IB Biology SL
Lillian Teoh [12D]

Research Question
To investigate how aerobic exercise affects the heart rate of a 16 year old male. The aerobic exercise I will be using to conduct this experiment is jumping jacks, commonly known as star jumps.

It is a physical jumping exercise performed by jumping to a position where both legs are spaced out from each other while hands are placed over the head like the shape of a star, and then returning to the original position of both feet together with arms by the sides.

DESIGN

Variables

Independent variable: Length of time to perform jumping jacks
Dependent variable: Pulse rate – the time between heart beats (after every minute)
Controlled variables:

a) Physical status
   - Height
   - Age
   - Gender
   - Weight
   - Dietary intake before exercise
   - Fitness level
   - Body size
b) Time taken for each jump (1 second)
c) Pulse rate before exercise (90 beats per minute)
d) Repetition (5 times for each value)
e) Time of exercise (4 pm)
f) Conditions in environment
   - Temperature in environment
   - Clothing and shoes

Prediction

Heart rate is the rate at which the heart beats per minute. Heart rate is measured by monitoring the pulse of a person. Every time the heart beats, it pumps a quantity of blood into our circulatory system. These beats cause a shock wave (pulse) which travels along the walls of the arteries. This pulse can be felt in several parts of the body[1]. In this experiment, an automatic blood pressure monitor is used on the arm to measure the pulse of the test subject.

A person performing physical activity would require a higher demand for energy. In order to get more energy, respiration needs to be increased. This means that a greater amount of oxygen and glucose is required by the body which can be obtained by increasing the rate of breathing so more oxygen can enter into the system.

To meet these increased needs, more blood must be delivered to the muscles during exercise. In order for this to happen, the heart must beat faster to pump more blood to the muscles to transport

[1] Elizabeth Haworth, Carol Forshaw, and Neil Moonie, in *GCSE Health and Social Care for Edexcel*, page 153.

oxygen and in addition remove waste products (carbon dioxide and water) in a shorter amount of time. Hence, this results in the increase of heart rate.

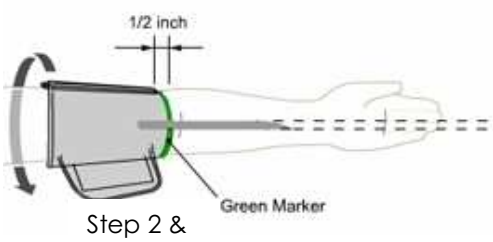
Based on this scientific knowledge, I can therefore predict that the heart rate will increase as the length of time performing jumping jacks increases. However, when the physical activity is stopped, the heart rate will gradually decrease back to the resting heart rate.

Method

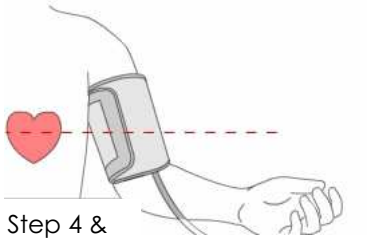
1. Measure resting heart rate (before exercise) using an automatic blood pressure monitor
2. Perform jumping jacks for amount of time indicated
3. Immediately measure pulse using the blood pressure monitor
4. Record pulse rate in a table
5. Rest until resting heart rate is achieved
6. Repeat the experiment for the next pre-set time.
7. Repeat the experiment 5 times for each length of time.

How to use an automatic blood pressure monitor[2]

1. Seat on a chair with feet flat on the ground
2. Slide left arm through the cuff and position the cuff about 0.5 inches above the elbow.
3. Position the green marker directly over the artery on the inside of the arm
4. Secure the cuff
5. Place arm on a table so that the cuff is at the same level as heart
6. Press the start button and remain still
7. The cuff will inflate and numbers will be displayed
8. When the measurement is complete, the cuff will deflate
9. The blood pressure and pulse rate will be displayed on the screen



Step 2 &


Step 4 &

Range and repetitions of experiment

[2] "Instructions for Upper Arm Blood Pressure Monitors," *Amazon.com: Omron Automatic Inflation Digital Blood Pressure Monitor: Health & Personal Care*, June 22, 2009, http://www.amazon.com/Omron-HEM-712C-Automatic-Pressure-IntelliSense/dp/B00006WNPX.

Range

The range of my experiment is from 0 minutes to 5 minutes. Any timing above 5 minutes would be too physically demanding for the test subject without rest. I decided to increase each value constantly by a minute each time as it would allow a significant enough change in the pulse rate to be recorded.

Repetitions

I decided to repeat the experiment 5 times for each length of time because this is the minimum value required to perform standard deviation. Standard deviation is important and should be applied to the results of this experiment because it is a useful way of finding out the reliability of the results obtained are and to measure how close it is to the average mean. The less the spread of the value from the mean, the more reliable the results are. In addition, by repeating the experiment for all samples, results obtained will be more accurate as it allows any anomalies to be detected and fixed or gained by external factors giving a more precise result.

Control of variables

This is constant

To ensure that this is a fair test, I only conducted this experiment using one test subject. The subject is a 16 year old male, who weighs 40kg, with a moderate fitness level. This would allow my variables to be kept constant. However, it is not as reliable as compared to conducting the experiment on more subjects. By conducting it with only one test subject, variables such as age, gender, fitness level, height, weight, diet and body size can be kept the same throughout the experiment.

Time taken to complete jump (second)

The time taken for each jump can be kept constant by observing a digital watch and counting out loud to make sure the test-subject is synchronized. This is so that the speed and style of jump will remain regular.

Use the time to complete the exercise (90 bpm)

After each time the experiment is conducted, the test subject will rest until the resting heart rate is achieved, which is 90 beats per minute. This is to ensure that the changes in pulse rate taken after the experiment can be compared to the rest of the results equally.

Time of exercise (4pm) [3]

I would conduct the experiment at 4 pm every day to make it a fair test between the other repetitions of the experiment. This is because exercising at different times of the day would have an impact on the subject's body. This is due to the different circadian rhythm of each person's body. This rhythm influences body functions such as blood pressure, hormone levels, heart rate and body temperature which are all factors that play a role in determining when the most appropriate time for exercising is. My test subject has chosen 4 pm to be the most appropriate time for him to engage in physical activity. This will therefore allow the results to be at the highest quality as possible.

Conditions when my hands

Temperature in environment[4]

[3] "Understanding Heart Rate, from MAPP," *Understanding Heart Rate and Exercise*, June 22, 2009, http://home.hia.no/~stephens/hrchngs.htm.

Temperature in the environment can be kept constant by keeping the place where the activity is carried out the same, which is at room temperature (around 24°). This is because the body adapts differently to different temperatures and this could affect the heart rate of the subject.

Clothing and shoes
There will be no changes in clothing and shoes. They will be kept the same throughout the experiment. The test subject will wear a cotton t-shirt, sport shorts and trainers. This is because the weight and material of the clothes and shoes may affect the body temperature of the test subject.

DATA COLLECTION AND PROCESSING

Raw data table

Length of time to perform jumping jacks (min) ± 0.5s	Pulse rate (bpm) ± 1 bpm				
	attempt 1	attempt 2	attempt 3	attempt 4	attempt 5
0	90	90	90	90	90
1	144	140	142	146	145
2	146	154	148	150	152
3	149	160	162	155	160
4	154	164	165	161	157
5	156	168	163	170	162

Treatment of uncertainties

I chose the treatment of uncertainties to be ± 1bpm for the pulse rate to account for the time between the stop of exercise and measuring the pulse rate and ± 0.5 seconds for the length of time to account for the delay in reaction to the start and stop of the experiment. So, this treatment of uncertainty will ensure that this factor is taken into account.

Qualitative observations

Throughout the experiment I have noticed that the test subject became tired quicker as the length of time to perform the physical activity increases. This could have reduced the efficiency of the experiment. Besides that, I also noticed that it takes a longer period of time for the heart rate to return to its resting state (increase in heart rate recovery period) as the length of physical activity increases.

Processed data

Calculations
Average = attempt 1 + attempt 2 + attempt 3 + attempt 4 + attempt 5

[4] "Understanding Heart Rate, from MAPP," *Understanding Heart Rate and Exercise*, June 22, 2009, http://home.hia.no/~stephens/hrchngs.htm.

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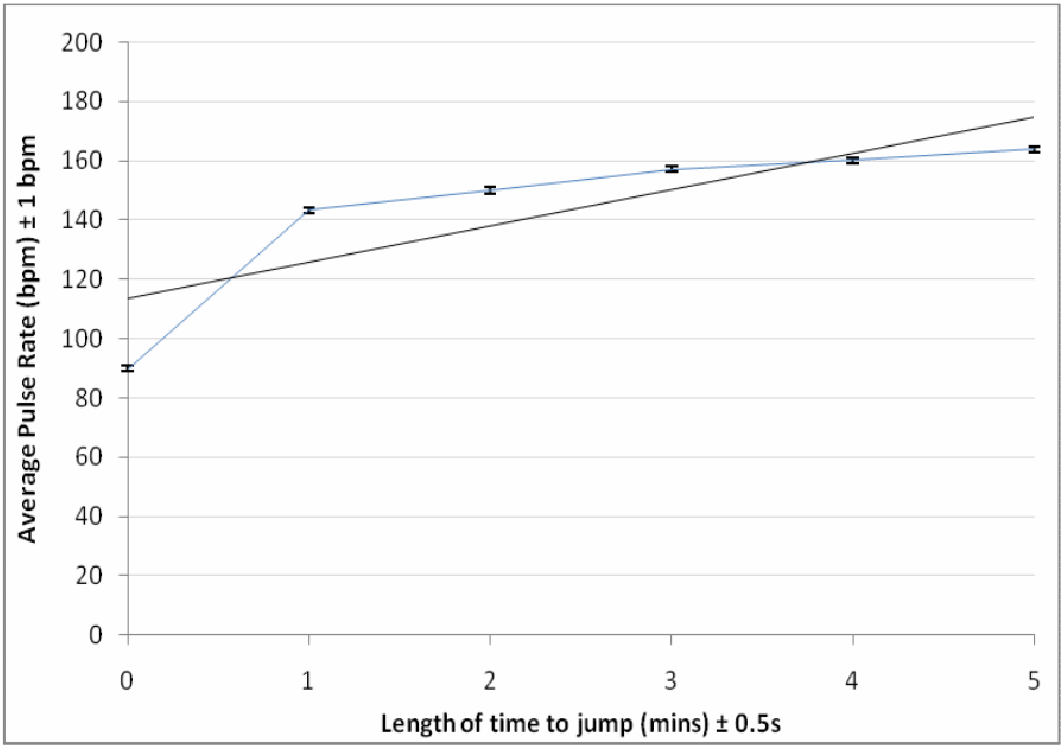
Standard deviation (done using a spreadsheet)

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2},$$

Working

Length of time to perform jumping jacks (min) ±0.5s	Pulse rate (bpm) ± 1 bpm					Calculations and working	Average heart rate (bpm)	Standard deviation
	attempt 1	attempt 2	attempt 3	attempt 4	attempt 5			
0	90	90	90	90	90	(90 X 5) ÷ 5	90	0
1	144	140	142	146	145	(144+ 140+142+146+145) ÷ 5	143	2
2	146	154	148	150	152	(146+154+148+150+152) ÷ 5	150	3
3	149	160	162	155	160	(149+160+162+155+160) ÷ 5	157	5
4	154	164	165	161	157	(154+164+165+161+157) ÷ 5	160	5
5	156	168	163	170	162	(156+168+163+170+162) ÷ 5	164	5

Presentation of processed data



CONCLUSION AND EVALUATION

Graph analysis

The graph above shows the average pulse rate after each length of time to perform jumping jacks; 0, 1, 2, 3, 4 and 5 minutes. The average pulse rate is taken to obtain a more accurate result. From this, we can see that aerobic exercise clearly has an effect on the pulse rate as it has risen quite notably when compared to the resting pulse rate. The black line on the graph represents the line of best fit while the black bars are error bars. From the line of best fit, we can see that the general trend of the graph is increasing, with a positive correlation. The average pulse rate increases the most from 0 minutes to 1 minute, which is a 50 bpm increase. I think that the reason for the significant increase is that the body was not prepared for the amount of stress it has undergone. However, the rest of the values of the length of time taken to perform the exercise increase at a slow but steady pace; from 1 to 2 minutes, the pulse rate increases by 7 bpm, from 2 to 3 minutes also by 7 bpm, from 3 to 4 minutes, 3 bpm and from 4 to 5 minutes 4 bpm. There are little changes in these values of pulse rate probably because the body has been conditioned and have adapted to the level of stress it went through.

Conclusion[5]

According to graph, the average pulse rate increases as the length of allocated time to perform jumping jacks increases.
Therefore, my prediction "[illegible]" is correct as it generally reflects the data collected. This in turn suggests that a person performing aerobic exercise will have an increase in their heart rate. This is due to the increase in demand for energy, which is obtained through respiration. The longer the time taken to do a particular physical activity, the more energy is loss and therefore more oxygen and glucose is required to compensate for the loss. The body reacts to this by increasing breathing rate to acquire more oxygen from the air.

Active muscles need greater intake of oxygen compared to inactive muscles. Because blood transports oxygen (and glucose) to the muscles, more blood must be delivered to them during exercise in order to meet the increase in demand. To do this, the heart has to beat faster to pump more blood thus resulting in the increase of pulse rate.

Evaluation of procedures

[illegible]
Overall, I am generally content with the way the experiment was carried out. However, there were a few minor flaws. Firstly, due to time constraints, it was quite difficult to perform the experiment at exactly the same time of the day. Also, the experiment was based around the schedule of the test subject so the time the experiment was conducted isn't consistent.

Besides that, there was a gap of about 5 seconds between the time taken after the experiment and before measuring the pulse rate. This is because the test subject has to walk to sit at the table, and the cuff has to be strapped to his arm before the measurement can be taken. This may have affected the results, although not that significantly.

[5] Jack H. Wilmore, David L. Costill, and W, Larry Kenney, in *Physiology of Sport and Exercise*, 4th ed, page 230.

Quality of data

The data obtained from the experiment was sufficient and valid for analysis. Throughout the experiment, I did not encounter any significant anomalies. Hence, the quality of data can be considered to be pretty good.

Precision and accuracy of data

The data obtained is quite precise. The standard deviation suggests that the data is reasonably accurate as they are a less than 5. However, this does not necessarily mean that the data is exact as the experiment only measures five samples.

Improving the investigation

The experiment as a whole can be improved if more time is allocated for it. With ample time, the reliability of data can be improved as the experiment can be conducted several more times for each time value to improve its accuracy. Also, with more time, the results can be more precise as each the experiment can be conducted over a longer period of time, thus giving the test subject plenty of chance to rest, so will be more efficient.

Also, the gap between the time taken after the experiment and before measuring the pulse rate can be reduced by making the test subject perform the exercise nearer to the table so as to eliminate the walking distance, therefore reducing the gap time. Apart from that, I think that the experiment went pretty smoothly.

BIBLIOGRAPHY

[1] Elizabeth Haworth, Carol Forshaw, and Neil Moonie, in *GCSE Health and Social Care for Edexcel*, page 153.

[2] "Instructions for Upper Arm Blood Pressure Monitors," *Amazon.com: Omron Automatic Inflation Digital Blood Pressure Monitor: Health & Personal Care*, June 22, 2009, http://www.amazon.com/Omron-HEM-712C-Automatic-Pressure-IntelliSense/dp/B00006WNPX.

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