

Exercise Metabolism

Lab 3

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## Introduction

Any physical movement can be put into 3 groups; power, speed and endurance. Examples of these forms of movement would be lifting a heavy object, sprinting a 100-m race and running a 10km, respectively. Ability to perform these tasks well is dependant on the quantity of energy your body can supply to complete them. The body has 3 energy systems: The Anaerobic A-Lactic (ATP-CP) Energy System, the Anaerobic Lactic (Glycolytic) Energy System, and the Aerobic Energy System. All of these systems are constantly active but at any time, however one is responsible for the majority of the energy used for each specific movement.

ATP stands for Adenosine Triphosphate and is the main supplier of all the body's energy. This energy release occurs when the molecule, which contains 3 phosphates, loses one phosphate becoming ADP (adenosine diphosphate). The release of this phosphate group also releases energy which can then be used to carry out any bodily function (Yukawa, Watanabe, & Noji, 2015).

The Anaerobic A-Lactic (ATP-CP) Energy System works immediately and without oxygen. This system is responsible for providing enough energy for a short period of time, giving the body short bursts of power that lasts less than 10 seconds (Gastin, 2001). The CP stands for creatine phosphate, which is stored in skeletal muscles. To produce quick energy, the CP donates a phosphate to a molecule of ADP, turning it into ATP, which is then used to supply energy to any quick, powerful movement performed by the body. There is a limited amount of CP in the body, which means after only 10-15 seconds, this energy source starts to decline and another provider must step in.

The Anaerobic Lactic (Glycolytic) Energy System is non-oxidative, and instead of oxygen, uses glucose from carbohydrates, or glycogen from the liver as its source for the synthesis of ATP. This system is responsible for providing energy to the body to accomplish all-out bursts of exercise that can last from 15 seconds to 2 minutes. In this situation, ATP is produced through glycolysis, a metabolic pathway that breaks down glucose into pyruvate. This process uses coenzymes and 2 ATP to provide energy to phosphorylate 4 molecules of ADP for a net production of 2 ATP (Brooks, Fahey, & Baldwin, 2005). There is very little energy produced this way, however the process provides small amounts of ATP very quickly, allowing the body to perform short, fast movements.

When there is not enough oxygen present, the pyruvate converts to lactic acid through fermentation. This increases the acidity in the body, which causes a burning sensation in muscles (Buchheit & Laursen, 2013). If an individual wishes to perform an athletic test for a longer period of time, then another energy system must kick in to help.

The Aerobic Energy System is supplied by oxygen and glucose and can last from 2 minutes to 2-4 hours. This system is the slowest supplier of ATP and includes glycolysis, the krebs cycle and the electron transport chain. However at the end of the chain, 38 ATP are produced for every 1 molecule of glucose (Zhang, Yu, Wang, Han, & Yang, 2015). Therefore this energy system can supply enough ATP for low intensity activities that last anywhere from two minutes to a few hours.

In this experiment, interval rest times will be tested to observe which time is optimal for recuperation in between bursts of energy. 0, 5, 10 and 15 seconds of rest will be given to participants during the jumping exercise in order to analyze the time needed for each energy

system to replenish itself. 0 and 15 seconds will be given to those sprinting the 15 metres, 15 times in order to determine velocity. Velocity is a measure of the distance over time (Li, Mo, & Chen, 2015) and can be calculated as follows:

$$V = d/t$$

In a study done by Fleischman et al. in 2010, participants' PCr levels were recorded after submaximal exercise, and found to have recovered after approximately 23 seconds. In another study done by Parasoglou, Xia, Chang, & Regatte in 2013, participants performed plantar flexions using resistance bands, and then had their PCr levels measured using an MRI. The recorded PCr recovery rate was found to be roughly 25 seconds. These studies suggest that the anaerobic A-Lactic (ATP-CP) energy system requires on average, 20 - 25 seconds to completely recover.

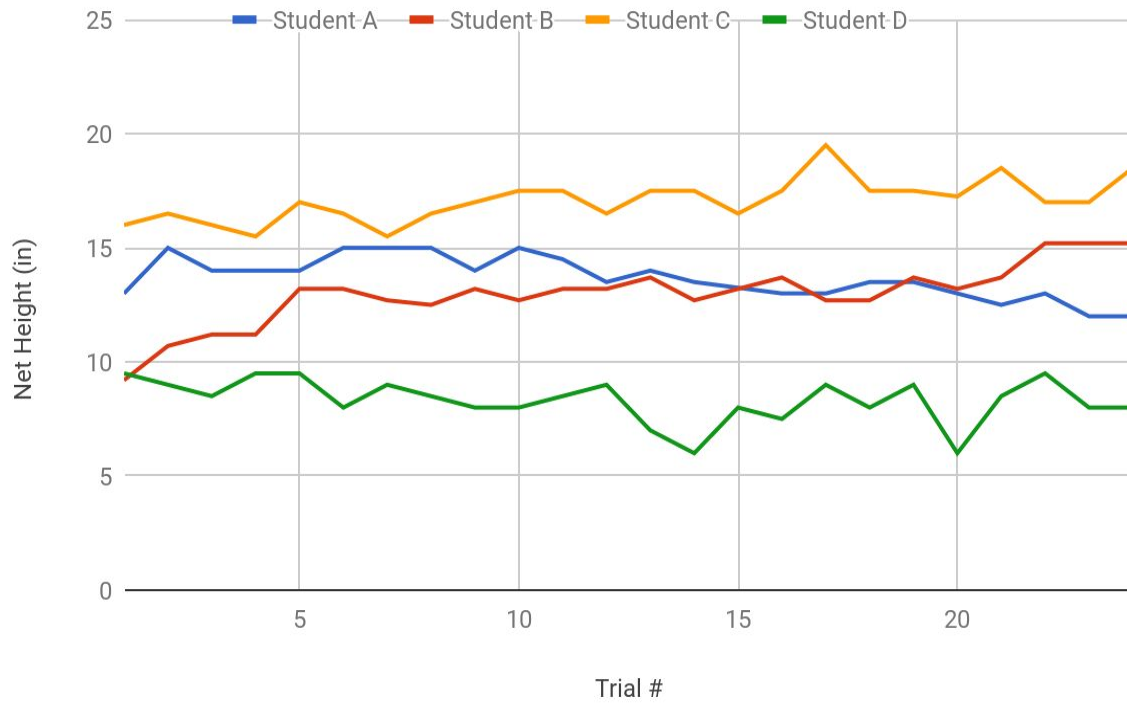
The purpose of this lab was to analyze the 3 energy systems responsible for allowing our body to perform various athletic tasks, and observe the needed recovery time for the body to be able to consistently repeat high intensity exercise. The results of this experiment could help better understand how to properly train each of the energy systems in an athletic based program.

Based on the previous studies done by Fleischman et al. in 2010, and Parasoglou, Xia, Chang, & Regatte in 2013, it is hypothesized that the Student D will have the most consistent jump heights over the 24 trials as they have 30 seconds of rest in between.

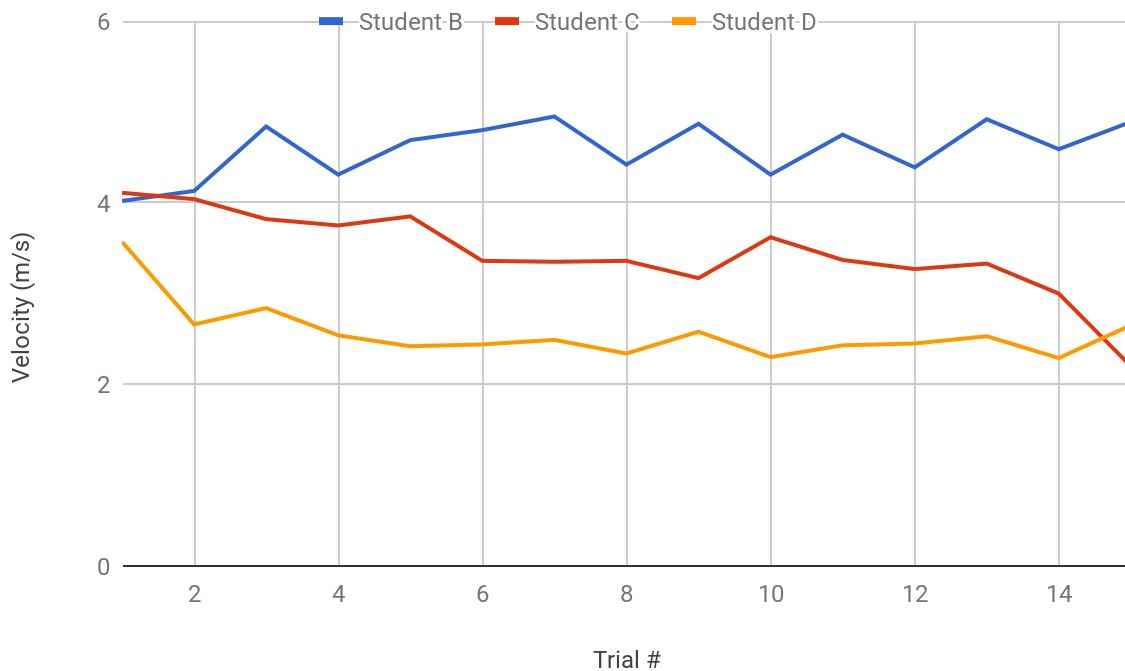
## Methodology

In this lab, located in the gym of Montpetit, Ottawa University, there were 4 females of ages ranging from 17-19 being tested. To perform this lab a measuring tape, a stopwatch and 2 cones were used. The first part of the lab involved each student measuring their initial height in inches, starting from the top of their vertically extended right arm against a wall. Student A was then instructed to jump with their arm extended 24 consecutive times with no rest inbetween, and the height of their arm was recorded each time. Students B, C and D were instructed to perform the same task but with 5, 15 and 30 seconds (respectively) of rest between jumps. The heights were recorded and subtracted from the student's initial height. A sample calculation is shown in the appendix. The heights were placed in a line graph using google spreadsheets. The second part of the lab was performed using 2 cones placed 15 metres apart of the gym floor. Student B was instructed to sprint back and forth between the cones 15 times, with a 15 second break at each cone. Student C was instructed to run back and forth between cones 15 times with no break. Student D was instructed to run back and forth between cones at a constant pace with no breaks. Each students time to run from cone to cone was recorded and placed in tables in the appendix. Each students velocity from cone to cone was calculated in the appendix using  $v=d/t$ . The velocities were graphed using google spreadsheets.

## Results



**Figure 1:** 24 Vertical Jumps in inches of 4 Students with Varying Rest Intervals



**Figure 2:** 15 Metre Sprint Velocities in metres per second of 3 Students with Varying Rest Intervals

Figure 1 shows Student A's jump height started at 13 inches and remained fairly constant, slightly decreasing towards the end of the 24 jumps. Student B's initial jump height was 9.2 inches, which slowly increased over the 24 jumps to 15.2 inches. Student C's initial jump height was the greatest, at 16 inches, which stayed fairly constant, ending at 18.5 inches. Student D has the lowest overall jump height, starting at 9.5 inches, and staying the mostly consistent through all 24 jumps.

Figure 2 shows that Student B had the greatest velocity throughout all fifteen laps in comparison to students C and D but student B also had the most varying times. Student C's time gradually decreased after each lap and Student D was the lowest speed but stayed consistent over all 24 laps.

## Discussion

This experiment was done to analyze the 3 energy systems responsible for allowing our body to perform various athletic tasks, and observe the needed recovery time for the body to be able to consistently repeat high and low intensity exercise. The previously stated hypothesis assumed Student D would have the most consistent jump heights due to their 30 second rest period allowing the ATP-CP system to replenish itself. The results of this experiment do not fully support the findings of similar studies done by Fleischman et al. in 2010, and Parasoglou, Xia, Chang, & Regatte in 2013, as Student D's jump height did not stay consistent, and eventually decreased. This can be due to experimental error, as each student was not performing each jump at their absolute maximum, therefore this student's results are not an accurate representation of the maximum energy given by the ATP - PC system. This error could also be in observing the height each student jumped as the observer was placed on the ground, this can be fixed by using a more technologically advanced measurement device, which senses exactly where the student touched the wall and records the height.

In Figure 1 it can be seen that Student A, who had no rest in between jumps, had a downward slope indicating decreasing jump heights after 24 jumps. This is due to their ATP-PC energy system having no time to replenish, therefore after 10 -15 seconds of jumping, the student's body begins to switch to another system which cannot supply enough energy fast enough to complete 24 vertical jumps in a row. Student B had 5 seconds of rest in between each jump and can be seen to have the most consistent jump heights. In Figure 1, Student B can be seen having the straightest line, indicating most consistent and improving jump heights, which could

indicate that the PCr resynthesis rate in leg muscles is approximately 5 seconds. However to improve the accuracy of this assumption, this experiment should be repeated and performed with several more trials and more participants, therefore allowing the averages to be calculated and more easily compared with less experimental and human error. To better measure the time at which PCr levels replenish themselves, more advanced technology should be used, such as an MRI machine. Using better technology to measure PCr levels in patients every 5 or 10 seconds immediately following maximal exercise would give a more exact rate of PCr resynthesis.

Figure 2 shows Student C's sprinting times decreased as each lap was completed. Student C was instructed to sprint 15 times from cone to cone with no rest time in between, which came to a total time of 67 seconds (as calculated in appendix). This is enough time for the anaerobic glycolytic energy system to power the legs of the runner. However this student progressively ran slower which could be due to the energy system not being able to produce enough ATP quickly enough for each trial.

Figure 2 shows Student B's sprinting times staying consistent over the 15 trials. Student B's average running time was 3.28 seconds, and their total running time of all 15 trials was 49.21 seconds (not including rest times). Student B had the fastest time to complete all 15 trials, and the fastest average, however this is due to their 15 second break to replenish the anaerobic glycolytic energy system, which was being used during their short bursts of speed. Student B rested for 15 seconds in between each sprint, and because their times were fairly consistent, this could indicate that the anaerobic glycolytic needs only 15 seconds to produce enough ATP through glycolysis to supply energy for a 15 metre sprint. Student B's sprinting results are consistent in the way that every second value is higher, which is due to the gym wall being much

closer to one cone compared to the other. This meant Student B had to slow down earlier when sprinting to one side of the gym in order to not hit the wall. This decreased her time every second trial which affected her velocities, giving every second trial a slower velocity. This is a source of error and should be fixed by placing the cones in such a way that each student has sufficient time to decrease their speed to 0m/s after touching each cone.

Student D's results in Figure 2 show her initial decrease after 3 trials followed by constant times for the rest of the remaining 15 trials. Student D's total running time at a constant pace was 88.59 seconds. Due to the endurance/cardiovascular nature of the constant running trials, the system responsible for providing majority of the energy to the runner was the aerobic system. This explains the consistency of Student D's times, the aerobic system can keep providing a steady slow of ATP for up to 4 hours. Student D has the slowest overall time and slowest average of 5.9 seconds however using the aerobic system, they could continue at that pace for longer than Student B or C. Student D would not have benefitted from a break compared to Student B because Student D was using an energy system that did not need to pause to replenish itself for a much longer time than Student B, who could only produce small amounts of fast energy that required pauses to recuperate.

If the total times for all three students is compared to how much distance was covered by each student, Student B ran the 225m in 49 seconds however, including their 15 second break, that isn't true. With the 15 second breaks included, Student C ran the distance the fastest at a time of 67 seconds.

To further this study in the future, a more accurate stopwatch should be used, to more precisely measure the exact time each student touches a cone. This could be done by placing a sensor under each cone to record the time.

A factor that could affect the results of this lab is previous athletic training. Similar to muscles in the body, energy systems can be improved through training and exercise. Therefore if a participant has any amount of athletic training history, their results could be influenced and their energy systems could replenish faster than the average participant. Age and gender could also play a role in energy system proficiency. According to the previously mentioned study done by Fleischman et al. in 2010, prepubertal children recovered their PCr levels in 20 seconds compared to the adolescents who recovered in 13 seconds. Gender could lead to differences in energy system proficiency due to the difference in hormones found in males vs females, with males producing higher levels of testosterone (a muscle building hormone) when compared to females (Kojo et al., 2014).

### **Conclusion**

Following the evaluation of each students jump heights with varying rest intervals, these results suggest 5 seconds to be the optimal rest period to allow the ATP - PC energy system to replenish. After observing 3 students sprint 15 metres with varying rest times and speeds, this experiment shows 15 seconds as the better rest interval for a higher speed. Future studies should consider evaluating more participants including males and females with varying ages and athletic abilities.

### Appendix

Table 1: 24 Vertical Jumps in Inches of 4 Females with Varying Rest Intervals

<u>Trials</u>	<u>Student A</u> <u>No rest</u>	<u>Student B</u> <u>5 second intervals</u>	<u>Student C</u> <u>15 second intervals</u>	<u>Student D</u> <u>30 second intervals</u>
1	13	9.2	16	9.5
2	15	10.7	16.5	9
3	14	11.2	16	8.5
4	14	11.2	15.5	9.5
5	14	13.2	17	9.5
6	15	13.2	16.5	8
7	15	12.7	15.5	9
8	15	12.5	16.5	8.5
9	14	13.2	17	8
10	15	12.7	17.5	8
11	14.5	13.2	17.5	8.5
12	13.5	13.2	16.5	9
13	14	13.7	17.5	7
14	13.5	12.7	17.5	6
15	13.25	13.2	16.5	8
16	13	13.7	17.5	7.5
17	13	12.7	19.5	9
18	13.5	12.7	17.5	8
19	13.5	13.7	17.5	9
20	13	13.2	17.25	6
21	12.5	13.7	18.5	8.5
22	13	15.2	17	9.5
23	12	15.2	17	8
24	12	15.2	18.5	8

Table 2: 15 Metre Sprint Times in seconds

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<u>Trials</u>	<u>Student B</u> <u>15 seconds rest</u>	<u>Student C</u> <u>No rest</u>	<u>Student D</u> <u>Constant pace</u>
1	3.73	3.65	4.2
2	3.63	3.71	5.64
3	3.10	3.93	5.28
4	3.48	4.00	5.91
5	3.20	3.9	6.2
6	3.12	4.46	6.15
7	3.03	4.48	6.03
8	3.39	4.73	6.41
9	3.08	4.14	5.82
10	3.48	4.45	6.51
11	3.16	4.59	6.18
12	3.42	4.5	6.13
13	3.05	4.83	5.93
14	3.27	5	6.54
15	3.07	6.8	5.66

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### Sample Net Height Calculation

$$\begin{aligned}\text{Net Height} &= \text{Measured Jump Height} - \text{Original Standing Height} \\ &= 30 \text{ inches} - 17 \text{ inches} \\ &= 13 \text{ inches}\end{aligned}$$

### Sample Velocity Calculation

$$\begin{aligned}\text{Velocity} &= \text{distance}/\text{time} \\ V &= 15\text{m} / 3.73 \text{ s} \\ &= 4.02 \text{ m/s}\end{aligned}$$

Trial	Student B velocity (m/s)	Student C velocity (m/s)	Student D velocity (m/s)
1	4.02	4.11	3.57
2	4.13	4.04	2.66
3	4.84	3.82	2.84
4	4.31	3.75	2.54
5	4.69	3.85	2.42
6	4.80	3.36	2.44
7	4.95	3.35	2.49
8	4.42	3.36	2.34
9	4.87	3.17	2.58
10	4.31	3.62	2.3
11	4.75	3.37	2.43
12	4.39	3.27	2.45
13	4.92	3.33	2.53
14	4.59	3.00	2.29
15	4.89	2.2	2.65

Average Jump Height of Students C and D

Total Running Time for Student B = Trial 1 Time + Trial 2 Time ... + Trial 15 Time

Total Running Time for Student B = 49.21 seconds

Average Running Time for Student B = Total Time / 15 Trials = 49.21 s / 15

Average Running Time for Student B = 3.28 seconds

Total Running Time for Student C = Trial 1 Time + Trial 2 Time ... + Trial 15 Time

Total Running Time for Student C = 67.17 seconds

Average Running Time for Student C = Total Time / 15 Trials = 67.17 s / 15

Average Running Time for Student C = 4.48 seconds

Total Running Time for Student D = Trial 1 Time + Trial 2 Time ... + Trial 15 Time

Total Running Time for Student D = 88.59 seconds

Average Running Time for Student D = Total Time / 15 Trials = 88.59 s / 15

Average Running Time for Student D = 5.9 seconds

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