Subject
Sport Exercise and Health Science

Title
The Effect of Aerobic Activity on Anaerobic Power

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Personal Engagement

The concept for this investigation was founded when considering the effect that the durations in which the energy systems interplay in the sports of Basketball, and Australian Rules Football. During each of the respective sports it is required of players to be both momentarily explosive and have considerable stamina and durability consistently throughout each match as well. This thought pattern lead to curiosity regarding whether the interaction of these two energy systems were of detriment or merit to each other, in particular the effect of the prolonged periods of exercise using primarily the aerobic system may have when the situation called for explosiveness drawn from the anaerobic system. Hence, this investigation was undertaken, as the investigator's personal interest was derived due to participation and passion in both sports outlined above.

Research Question

To what effect does aerobic exercise in the form of a jog at 6km/hour for 3 minutes and 30 seconds influence anaerobic power in the form of standing broad jump(m)?

Introduction

Anaerobic power is defined by the Medical Dictionary as, "Maximal power (work per unit time) developed during all-out, short term physical effort; and reflects energy output capacity of intramuscular high energy phosphates"[1].
Aerobic exercise is defined by the Medical Dictionary as, "movement or activity that results in increases in heart rate and depth and rate of ventilation".[2]

This investigation focuses on the potential effect that aerobic exercise, or the use of the aerobic energy system has upon anaerobic power, or more specifically the energy output of the ATP-PC system. Both energy systems while quite different revolve around the re-synthesis of a single compound; adenosine tri-phosphate (ATP).
Adenosine tri-phosphate (ATP) is a compound that provides energy for bodily functions.[3]ATP has three phosphate groups, bound to one adenine molecule, the bond between the second and third phosphate is highly unstable and has a high energy potential. Through a process of hydrolysis, the bond between the second and third phosphate groups is severed, and energy is released.[4] Resulting in a floating phosphate group and energy deficient adenosine diphosphate (ADP). However, the body only stores 2 – 3 seconds worth of ATP[6], and therefore this ADP must be resynthesised into ATP by the body's energy systems.

The primary role of the ATP-PC system is to fulfil the need for short-term re-synthesis of ATP, using the body's stores of phosphocreatine(PC). By hydrolysing the bond between the phosphate and creatine groups enough energy is created by which the phosphate group from PC can be 'donated' to the energy deficient ADP.[5] For every molecule of ATP re-synthesised one molecule of PC must be split. ADP then becomes ATP and is once again ready for intramuscular use to power muscular contraction. This energy system is most prominent in explosive activities requiring short burst of near maximal effort, such as a broad jump.

The primary role of the aerobic energy system is the longer term re-synthesis of ATP through aerobic glycolysis, the citric acid cycle, and most prominent the electron transport chain.[6] The process is fuelled by glycogen stores and triglycerides which are broken down into glucose (glycogenolysis) and fatty acids (lipolysis) respectively. Glucose then undergoes glycolysis by which it is converted to pyruvate, this re-synthesises 2 ATP molecules. Pyruvate is then oxidised into acetyl CoA; acetyl CoA then merges with four carbon acceptor molecules to become citrate.[7] Fatty acids rather are converted directly into acetyl CoA and continue the process in the same manner as glucose henceforth. Citrate is then used in the citric acid cycle in a series of enzymatic chemical reactions to produce a further 2 ATP molecules.[8] The by-product of these reactions is NADH $FADH_2$.[4] The hydrogen in NADH and $FADH_2$ is oxidised and exothermically split into hydrogen ions and highly charged electrons.[4] These electrons then generate the energy for the resynthesis of ~34 ATP molecules in the case of glucose and ~130 ATP molecules in the case of fatty acids.[9]

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[1] TheFreeDictionary.com. (2018). *anaerobic power*. [online] Available at: https://medical-dictionary.thefreedictionary.com/anaerobic+power [Accessed 17 Apr. 2018].
[2] TheFreeDictionary.com. (2018). *aerobic exercise*. [online] Available at: https://medical-dictionary.thefreedictionary.com/aerobic+exercise [Accessed 17 Apr. 2018].
[3] G. C. Bogdanis, M. E. Nevill, L. H. Boobis, and H. K. A. Lakomy, "Contribution of phosphocreatine and aerobic metabolism to energy supply during repeated sprint exercise," Journal of Applied Physiology, vol. 80, no. 3, pp. 876–884, 1996.
[4] Bennett, A. (1980). The Metabolic Foundations of Vertebrate Behavior. *BioScience*, 30(7), pp.452-456.
[5] Baker, J., McCormick, M. and Robergs, R. (2010). Interaction among Skeletal Muscle Metabolic Energy Systems during Intense Exercise. *Journal of Nutrition and Metabolism*, 2010, pp.1-13.
[6] The Electron Transport Chain. (2014). *The American Biology Teacher*, 76(7), pp.456-458.
[7] Jones, W. and Bianchi, K. (2015). Aerobic Glycolysis: Beyond Proliferation. *Frontiers in Immunology*, 6.
[8] Krebs, E. (1993). Protein phosphorylation and cellular regulation I. *Bioscience Reports*, 13(3), pp.127-142.
[9] Sproule, J. (2012). *IB Sports, Exercise and Health Science*. Oxford: Oxford University Press.

Through this investigation, an attempt is made to examine the way in which the metabolic processes involved in the aerobic energy system will influence the metabolic processes involved in the ATP-PC system in terms of athletic performance. The aerobic energy system is stimulated through the intervention of a light jog on the treadmill at 6km/hr for 3 minutes and 30 seconds, while the ATP-PC system is stimulated through a broad jump. The influence of the aerobic system on the ATP-PC system will be ascertained by comparisons of results of broad jumps both prior to and post the completion of the aforementioned aerobic intervention.
While the aerobic energy system is potent in terms of quantity of ATP re-synthesis, it is a slower process that requires the presence of oxygen. Therefore, it should be expected that despite any ATP re-synthesis while jogging, broad jump performance will be detrimentally effected due to a combination of depletion of ATP stores from aerobic exercise, and insufficient time to re-synthesise ADP into ATP through the bodily energy systems.

Hypothesis

Subject's achieved displacement in the broad jump will be further prior to aerobic exercise as opposed to following the intervention of aerobic exercise due to greater reserves of adenosine tri-phosphate that have been re-synthesised through the body's energy systems, as aerobic exercise is likely to deplete these stores.

Variables

Independent variables: Defined as the variable which is manipulated in order to have an effect upon the dependent variable.

Independent Variable(s)	Method of Control
State of the subject (pre or post aerobic activity)	Subject's standing broad jump will be recorded both immediately after aerobic activity (light jogging at 6km/hr for 3 minutes and 30 seconds) and prior to conducting any aerobic activity.

Dependent Variable: Defined as what the investigator measures or observes as a response due to a change in the independent variable.

Dependent Variable	Method of Control
Displacement achieved through the standing broad jump	Displacement will be measured using a tape measure following every completion of a standing broad jump for each subject (±5mm)

Controlled Variables: Defined as those variables which are deliberately fixed and controlled by the investigator.

Controlled Variable	Method of Control	Reason for Control
Surface	The same surface will be used for all 5 subjects on all 5 trials	Varying surface density can impact the conservation of energy dictated by Newton's Laws. If the surface is less dense, there is likely to be a greater amount of energy lost or absorbed into the surface, and not re-directed through the subject's body leading to a shorter jump and less explosive movements.[10]
Duration of aerobic intervention	The time spent jogging on the treadmill will be timed using a Casio h-3 stopwatch (±5ms) to 3minutes and 30 seconds	Duration of exercise is positively correlated to ATP consumed[11], therefore in order to maintain consistent results in the broad jump for all subjects the duration was timed.
Intensity of Aerobic Intervention	The Cybex treadmill speedometer (±5m/h) will be used to ensure all subjects completed jogging at an intensity of 6km/hour	Intensity of exercise can dictate the energy system by which ATP is re-synthesised[12], and the amount of ATP consumed therefore the intensity was set at a submaximal level using the treadmill speedometer.
Age and Gender of Subjects	All subjects selected will be between the ages of 15-17 and all were male	Age has been shown to have a negative correlation with anaerobic performance.[13] That being as age increases past the approximate age of 32-35 years (depending on the individual) anaerobic power decreases. This is likely to have a direct impact on broad jump results. Furthermore, the gender of subjects also influences results, as males mainly due to body composition have been shown to have higher VO_2 max as well as anaerobic capabilities than females.[14]

[10] Murphy, K., Hatfield, D., Nicoll, J., Henderson, J., Sullivan, W. and Riebe, D. (2014). The Effects Of Different Athletic Playing Surfaces On Jump Height, Force, And Power. *Medicine & Science in Sports & Exercise*, 46, p.259.
[11] Sproule, J. (2012). *IB Sports, Exercise and Health Science*. Oxford: Oxford University Press.
[12] Sproule, J. (2012). *IB Sports, Exercise and Health Science*. Oxford: Oxford University Press.
[13] Rittweger, J., di Prampero, P., Maffulli, N. and Narici, M. (2009). Sprint and endurance power and ageing: an analysis of master athletic world records. *Proceedings of the Royal Society B: Biological Sciences*, 276(1657), pp.683-689.
[14] Sproule, J. (2012). *IB Sports, Exercise and Health Science*. Oxford: Oxford University Press.

Consistent Equipment	The same Cybex treadmill, measuring tape, and Casio stopwatch will be used throughout the entire investigation	Varying equipment can have differing degrees of error resulting in inconsistent duration and intensity of exercise, as well as measurement of broad jump.
Air Temperature	The Daikin air conditioning system will be set to 21 degrees prior to conducting the investigation	Studies have found that when athletes who are accustomed to heat are exposed to high temperatures can actually cause increased cardiac output through increased stroke volume, increased plasma volume, and sweat rate, as well as decreased core temperature.[15] All of which are likely to influence athletic performance within this investigation. Therefore, a neutral temperature will be set to aid consistency and repeatability.
Equilibration Period Given following each Broad Jump	Stopwatch will be used to time 3 minutes from the conclusion of each broad jump to the start of the next.	Subjects that are afforded greater recovery time are able to experience greater re-synthesis of ATP[16] and therefore are likely to perform better than a subject given less rest. Therefore, this variable will be controlled in order to maintain the consistency of the investigation.

<u>Confounding Variables:</u> Defined as those variables which cannot be controlled and may have a direct effect on the independent or dependent variables.

Confounding Variable	Effect of Variable
Broad Jump Technique	Studies have shown that by utilising greater stretch elasticity of muscles athletes are able to produce consistently more power, this was found to be particularly prominent within the muscles of the posterior chain and lower body,[17] all of which were implicated in this study by the broad jump. Unfortunately, due to the individuality of the subjects and the slightly differing technique, there is no way for this stretch elasticity to be controlled. Therefore, subjects who better utilise the stretch elasticity of their posterior chain are likely to gain better results in the broad jump and vice versa. However, the influence of this is only slight between subjects leading to the minimisation of the impact of this variable.
Body Composition of Subjects	It has been shown that body composition can directly influence athletic performance.[18]Unfortunately, these variables aren't measurable for this investigation. In this investigation, those subjects who carry more muscle mass in the lower portion of their body and had relatively low levels of adipose tissue, will be able to achieve more displacement with the broad jump than those who do not. Despite the potential for variability, the body composition of the subjects given age gender, and demographic should be roughly similar.
Prior Sporting History	As previously mentioned those subjects who have sporting background in anaerobic sports, or sports which involve prolonged periods of aerobic work, followed by brief anaerobic bursts have acclimatised to the stimulus of their sport and thus will achieve more displacement in the broad jump. Unfortunately, due to the random selection complete control of prior sporting history isn't possible. Despite this all subjects will have a background in some sport due too demographic, and therefore will be relatively familiar with athletic feats such as the broad jump minimising the influence of this variable.
Arousal	Arousal levels can cause varying degrees of concentration and attention, while also triggering some anxiety in the brain which depending on severity may hinder and improve athletic performance.[19]Despite best effort to maintain a neutral environment for all subjects, there is no way of ascertaining arousal levels of subjects which may lead to inconsistencies in the results.

[15] Sandström, M., Siegler, J., Lovell, R., Madden, L. and McNaughton, L. (2008). The effect of 15 consecutive days of heat–exercise acclimation on heat shock protein 70. *Cell Stress and Chaperones*, 13(2), pp.169-175.
[16] G. C. Bogdanis, M. E. Nevill, L. H. Boobis, and H. K. A. Lakomy, "Contribution of phosphocreatine and aerobic metabolism to energy supply during repeated sprint exercise," Journal of Applied Physiology, vol. 80, no. 3, pp. 876–884, 1996
[17] Brunello, E., Reconditi, M., Elangovan, R., Linari, M., Sun, Y., Narayanan, T., Panine, P., Piazzesi, G., Irving, M. and Lombardi, V. (2007). Skeletal muscle resists stretch by rapid binding of the second motor domain of myosin to actin. *Proceedings of the National Academy of Sciences*, 104(50), pp.20114-20119.
[18] Yavuz, S. (2017). Investigation of maximal oxygen consumption capacity and body composition in children. *New Trends and Issues Proceedings on Humanities and Social Sciences*, 2(1), pp.29-36.
[19] Howland, J. (2007). Mental Skills Training for Coaches to Help Athletes Focus Their Attention, Manage Arousal, and Improve Performance in Sport. *Journal of Education*, 187(1), pp.49-66.

Apparatus

Equipment	Purpose
Cybex Treadmill x 1	With which to conduct aerobic activity (light jogging) (±5m/hr)
Tape Measure x1	With which to measure the displacement achieved through standing broad jump (±0.5cm)
Apple Mac Notebook x 1	With which to record the raw data obtained from the investigation
Casio Stopwatch x 1	With which to time the duration of the aerobic exercise intervention (±5ms)
Roll of Tape x 1	With which to fasten the tape measure to the floor in order to ensure each measurement remains consistent

Safety and Ethical and Environmental Considerations

This investigation was conducted on human subjects and therefore warrants thorough and clear observation of potential health or safety hazards, thus the following pre-cautions were taken. Prior to the completion of any kind of physical activity all participants were asked to complete a PAR-Q (see appendix) to assess their capability to complete the investigation without harm. Furthermore, all subjects were asked about any prior injuries they may have sustained which may affect performance of the investigation. Compounding upon this all subjects were told at any stage should they feel uncomfortable or any physical discomfort to report it immediately and cease activity. In order to prevent the acquisition of any injuries all subject completed a warm up consisting of mainly stretching (primarily static) in order to ensure muscles were loosened and circumstances conducive to muscle and tendon tears were avoided. Following the completion of the investigation all subjects conducted a dynamic cool down to prevent any potential soreness. Each subject completed these various examinations and pre-requisites and were all determined fit to participate in the investigation. In regards to environmental considerations while the investigation has little impact on the environment, efforts were made to turn off the treadmill after use. Further, the Daikin air-conditioning system was only used for the duration of the investigation and was turned off immediately at the conclusion of the investigation. Both actions were undertaken with the aim of minimising the use of electricity throughout the investigation, thereby reducing the need for energy from fossil fuels aiding the preservation of the environment by reducing fossil fuel consumption.

Sampling

In an attempt to help limit the bias of the selection of subjects, random sampling was adopted as a method to help aid this process. As outlined in the *Controlled Variable Table* 5 subjects were randomly selected from a SEHS class (all male aged 15 -17) to partake in the practical investigation by the supervising teacher. The use of completely external third party to select subjects from the individuals available helped to further eliminate potential bias from the investigator in terms of subject selection.

Method

1. Have supervising authority select 5 subjects at random from the group available consistent to the *Controlled Variable Table*
2. Ensure all safety and ethical considerations are observed and controlled variables are kept consistent (see *Controlled Variable Table*, as well as *Safety and Ethical Considerations*)
3. Have 5 selected subjects complete PAR-Q form ("see safety and ethical considerations")
4. Have 5 subjects complete a warmup of static stretching
5. Using the roll of tape to fix the tape measure to the floor in a straight line
6. Have a subject complete 5 broad jumps, ensuring that at the conclusion of each jump the subject is given time for equilibration so that separate trials do not influence each other. Time awarded for recovery period was 3 minutes, as studies indicate that this is an appropriate period for the restoration of ATP in type 2 muscle fibers that are heavily involved in the broad jump.[20] [21] This should be timed using the stopwatch.
7. Results should be measured and recorded for each broad jump using a tape measure and Mac Notebook respectively **(Note*: all measurements of broad jump should be measured from the back of the subject's heel to the starting line)**
8. Repeat steps 6 and 7 for the remaining four subjects consistent to standards outlined previously
9. Have a subject complete a light jog on the treadmill at a pace of 6km/hr (treadmill speedometer) for 3 minutes and 30 seconds. Treadmill speedometer should be used to set the exercise intensity and stopwatch should be used to ensure appropriate duration is achieved
10. Immediately after the cessation of jogging have the subject complete 5 broad jumps, each jump result should be measured and recorded consistent to step 6 and 7 above
11. Repeat steps 9 and 10 for the remaining four subjects
12. The conduction of the above steps should result in 5 subjects completing 5 trials for 2 different treatments

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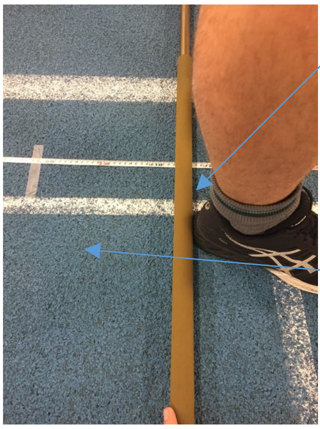
[20] BURLESON, M., O'BRYANT, H., STONE, M., COLLINS, M. and TRIPLETT-McBRIDE, T. (1998). Effect of weight training exercise and treadmill exercise on post-exercise oxygen consumption. *Medicine &amp Science in Sports &amp Exercise*, 30(4), pp.518-522.

[21] "Metabolic response of type I and II muscle fibers during repeated bouts of maximal exercise in humans," American Journal of Physiology, vol. 271, no. 1, pp. E38–E43, 1996.

13. Have all 5 subjects complete a dynamic cool-down
14. Gather equipment and store away in designated place for future use.

Diagrams and Photos



Measurement of Broad Jump displacement (from back of foot)

Subject completing aerobic intervention on treadmill

Surface was consistent throughout the investigation

Speed fixed using treadmill speedometer

Figure 1.1: Demonstration of the measurement process of broad jump displacement

Figure 1.2: Demonstration of the aerobic intervention through jogging on the treadmill

Presentation of Raw Data

Raw data will be presented in a table that separates the subjects (1-5), trials (1-5), in addition to the state of the subject; pre or post aerobic activity. Data is tabulated through the use of Microsoft Excel. All data has been rounded to 3 significant figures

Raw Data Table

The Effect of Aerobic Exercise, via light jogging on Anaerobic Power via broad jump (3 sig fig)			
		Pre Aerobic Exercise	**Post Aerobic Exercise**
	Trial	**(m) (±5mm)**	**(m)(±5mm)**
Subject 1	1	2.05	2.10
	2	2.23	2.22
	3	2.14	2.04[5]
	4	2.17	2.09
	5	2.29	2.12
Subject 2	1	2.25	2.28
	2	2.27	2.31[6]
	3	2.38	2.39
	4	2.37	2.40
	5	2.37	2.33
Subject 3	1	2.50[1]	2.30
	2	2.44	2.38
	3	2.37	2.37
	4	2.41	2.32
	5	2.37	2.31[8]
Subject 4	1	2.11[2]	2.14
	2	2.19	2.25
	3	2.27	2.21[9]
	4	2.21[3]	2.04
	5	2.12[4]	2.06
Subject 5	1	2.97[7]	2.78[10]
	2	3.05	2.85
	3	2.90	2.89
	4	3.02	2.81
	5	2.91	2.78

Area of Uncertainty

Mathematically it is widely accepted that the degree of uncertainty should be established as half the smallest unit of measurement, therefore pertaining to the displacement achieved by each subject for the standing broad jump (dependent variable), an error margin of ± 5 millimetres (mm) should be used due to the potential inaccuracy of the measuring tape. In addition to this, displacement was determined by eye in relation to a tape measure therefore a degree of human error is also inherent, present in the potential for parallax error. However, the individual recording measurements remained the same throughout the entirety of the investigation and therefore the error was kept consistent. Furthermore, a degree of uncertainty also applies to the Cybex treadmill, in which aerobic activity (independent variable) was conducted, the exercise intensity has a degree of uncertainty of ± 0.5 metres/hour (m/hr), as determined form the Cybex Website. This mechanical error was kept consistent by having all 5 subjects use the same treadmill. Another application of uncertainty of this investigation relates to the Casio stopwatch used to time the aerobic activity intervention. The degree of uncertainty for this is ± 5 milliseconds (ms), as obtained from the Casio Website, due to mechanical error of the stopwatch itself.

Anomalies in the Raw Data

Throughout the investigation, results were consistently clustered, except for one particular subject. It should be noted that subject 5, is an elite, national level anaerobic athlete, who competes in long jump, and the hurdles. As such, a result of exposure to training stimulus over time, his body has adapted, and his scores are significantly higher than other subjects. However due to the random selection of participants there is no obvious reason to exclude any of the data points obtained from the subject from further calculations, and as such all data present in the raw data table above will be used for processing of the data.

Qualitative Recordings

1. Subject fell backwards after completing the broad jump and re-trial was awarded
2. Subject fell forward onto hands after completing broad jump, no shift in landing foot position was observed and measurement of jump was conducted as usual
3. Subject complained of slight ankle discomfort, but agreed to continue to participate in investigation
4. Subject fell forward onto hands after completing broad jump, no shift in landing foot position was observed and measurement of jump was conducted as usual
5. Subject shifted over starting line when preparing to jump
6. Subject fell forward onto hands after completing broad jump, no shift in landing foot position was observed and measurement of jump was conducted as usual
7. Subject fell backwards after the jump, and re-trial was awarded. No injury was sustained
8. Subject fell forward onto hands after completing broad jump, no shift in landing foot position was observed and measurement of jump was conducted as usual
9. Subject complained of knee discomfort, agreed to continue with investigation.
10. Student walked through the investigation, kicking a ball distracting the subject from the broad jump, re-trial was awarded.

Processed Data

As no anomalies outside the parameters of the investigation occurred, all data contained in the *Raw Data Table* will be included in all calculations. The data from the table will be used to calculate the mean, standard deviation, percentage change, and t-test for all 5 subjects, both pre and post aerobic intervention. All data presented in *Processed Data* is rounded to 3 significant figures.

<u>Mean</u>

Is considered the center of the data, and a form of averaging data.

Mean is calculated as;

$$\bar{x} = \frac{\sum x}{n}$$

*Where n is the number of scores, and x is the scores.

Example: Subject 1 Pre Intervention

$$\bar{x} = \frac{2.05 + 2.23 + 2.14 + 2.17 + 2.29}{5} = 2.18(3\ significant\ figures)$$

<u>Standard Deviation (SD)</u>

Standard deviation refers to the spread of scores around the mean and assesses the overall accuracy of the experiment. A low SD indicates a more clustered data, while a higher SD indicates a wider range of data around the mean. It is important to note that in a set of normally distributed data, 68% of all data will lie within ± 1 SD from the mean, while 95% of all data will lie within ± 2 SD from the mean.

$$s = \sqrt{\frac{1}{n-1}\Sigma(x-\bar{x})^2}$$

Example: Subject 1 Pre intervention
s=0.091(3significant figures)

Percentage Change

Percentage change is used to examine the degree of change from one treatment to another, relative to the original treatment. This is will be used by presenting the percentage change of each subject's mean performance, from pre aerobic activity to post.

$$\%\Delta = \frac{|V_{pre} - V_{po}|}{V_{pre}} \times 100$$

Where Vpre = Value pre aerobic activity and Vpo = Value post aerobic activity.

Example Subject 1:

$$\%\Delta = \frac{|2.18 - 2.11|}{2.18} \times 100$$

= 3.21 (3 significant figures)

Processed Data Table

		Mean (cm)	Standard Deviation (Sample)	Percentage Change (%)
Subject 1	Pre Aerobic Activity	2.18	0.091	(-)3.21
	Post Aerobic Activity	2.11	0.0662	
Subject 2	Pre Aerobic Activity	2.33	0.0626	(+)0.429
	Post Aerobic Activity	2.34	0.0517	
Subject 3	Pre Aerobic Activity	2.42	0.0545	(-)5.79
	Post Aerobic Activity	2.28	0.157	
Subject 4	Pre Aerobic Activity	2.18	0.0663	(-)1.83
	Post Aerobic Activity	2.14	0.0914	
Subject 5	Pre Aerobic Activity	2.97	0.066	(-)5.05
	Post Aerobic Activity	2.82	0.0476	

***Note: all calculations presented in the *Processed Data Table* are rounded to 3 significant figures.**

Processed Degree of Uncertainty and Anomalies

As was previously mentioned, all data observed was subject to human error through any potential parallax error or visual misperception regarding the measurement of the broad jump. Furthermore, the intensity of aerobic exercise was also subject to mechanical error due to the uncertainty given of ±0.5m/hour in reference to the treadmill speed. Due to the area of uncertainty inherent in the raw data collection of this investigation it is reasonable to further imply that all processed data of this investigation will similarly encounter the same area of uncertainty, which may detriment accuracy. However, the reliability of this investigation can still be considered high, due to the maintained consistencies throughout the investigation in relation to error and measurement.

No anomalies outside the parameters of the investigation were obvious and therefore all data in the above table will be included in graphical representations.

Data was tabulated through the use of Microsoft Excel.

T-tests

T-tests assess the level of significance of the difference between the dependent variable in regards to the independent variable. Means were used rather than raw data as this is a more accurate reflection of the center of the data. When $p < 0.05$ the difference statistics are deemed significant. However as can be observed from the screenshot on the right $p = 0.0613$, which is deemed not quite statistically significant. Although the difference in data pre and post aerobic intervention were deemed insignificant, the closeness of the p value to 0.05 indicates that the data lies close to the threshold of what is considered significant.

Paired *t* test results

P value and statistical significance:
The two-tailed P value equals 0.0613
By conventional criteria, this difference is considered to be not quite statistically significant.

Confidence interval:
The mean of Pre Aerobic minus Post Aerobic equals 0.0780
95% confidence interval of this difference: From -0.0059 to 0.1619

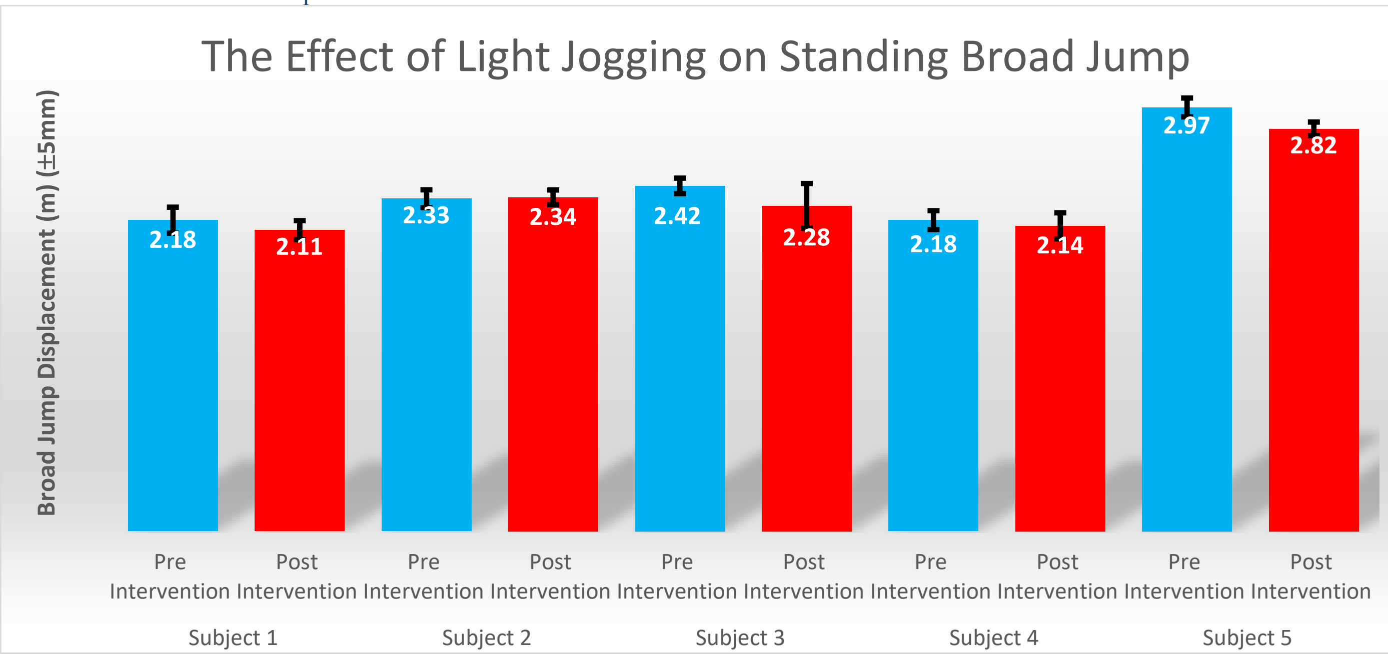
Intermediate values used in calculations:
t = 2.5800
df = 4
standard error of difference = 0.030

Learn more:
GraphPad's web site includes portions of the manual for GraphPad Prism that can help you learn statistics. First, review the meaning of P values and confidence intervals . Then learn how to interpret results from an unpaired or paired *t* test. These links include GraphPad's popular *analysis checklists* .

Review your data:

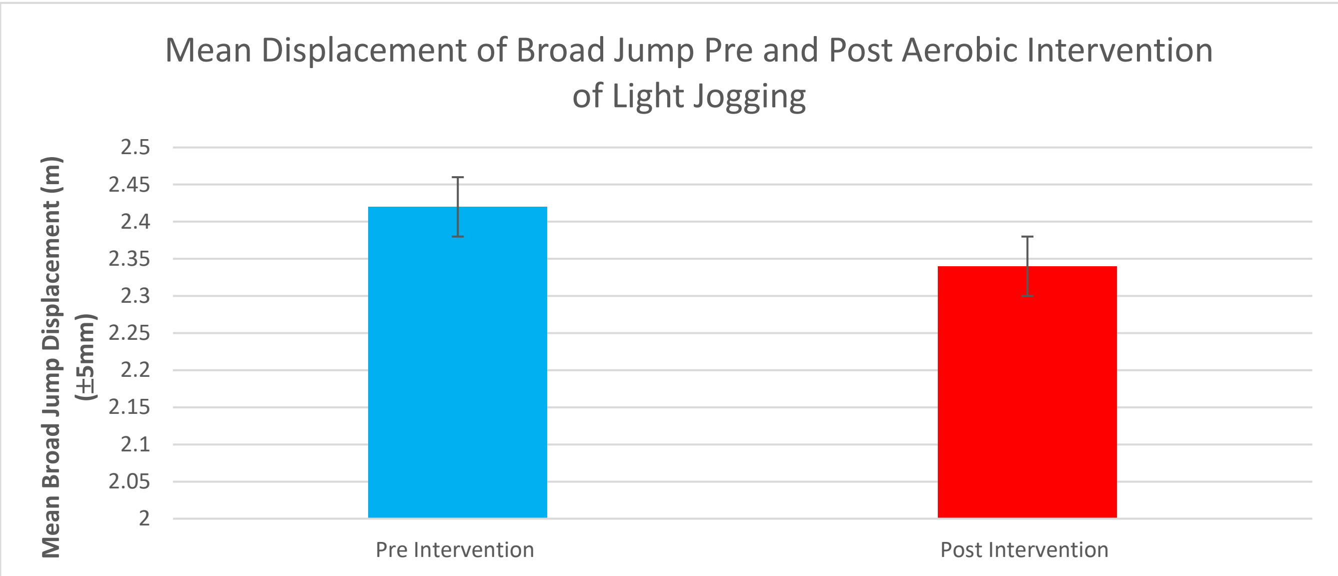
Group	Pre Aerobic	Post Aerobic
Mean	2.4160	2.3380
SD	0.3262	0.2859
SEM	0.1459	0.1278
N	5	5

Processed Data Column Graph



Note: All data presented in *Processed Data Column Graph* has been taken from *Processed Data Table.
All data in *Processed Data Column Graph* is presented in 3 significant figures

Mean Displacement Column Graph



Data in *Mean Displacement Column Graph* is rounded to 3 significant figures
Note: Scale used on the y axis of the *Mean Displacement Column Graph* ranges from 2m to 2.5m, with intervals of 0.05m. This particular scale was used so that the differences between the mean values for pre and post intervention could be more clearly presented and seen.

Data Analysis

As can be seen from the *Mean Displacement Column Graph*, visually, processed data indicates that there was a reduction of performance post intervention compared to pre intervention. This trend can be identified when considering the mean values of 2.42m for pre intervention and 2.34m for post intervention in addition to the reduction in mean displacement of 0.08m (from pre to post intervention). The exception to this trend is Subject 2 who experienced a 0.01m increase in broad jump displacement on average. This could be attributed to a number of factors such as; habituation, prior sporting background (experience in a sport that demands extended aerobic activity followed by brief bursts of anaerobic power), or possibly even increased competitive drive against fellow subjects. The most significant drops in performance following jogging were seen from Subject 3 and Subject 5, who experienced 0.14m and 0.15m reductions in broad jump displacement respectively.

Furthermore, while most of the results for broad jump were somewhat clustered around approximately 2.20m, Subject 5 had achieved significantly more displacement than fellow subjects, this is most likely attributed to prior sporting

experience, as it was noted within the qualitative recordings that the subject admitted to be an elite anaerobic athlete in long jump, a movement relatively similar to the broad jump, likely aiding him in performance.
The **error bars seen on both graphs are a graphical representation of the variability of the data**, and illustrate visually how closely clustered the data points were. Furthermore, the figures for the columns in the *Processed Data Column Graph* were obtained from the mean scores of each subject both pre and post intervention seen in the *Processed Data Table*. It should be noted that the in general the standard deviation of each subject was relatively small, this suggests that all the scores were relatively clustered around the mean presenting quite a narrow range of data. This may allude to the accuracy of the investigation, but may also be a by-product of the test itself. As the broad jump is a test of maximal effort, meaning all participants produce a 90-100% effort for every broad jump.[22] Therefore much of the motivational and psychological elements of persuading subjects to perform to the best of their ability is removed, allowing variations in the data to be somewhat limited.
The percentage change figures in *Processed Data Table* indicate that while there may have been some changes in the performance of the broad jump post aerobic intervention with respect to pre-intervention these changes are minimal relative to the actual broad jump values. The largest percentage change was 5.79% from Subject 3. It should also be noted that all percentage changes save for Subject 2 were actually negative in that the values decreased following the jog. The smallest percentage change was from Subject 2, 0.429%, which is quite insignificant and practically negligible. In light of this apparent insignificance a T-test will be conducted to assess the actual significance of the difference in performance in regards to the independent variable.
Accuracy and Reliability
As a prefacing statement it should also be noted that the previously mentioned error both mechanical and human, pertaining to the timing of the stopwatch, and parallax error be considered in terms of the accuracy of this processed data. Further the mechanical error in the uncertainty of the tape measure (±05.5cm), treadmill (±0.5m/hour) should further be considered in relevance to influence on reliability. However, it can be stated that due to the consistency in maintaining controlled variables and utilising the same equipment (tape, treadmill, stopwatch) for all 5 subject conducting all 5 trials for both treatments maintains the consistency of the investigation thereby limiting the impact of the uncertainty on reliability.

Conclusion

Summary of Results

The results of the investigation predominantly suggested that performance in terms of displacement of the broad jump were detrimentally influenced by the aerobic intervention of jogging, as illustrated in the *Processed Data Column Graph* and *Mean Displacement Column Graph*, which both exhibit mean results both pre and post intervention. Despite this Subject 2 displayed results converse to this in which mean broad jump displacement improved, 0.01m following the aerobic intervention of jogging. However, it should be noted that this improvement was very marginal. In terms of pure quantitative analysis Subject 2's results can be considered somewhat of an anomaly as the data seemingly defies the trends of data exhibited in the results from other subjects all experiencing a -3% to -6% change following the jog relative to results before the jog. However as was noted earlier throughout the *Qualitative Recordings,* nothing outside the parameters of the investigation (controlled variables) occurred during this subject's trials and therefore data can be assumed to be consistent to the standards set by other subjects.

Explanation of the slight improvement in broad jump performance may be attributed to a number of factors however, most prominently likely is habituation, causing the subject to become more familiar with the movement, in this instance the broad jump, and adapt technique as the subject learns kinaesthetically thereby influencing results as more trials are conducted.[23] Thus the subject's technique may have been more optimal for performance in the broad jumps conducted after the aerobic intervention due to learning and increased familiarity. Linking to this aspect of habituation, the investigator deems it likely that a greater degree of muscle stretch elasticity was utilised in the trials conducted following the aerobic intervention, allowing the subject to produce greater power output[24] compared to when less stretch elasticity is used, thereby contributing to improving results, contradictory to the hypothesis.

While mathematical processes of *Mean* and *Percentage Change* supported the statements made above regarding the trend of diminishing performance post aerobic exercise, were valid, it is extremely relevant that the results of the *T-test* should also be taken into account. In this regard the difference between performance before and after the aerobic intervention surmounted to be statistically insignificant indicated by the result, p=0.0613. While the change may have been deemed statistically insignificant the closeness of the result (p=0.0613) to the threshold of significance (p=0.05) also should be noted, insinuating that results approach but do not quite reach statistical significance.

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[24] Brunello, E., Reconditi, M., Elangovan, R., Linari, M., Sun, Y., Narayanan, T., Panine, P., Piazzesi, G., Irving, M. and Lombardi, V. (2007). Skeletal muscle resists stretch by rapid binding of the second motor domain of myosin to actin. *Proceedings of the National Academy of Sciences*, 104(50), pp.20114-20119.

Other than the previously noted statistical anomaly present in Subject 2's results, all other results of the broad jump pre and post aerobic intervention supported the hypothesis of; **Subjects performance in the broad jump will be better prior to aerobic exercise as opposed to following the intervention of aerobic exercise due to greater reserves of adenosine tri-phosphate that have been re-synthesised through the body's energy systems, as aerobic exercise is likely to deplete these stores.**

Comparison to Literature

Subject 2's abnormal results contradict all relevant literature, while conversely the other results are supported by studies and research. Studies indicate that the aerobic activity of jogging as an intervention would have caused depletion of ATP stores thereby deducting from the anaerobic performance of the broad jump.[25] One particular study concluded that aerobic training had significant effect on excess post oxygen consumption (EPOC) and therefore indicates that aerobic exercise has the immediate effect of creating an oxygen deficit, hence the EPOC.[26] This indicates that aerobic exercise has fatiguing effects that can detrimentally influence performance through depletion of ATP stores. This depletion of ATP thereby results in a lack of energy to perform anaerobically in the subsequent broad jump epitomised by decreased displacement witnessed in the general trend of results. This investigation is somewhat of a pilot study, in terms of specific variables, other studies, have come to concrete conclusions that aerobic exercise causes definite depletion in ATP stores which was measured through EPOC.[27] Another study,[28] concluded that; "The American College of Sports Medicine (ACSM) defines aerobic exercise as any activity that uses large muscle groups, can be maintained continuously and is rhythmic in nature. As the name implies, muscle groups activated by this type of exercise rely on aerobic metabolism to extract energy in the form of adenosine triphosphate (ATP) from amino acids, carbohydrates and fatty acids." As such the results from this investigation, them being the decrease in anaerobic performance following aerobic intervention align with what would be expected given the inference from other previously listed studies. Furthermore, other academic sources such as Sproule confirm that aerobic activity does indeed deplete ATP stores.[29] Therefore, it logically follows that the conclusions drawn from this investigation are supported by a plethora of pre-existing academic studies.[30] [31]

Scientific Explanation of Results

Other than in the case of Subject 2, whose results were the only observed data that increased following intervention (+0.429%) the remainder of the data is scientifically explicable. Mainly through the process of ATP re-synthesis of the various bodily energy systems in this instance the aerobic energy system, otherwise known as mitochondrial respiration system and the ATP-PC system otherwise known as the Phosphagen system.

When conducting the 'control' trial (pre-intervention), subjects had yet to be forced to exert noticeable effort (through the aerobic intervention), and thereby ATP stores were relatively full, through the body's natural process of ATP resynthesis through energy systems with slight variation depending on the individual, which is exhibited by the 13cm decrease in subject 3's jumps from trial 1 to trail 5, in comparison too subject 5's much smaller 6cm decrease from trial 1 to 5. Upon commencing the broad jumps, the body's 2-3 second stores of ATP are rapidly consumed and converted to ADP. [32] Due to the anaerobic nature of the exercise are re-synthesised through the phosphagen pathways by which, the molecule phospho-creatine, is exothermically hydrolysed, providing not only the phosphate group to be re-bound to energy deficient ADP, but also the energy necessary for such a metabolic reaction.[33] However, this relatively simple process becomes more convoluted with the involvement of aerobic activity.

When commencing aerobic activity there is an immediate oxygen deficit, hence the aforementioned EPOC.[34] Further once ATP stores have been depleted re-synthesis of ATP from ADP occurs through mitochondrial respiration, occurring in the stages of, aerobic glycolysis, the citric acid cycle (Krebs cycle), and ultimately the electron transport chain. [35] [36] By using stored glycogen and triglycerides as fuel the limit to this energy system is theoretically infinite.[37] Despite this

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[25] Drummond, M., Vehrs, P., Schaalje, G. and Parcell, A. (2005). Aerobic and resistance exercise sequence affects excess postexercise oxygen consumption. *Journal of strength and conditioning research*, 19(2), pp.332-337.

[26] Drummond, M., Vehrs, P., Schaalje, G. and Parcell, A. (2005). Aerobic and resistance exercise sequence affects excess postexercise oxygen consumption. *Journal of strength and conditioning research*, 19(2), pp.332-337.

[27] Drummond, M., Vehrs, P., Schaalje, G. and Parcell, A. (2005). Aerobic and resistance exercise sequence affects excess postexercise oxygen consumption. *Journal of strength and conditioning research*, 19(2), pp.332-337.

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[31] Baker, J., McCormick, M. and Robergs, R. (2010). Interaction among Skeletal Muscle Metabolic Energy Systems during Intense Exercise. *Journal of Nutrition and Metabolism*, 2010, pp.1-13.

[32] Sproule, J. (2012). *IB Sports, Exercise and Health Science*. Oxford: Oxford University Press.

[33] Guimarães-Ferreira, L. (2014). Role of the phosphocreatine system on energetic homeostasis in skeletal and cardiac muscles. *Einstein (São Paulo)*, 12(1), pp.126-131.

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[35] IPT. (n.d.). *The Aerobic Energy System*. [online] Available at: https://www.iptaustralia.com.au/fitness-articles/energy-systems/aerobic-system [Accessed 3 Feb. 2018].

[36] Krebs, E. (1993). Protein phosphorylation and cellular regulation I. *Bioscience Reports*, 13(3), pp.127-142.

[37] Bennett, A. (1980). The Metabolic Foundations of Vertebrate Behavior. *BioScience*, 30(7), pp.452-456.

the process of re-synthesis is much more delayed than the phosphagen system. In this regard the short term phenomenon of oxygen deficit occurs, and fatigue can be induced.[38] Therefore, when applying these scientific principles, the anaerobic exercise of broad jump can be detrimentally effected by the intervention of aerobic exercise, primarily due to the oxygen deficit, and incapability of the aerobic energy system to re-synthesise ATP sufficiently in the short term as was stipulated by the 3 minute 30 second jog. This was witnessed given the trend of data shown in the mean and percentage change from pre-aerobic intervention and post aerobic intervention respectively.

Evaluation

Although the investigation design was sound there were many flaws of varying significance throughout the investigation, particularly when regarding the execution, and practical aspects of the investigation. In general, all accuracy and reliability of any investigation can be improved through more subjects conducting more trials, with more precise equipment. However, beyond this there were specific limitations on this investigation that may have been amended. The flaws of the investigation will be outlined in the table below;

Evaluation of Identified Weaknesses Table

Identified Weakness	Level of Significance	Suggested Improvement
Disruption of Investigation from External Sources	High Significance – Due to the open nature of the investigation being conducted in a school fitness center, there were a number of distracting factors that influenced subjects participating in the investigation including external noise from the loud speakers, in addition to non-participating individuals walking through and disrupting the investigation area. This effect was particularly prominent in Subject 5 Post Aerobic Intervention Trial 1, as was noted in the qualitative observations. These distractions were epitomised by this instance, culminating in a full re-trial being awarded.	Within reason it may be possible to book the fitness center during planned investigation time to ensure that it is vacant thereby removing these external distractions. By eliminating these distractions impairments in motor performance can be avoided.[39]This would aim to increase the validity and reliability of the investigation, by eliciting more consistent performance from subjects, without interference from external sources, thereby allowing the direct influence of aerobic exercise on anaerobic power to be more accurately assessed through data.
Rest Periods	High Significance – The rest periods given between broad jumps were slightly variable for each subject, despite best efforts to control this variable, mainly due to the individual variance in each subject's set up time of stance prior to the broad jump. Some subjects, particularly Subject 4 in trial 4, pre intervention, when complaining of ankle discomfort (See *qualitative Observations*) took up to 20 seconds longer after instruction had been given to jump again a significant period of time. This may have led to discrepancies regarding the amount of ATP resynthesis through the ATP-PC system during these rest periods. [40] [41] This may have led to those subjects with longer rest periods to perform better, leading to inconsistencies in the data. In particular it was noted that Subject 4 had slightly varied equilibration times due to differing technique (See *Confounding Variable Table*), when initiating the initial foot placement, thereby influencing all of the data from Subject 4 both pre and post intervention.	It would be possible to entirely dictate to subjects the amount of rest period allocated with absolutely no flexibility whatsoever, and inform subjects the exact rest time they have for each broad jump. Further this could be enforced more strictly by the investigator disallowing data that has not been completed to right standard into results. Thereby this maintains consistency and may help to increase the validity of the investigation by allowing a more direct comparison of aerobic exercise and anaerobic performance.
Different Foot Apparatus for each Subject	Medium Significance – The differing shoe brands and models may have impacted the performance of each individual subject. As was previously included in the *Controlled Variable Table* similarly the conservation of energy principles of Newton's Laws also applies	An alternative may have been to instruct all subjects to conduct the broad jump aspect of the investigation barefoot, thereby increasing reliability by removing the potential for variation in individual footwear. However, in order to do this proper research and ethical/safety

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[39] Hemond, C., Brown, R. and Robertson, E. (2010). A Distraction Can Impair or Enhance Motor Performance. *Journal of Neuroscience*, 30(2), pp.650-654.
[40] IPT. (n.d.). *Anaerobic Energy System*. [online] Available at: https://www.iptaustralia.com.au/fitness-articles/energy-systems/anaerobic-system [Accessed 3 Feb. 2018].
[41] Sproule, J. (2012). *IB Sports, Exercise and Health Science*. Oxford: Oxford University Press.

	here, with differing shoes providing differing power outputs.[42]	considerations would have to be undertaken.
Time Restrictions	Medium Significance – The time restrictions given to complete the investigation caused the process of the PAR-Q to be rushed, and further the explanation of the investigation to subjects. This resulted in some confusion on the behalf of the participants, resulting in further questions that required answering, which deducted from the allotted time set for the completion of each component of the investigation outlined in the *Method.* As a result, the measurement of Subject 5's post intervention trials (1-5) was somewhat rushed which may have influenced to accuracy of the data.	Time restriction could have been reduced through conducting the investigation outside school hours, removing the time restrictions of periods, and decreasing the need to rush through collecting data. Furthermore, the planning process could have been more considerate in allocating time for questions from participants. Largely, this would have allowed for greater degree of accuracy.
Human Bias	Low Significance – There was some room for error regarding the measurement of broad jump displacement, due to visual effects such as the parallax error, or simple human bias. However, this was limited as the investigator taking measurements remained constant maintaining consistency of the results.	Attempts could be made to obtain equipment to mechanise the process, and thereby remove the potential for human bias, however this may be costly. Another alternative is to have two individuals measuring broad jump results, and the mean of the two results presented by each individual used to increase accuracy.
Mechanical Error	Low Significance – The mechanical error outlined previously, regarding the stopwatch, treadmill, and tape measure may also have slightly impacted the investigation, however this was limited as the same equipment was used for all subjects and all trials, maintaining consistency.	The use of more precise equipment with smaller degrees of error or uncertainty is the only way to improve this weakness. This would move to increase the accuracy of data, by reducing the potential for error.

Strengths

While there were inherent weaknesses to the investigation, there were also some strengths. Having used jogging as the form of aerobic intervention lends itself quite well to the investigation in that the muscle in which load is placed in much the same as in broad jump. Further, it maintains validity as both forms of exercise, both broad jump and jogging use a wide array of skeletal muscle, reducing the limitations had only the impacts on one muscle group been considered. Using jogging as the aerobic intervention as opposed to arm ergometry or some other medium of aerobic exercise aided the investigations validity. Furthermore, the random subject selection removed the potential for bias to contaminate results, allowing a more accurate portrayal of the results to be seen.

Extension of Research

The investigator would like to propose that perhaps further study could be undertaken into a comparison of the effect of both aerobic and anaerobic interventions on broad jump displacement could be addressed, to provide a greater degree of context and a wider base of knowledge in terms of the comparative feature of the energy systems. Furthering this vein of exploration, some consideration of the lactic acid system could be made. However, some difficulties regarding the acidosis within skeletal muscle would be expected, given that the fatigue inducing hydrogen ions would cause decreases in performance through increasing muscle acidity, and decreasing ability to generate muscular force through contraction, therefore the data post lactic intervention would likely be both inaccurate and invalid, given that it would be largely decremented by the by-products of the lactic system. Therefore, it is likely that for this extension of research to take place, a completely different investigation be undertaken, with vastly different method to appropriately address the acidosis present within the lactic acid system.

Synthesis

To synthesise, the investigator believes the investigation, despite its inherent flaws, to be valid and as accurate as resources allowed. Further, given the little research conducted into the specificity of this particular investigation around the influence aerobic exercise has on anaerobic performance, the investigation proves unique and may provide a point of cross reference for further study into the future in relation to the selected variables.

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Appendix: PAR-Q

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☒	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☒	**2. Do you feel pain in your chest when you do physical activity?**
☐	☒	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☒	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☒	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☒	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☒	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME Darcy Edwards

SIGNATURE ______ DATE 11/10/17

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority) ______ WITNESS ______

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

1:12

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continued on other side...