

Exploring the relationship between Heart Rate (HR) and Ventilation Rate (R) in humans.

The Research Question

In this investigation I will be considering the following **general research question**:

‘Does increased exercise affect the ventilation rate and heart rate in mammals?’

Through assessing ventilation and heart rates prior to and following exercise, I will be able to evaluate whether a correlation exists between **increased** exercise and heart/ventilation rate in order to either prove or disprove my original hypothesis, set out **below**.

The following is my **focussed research question**:

‘Does a one minute stint of intensive exercise have an effect upon the heart and ventilation rates of 17 year old humans, where these rates are measured prior to and immediately following exercise?’

The Hypothesis

‘For this investigation, I expect to find that as exercise intensity increases, so too will heart rate and ventilation rate’.

During exercise, the partial pressure of Carbon Dioxide at the tissues is greater than at rest due to an increase cell respiration – where Carbon Dioxide is produced as a by-product in both the Link Reaction and Krebs cycle. As more ATP is required, the more times the cell respiration process must take place, which produces both more ATP and Carbon Dioxide. In order for cell respiration to take place in the tissues, oxygen is required there to act as the final electron acceptor in chemiosmosis – where it is reduced to form water (another by-product). In exercise, more ATP is required, so the rate of cell respiration is increased – and therefore more oxygen is required to prevent anaerobic respiration from taking place.

Partial pressures of carbon dioxide at the tissues are relatively high due to the aforementioned reasons, while the partial pressure of carbon dioxide in the blood is low. Carbon dioxide in the tissues displaces the oxygen within the haemoglobin in the blood, resulting in the oxygen diffusing into the tissues and the carbon dioxide combining with haemoglobin to be transported back to the lungs, in the blood. The oxygen within the tissues is then used in cell respiration, as previously explained.

Partial pressures of oxygen at the lungs are relatively high upon inspiration, whereas in the blood at the lungs the partial pressure of oxygen is low due to the presence of carbon dioxide within the haemoglobin. As a result, oxygen displaces carbon dioxide from the haemoglobin, which can then be transported to the tissues. Carbon dioxide diffuses across the basement membrane, into the alveoli and is expelled from the lungs upon expiration. Ventilation is required for the inhalation of oxygen and the exhalation of carbon dioxide in this process.

In order for the exchange of these gases to take place both at the tissues and at the lungs, differences must be maintained between the partial pressures of these gases in the bloodstream and the partial pressures of these gases in the tissues/alveoli. This difference is maintained through the constant movement of blood around the body. During exercise, cell respiration rate increases,

Comment [PB1]: PE: No real reason given for this investigation. No sign of personal implication.

Comment [PB2]: Ex The research question does not imply that there is a range of intensities so a correlation will not be possible.

Comment [CB3]:
Comm It is not certain that the candidate knows what a correlation is.

Comment [PB4]: Ex Research question focussed but it remains fairly trivial as an investigation.

Comment [PB5]: Ex Methodology

Comment [PB6]: Ex: Theoretical context correct

Comment [PB7]: Comm terminology used correctly

requiring both more oxygen and producing more carbon dioxide. As a result, heart rate must increase upon exercise in order to both continue to provide the gradient for gas exchange to occur at the tissues and at the lungs, and to provide sufficient amounts of haemoglobin for the transport of these gases – through the provision of erythrocytes containing haemoglobin. Ventilation rate must also increase, in order for this greater **volume** of carbon dioxide to be removed from the blood stream (and expelled from the body) and to provide a greater volume of oxygen to be transported to the tissues (through the blood stream) for cell respiration. Ventilation rate also increases upon exercise to maintain the difference in **partial pressures of carbon dioxide and oxygen** between the bloodstream and the alveoli, so that gas exchange can occur between these areas, when volumes of these gases increase due to increased activity, and hence increased **HR**.

Comment [PB8]: Ex Concentration would be more appropriate than volume.

Comment [PB9]: Ex This is better

Comment [PB10]: Comm Not a standard abbreviation, would be better in full

Variables

Independent and Dependent Variables

The **Independent Variable (IV)** is the **Exercise**, as it is as a result of a change in this variable that leads to a change in my dependant variables, the ventilation rate and heart rate. As **the rate of exercise increases**, the HR and VR are required to respond similarly in order for gas exchange to occur at the required **rate**.

Comment [PB11]: Ex Rate or duration? Or both?

The **Dependent Variables (DV)** will therefore be the **Ventilation Rate** and **Heart Rate**, as according to my hypothesis, both rates are affected by a change in my independent variable – exercise. As the IV either increases/decreases, ventilation rate and heart rate is required to respond similarly due to a need for the exchange of these gases between the bloodstream and the tissues/alveoli to occur at a greater rate.

Comment [CB12]: Comm Not clear again.

Confounding Variables

- HR prior to test/VR prior to the test – prior to the test, the **HR/VR** of the participants may not be at resting levels. This has the effect of increasing VR due to increased gas exchange as a result of greater levels of cell respiration. To ensure that the HR is at resting at the beginning of the test, I plan to ask the participant to remain seated for ten minutes – ensuring that the HR is at a resting level and is not artificially raised, and hence avoiding possible distortion of results subsequently due to artificial readings.
- Exercise Task – in order to avoid participants partaking in exercise differently in reference to the flight of stairs used, I will ask each participant to use the same flight and will clearly explain to them **which section to use**. Differences in the nature of the exercise could lead to distortion of results due to differences between the levels of exercise required of each participant – hence affecting the heart rate and ventilation rate differently.

Comment [PB13]:
Ex

•What about the participants? Age? Mass? Fitness? Prior activity? Distance from meals? Etc

•How were the measurements taken? Posture? Seems to be using stethoscope so presumably directly measuring heart rate not pulse.

Comment [PB14]: Comm Ambiguous. The candidate means heart rate or ventilation rate. It looks like a ratio.

Comment [PB15]: Ex And which section is it? This is not clear.

Apparatus

For this investigation I will require the following equipment:

- One Stethoscope
- One digital stopwatch
- Flight of stairs

Method

Outline of experiment

- 1) HR and VR will be taken at rest prior to exercise in order for these values to be used in the final comparison. HR measured using stethoscope, VR assessed by participant.
- 2) One minute of strenuous exercise will then be undertaken by each participant – involving running repeats of a staircase for one minute.
- 3) HR and VR will be taken immediately following the exercise minute in order for these values to be used in the final comparison. HR measured using stethoscope, VR will be assessed by participant.

Control of Independent Variable – Exercise

The variable which I will directly control is the amount of exercise that the participants will undertake. According to my hypothesis, the level of exercise undertaken will have an effect upon both dependant variables.

I will control this variable in the following ways:

- Ensure that all participants partake in the allotted time of exercise only, in order for this to be kept constant and to avoid an effect upon the outcome.
- Ensure that the exercise is completed across an identical course by each participant, in case discrepancies in exercise intensity are caused, distorting the outcome.

Details of Measurements taken and relevance to the hypothesis

Heart Rate – Will be taken at rest prior to exercise being completed and directly following the one minute period of exercise. This will be measured in beats per minute (bpm)

These readings are relevant to the hypothesis as it will provide the HR readings for comparison prior to and following exercise, and hence will be used to assess the presence of a correlation between exercise level and HR.

Ventilation Rate - Will be taken at rest prior to exercise being completed and directly following the one minute period of exercise. This will be measured in breaths per minute.

These readings are relevant to the hypothesis as they will provide the VR readings for the comparison of these readings at crucial points prior to and following exercise, and hence will be used to assess the presence of a correlation between VR and exercise level.

Comment [PB16]: Ex Number of steps? Height of steps? At least the same set is used for each volunteer.

Comment [PB17]: Comm Difficult to see how this method could be easily followed and repeated. There is too much detail missing.

Comment [PB18]: Ex This is not objective and there is no clear protocol given.

Comment [CB19]: Ex No sign of a consent form or safety precautions.

Comment [PB20]: Ex The intensity is constant i.e. it is not a variable as implied by the research question. I think the candidate is using the rest period as one level and running as the other. These are not necessarily comparable.

Comment [PB21]: Ex The mass of the participant is not recorded. This makes a difference to the work done lifting the body up stairs. An exercise bike would have provided better control.

Comment [PB22]: Ex How? While sitting? Standing? A stethoscope is used so presumably it is by directly listening to heart.

Comment [PB23]: Ex Again how? Sitting? Standing?

Comment [PB24]: Ex How precisely?

Comment [PB25]: Ex No correlation is possible the intensity of the exercise does not vary or at least there are only two levels.

Comment [CB26]: Comm I am not sure correlation is meant here.

Comment [PB27]: Ex How precisely?

Comment [PB28]: Ex Meaning what? Just once before and once after?

Calculation of percentage change in each dependent variable would then be possible to aid comparison and identify unexpected/anomalous results.

Details of Repeats

The importance of repeats in this experiment is paramount in order for any outliers to be identified. I hope to conduct the experiment three times for each participant to this end, allowing me to take a mean average for HR and VR readings at each point of the investigation – giving an overall more accurate and reliable reading, upon which an assessment of the hypothesis can be made from scrutinised data and the variability of this data assessed.

Comment [PB29]: Ex Method collects sufficient data for analysis

- Data Collection and Processing

Table to show resting heart rates and ventilation rates, and heart rates and ventilation rates immediately following one minute of exercise, of ten participants of an equal gender split.

Comment [PB30]: An Some raw data presented but it is insufficient. Are these the raw data away? Were the heart beats and ventilation counted for a full minute?

Comment [CB31]: Comm Unambiguous presentation and the conventions are respected.

Comment [PB33]: An Qualitative observations

Comment [PB32]: An This uncertainty would depend upon the time spent counting and as the details are not given it is difficult to confirm.

Participant Gender	Resting Heart Rate (beats/min) (+/- 0.5)	Heart Rate immediately following exercise (beats/min) (+/- 0.5)	Resting ventilation rate (breaths/min) (+/- 0.5)	Ventilation rate immediately following exercise (breaths/min) (+/- 0.5)	Observations
Female 1	68	140	20	30	1 Prior to the investigation each participant appeared to vary in immediate breathing rate, due to varying activity prior to the test, demonstrating an additional variable. 2 Following exercise, most participants appeared to be breathing both more deeply and more regularly with some exceptions (females 2 and 5). 3 Some participants appeared flushed following exercise. In particular males 1 and 2 and female 4.
Female 2	66	130	18	14	
Female 3	90	154	16	38	
Female 4	78	72	14	24	
Female 5	78	128	24	24	
Male 1	100	168	14	24	
Male 2	112	166	28	52	
Male 3	64	104	22	30	
Male 4	80	100	18	28	
Male 5	72	130	12	26	

Comment [PB34]: Comm Page break needed
All these calculations are a bit tedious, not concise.

Calculating percentage change in HR and VR

Comm The processing is difficult to follow

Comm Why to two decimal places?

Heart Rate – (beats/minute) - Final Values to 2 decimal places

$68/100=0.68$ ($140/0.68=205.88\%$) ($205.88-100=105.88\%$)

$66/100=0.66$ ($130/0.66=196.97\%$) ($196.97-100=96.97\%$)

$90/100=0.90$ ($154/0.90=171.11\%$) ($171.11-100=71.11\%$)

$78/100=0.78$ ($72/0.78=92.31\%$) ($92.31-100=-7.69\%$)

$78/100=0.78$ ($128/0.78=164.10\%$) ($164.10-100=64.10\%$)

$100/100=1.00$ ($168/1=168.00\%$) ($168.00-100=68.00\%$)

$112/100=1.12$ ($166/1.12=148.21\%$) ($148.21-100=48.21\%$)

$64/100=0.64$ ($104/0.64=162.5\%$) ($162.5-100=62.50\%$)

$80/100=0.80$ ($100/0.80=125\%$) ($125.00-100=25.00\%$)

$72/100=0.72$ ($130/0.72=180.56\%$) ($180.56-100=80.56\%$)

Ventilation Rate (Breaths/minute) – Final Values to 2 decimal places

$20/100=0.20$ ($30/0.2=150\%$) ($150-100=50.00\%$)

$18/100=0.18$ ($14/0.18=77.78\%$) ($77.78-100=-22.22\%$)

$16/100=0.16$ ($38/0.16=237.5\%$) ($237.50-100=137.50\%$)

$14/100=0.14$ ($24/0.14=171.43\%$) ($171.43-100=71.43\%$)

$24/100=0.24$ ($24/0.24=100\%$) ($100-100=0.00\%$)

$14/100=0.14$ ($24/0.14=171.43\%$) ($171.43-100=71.43\%$)

$28/100=0.28$ ($52/0.28=185.71\%$) ($185.71-100=85.71\%$)

$22/100=0.22$ ($30/0.22=136.36\%$) ($136.36-100=36.36\%$)

$18/100=0.18$ ($28/0.18=155.56\%$) ($155.56-100=55.56\%$)

$12/100=0.12$ ($26/0.12=216.67\%$) ($216.67-100=116.67\%$)

Table to show the percentage change in ventilation rate and heart rate at rest and immediately following a one minute period of exercise for ten participants of an equal gender split.

Comment [PB35]: Comm Tabulation is well done
An Appropriate processing

Participant Gender	Percentage change in ventilation rate between before and following exercise (%) (+/- 0.005)	Percentage change in heart rate between before and following exercise (%) (+/-0.005)
Female 1	50.00	105.88
Female 2	-22.22	96.97
Female 3	137.50	71.11
Female 4	71.43	-7.69
Female 5	0.00	64.10
Male 1	71.43	68.00
Male 2	85.71	48.21
Male 3	36.36	62.50
Male 4	55.56	25.00
Male 5	116.67	80.56

Average Percentage Change for Ventilation Rate:

$$(50 + -22.22 + 137.50 + 71.43 + 0.00 + 71.43 + 85.71 + 36.36 + 55.56 + 116.67) / 10 = 60.244\%$$

Average Percentage Change for Heart Rate:

$$(105.88 + 96.97 + 71.11 + -7.69 + 64.10 + 68.00 + 48.21 + 62.50 + 25.00 + 80.56) / 10 = 61.464\%$$

Mann-Whitney U-Test

In order to assess the significance of my results, I conducted a 'Mann-Whitney U-Test' (MWUT) upon my results for HR and VR. This test compared the median values for the resting heart and ventilation rates and compared them to the median of the readings following exercise.

Comment [PB36]: An Successful processing though this is not really necessary.

Comment [PB37]: An Why choose this test? The data would have permitted a t-test but the distribution may not be normal.

Comm Not easy to follow the processing

Comment [PB38]: Comm Not a standard abbreviation.

The MWUT for heart rate produced the U value of 9.0, and the values from the tables of 23 at 5% and 19 at 2%. This means that there is a 5% chance of getting below 23 if there was no difference between the data, and similarly there would be a 2% chance of getting below 19. This therefore meant that my result was significant at 2%.

Comment [PB39]: An Meaning what?
This is not well explained. Poor interpretation.

Comment [PB40]: Comm Interpretation difficult to follow.

The MWUT for ventilation rate produced the U value of 14.0, and the values from the table were 23 at 5% and 19 at 2%. This means that there is a 5% chance of getting below 23 if there was no difference between the data, and similarly there would be a 2% chance of getting below 19. This meant that my result was significant at 2%.

Comment [PB41]: An No consideration of uncertainties

- **Conclusion and Evaluation**

Conclusion

Identified Trends

As stated in my hypothesis, prior to the investigation I expected to observe a correlation between exercise level and heart and ventilation rates. I predicted that as the exercise level increased so too would the heart and ventilation rates (HR and VR).

Comment [PB42]: An But this is not possible from two activity levels.

This hypothesis is supported by the general trend of the graphs showing the percentage change in HR and VR. For the HR graph, nine out of ten participants demonstrated a positive change in heart rate. The greatest change was in female 1 who experienced a +105.88% increase in her resting heart rate following one minute of exercise. The average percentage change in heart rate was +61.464%, hence demonstrating that from the mean average, increased exercise level leads to a positive percentage change in heart rate.

Comment [PB43]: Ev Conclusion inappropriate. There is a difference and that difference may be significant but there is not a trend.

Comment [PB44]: Comm What graphs? None are included.

Comment [PB45]: Ev Some justification but remains superficial.

Similar trends are present in the VR graph, where eight out of ten participants demonstrated a positive change in ventilation rate. The greatest change was in female 3 who experienced a +137.50% increase in her resting ventilation rate following one minute of exercise. The average percentage change in ventilation rate was +60.244%, hence demonstrating that from the mean average, increased exercise level leads to a positive percentage change in ventilation rate.

Placing these trends within the biological context set out in my hypothesis, as exercise level increases from the resting level, the rate at which gas exchange is required to take place increases, and therefore ventilation and heart rates also increase in order to facilitate this increased demand for the removal of carbon dioxide from the bloodstream and the provision of oxygen at the tissues. This hypothesis was demonstrated by the general trends above and I can therefore conclude that I can accept this hypothesis.

Comment [PB46]: Ev Compares the scientific context though superficial

Mann-Whitney U-Test

As demonstrated by the explanation of the test above, both sets of results were significant at 2%, and I can therefore conclude that a significant difference exists between the data for the resting ventilation and heart rates, and the repeat of these measurements. This therefore means that I can accept the original hypothesis – that an increase in the level of exercise causes an increase in HR and VR.

Comment [PB47]: Ev As we know very little about the exercise (stairs for 1 min) it is difficult to make a judgement on the significance.

Unexpected and Anomalous Data

The results for the HR assessment show that female 4 demonstrated a negative 7.69% change in resting heart rate following the one minute period of exercise. This is unexpected as it directly contradicts my hypothesis that heart rate should increase as the level of exercise increases. However, this result could be explained by the fact that with this participant I had problems taking the heart rate immediately following exercise, and by the time these problems had been resolved, the HR had decreased due to the lessened demand for rapid carbon dioxide and oxygen exchange.

Comment [PB48]: Ev Weaknesses identified.

The results from the VR assessment show that female 2 demonstrated a negative 22.22% change in resting ventilation rate following the one minute period of exercise. Also, female 5 did not demonstrate any change in ventilation rate – 0.00%. These results are unexpected as they directly contradict my hypothesis that ventilation rate should increase as the level of exercise increases. A number of explanations could be offered for these results including:

Comment [PB49]: Ev Has not considered the problem of the participants counting their own ventilations.

- The idea that the participants did not exert themselves to a great enough capacity during the exercise, and therefore VR did not need to increase in order for the required rate of carbon dioxide and oxygen exchange to be maintained.
- The idea that the ventilation rate was already raised prior to the participants taking the test, resulting in the exercise not having any effect upon the 'resting' heart rate recorded.
- The idea that the exercise completed did not require the participants to increase the rate at which carbon dioxide and oxygen needed to be removed/taken in to sustain cell respiration.

Comment [PB50]: Ev Weaknesses identified though most of this is speculation.

Comment [PB51]: Comm Repeat of the first explanation

Data Variability

Despite planning to complete repeats upon my participants, I was unable to do so due to time restraints. I have therefore been unable to calculate a mean average for my results, and have no upper and lower bounds of results to analyse in reference to data variability.

Comment [PB52]: Comm Both words together is superfluous

I am however able to comment upon variability of data between participants. From my HR results, the greatest percentage increase was 105.88%, while the lowest percentage increase was 25.00%. From my VR, the greatest percentage increase was 137.50%, while the lowest percentage increase was 50.00%. There is therefore a high variability between

percentage increases across participants. This means that although I was able to predict the general trend within my hypothesis, across my participants I would be unable to predict the percentage increase prior to completing my experiment, due to other compounding factors which are not assessed in this investigation such as general metabolic rate etc.

Comment [PB53]: Comm Not concise

Evaluation

In evaluation of the results in the light of the overall explanation, I would conclude that the results demonstrated the trend which I had predicted in my hypothesis and therefore fulfil the general aim of the investigation. However I realise that without a basis for the comparison of these results with others, it is difficult to be sure of the final conclusion.

Comment [PB54]: Comm Not concise

One weakness of this experiment was that I was unable to conduct repeats due to the timescale allowed/that was required by the nature of this type of experiment, and was therefore unable to compare my acquired results with results from the repeated experiment. This led to an inability to analyse the data variability in detail, or for the data to be scrutinised. My suggestion to improve this area of the method would be to increase the time allowed for each participant so that two further repeats could be scheduled at regular intervals following the initial experiment. This would allow me to assess data variability more effectively, and strengthen my conclusion – as the decision upon the original hypothesis would be based upon data which had been scrutinised by comparison to repeated data of the same investigation.

Comment [PB55]: Comm Repetition

Comment [PB56]: Comm Repetition

The second weakness of this experiment was that I was unable to control the confounding variable of HR/VR prior to the test. As my participants also volunteered to assist in the experiments of others, I was unable to control their activity and ensure that the HR/VR rates taken prior to exercise were in fact their resting rates. Also, my timescale did not allow time for asking each participant to 'rest' for two minutes as previously planned prior to the 'resting' readings taking place. This may have distorted the results, as the HR/VR may be artificially high prior to the test. In order to prevent distortion of results again and improve the method, I would ensure that the participants had to 'rest' for a constant period of time prior to the resting readings being taken, hence eliminating the risk of the HR/VR not being at a resting level.

Comment [PB57]: Ev Valid limitation

Comment [PB58]: Ev Improvement suggested.

The third weakness of this experiment was the inability of the exercise to increase the heart and ventilation rates of some participants – resulting in some unexpected results which did not correlate with the original hypothesis. My suggested improvement would therefore be to employ the technique of calculating the anaerobic threshold of the participants (80%-90% of maximum heart rate), and tailor the exercise appropriately through a treadmill to the fitness level of the individual participant, to ensure that the exercise is at a level at which the heart and ventilation rates have the opportunity to be raised by the exercise completed in order to demonstrate the hypothesis. By using this technique, the problem of

Comment [PB59]: Ev Probably due to weakness explained in previous paragraph.

Comment [PB60]: Ev Valid suggestion

non-suitable exercise levels would be eliminated, while a more accurate assessment of the effect of increased exercise upon VR and HR can be made.

I would also alter the technique used to assess heart rate and ventilation rate, as these were not sufficiently accurate for these assessments. For heart rate, I would fit a digital heart rate monitor to each participant in order to track their HR throughout the entire investigation on a computer. This would allow me to take readings continuously and take averages of these results when necessary – hence providing a more accurate final outcome. For ventilation rate, I would use a respiratory rate monitor to the same end. This would eliminate the self-assessment of ventilation rate by the participants (which can distort the result due to the awareness of the participant that their breathing is being monitored), and the relative unreliability of the use of the stethoscope (where inexperienced users are unable to find the pulse of the participant). Essentially, as well as the elimination of human error, a continuous reading of heart and ventilation rates can be kept, and averages taken at key times for the processing of this data for use in the final conclusion.

Comment [PB61]: Ev Too vague

Comment [PB62]: Ev Valid improvement.

Comment [PB63]: Ev Extensions proposed. Periods? What key times?