Name: Wesley Towstik

**LAB: THE EFFECT OF EXERCISE ON CELLULAR RESPIRATION**

Introduction:
Cellular respiration is the process that cells use to break down glucose; this releases energy that is used to produce ATP. Cellular respiration involves a series of enzyme-catalysed reactions.

The equation below shows the complete oxidation of glucose during aerobic cellular respiration. Oxygen is required for this energy-releasing process to occur.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + 686 kilocalories of energy/mole of glucose oxidized

By studying the equation above, you will notice there are three ways cellular respiration could be measured. One could measure the:

1.Consumption of $O_2$
2. Production of $CO_2$
3. Release of energy during cellular respiration[1]

In this experiment the relative rate of $CO_2$ production will be measured. Bromthymol blue (BTB) is an indicator that turns yellow in the presence of an acid. Since $CO_2$ combines with $H_2O$ to produce carbonic acid, BTB can be used to detect the presence of $CO_2$.

Since exercising requires more energy than resting, the effect of the cellular respiration of exercise on $CO_2$ production will be tested; the time it takes BTB to turn from blue to yellow will be measured after different time increments of exercising. Since increasing time increment of exercise should require more energy, it is expected that the rate of $CO_2$ production will increase; therefore the time it takes for BTB to change color will decrease.

Research Question: What is the effect on increasing time of exercise on the rate of $CO_2$ production?

Variables:

The independent variable is time spent exercising
The different levels of the independent variable are 30 seconds, 60 seconds and 90 seconds
The dependent variable is the time taken to change BTB color
The controlled variables include type of exercise, volume of BTB, straw length, color gauged, same timer per test subject, same test subject per trial.

[1] (The College Board, 2001)

**Materials:**
27 test tubes
87 mL of BTB
27 1-mL plastic pipettes
27 10-mL graduated cylinders +/- .1ml
27 straws cut to a length of 10.0 cm +/- .05 cm
27 timers
27 Lab aprons
27 pair of Safety goggles

**Procedure:**
1. Have the human test subject rest by sitting in a chair for at least 30 seconds

2. Use a 1-mL plastic pipette to place BTB into a 10-mL graduated cylinder until the BTB reaches the 1-mL mark. Pour the BTB into a test tube.

3. Have the test subject exercise for 30 seconds by doing jumping jacks.

4. Immediately have the test subject exhale normally through the straw into the test tube containing BTB (without immersing the straw in the BTB) and simultaneously start the timer. Record the time in seconds that it takes for the BTB to start to change color. Discard the BTB in the sink and rinse out the test tube thoroughly.

5. Repeat steps 1-4 2 more times, increasing the exercise jumping jacks by

   30 seconds each time.

6. Repeat steps 1-5 with 23 more test subjects.

7. To keep controlled variables constant, assign counter to count out loud, measure the same amount/ volume of BTB out, Cut straw length same 27 times.

**Data Table:**

| | Class Data Combined<br>Time taken to change BTB color (seconds) | | | | | | |
|---|---|---|---|---|---|---|---|
| Trial Number | Time spent exercising Increment One 30 seconds (+/- .001 seconds) | Time spent exercising Increment Two 60 Seconds (+/- .001 seconds) | Time spent exercising Increment Three 90 seconds (+/- .001 seconds) | Type of Exercise | Straw Length (+/- .05 cm) | Amount of BTB (+/- .1ml) | Rest Time Between Each increment and Trial (Seconds) |
| 1 | 45.46 | 42.38 | 31.09 | Jumping Jacks | 10.0 | 1 | 30 |
| 2 | 20.69 | 50.16 | 32.00 | Jumping Jacks | 10.0 | 1 | 30 |
| 3 | 26.45 | 27.02 | 17.43 | Jumping Jacks | 10.0 | 1 | 30 |
| 4 | 36.31 | 16.36 | 25.68 | Jumping Jacks | 10.0 | 1 | 30 |
| 5 | 36.73 | 28.59 | 26.26 | Jumping Jacks | 10.0 | 1 | 30 |
| 6 | 25.21 | 29.08 | 15.55 | Jumping Jacks | 10.0 | 1 | 30 |
| 7 | 31.07 | 17.50 | 14.22 | Jumping Jacks | 10.0 | 1 | 30 |
| 8 | 32.28 | 28.68 | 19.03 | Jumping Jacks | 10.0 | 1 | 30 |
| 9 | 35.16* | 23.46* | 23.83* | Jumping Jacks | 10.0 | 1 | 30 |
| 10 | 34.29 | 32.47 | 21.17 | Jumping Jacks | 10.0 | 1 | 30 |
| 11 | 35.83 | 15.34 | 19.37 | Jumping Jacks | 10.0 | 1 | 30 |
| 12 | 27.87 | 29.69 | 20.65 | Jumping Jacks | 10.0 | 1 | 30 |
| 13 | 29.37 | 34.61 | 37.65 | Jumping Jacks | 10.0 | 1 | 30 |
| 14 | 33.07 | 48.65 | 29.73 | Jumping Jacks | 10.0 | 1 | 30 |
| 15 | 34.60 | 55.31 | 29.69 | Jumping Jacks | 10.0 | 1 | 30 |
| 16 | 43.58 | 33.25 | 18.13 | Jumping Jacks | 10.0 | 1 | 30 |
| 17 | 35.54 | 31.31 | 17.00 | Jumping Jacks | 10.0 | 1 | 30 |
| 18 | 39.54 | 24.74 | 21.61 | Jumping Jacks | 10.0 | 1 | 30 |
| 19 | 24.15 | 31.43 | 19.36 | Jumping Jacks | 10.0 | 1 | 30 |
| 20 | 53.66 | 39.00 | 22.47 | Jumping Jacks | 10.0 | 1 | 30 |
| 21 | 29.01 | 28.05 | 26.43 | Jumping Jacks | 10.0 | 1 | 30 |
| 22 | 52.00 | 33.00 | 28.81 | Jumping Jacks | 10.0 | 1 | 30 |
| 23 | 42.78 | 42.04 | 21.07 | Jumping Jacks | 10.0 | 1 | 30 |
| 24 | 42.00 | 40.00 | 20.00 | Jumping Jacks | 10.0 | 1 | 30 |
| 25 | 42.00 | 40.00 | 27.09 | Jumping Jacks | 10.0 | 1 | 30 |
| 26 | 35.16 | 25.49 | 20.00 | Jumping Jacks | 10.0 | 1 | 30 |
| 27 | 31.54 | 29.28 | 26.07 | Jumping Jacks | 10.0 | 1 | 30 |
| | | | | | | | |
| *Data collected personally by Individual | | | | | | | |

**Calculations:**

Sample Calculation for Average time for color change of BTB per increment

Average time for color change of BTB per increment = (Trial 1+Trial 2+ Trial 3+Trial 4+Trial 5+Tral 6+ Trial 7 + Trial 8 + Trial 9 + Trial 10 + Trial 11 + Trial 12+ Trial 13+ Trial 14 + Trial 15 + Trial 16 + Trial 17 + Trial 18 + Trial 19 + Trial 20 + Trial 21 + Trial 22 + Trial 23 + Trial 24+ Trial 25+ Trial 26+ Trial 27) / (Total Number of Trials)

Increment One = 30 seconds
Total Number of Trials = 27
Average Time for color change of BTB per increment = (45.46+20.69+26.45+36.31+36.73+25.21+31.07+32.28+35.16+34.29+35.83+27.87+29.37+33.07+34.60+43.58+35.54+39.54+24.15+53.66+29.01+52.00+42.78+42.00+42.00+35.16+31.54)/(24)
Average Time for color change of BTB per increment one of 30 seconds = 35.38seconds
Average Time for color change of BTB per increment two of 60 seconds =29.69seconds
Average Time for color change of BTB per increment three of 90 seconds = 20.68 seconds

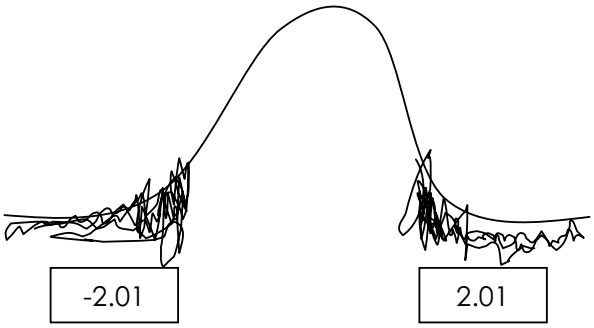
Sample Calculation for Standard Deviation
Input column "Increment One 30 seconds" into Graphing Calculator
Calc "1-Var Stats"
One Standard Deviation = 7.966757375 seconds
Round to 4 Significant digits because smallest unit of data is 4 Significant digits
One Standard Deviation = 7.968 seconds

One Standard Deviation "Increment One 30 seconds"=7.968 seconds
One Standard Deviation "Increment Two 60 seconds"= 9.850 seconds
One Standard Deviation "Increment Three 90 seconds" = 5.669 seconds

Sample Calculation for T-Test

1. Identify the Null Hypothesis
The average time it takes to change the color of BTB between increment one and increment two are not significantly different.
2. Identify the Significance Level (a),
(a) = .05
3. Calculate Degrees of freedom
Degrees of freedom = Sum of sample sizes(n) – 2
n= 27
$n_2$=27
$n_3$=27
Degrees of freedom = 27+27-2

52= 54-2
4. Calculate Sample size
$n_1$=27
$n_2$=27
$n_3$=27
5. Find Value of t from t table
Value of t = 2.01
6. Find Rejection Region(RR)




7. Find t calculated and probability value (p)
T calculated=6.38
P=7.26 *$10^{-8}$
8. Decision
T calculated is greater than t table value 2.01
Reject null hypothesis
9. Conclusion
Using alpha level of .05 the average time taken to change the color of BTB of increment one is significantly different from the average time taken to change the color of BTB of increment three

**Calculations Data Table:**

| | Average Time taken to change BTB color(seconds) | One Standard Deviation(seconds) |
|---|---|---|
| Increment One 30 Seconds | 35.38 | 7.968 |
| Increment Two 60 Seconds | 29.69 | 9.850 |
| Increment Three 90 Seconds | 20.68 | 5.669 |

**Conclusion:**

The effect of increasing time of exercise increased $CO_2$ production an indicator of increased cellular respiration. This can be observed through noting the time taken for BTB to change color as the time doing jumping jacks increased. As duration of exercise increased, the average time taken for BTB to change color decreased. This is visible because the average time for increment one of 30 seconds was 35.38 seconds while increment two of 60 seconds was lower at 29.69 seconds and finally increment three of 90 seconds was the lowest at 20.68 seconds. Given there was such a large spread of data and standard deviation was calculated to clarify the distribution of data and also to identify whether any of it overlapped. The error bars appearing on the graph overlap between time increments one of 30 seconds and time increment two of 60 seconds well into each other's bars showing that while their averages suggest that the two increments are fundamentally different. The spread of data around their mean shows that in fact they are not bring into question the design of this experiment. Overall the graph showed a consistent decline from increment one to increment three backing the assertion that increasing time of exercise also increases $CO_2$ as shown by the faster BTB color change.

Since the error bars between increment one and increment three however did not overlap a t-test was performed in order to identify whether the difference between the two increments was significantly different. Results showed that using alpha level of .05 the average time taken to change the color of BTB of increment one is significantly different from the average time taken to change the color of BTB of increment three. Suggesting that if yet another increment of time was added it would produce even faster color changes of BTB. Although the increased rate of $CO_2$ production does not immediately decrease the time taken for BTB to change color, it does eventually.

The primary source of error comes from the lack of clarity within the procedure. Since time constraints did not allow for enough time to wait until the color of BTB changed into a complete yellow the procedure was modified to any kind of color change. The BTB was dark in color and data was collected with many different subjects with varying degrees of eye sight proficiency and different definitions of what constitutes a color change. This source of error throws off the average of each increment by an unknown amount and gives an explanation as to why the standard deviation is high among all three increments. However because each persons definition was kept consistent between each increment while accuracy is thrown off greatly, precision is still relatively maintained. Additionally procedural error came from step 4 of the procedure where the straw was instructed to be placed in the test tube but not immersed in the BTB. Without full immersion in the BTB it affected the rate at which $CO_2$ reached the BTB which has untold affects on the rate of color change. This failure throws off accuracy because it affects how much of the $CO_2$ actually reached the BTB but also throws off precision because not everyone held the straw the same distance from the BTB and so the amount of $CO_2$ to reach the BTB varies.

In order to improve the lab and prevent error while also remaining within time constraints the procedure should be modified with at least two changes. First a formal method for identifying when a color change has actually occurred should be introduced into the lab. This method would first exhibit a quick demonstration of the original color of BTB and then a sample run through of procedure until the BTB changes from a dark blue to a dark green so that everyone can observe

what a change in color looks like. While the BTB may become a different color before its change to dark green, throwing off accuracy slightly, precision will be maintained minimizing error. Second, the straw length should be increased to a point where it will be allowed to immerse into the BTB fluid. This would allow whatever $CO_2$ is produced by the user to sufficiently reach the BTB and would allow the rate of color change to be accurately gauged. Furthermore with the modification of straw length a formal method for breathing should be developed so that way the subject does not accidentally inhale BTB. This method would involve simple inhaling via the nose and then exhaling via the mouth.