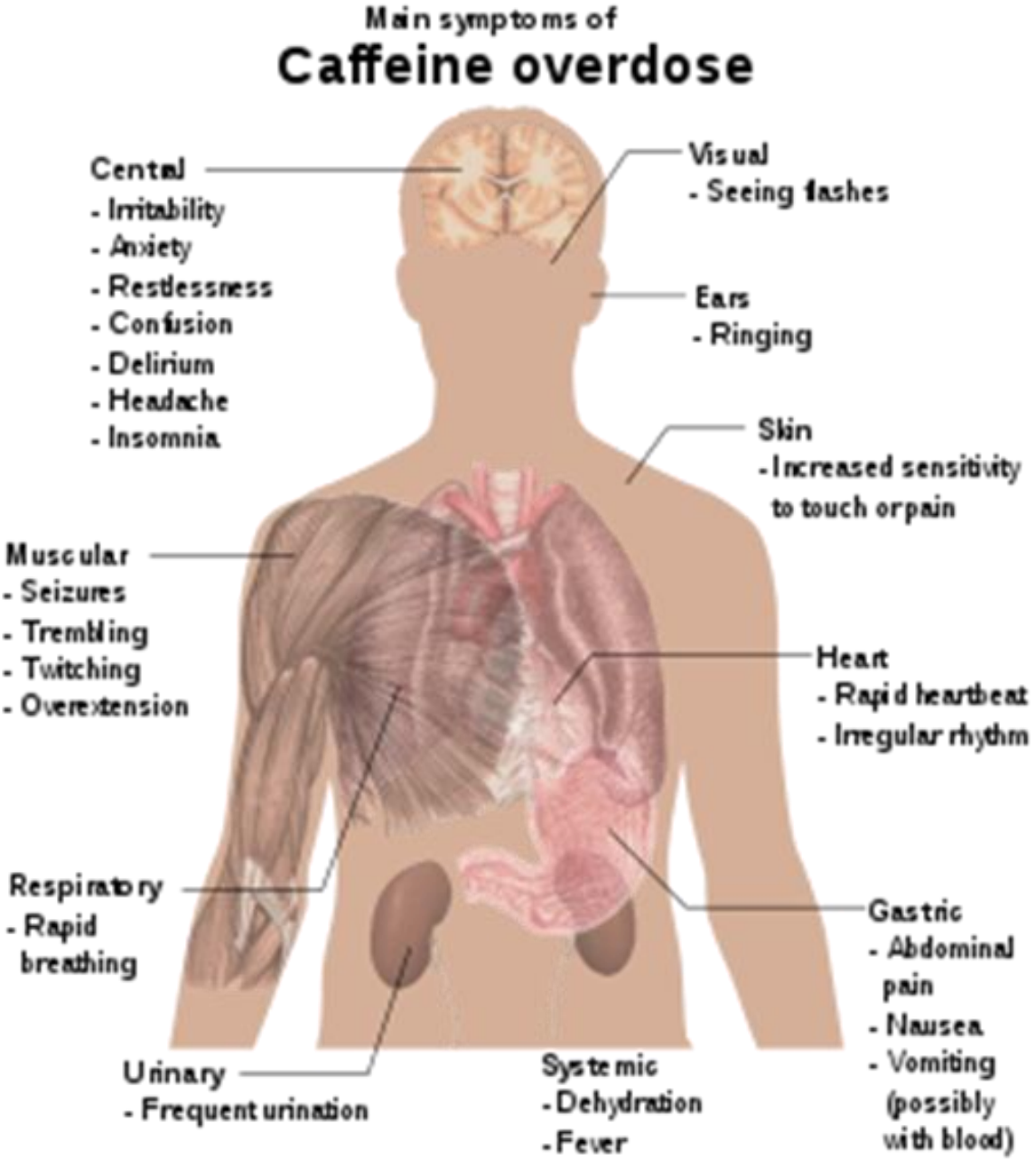
The image below displays caffeine's chemical structure.



Caffeine can be quantified in blood, plasma, or serum to monitor toxicity and/or individual rates of metabolism. The rate at which caffeine is metabolised may often depend on genetics, gender, smoking habits, obesity and pregnancy. Plasma caffeine levels are usually in the range of 2–10 mg/L in coffee drinkers, 12–36 mg/L and 40–400 mg/L in victims of acute toxicity.

Resource One
Data Source

Figure 2
Symptoms of caffeine overdose



Resource One Activities

Activities

1) Can you list three sources of caffeine that contain equivalent to or more than 80 mg of caffeine per serving?

2) What percentage of the adult western population DOES NOT consume at least one caffeinated food source/drink per day?

3) What is the most well recognised source of caffeine and from which two plants is this typically cultivated from?

4) List 5 sources of caffeine cultivation?

5) Analyse table 1 and suggest how many bars of dark chocolate a healthy adult would need to consume before risking caffeine toxicity?

6) What is caffeine's medical name?

7) What is caffeine's main mechanism of action?

8) Using table 1. Estimate how much caffeine you consume per day?

9) Using the image depicting caffeine's chemical structure, rearrange the below table to display how many of each atom caffeine contains.

a) Carbon	10
b) Nitrogen	8
c) Oxygen	4
d) Hydrogen	2

Resource One Activities

Activities

10) Fill in the blank spaces below to complete caffeine's chemical structure
    - C_ H_ N _ O_

11) List 5 neurological symptoms associated with caffeine toxicity?

12) Create a comic strip depicting the cultivation, preparation and consumption of caffeine in a food/drink source of your choice.

13) Create a diet log of food/drink items you have eaten over the last 3 days and identify which sources contain caffeine (extension task – estimate the content of caffeine per item and then explore the absolute value to compare against).

Resource One
Further Reading

Explore

Human consumption of caffeine – https://link.springer.com/chapter/10.1007/978-3-642-69823-1_4

What is caffeine? - https://www.youtube.com/watch?v=Xl1XBJLfIDU

Resource Two Overview

Topic	Caffeine Associated Mechanisms of Action
A-Level Modules	- Neuromuscular system - Diet and nutrition and their effect on physical activity
Objectives	After completing this resource you should be able to discuss ✓ How caffeine functions as an adenosine receptor antagonist ✓ How adenosine receptor antagonism may enhance neuromuscular transmission ✓ How caffeine may cause the secretion of β-endorphins
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

Resource Two
Data Source

The mechanisms by which caffeine exerts a benefit effect are multifactorial. The most prominent and important mechanism is caffeine's ability to antagonise adenosine receptors in the brain.

Deep Dive

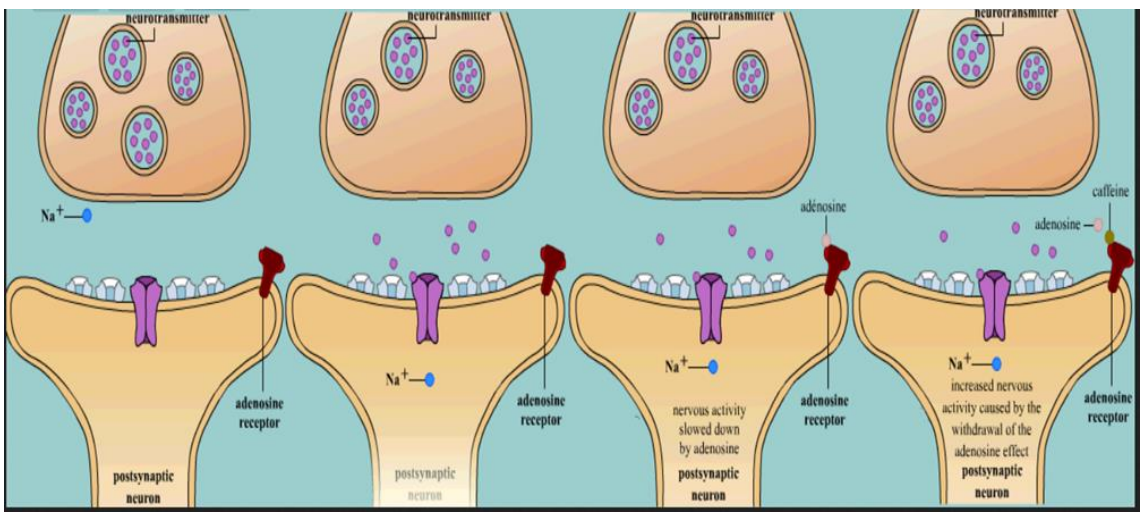
Caffeine molecules inhibit the purinergic G protein-coupled adenosine receptors in the brain which in turn cause central nervous stimulation (simply: central nervous stimulation is increased electrical activity which passes down from the brain and through the spinal cord causing stimulation of muscle, tissues and cells).

In contrast, adenosine itself is considered a brain neurotransmitter and an adenosine receptor agonist (a substance which slows down central nervous activity).

Figure 1

Adenosine receptor activity

The image below helps visually depict this complicated mechanism.



Note: sodium (Na+) causes the release of the purple neurotransmitter "adenosine". Adenosine attaches to the receptor site and slows down central nervous activity. In the final depiction, we see how caffeine inhibits this receptor site to stimulate central nervous activity by blocking adenosine!

Resource Two
Data Source

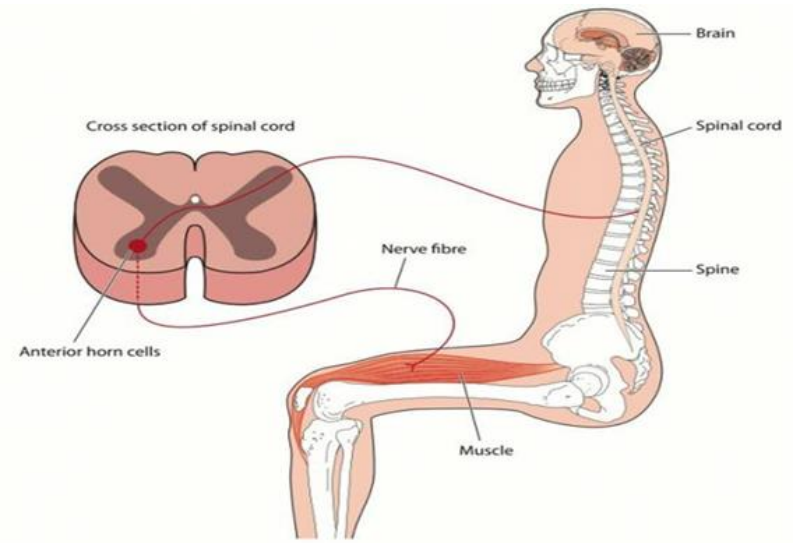
A benefit associated with caffeine's ability to increase central nervous stimulation is enhanced muscular force production. As the electrical impulses which are emitted from the central nervous system increase in magnitude, more muscular motor units (which are merely bundles and bundles of muscle fibres) are recruited per muscular contraction (via nerve fibre stimulation) which causes this increase in force. The scientific terms for this response are enhanced neuromuscular transmission and maximal muscle activation.

Finally, caffeine may also cause the secretion of β-endorphins and promote a significant thermogenic response! Endorphins are brain neurotransmitters which activate the body's opiate receptors, causing a pain blocking effect and general feelings of goodness (interestingly β-endorphins are also released during exercise and have been found to improve people's mood states).

The thermogenic response associated with caffeine consumption is generally associated with an increased metabolic rate which can subsequently cause increments in perceptual feelings of arousal, aggression (sport associated), motivation and energy. Indeed, the mechanisms of action associated with caffeine are multifactorial and can significantly benefit everyday life.

Figure 2

The neuromuscular pathway



Resource Two
Data Source

Finally, caffeine may also cause the secretion of β-endorphins and promote a significant thermogenic response! Endorphins are brain neurotransmitters which activate the body's opiate receptors, causing a pain blocking effect and general feelings of goodness (interestingly β-endorphins are also released during exercise and have been found to improve people's mood states).

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Resource Two Activities

Activities 1. Complete the below multiple-choice questions.

	A	B	C	D
What is caffeine's primary mechanism of action?	Adenosine receptor antagonism	Glycogen sparing	Central nervous stimulation	Free fatty acid oxidation
What does an adenosine receptor agonist cause?	Central nervous stimulation	Central nervous downregulation	Free fatty acid oxidation	Production of β-endorphins
What effect may caffeine have on the central nervous system?	Glycogen sparing	Central nervous stimulation	Reduced potential	downregulation
What effect may caffeine have on muscular force production?	Augmented	Decreased	No effect	Elongation of each contraction
Can you identify the negative health effect associated with an overly stimulated central nervous system?	Increased heart rate	Drowsiness	Worrying	Too much energy
What are β-endorphins?	Brain neurotransmitters	Lipids	Nerve cells	Adenosine receptor antagonists
By what order does an electrical impulse stimulate a muscular motor unit?	Brain, spinal cord, muscular motor unit	Spinal cord, brain, muscular motor unit	Brain, bone cells, muscular motor unit	Adenosine receptor, brain, muscular motor unit, spinal cord
What negative health effect may the production of β-endorphins cause?	Increased heart rate	Reduced pain perception	Reductions in oxygen consumption	increased fat metabolism
What may caffeine's thermogenic impetus cause?	Reductions in arousal and a better sleep.	Reduced pain perception, aggression and greater fine motor control.	Increased arousal, energy, motivation and aggression	Increased protein metabolism.

Resource Two Activities

Activities

2. Without referring back to the data source, can you recreate the mechanisms associated with adenosine and caffeine, and adenosine receptors?

3. Can you predict what would happen if the central nervous system was stimulated through a caffeine overdose?

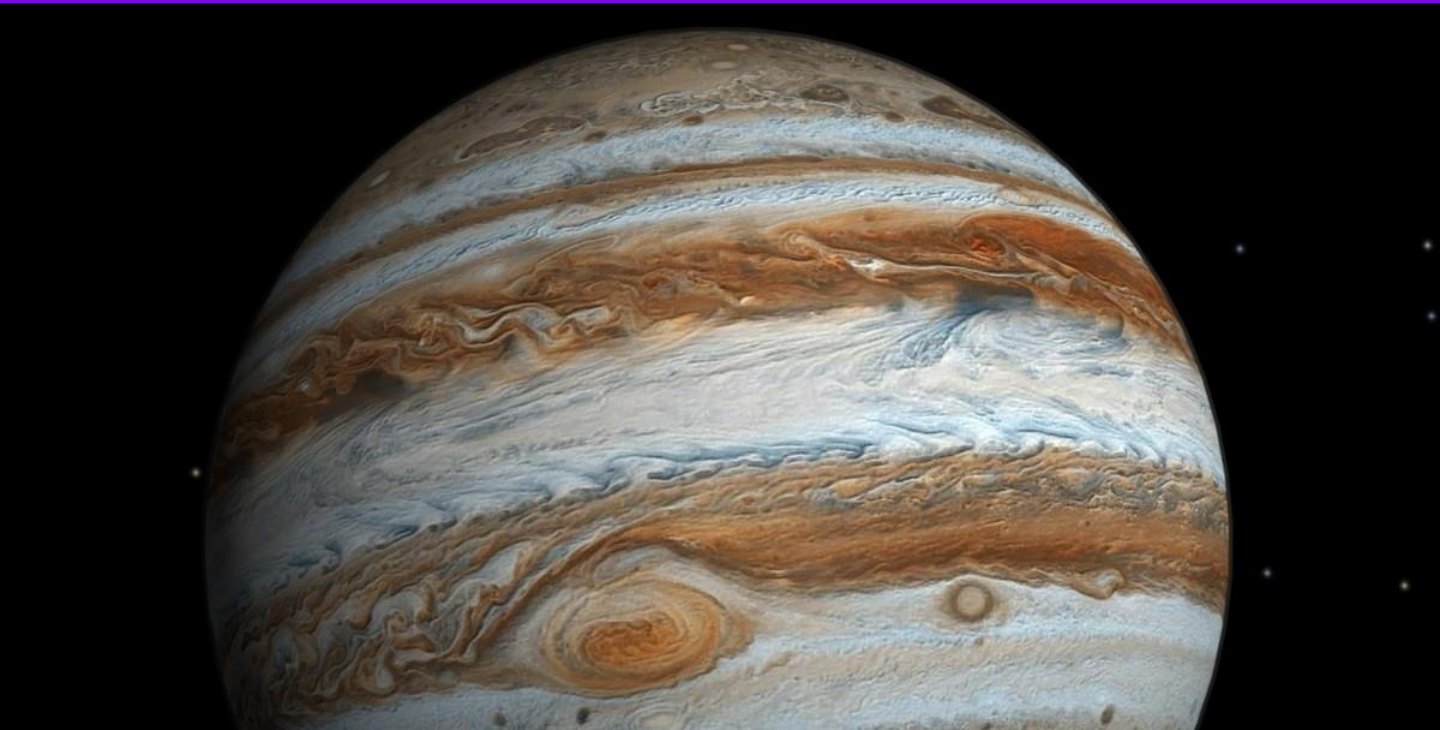
Resource Two
Further Reading

Explore

Caffeine and adenosine receptors - https://www.youtube.com/watch?v=jOfquPE1cnU Caffeine and the central nervous system - https://www.ncbi.nlm.nih.gov/pubmed/1356551

Resource Three Overview

Topic	Caffeine Use in Sport and Exercise
A-Level Modules	Diet and nutrition and their effect on physical activity
Objectives	After completing this resource you should be able to understand: ✓ Statistics associated with caffeine use across sport and exercise ✓ Recommended dosages and ingestion period ✓ How caffeine may improve sport and exercise performance through analysis of real-life research ✓ How to analyse mean differences to quantify the findings of research projects
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading



Resource Three
Data Source

Approximately 90% of adults consume caffeine in their everyday eating habits. Furthermore, 3 out of 4 British athletes consume caffeine prior to exercise performance. The typical dosage of caffeine that has been observed to improve sport and exercise performance ranges from 3 – 9 milligrams per kilogram of body mass but benefits have been incurred from lower and higher dosages than the aforementioned. However, any athlete who is not used to consuming caffeine is recommended to start at the lower end of the dosage spectrum as for some individuals too great a dose may actually impair performance through negative side effects including nausea, headaches, jittering, blurred vision etc.

The higher end range of dosages are only recommended to those individuals who experience no performance benefit at lower dosages. This perception may actually change over time with some individuals developing a tolerance. Once ingested, peak caffeine concentrations are detected in blood stream 1-hour post ingestion.

Caffeine may improve numerous cognitive and behavioural mechanisms associated with successful sport and exercise performance, including: alertness, concentration, energy levels, and self-reported feelings of fatigue. Caffeine has also been observed to directly improve performance across a range of sports including soccer, rugby, cycling, running, weightlifting and many others. These benefits are governed mainly by caffeine's ability to antagonise adenosine receptors (in essence: caffeine blocks adenosine from attaching to adenosine receptor sites) which subsequently augments central nervous stimulation and the force generated during skeletal muscular contractions (greater muscular force allows athletes to jump higher, run for longer, run faster, cycle faster, life more weight etc.).

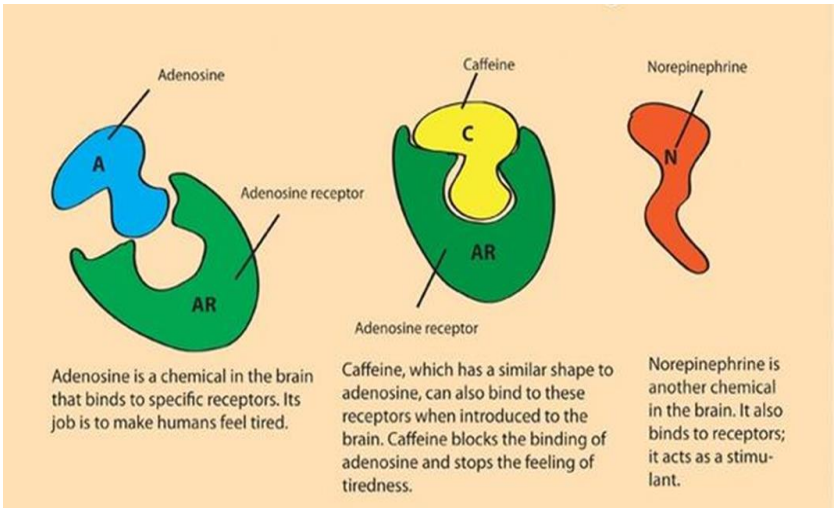
Resource Three
Data Source

The image below helps explain this complex mechanism in greater detail. Caffeine's effects normally last between 1.5 – 9.5 hours in healthy individuals.

Figure 1

Adenosine and nor-epinephrine

Deep Dive



A study by Del Coso et al. (2012) found ingestion of a caffeine containing energy drink at a dosage of 3 milligrams per kilogram of body mass, 60 minutes prior to a simulated soccer performance, to improve average jump height (+3%; +1.1cm), peak running speed (+3%; +0.7km·h−1), total distance covered (6%; 430m) and the number of sprints performed (25%; 5.2) versus a control.

This study is an example of how real-life research provides us with further knowledge how caffeine can be used to improve sport and exercise performance.

Table 1 is an example of how real-life research is at times presented. The below table represents individual times during a 100m sprint either before or after consuming 4 milligrams per kilogram body mass of caffeine.

Resource Three
Data Source

Table 1

100 m sprint times in seconds following caffeine and placebo consumption

Participant	Caffeine	Placebo
1	11.6	11.4
2	11.7	11.3
3	12.1	12.2
4	12.4	13
5	12.3	12.3
6	11.3	11.8
7	10.6	10.4
8	12.3	12.3
9	12.6	12.7
10	11.5	12.2
Average		

Resource Three Activities

Activities

1) What is the main mechanism that is associated with caffeine's beneficial effects on sport and exercise performance?

2) With regards to table 1. Can you calculate the mean change between caffeine and placebo trials? (Note: we must add all individual scores and divide this number by the total amount of individual scores to calculate the mean).

3) Can you calculate the difference between caffeine and placebo trials for each individual?

4) How many individuals performed greater during the caffeine trial?

5) Can you explain how caffeine may have improved sprint performance?

6) For those individuals who displayed no difference/performed worse during the caffeine trial, can you evaluate why this may have occurred?

7) What is the prevalence of caffeine use across British athletes (can you also provide this as a %)?

8) During the study by Del Coso et al. (2012), what factors do you feel were important in observing the performance benefit they perceived?

Resource Three Activities

Activities

9) How long do caffeine's effects typically last in healthy individuals?

10) What is the recommended range of caffeine dosages to improve sport and exercise performance?

11) What may occur if somebody who is not used to using caffeine, consumes a higher end dosage?

12) Create a comic strip outlining what dosage, how long before and for what benefit you would recommend caffeine to improve a soccer players performance.

Resource Three
Further Reading

Explore

Caffeine and exercise - https://www.youtube.com/watch?v=SBEiJBiYqBQ

Del Coso et al. (2012) - https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0031380

Caffeine tolerance - https://www.youtube.com/watch?v=yci3OGQS0Qw

Resource Four Overview

Topic	Caffeine and health concerns
A-Level Modules	Diet and nutrition and their effect on physical activity
Objectives	After completing this resource you should be able to understand: ✓ The prevalence of caffeine consumption across the general population and British athletes. ✓ The basic concepts of caffeine metabolism ✓ Caffeine dosage responses and caffeine toxicity ✓ The health concerns associated with caffeine consumption ✓ How genetic polymorphisms may influence caffeine metabolism and health
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading
Context	Caffeine is amongst the most frequently consumed psychoactive substances in the world. Approximately 3 out of 4 British athletes consume caffeine prior to competition. Moreover, approximately 90% of the worlds adult population is thought to consume at least one caffeinated beverage per day. Caffeine has a host of benefits including increased alertness, concentration, cognitive function, muscle force production and many more. Typically, these benefits are associated with caffeine's ability to augment central nervous stimulation through a process labelled adenosine receptor antagonism. However, the benefits associated with caffeine may come at a price for some individuals.

Resource Four
Data Source

Providing evidence

Caffeine is classified by the US food and drug administration as generally safe, however, caffeine can prove toxic at approximate dosages equivalent to 400 – 500 mg for adults. To put this into context an ordinary cup of homemade coffee contains 80 - 175 mg of caffeine, therefore it would require a healthy adult to consume approximately 3 - 5 ordinary cups of coffee to reach such a toxic dose. Yet, considerably lower dosages (as little as 100 - 200 mg) can prove debilitative to the health of individuals who are considered slow caffeine metabolisers.

Figure 1

Symptoms of caffeine overdose

Slower rates of caffeine metabolism cause prolongation of symptoms and sensations associated with caffeine's stimulatory effects, some examples include increased blood

pressure and heart rate, and heightened feelings of anxiety, depression and insomnia. Once more, in healthy individuals these debilitative effects will generally prove miniscule (unless unsafe dosages have been consumed, or caffeine is consumed prior to sleep/rest etc.), however, individuals who display pre-existing cardiovascular (cardiac arrythmia, hypertension, heart disease) and/or psychological concerns (anxiety, depression etc.) are at particular risk.

Caffeine metabolism occurs at a rate of between 70-80% in healthy individuals, it is primarily metabolised (70-80%) via N-3 demethylation by liver cytochrome (CYP) 1A2 to paraxanthine (84%), theobromine (12%), and theophylline (4%). The plasma half-life of caffeine typically extends between 1.5 – 9.5 hours. Polymorphisms in the gene CYP1A2 may explain individual differences in caffeine metabolism. The homozygote genotype AA is considered a fast caffeine metaboliser whilst AC and CC genotypes are considered slow metabolisers.

Slower rates of caffeine metabolism may increase the plasma half-life of caffeine up to 16 hours, this may augment the risk of myocardial infarctions, dysregulated sleep patterns, increased blood pressure and other debilitative health states. In some populations these polymorphisms are significantly more prominent, for example women are generally considered slower metabolisers versus men, whilst pregnant women are considerably slower caffeine metabolisers versus non-pregnant women (thus caffeine can also prove detrimental to foetus health and development).

Caffeine has also been observed to catalyse production of catecholamines. Catecholamines are hormones produced by the adrenal glands. The main catecholamines produced by

adrenaline), and norepinephrine. These catecholamines have been observed to cause damage to myocardial cells especially during periods of biological stress (e.g. sport and exercise performance) where catecholamine production is already naturally augmented. Moreover, Individuals homozygous for the 'slow metabolism' allele CYP1A2 display reduced activity of the enzyme catechol-O-methyl transferase Catechol-O-methyl transferase is responsible for increasing metabolism of catecholamines (thus downregulating its potentially harmful effects).

Resource Four Activities

Activities

1) What percentage of British athletes consume caffeine on a daily basis?
2) What percentage of the general population consume caffeine on a daily basis?
3) List 3 benefits associated with caffeine use?
4) According to the US food and drug administration, how much caffeine would you be required to consume as an adult for it to be considered toxic?
5) Polymorphisms in which gene may result in increased rates of caffeine metabolism?
6) Explain why extended periods of caffeine metabolism may prove detrimental to health?
7) Are the risks associated with caffeine consumption the same for all populations? Explain your answer.
8) What percentage of caffeine is metabolised to theobromine, paraxanthine and theophylline?
9) What is the typical plasma half-life of caffeine?
10) What are catecholamines?
11) What are the three main catecholamines?
12) What is the purpose of catecholamines?
13) Explain why individuals considered 'slow caffeine metabolisers' may be at an increased risk of catecholamines?
14) With regards to catecholamines, why would individuals who consume caffeine prior to sport and exercise performance be at an increased risk versus those who do not?
15) Create a flyer outlining how caffeine may cause potential health concerns in individuals who display genetic polymorphisms versus those who do not?

Resource Four
Further Reading

Explore

Caffeine metabolism and genetics - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3381939/

Negative effects of caffeine - https://www.youtube.com/watch?v=htBRg61e6rw.

Resource Five Overview

Topic	Caffeine and the placebo effect
A-Level Modules	Diet and nutrition and their effect on physical activity
Objectives	After completing this resource you should be able to understand: ✓ The difference between a placebo and the placebo effect is ✓ How expectancies for caffeine consumption may significantly influence the placebo effect ✓ How expectancies are generally unaccounted for across the broader caffeine literature ✓ How expectancies may help reduce the negative health concerns associated with caffeine consumption in some populations
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

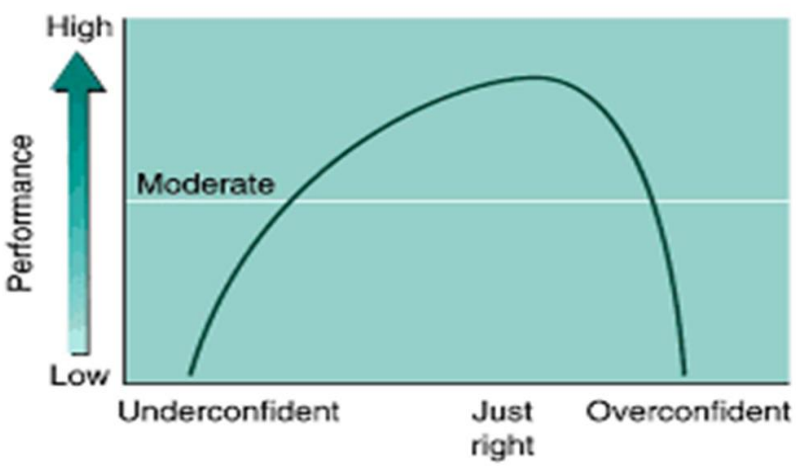
Resource Five
Data Source

Active Reading

Placebos are considered pharmacologically inert compounds and are typically used to compare against the effects of nutritional supplements. In contrast, the placebo effect is considered a procedure or substance that is administered with expectations that it will modify a symptom or sensation but unbeknown to its recipient is merely a placebo! Expectancy is closely associated and, in some instances, assumed to have a direct relationship with the placebo effect. In simple terms, the more we expect a substance or procedure to have an effect, the greater effect we will probably observe. According to expectancy theory the placebo effect is mediated by observational (e.g. advertisement campaigns, billboards, vicarious experiences etc.) and verbal (word of mouth, the radio etc.) learning mechanisms. Thus, the effectiveness of a placebo will likely be influenced by an individuals pre-existing perceptions and opinions. Ultimately, if these perceptions are negative we may even see a reverse placebo effect (this is actually defined as a nocebo effect). Interestingly, during a study in 2016, an author called Jason Tallis (and colleagues) suggested, if expectations for caffeine consumption are not controlled they may cause individuals to become so over confident that we see a detrimental performance effect (for a visual depiction of this relationship, see the figure below).

Figure 1

The inverted U hypothesis



Resource Five
Data Source

Expectancies may be best modulated by more salient feedback techniques. For example, if a study is exploring the effects of placebo coffee on sport and exercise performance, by deceptively preparing decaffeinated coffee in front of participants we may increase expectations to a greater extent than if we were to merely tell them they were receiving caffeinated coffee. Decaffeinated coffee smells and tastes very similar to caffeinated coffee, thus we are stimulating more senses and our deception will likely be more successful.

Unfortunately, at present there are only 17 published research studies that have explored caffeine expectancies, therefore the mechanisms associated with its influence are relatively unknown. Though, we can hypothesise that expectations will likely increase subjective confidence, motivation and arousal which may help explain the benefits observed on sport and exercise performance across a vast proportion of these studies.

Studies assessing the general effects of caffeine typically do not account for the influence of expectancies, with most studies attributing performance effects to caffeine's ability to antagonise adenosine receptors (and subsequently increase central nervous stimulation). However, we believe this mechanism only partially tells the story as some research studies have found caffeine's psychological influence to be comparable or even greater than the pharmacological effect (see review paper by Shabir et al. (2018) in the further reading section) on sport, exercise and cognitive performance.

To more effectively explore caffeine's proposed mechanisms of action, studies may wish to adopt a double-dissociation design. Effectively, this consists of four groups which allow

comparison of the pharmacological (given caffeine/told placebo), psychological (given placebo/told caffeine) and synergistic (given caffeine/told caffeine) effects of caffeine and finally an isolated placebo (given placebo/told placebo). However, the effectiveness of this research design will depend on how well people are deceived into believing they have received caffeine when they haven't, or they have received a placebo when actually consuming caffeine.

As previously suggested, this will depend on the saliency of techniques used but also individuals pre-existing perceptions and opinions.

Moreover, studies should implement quantitative and qualitative analysis. Simply, quantitative analysis is interested in quantifying numbers (e.g. how much faster does A run 100m versus B), whereas qualitative analysis explores subjective perceptions (e.g. interview procedures, questionnaires etc.) that are likely to be different from person to person and experience to experience.

As we have made mention numerous times, expectations are influenced by various interpersonal factors that can really only be explored through qualitative analysis!

Resource Five Activities

Activities

1) Can you differentiate between a placebo and the placebo effect?
2) What are expectancies?
3) List 3 factors that may influence an individual's expectancies?
4) What type of individuals may be least responsive to placebos?
5) Using evidence from the data source explain how expectancies may be best modulated?
6) List 3 psychological constructs that are likely influenced by expectancies?
7) Provide your opinion on why expectancies are generally unaccounted for across the broader caffeine literature?
8) Can you think of any ethical concerns when administering placebos?
9) Explain the double-dissociation design?
10) What methods should be considered to most effectively utilise the double-dissociation design?
11) What is the nocebo effect?
12) Differentiate between quantitative versus qualitative analysis?
13) Why is qualitative analysis important when exploring the placebo effect?
14) Describe one way of collecting qualitative data?
15) Create a comic strip outlining how you would administer caffeine placebos to help individuals perform better during sport and exercise.

Resource Five
Further Reading

Explore

Caffeine and the placebo effect, a review - https://www.mdpi.com/2072-6643/10/10/1528

The placebo effect and sports performance - https://www.youtube.com/watch?v=HCGnUISaZ7w

Resource Six Overview

Topic	Caffeine placebos as an alternative to active caffeine?
A-Level Modules	Diet and nutrition and their effect on physical activity

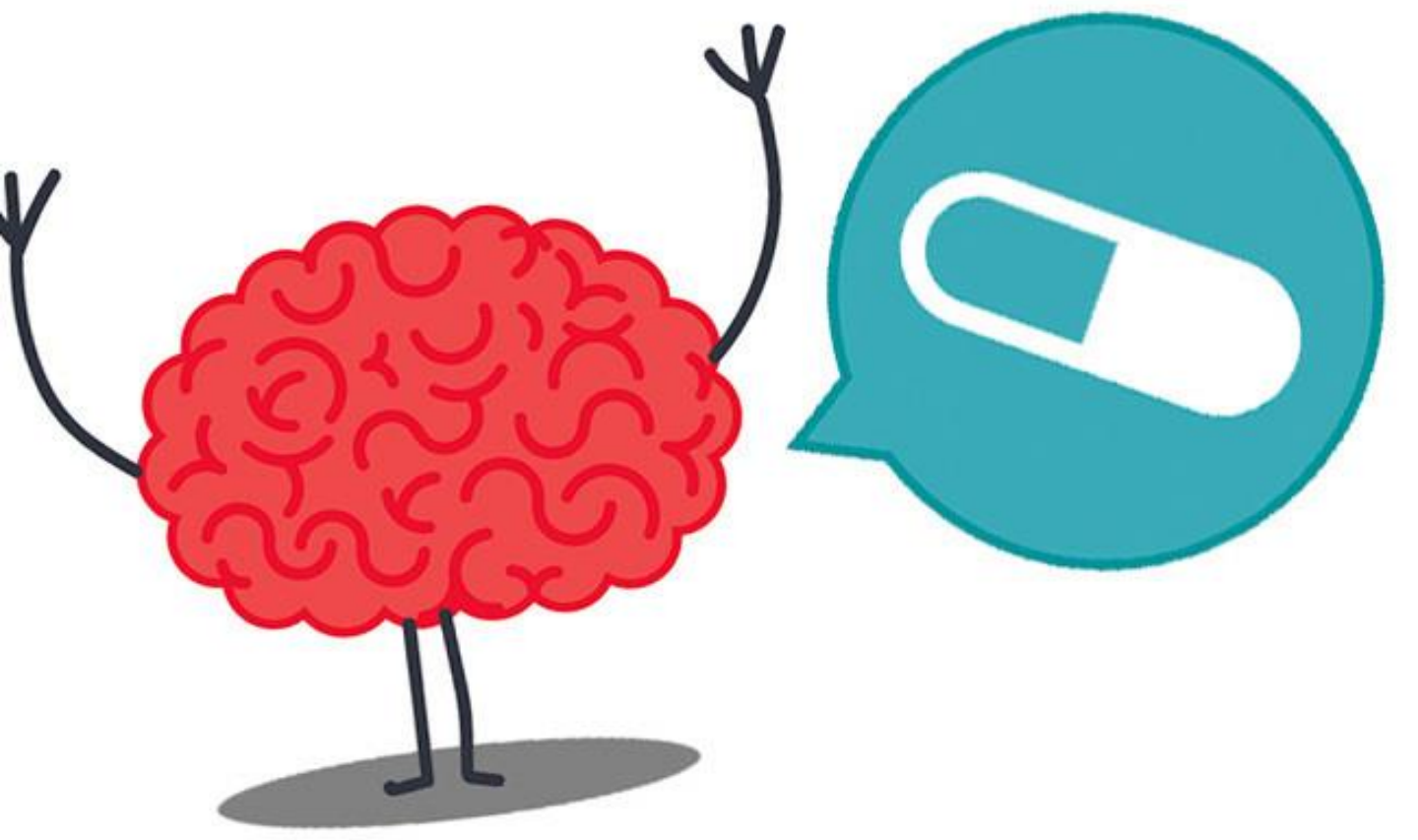
Objectives

After completing this resource you should be able to explain

- ✓ What are caffeine placebos
- ✓ What factors will influence how effective a caffeine placebo is
- ✓ How caffeine placebos may reduce the health concerns associated with active caffeine in some populations
- ✓ Scientific literature pertaining to caffeine placebos, and, sport and exercise performance

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading



Resource Six
Data Source

Three out of four British athletes consume caffeine for ergogenic purposes. Caffeine's main mechanism of action is associated with the antagonism of adenosine receptors, and subsequent increments in central nervous stimulation. Although caffeine is generally safe to consume, for some populations the benefits of caffeine on sport and exercise performance may come at a significant cost. For example, individuals who are predisposed to heart disease, cardiac arrythmia, hypertension and/or suffer from anxiety, depression and insomnia are at particular risk. Moreover, individuals who display polymorphisms in the gene CYP1A2 may display prolonged caffeine plasma half-life, which will likely increase the severity of symptoms and sensations (e.g. increased heart rate, blood pressure etc.) associated with caffeine use. These polymorphisms are considered of greater prevalence in females, which for pregnant individuals may also pose a threat to foetus health and development.

A potential alternate solution to this issue is the use of caffeine placebos. Placebos are merely inert substances, compounds or interventions that contain no pharmacological ingredient. However, by manipulating expectancies, placebos can cause powerful and meaningful effects whilst significantly reducing any risks to health (remember placebos do not contain any active ingredient – in caffeine's case think decaffeinated coffee as an alternate to caffeinated coffee). Therefore, caffeine placebos may be defined as inert interventions that are successfully administered by manipulating a recipient's expectancies to ensure they believe they are receiving caffeine! Some techniques that can be used to increase caffeine placebo efficacy are verbal information (e.g. verbally explaining the benefits of caffeine) and/or observational learning (e.g. watching a video displaying how caffeine improves sport and exercise performance) with more salient techniques usually of greater

significance here (e.g. using the findings of scientific research when verbally explaining the benefits of caffeine and/or having individual watch decaffeinated coffee being made, whilst under the false assumption it is caffeinated coffee). Additionally, some habitual factors may also help increase placebo efficacy, these include: if an individual is a habitual caffeine user, whether they have been predisposed to any conditioning effects (conditioning effects are considered learned responses over a longer period of time, these can often be conscious or sub-conscious, whereas expectancies or cognitive processes usually consciously driven) or hold any habitual expectancies (e.g. do friends consume caffeine, does their favourite sports player advertise caffeine), their intrigue in nutritional supplements and their relationship with who is administering the placebo (think a medicine being prescribed by a random person on the street versus a doctor). Interestingly the same factors that may increase the efficacy of the placebo effect, may also cause a nocebo effect (or a negative effect). For example, if an individual has been predisposed to negative information regarding caffeine or if an individual believes nutritional supplements induce negative side effects then they are more likely to respond negatively to the placebo effect.

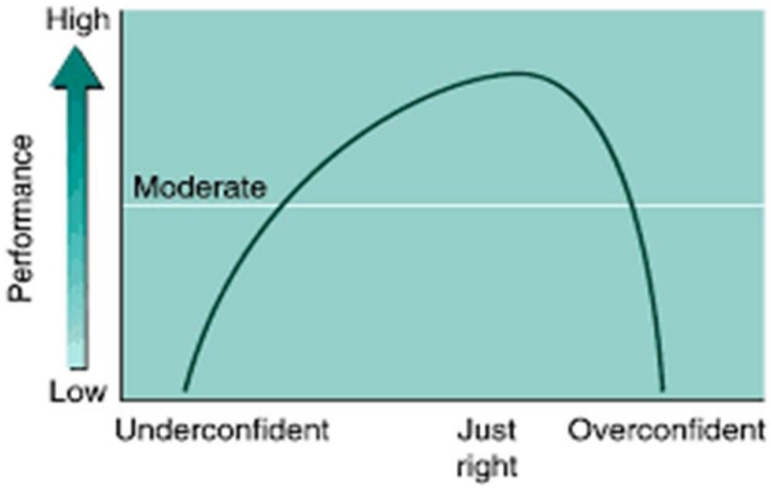
The mechanisms associated with caffeine expectancies and the placebo effect are yet to be explored in significant detail. However, at present two key mechanisms associated with endurance performance are increments in motivation and/or reductions in perceptual exertion (or feelings of fatigue). There is an argument that any psychological construct may be influenced here, for example belief of receiving a beneficial sports supplement like caffeine may cause increases in confidence, determination, and belief, all of which may improve performance. However, a research study by Jason Tallis (and colleagues) in 2016 suggested that

Resource Six
Data Source

too great an expectation may cause individuals to become overly reliant on the placebo effect and subsequently cause reductions in effort (this may be highlighted in the figure below).

Figure 1

The inverted U hypothesis



Interestingly, a review paper by Shabir and colleagues in 2018 suggested that the psychological effects of caffeine may actually help improve the effectiveness of active caffeine in potential users. For example, although sensitivity to caffeine may be manipulated acutely through periods of abstinence, generally, an individual cannot improve the sensitivity of their adenosine receptors. However, by educating individuals and explaining the benefits of caffeine, psychological constructs like motivation, determination and confidence may be enhanced improving the overall efficacy of active caffeine! Yet, it may be considered unethical and potentially unprofessional practice in some situations to deceive individuals into believing they are consuming an active ingredient when they are not. However, some research suggests knowing you are consuming a placebo after realising it can improve performance can within itself enhance performance (you may need to re-read that sentence a few times)! Plenty to ponder...

Resource Six Activities

Activities

1) Can you explain what caffeine placebos are?
2) List 3 health concerns associated with caffeine?
3) Are all populations at the same health risks of caffeine, explain your answer?
4) What techniques can be used to increase caffeine placebo efficacy?
5) What habitual factors will influence the effectiveness of caffeine placebos?
6) How may caffeine placebos reduce the health concerns associated with caffeine?
7) Based on the findings of Shabir et al. (2018), why may expectations for caffeine use help improve active caffeine efficacy?
8) Describe what Figure 1 is telling us about caffeine expectancies?
9) Describe 3 factors which may prevent an individual from experiencing a beneficial placebo effect?
10) What is a nocebo effect?
11) What ethical issues may be presented when administering placebos?
12) What are the differences between expectancies and conditioning effects?
13) List and describe 3 mechanisms associated with caffeine placebos?
14) Create a poster highlighting the benefits of using caffeine placebos as opposed to active caffeine for ALL populations.

Resource Six
Further Reading

Explore

Caffeine and the placebo effect, a review - https://www.mdpi.com/2072-6643/10/10/1528

Negative effects of caffeine - https://www.youtube.com/watch?v=htBRg61e6rw&t=85s

Final Reflection

Deep Dive

BROUGHT TO YOU BY RBC ACCESS ED

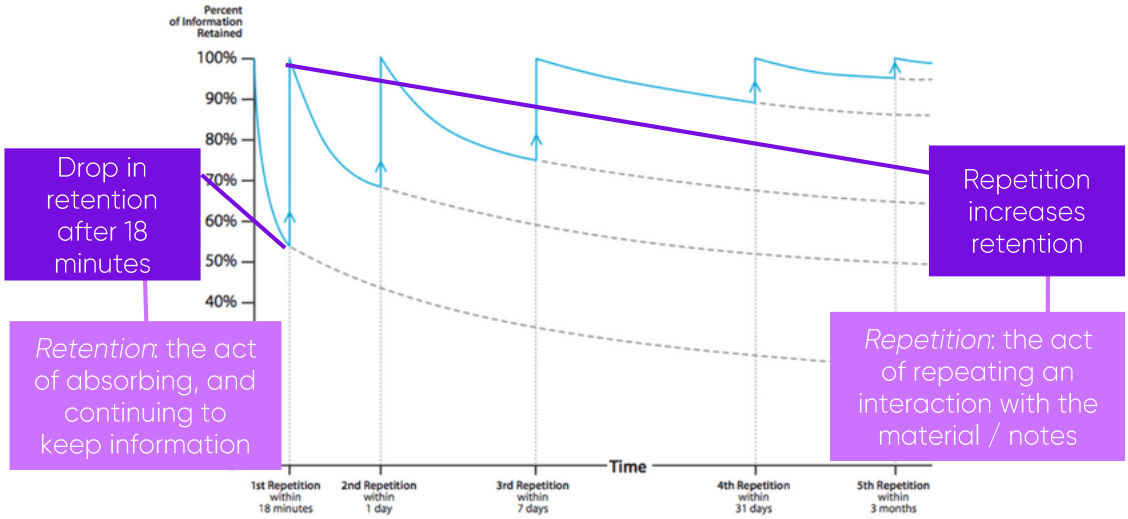
Topic	A deeper look into Caffeine and the placebo effect
Objectives	Now you have had an opportunity to study the 6 associated resource packs, we would strongly encourage you to take part in the task below. Effectively, by taking part in this task not only will you be informing others about caffeine expectancies, but your own breadth of knowledge will expand and perhaps this might even initiate some novel and exciting research somewhere down the line!
Instructions	Design a poster or PowerPoint presentation (approximately 10 minutes) explaining why caffeine expectancies and the placebo effect is an important area of research. When designing this try to outline the benefits associated with placebo caffeine versus physiologically active caffeine (and perhaps use evidence from real life research projects as per Shabir et al. (2018) and Del Coso et al. (2012)). In your final slides you should aim to design an experimental study that you feel might add something interesting to this area of practice.

University Study Skills
Cornell Notes

Why is good note taking important?

If it feels like you forget new information almost as quickly as you hear it, even if you write it down, that's because we tend to lose almost 40% of new information within the first 24 hours of first reading or hearing it.

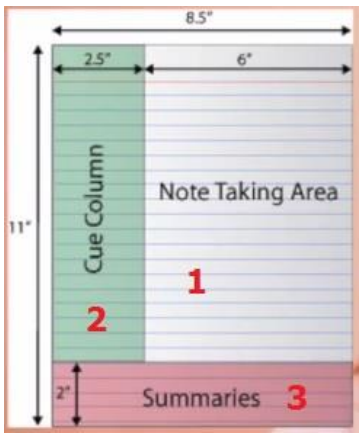
If we take notes effectively, however, we can retain and retrieve almost 100% of the information we receive. Consider this graph on the rate of forgetting with study/repetition:



Learning a new system

The Cornell Note System was developed in the 1950s at the University of Cornell in the USA. The system includes interacting with your notes and is suitable for all subjects. There are three steps to the Cornell Note System.

Step 1: Note-Taking



1. <u>Create Format</u>: Notes are set up in the Cornell Way. This means creating 3 boxes like the ones on the left. You should put your name, date, and topic at the top of the page.

2. <u>Write and Organise</u>: You then take your notes in area on the right side of the page. You should organise these notes by keeping a line or a space between 'chunks' /main ideas of information. You can also use bullet points for lists of information to help organise your notes.

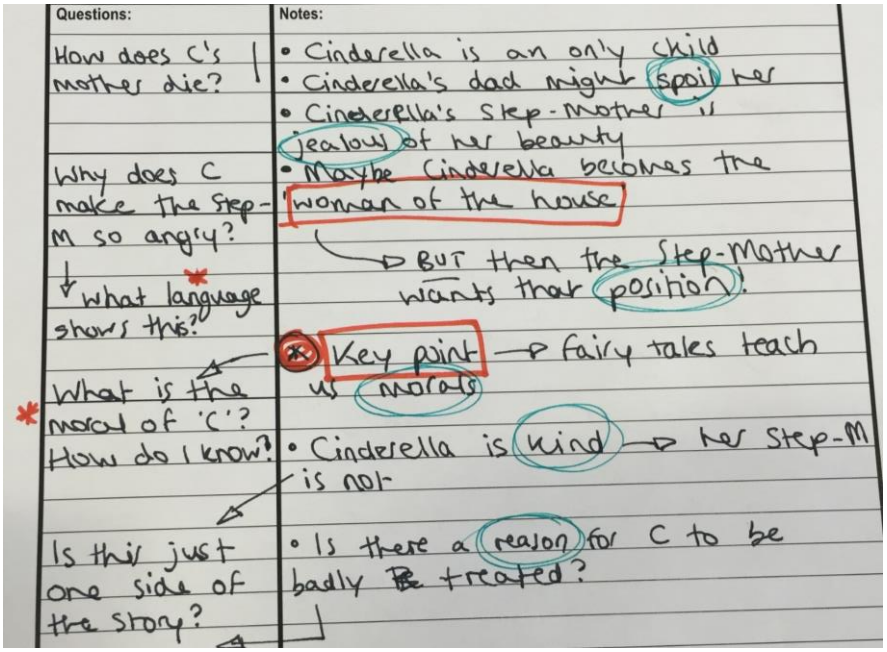
Step 2 Note-Making

1. Revise and Edit Notes: Go back to box 1, the note taking area and spend some time revising and editing. You can do this by: highlighting 'chunks' of information with a number or a colour; circling all key words in a different colour; highlighting main ideas; adding new information in another colour

2. Note Key Idea: Go to box 2 on the left hand side of the page and develop some questions about the main ideas in your notes. The questions should be 'high level'. This means they should encourage you to think deeper about the ideas. Example 'high level' questions would be:

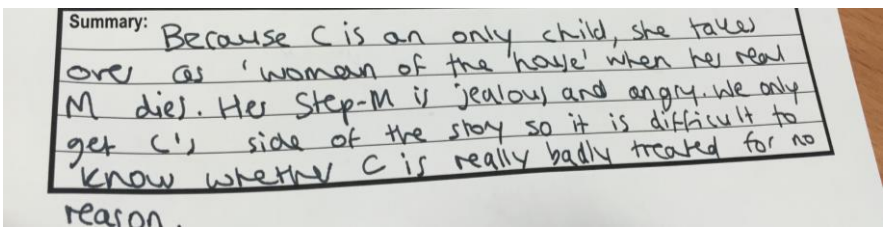
- Which is most important / significant reason for...
- To what extent...
- How does the (data / text / ideas) support the viewpoint?
- How do we know that...

Here is an example of step 1 and step 2 for notes on the story of Cinderella:



Step 3 Note-Interacting

1. Summary: Go to box 3 at the bottom of the page and summarise the main ideas in box 1 and answer the essential questions in box 2.



Give the Cornell Note Taking System a try and see if it works for you!

University Study Skills
Key Instruction Words

These words will often be used when university tutors set you essay questions - it is a good idea to carefully read instruction words before attempting to answer the question.

Analyse – When you analyse something you consider it carefully and in detail in order to understand and explain it. To analyse, identify the main parts or ideas of a subject and examine or interpret the connections between them.

Comment on – When you comment on a subject or the ideas in a subject, you say something that gives your opinion about it or an explanation for it.

Compare – To compare things means to point out the differences or similarities between them. A comparison essay would involve examining qualities/characteristics of a subject and emphasising the similarities and differences.

Contrast – When you contrast two subjects you show how they differ when compared with each other. A contrast essay should emphasise striking differences between two elements.

Compare and contrast – To write a compare and contrast essay you would examine the similarities and differences of two subjects.

Criticise – When you criticise you make judgments about a subject after thinking about it carefully and deeply. Express your judgement with respect to the correctness or merit of the factors under consideration. Give the results of your own analysis and discuss the limitations and contributions of the factors in question. Support your judgement with evidence.

Define – When you define something you show, describe, or state clearly what it is and what it is like, you can also say what its limits are. Do not include details but do include what distinguishes it from the other related things, sometimes by giving examples.

Describe – To describe in an essay requires you to give a detailed account of characteristics, properties or qualities of a subject.

Discuss – To discuss in an essay consider your subject from different points of view. Examine, analyse and present considerations for and against the problem or statement.

University Study Skills
Key Instruction Words

Evaluate – When you evaluate in an essay, decide on your subject's significance, value, or quality after carefully studying its good and bad features. Use authoritative (e.g. from established authors or theorists in the field) and, to some extent, personal appraisal of both contributions and limitations of the subject. Similar to **assess**.

Illustrate – If asked to illustrate in an essay, explain the points that you are making clearly by using examples, diagrams, statistics etc.

Interpret – In an essay that requires you to interpret, you should translate, solve, give examples, or comment upon the subject and evaluate it in terms of your judgement or reaction. Basically, give an explanation of what your subject means. Similar to **explain**.

Justify – When asked to justify a statement in an essay you should provide the reasons and grounds for the conclusions you draw from the statement. Present your evidence in a form that will convince your reader.

Outline – Outlining requires that you explain ideas, plans, or theories in a general way, without giving all the details. Organise and systematically describe the main points or general principles. Use essential supplementary material, but omit minor details.

Prove – When proving a statement, experiment or theory in an essay, you must confirm or verify it. You are expected to evaluate the material and present experimental evidence and/or logical argument.

Relate – To relate two things, you should state or claim the connection or link between them. Show the relationship by emphasising these connections and associations.

Review – When you review, critically examine, analyse and comment on the major points of a subject in an organised manner

University Guidance

Exploring Careers and Study Options

- ✓ Find job descriptions, salaries and hours, routes into different careers, and more at https://www.startprofile.com/
- ✓ Research career and study choices, and see videos of those who have pursued various routes at http://www.careerpilot.org.uk/
- ✓ See videos about what it's like to work in different jobs and for different organisations at https://www.careersbox.co.uk/
- ✓ Find out what different degrees could lead to, how to choose the right course for you, and how to apply for courses and student finance at https://www.prospects.ac.uk/
- ✓ Explore job descriptions and career options, and contact careers advisers at https://nationalcareersservice.direct.gov.uk/
- ✓ Discover which subjects and qualifications (not just A levels) lead to different degrees, and what careers these degrees can lead to, at http://www.russellgroup.ac.uk/media/5457/informed-choices-2016.pdf

Comparing Universities

- ✓ https://www.whatuni.com/
- ✓ http://unistats.direct.gov.uk/
- ✓ https://www.thecompleteuniversityguide.co.uk/
- ✓ Which? Explorer tool – find out your degree options based on your A level and BTEC subjects: https://university.which.co.uk/

UCAS

- ✓ Key dates and deadlines: https://university.which.co.uk/advice/ucas-application/ucas-deadlines-key-application-dates
- ✓ Untangle UCAS terminology at https://www.ucas.com/corporate/about-us/who-we-are/ucas-terms-explained
- ✓ Get advice on writing a UCAS personal statement at https://www.ucas.com/ucas/undergraduate/getting-started/when-apply/how-write-ucas-undergraduate-personal-statement
- ✓ You can also find a template to help you structure a UCAS statement, at https://www.ucas.com/sites/default/files/ucas-personal-statement-worksheet.pdf
- ✓ How to survive Clearing: https://university.which.co.uk/advice/clearing-results-day/the-survivors-guide-to-clearing

Subject Guidance

Sport and Exercise at University

- ✓ Sport scientists investigate biological and psychological constructs that effect sport and exercise performance
- ✓ Sport scientists will need a high level of skill and ability in science and be good at solving problems. Working accurately and having an eye for detail will help you when analysing data
- ✓ You can find out more about different courses and entry requirements by exploring the UCAS Sport and exercise Guide online: https://digital.ucas.com/search/results?SearchText=sport+and+exercise+science&pageNumber=3
- ✓ You can find out more about the different careers by exploring the UCAS Biochemists Careers online; https://www.ucas.com/ucas/after-gcses/find-career-ideas/explore-jobs?k=sport&f=/job-subjects/physical-education

A Deeper Look Into Sport and Exercise

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