EXP: The effect of exercise on the circulatory and respiratory systems

Introduction:
When you breathe in, the respiratory system is supplied with fresh oxygen. The oxygen moves into the lungs and then diffuses into the blood within the capillaries. This oxygenated blood moves towards the heart before being pumped throughout the body.

Blood delivers vital nutrients (like glucose), oxygen, and other chemicals to every cell in your body. Once in the cells, oxygen burns these nutrients to make energy in the form of ATP. Carbon dioxide gas is produced as a waste product during the process of aerobic cellular respiration. This gas is carried by the blood back to the heart and lungs so that it can leave the body.

Figure 1 below depicts the circulatory system and how it links the respiratory, cardiovascular and musculoskeletal systems.

![Figure 1. The circulatory system](image)

Exercise stresses the body and as such, the cells, such as muscles, increase their oxygen and energy demands. The heart would have to pump faster in order to meet these demands and remove the waste products before they can build up to toxic levels. As the heart pumps faster, the breathing rate would likely increase. This would result in a higher number of shallower breaths being taken.

Aim:
To determine whether exercise increases a subject’s heart rate and also decreases the volume of air being exhaled, as determined by the circumference of a balloon filled during exhalation.

Hypothesis:
As the duration of the exercise increases, it is expected that the subject’s heart rate (bpm) will increase to facilitate the transport of gases around the body. It is also predicted that the volume of gas being inhaled and exhaled with each breath will decrease as the heart and breathing rates both increase. This will be determined by a decrease in the circumference of a balloon (cm) blown up by a single exhalation.
Materials:
- 1x subject
- 1x balloon
- string (approx 1m in length)
- 1x stopwatch
- 1x ruler (1m)

Variables:

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Dependent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>The duration of the exercise undertaken (min)</td>
<td>The heart rate (bpm). The subjects will record their own pulse for 30s and double it to get a reading of their heart rate in beats per minute.</td>
</tr>
<tr>
<td>The range of investigation was between 0-2min. This range was selected to allow multiple trials to be conducted within a short time frame, whilst allowing time between trials for the heart rate to return to near normal levels.</td>
<td>The exhalation volume, as determined by the circumference of a balloon (cm). The subjects will breathe into the balloon immediately following each trial. The experimenter will use a piece of string to record the circumference of the balloon at a specified point.</td>
</tr>
</tbody>
</table>

Controlled variables
- paired results (same subject tested at rest and after exercise)
- the activity (ie. star jumps) were the same across all trials
- no talking or other forms of activity were permitted during the trials to reduce the impact of additional exercise on the body’s responses
- the same stopwatch used to measure the length of each trial to reduce any instrumental uncertainty
- the same balloon used
- the same point on balloon used, made possible by marking the point where the string should be placed to ensure that a reliable comparison could be made
- the same string and ruler used to determine the circumference of the balloon to reduce any instrumental uncertainty
- the environmental conditions kept constant to ensure that temperature and humidity did not influence the subject’s physiological responses

Method:
1. Collect all equipment and draw a line on the balloon to act as a marker for all trials.
2. Record heart rate in beats per minute by taking the pulse for 30 seconds and doubling it.
3. Breathe a normal breath into the balloon (pre-stretched).
4. Wrap the string around the balloon at the marker. Measure the circumference of the balloon by recording the string length. (nb. another person might be needed to help at this point)
5. Perform 2 minutes of star jumps.
6. Immediately breathe into the balloon and measure the circumference.
7. Take pulse for 30 seconds and double it.
8. Repeat Steps 5-7 twice more, waiting for 10min between each trial.
9. Calculate the average active heart rate and balloon circumference.
10. Present averages as a column graph along with the resting heart rate and balloon circumference.
Data collection:

Table 1: Subject’s heart rate (bpm) record before and after exercise

<table>
<thead>
<tr>
<th>Length of exercise (min)</th>
<th>Heart rate (bpm)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial 1</td>
<td>Trial 2</td>
<td>Trial 3</td>
</tr>
<tr>
<td>0</td>
<td>67</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>96</td>
<td>132</td>
<td>143</td>
</tr>
</tbody>
</table>

Table 2: Circumference of the balloon (cm) record before and after exercise

<table>
<thead>
<tr>
<th>Length of exercise (min)</th>
<th>Balloon circumference (cm)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial 1</td>
<td>Trial 2</td>
<td>Trial 3</td>
</tr>
<tr>
<td>0</td>
<td>43.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>41.3</td>
<td>40.8</td>
<td>39.4</td>
</tr>
</tbody>
</table>

Data processing:

In order to determine the central tendency of the results, the average heart rate and balloon circumference needed to be calculated. This was done using the =AVERAGE formula in Pages and the results can be found in Table 3.

Table 3: Average heart rate (bpm) and balloon circumference (cm) before and after exercise

<table>
<thead>
<tr>
<th>Length of exercise (min)</th>
<th>Average heart rate (bpm)</th>
<th>Average balloon circumference (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>67</td>
<td>43.2</td>
</tr>
<tr>
<td>2</td>
<td>124</td>
<td>40.5</td>
</tr>
</tbody>
</table>

To allow for greater interpretation of the general trends in the data, the data has been presented as a column graph below (Figure 3).

Figure 3: The relationship between exercise and a subject’s heart rate (bpm) and exhalation volume, as determined by balloon circumference (cm)
**Discussion:**
The results of this experiment indicate that as exercise is performed, the heart rate will increase. The average heart rate after exercise was 124bpm, with the highest heart rate being recorded at 143bpm. There is a significant difference between this elevated heart rate and the resting heart rate of 67bpm. These results support the hypothesis made, as the heart would have needed to pump faster to deliver oxygen and nutrients to the exercising muscle cells and remove the waste products of cellular respiration.

It should also be noted that the heart rates recorded for each successive trial also increased. For example, while all trials were significantly higher than the resting heart rate, the result from Trial 3 was higher than that of Trial 2 which was itself higher than Trial 1 (Table 1). This may be the result of summative stress on the body, as the body may not have returned to a complete state of rest within the 10min time allocated to recovery between each trial.

Likewise, the balloon circumferences recorded before and after exercise also supported the the hypothesis made. The balloon circumference went from 43.2cm to an average of 40.5cm, suggesting that as the subject performed exercise, their breathing became shallower and the volume of air exhaled in each breath was reduced. The balloon circumference results also became smaller with each successive trial, supporting the theory that the effects of the exercise were compounding without adequate recovery between trials.

There were no data values recorded that did not fit with either the expected results or the other results collected for that particular condition. Further trials and test conditions may have helped highlight any anomalous data.

**Evaluation:**
Despite efforts to control the method for collecting data, errors were made. More care is needed in the future to ensure consistency across trials. Individual reaction times could also have influenced the data.

The individual was relied upon to self-assess their activity, and star jump at the same pace for each trial. A metronome or other ticking device could have been used to guide the star jumps so that the same pace and intensity of exercise was used for all trials.

The subject's were also required to measure their own pulse for 30s and double it. This means that any slowing of the heart rate in the second 30s would not be considered. There is also considerable room for error here, as the subject's may count or calculate their heart rate incorrectly, or even be unsure how exactly what they were supposed to be counting. A device, such as a heart monitor or FitBit, could have been used to ensure that the measurement of the heart rate was consistent and reliable throughout the experiment.

An indirect method was used to determine the change in exhalation volume. The recording and use of the balloon circumference was another source of error. The same balloon was used throughout the trials for hygiene purposes; however, this could have resulted in the balloon becoming increasingly stretchy with each successive trial. Also the position of the string and subsequent measuring of its length opened the data up to considerable procedural and instrumental error. A device, such as a respirometer or spirometer, for recording the volume of exhaled air directly should...
have been used. Including a record of the number of breaths taken in the same minute as the pulse was being measured could have added another level to the interpretation of the data, as it would have allowed the reason for the decreased exhalation volume to be determined rather than hypothesised.

Any trials in which the subject was talking or laughing or interrupted in any way were discarded and an additional trial was conducted. This helped to minimise the variables; however, it may have exacerbated the trend that was seen with each successive trial. This could be avoided by ensuring that the subject's had brought their heart rate back to their resting heart rate before commencing another trial.

The method used allowed for the collection of consistent, but not necessarily reliable, data. Only three trials were conducted and only one type and duration of exercise was investigated. Ten trials and/or addition exercise durations or intensities are recommended for future investigations. Also, had multiple subjects been tested and compared, the results would have allowed a clear trend to be established. It would be interesting to see if the current trend continued as the duration of exercise continued to increase.

Conclusion:
It was determined that exercise affects the circulatory system by increasing the heart rate and reducing the exhalation volume. It is expected that the trends observed would continue as the duration or intensity of exercise increased, but this is likely to stop at a certain point where it is no longer safe/feasible to do so. The results support the hypothesis made during the design stage of this experiment.

The results of this experiment could be applied to the field of sports exercise, providing health recommendations for students performing exercise. However, given the narrow scope of this experiment, further investigation would be needed before any generalisations could be made.

References:

The Circulatory System. The McGraw-Hill Companies. Date accessed: 26/02/2017 https://s-media-cache-ak0.pinimg.com/564x/8a/64/63/8a64636fd3d3b83d709723c7cec8489d.jpg