SPSC-4256 Sport Science Applied Research - Final Written Submission

"Oxygen Metabolism Analysis Under Hypotensive Risk in Maximal Anaerobic Stress".

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Introduction

The present project has been written with the intention of carrying out a comprehensive analysis of oxygen metabolism during maximum efforts in weightlifting, specifically in the deadlift. Currently, there is a growing issue surrounding weightlifting; this risk has always existed but has increased in recent years. This is the risk of syncope or hypotensive episodes during or after a heavy lift. According to the author of the project, it can be hypothesized that the reason for this, is the lack of experience in weight training. Every day, the number of people entering the world of weightlifting increases almost exponentially, and often they do so without prior training. Specifically, without undergoing proper conditioning like other athletes do, this hinders or delays the speed and synchronization of metabolic adaptations with muscular adaptations. In other words, novice athletes develop their ability to lift weights muscularly, but they do not adequately train their respiratory capacity. It is for this reason that the project was designed with the idea that by adding conditioning to a weightlifting meso-cycle the risk of hypotension (fainting) can be decrease when performing deadlift, a lift with more recurrent accidents, with maximum loads.

The study also endeavors to determine how conditioning training can improve weightlifting athletes' capacity to endure critical efforts in deadlifting, and diminish the probability of hypoxia-related syncope events post or during lift. The more structured hypothesis is that oxygen metabolism is a determining factor in WeigthLifting and not only a standard placement test, like is used commonly for; by examining the hypotensive or syncope possible occurrence (fainting) during or after high-intensity anaerobic efforts linked to untrained respiratory capacity (Compton et al., 1973). The research will demonstrate that by embracing hybrid cycles of training—a fusion of anaerobic and conditioning aerobic training—athletes can unlock uncharted potential and substantially diminish the risk of these episodes.

Literature Review

Syncope episodes are intrinsically tied to inadequacies in respiratory competence, like the volume of oxygen absorbed per inspiration or oxygen-bonded hemoglobin by O2Sat, culminating in a disconcerting disparity between oxygen supply and demand within skeletal muscles and other body systems (Compton et al., 1973). In the case of weightlifting, more precisely deadlifting, the aerobic energy system triggers first; using mainly oxygen to produce ATP (Adenosine Tri-phosphate), the body's energy currency. The continuous stress of this system due to the intensity increase of the movement, generates an oxygen deficit within the agonist muscles (main muscular effectors): Biceps Femoris (BFm) and Gluteus Maximus (GM) in the case of deadlifting. Oxygen is divided as well between antagonist muscle (opposite muscle to the antagonist, eccentric contraction), synergetic muscles

(muscles that contract in the same direction or with the same intention of the agonist), and structural muscles (muscles that contract mostly in isotonic/metric fashion to hold the system in place). All these muscles make up for the rest of the tension needed for the lift.; worth mentioning, there is a high consumption of oxygen systemic (Wagner, 2012), not just by the muscles.

When the low oxygen threshold is achieved, the system uses the anaerobic energy pathways, which in essence are the same at a cellular level, but require no oxygen (Sözen & Akyıldız, 2018). Lastly, the muscle keeps running out of substrate and time to generate enough ATP to supply the energy demands of the exercise, which then pushes the muscle into fermentation, where only the sugar-based pathway of glycolysis can generate energy (Rios et al., 2024). At this point, the muscle has suffered multiple subtract losses and tears all over the fibers, accompanied by systemic oxygen deficiency; leading to a phenomenon known as hypoxia, which affects the oxygen perfusion ability of the cardiorespiratory system. In practical terms, the athlete increases their breathing rate to inhale as much oxygen as possible, to enrich the blood with it; but fast shallow breaths do not contain a high concentration of oxygen, and even if they did there is only a finite amount of hemoglobin (HB) in the blood that can carry that oxygen, so it reaches the muscle (Juinaidi, 2002). Same case for the oxygen transference into the sarcomere, a finite amount of myoglobin (MB) can collect oxygen and push it into the motor units. That's why weightlifting opted out for deeper inhalations, that can collect more oxygen from the environment, and allow the athlete to create internal pressure mediated by diaphragmatic breathing and core tridimensional contraction, known as bracing (Storey & Smith, 2012).

Putting all the pieces together, the hypoxia obligates the body to push the limited oxygen to the vital organs, leaving the muscle without its most efficient ATP production process, forcing the muscle to draw upon anaerobic and fermentation inside of the muscle. The high intensity of the lift will increase still the blood pressure to recirculate the oxygen and the metabolic waste of the muscles fermenting, which will be lactate acid; becoming a great marker for anaerobic activity.

The next systemic action or consequence will be the regulation of pressure and waste by vasodilation of the capillaries, so the blood can reach the liver faster and be alkalized. The problem with this is that once the lift is culminating, the athlete will have to let go of the air, and the body will not have oxygen intake for a short period while the standing position is held; in most cases, the diaphragm begins to collapse due to the residual pressure of the exhalation and the weight carried, which means hypoxia will still be in place, and the remaining (Blood saturation in mol/mL) can't supply the brain with enough oxygen, resulting in lost of conciseness by syncope (Compton et al., 1973; Ibbotson, 1987).

Based on the initial concepts explain above, the main focus of the researcher is not just understanding how oxygen metabolism is related to energy production during shorts outburst of strength, like in weightlifting, but to identify tendencies in the data collected to relate with possible aerobic and anaerobic adaptations seen after the implementation of a hybrid training meso-cycle. The body is an incredible machine, is meant to perceive its environment an adapt to it; in the case of sports, the body takes the input of constant strain on every system in the athlete, as a life or dead situation, and it triggers a set of physiological changes, to make the athlete more suitable to survive in this conditions. This assuming that the conditions persist, here the base of training, practice and discipline; body will only adapt and maintain those adaptations if the stimuli are constant, in order words, if the adaptations are needed to “survive” on a day to day bases.

Regarding the systems involve in energy production and usage, practically the entire system will be at play, but the major focus areas, and the ones that can be studied during the experiment are: muscular system, respiratory system, endocrine system, circulatory system and nervous system. That being said, it is wise to clarify that the study endeavor in understanding oxygen metabolism and its adaptations related to mostly anaerobic efforts. Meaning, only mention of the system and some of the known adaptation seen on them, is require to understand the phenomenon, and assume they are the physiological reason for the data behavior.

Muscular system.

The physiological adaptations of the muscular system to weight lifting are of great complexity and depth, reflecting a dynamic interaction between a variety of biological processes, from cell signaling to gene expression and hormonal modulation. Weight lifting, as a form of high-intensity anaerobic exercise, triggers a series of adaptive responses in skeletal muscle tissue with the main objective of improving force generation capacity and muscular endurance.

At the cellular level, weight lifting activates a variety of intracellular signaling pathways, including protein phosphorylation pathways such as AMPK (AMP-activated protein kinase) and CaMK (calcium/calmodulin-activated protein kinase). (Hoppeler H, Vogt M (2001).These signaling pathways converge on the phosphorylation of key proteins involved in the regulation of muscle growth and adaptation, such as Akt (protein kinase B) and ERK (extracellular signal-regulated protein kinase), triggering anabolic and adaptive responses in the tissue. muscular.

Protein phosphorylation is a fundamental process in the regulation of various cellular functions. It consists of the addition of phosphate groups to specific amino acid residues in proteins, usually serine, threonine or tyrosine. This chemical modification can have a significant impact on the protein's activity, subcellular localization, or interaction with other molecules. It is carried out by enzymes called protein kinases, which transfer a phosphate group from an ATP (adenosine triphosphate) molecule to the target protein. This process may be reversible, as protein phosphatases remove phosphate groups, thus regulating protein activity. It plays a crucial role in regulating a variety of cellular processes, such as signal transduction, cell cycle regulation, metabolism, cell motility, among others. In the context of weight lifting, protein phosphorylation is part of the mechanism by which muscle cells adapt their metabolism and contractile capacity to cope with the stress induced by high-intensity exercise.

Gene expression is also modulated by weight lifting, with an increase in the transcription of genes related to muscle protein synthesis, such as IGF-1 (insulin-like growth factor 1), FGF (insulin-like growth factor 1), fibroblasts) and HGF (hepatocyte growth factor). These growth factors promote muscle protein synthesis and muscle hypertrophy through anabolic signaling pathways, contributing to the growth and adaptation of muscle tissue. Examples of its functions are:

- IGF-1 (Insulin-like growth factor 1): It is an anabolic growth factor that is produced in response to growth hormone (GH) stimulation and resistance exercise. IGF-1 promotes muscle protein synthesis and muscle hypertrophy. Additionally, it plays a role in the proliferation and differentiation of satellite cells, which are precursor cells for muscle fibers. Activation of the IGF-1 signaling pathway is crucial for protein synthesis and muscle growth.
- FGF (Fibroblast Growth Factor): FGF has multiple functions, but in the context of muscle adaptations, it has been shown that it can stimulate the proliferation of satellite cells and promote angiogenesis, which is the formation of new blood vessels. These actions can contribute to muscle growth and repair, as well as the adequate delivery of oxygen and nutrients to muscle tissues.
- HGF (Hepatocyte Growth Factor): HGF is known for its role in tissue repair and regeneration. HGF has been shown to have effects on the proliferation and migration of satellite cells, as well as the differentiation and fusion of these cells with muscle fibers, contributing to muscle hypertrophy and regeneration after exercise.

Regarding neuronal adaptations, “satellite” cells have been mentioned several times, which are specialized as progenitors, found in skeletal muscle tissue. They are located in the basement membrane that surrounds the muscle fibers and are in a state of latency under normal conditions. However, in response to muscle damage induced by intense exercise, it goes into action to contribute to the repair and growth of muscle tissue (Geiser J, Vogt M, Billeter R,2001).

When muscle damage occurs, whether from mechanical stress or intense exercise, “satellite” cells become activated and begin to proliferate. These cells can fuse with damaged muscle fibers or regenerate new muscle fibers, which contributes to muscle recovery and growth. In addition, “satellite” cells secrete growth factors and cytokines that promote muscle regeneration and modulate the inflammatory response in damaged tissue.

In the context of weight lifting, “satellite” cells play a crucial role in muscle adaptation to exercise. They participate in the repair of muscle micro-injuries induced by weight lifting, thus promoting hypertrophy and improving muscle performance. In addition, “satellite” cells can also contribute to the long-term adaptation of the muscle through the formation of new muscle fibers and the improvement of vascularization of muscle tissue.

On a hormonal level, lifting weights causes the release of various hormones that regulate metabolism and muscle function. Anabolic hormones include testosterone, growth hormone (GH), and insulin, which promote muscle protein synthesis and muscle recovery. (Chiu LL, Chou SW, Cho YM, 2004) However, a catabolic response also occurs with the release of hormones such as cortisol and thyroid-stimulating hormone (TSH), which can have negative effects on muscle tissue by promoting protein breakdown and muscle fatigue. These hormones work specifically and synergistically in actions such as:

- Testosterone: As an anabolic steroid hormone par excellence, testosterone plays a crucial role in regulating muscle growth and protein synthesis. Its release increases during and after resistance exercise, promoting muscle hypertrophy and post-workout recovery. Testosterone also improves muscle strength and power by increasing the number and activity of androgen receptors in muscle cells.

- Growth hormone (GH): GH is a peptide hormone that stimulates growth and tissue regeneration throughout the body, including muscle tissue. During weight lifting, GH release increases, which stimulates muscle protein synthesis and hypertrophy. GH also has lipolytic effects, promoting the use of fat as a source of energy during exercise.
- Insulin: Insulin is an anabolic hormone that regulates carbohydrate and protein metabolism. During resistance exercise, insulin secretion increases, which facilitates the uptake of glucose and amino acids by muscle cells. This promotes glycogen and muscle protein synthesis, which is crucial for muscle recovery and growth.
- Cortisol: Cortisol is a catabolic hormone that is released in response to stress, including stress induced by exercise. During weight lifting, cortisol levels increase, which can have negative effects on muscle tissue by promoting muscle protein breakdown and gluconeogenesis; However, tissue deterioration is also necessary for its growth, and in adequate doses, cortisol also plays a role in energy mobilization and adaptation to stress.
- Thyroid-stimulating hormone (TSH): TSH is secreted by the pituitary gland and regulates the function of the thyroid gland, which in turn controls basal metabolism and metabolic activity in tissues, including skeletal muscle. During resistance exercise, TSH may increase slightly to adjust metabolism in response to physical stress (Clark SA, Bourdon PC, Schmidt, 2007).

Adding to all the aforementioned processes, weight lifting triggers a series of significant adaptations in the composition and function of muscle fibers, which are crucial to improve the force and power generation capacity of the muscle, as well as to optimize its ability to efficiently use energy substrates during muscle contraction.

One of the most notable adaptations is the increase in the size and density of type II muscle fibers, also known as fast-twitch fibers. These muscle fibers are responsible for the generation of force and power, and have the ability to produce a rapid and powerful contraction. The stimuli of weightlifting exercise enhance the recruitment and activation of these fast-twitch muscle fibers, resulting in an increase in their size and density. This process, known as muscle hypertrophy, allows the muscle to generate more force and power in response to the external load applied during weight lifting.

Besides the increase in the size and density of type II muscle fibers, weight lifting also promotes improvements in the ability of these muscle fibers to utilize energy substrates during muscle contraction. During high-intensity exercise, muscle fibers rely primarily on phosphocreatine and muscle glycogen as energy sources for rapid and powerful muscle contraction. Strength training increases the muscle's ability to store phosphocreatine and glycogen, as well as to use these substrates more efficiently during exercise. This results in an improvement in muscular endurance and a reduction in muscle fatigue during weight lifting, allowing the individual to perform more repetitions or lift heavier loads with less fatigue.

In summary, weight lifting triggers a wide range of physiological adaptations in the muscular system that aim to improve muscular strength, power, and endurance. These adaptations involve complex cellular, molecular, and hormonal processes that regulate muscle protein synthesis, energy metabolism, and contractile function of skeletal muscle tissue (Friedmann B, Frese F, 2007). A detailed understanding of these adaptations is critical to designing effective strength training programs and maximizing the benefits of weightlifting in terms of health and physical performance.

Specifically entering the focus of the study, the adaptations that are mainly related to the muscular system and the systems that support it, is the improvement of the metabolic capacity of muscle fibers; specifically, the use of phosphocreatine and glycogen immediately in response to short-duration maximal explosive effort. Phosphocreatine (PCr) is a molecule that acts as a high-power energy reserve in skeletal muscle, allowing the rapid regeneration of ATP (adenosine triphosphate), the main source of energy used during muscle contraction. On the other hand, glycogen is the stored form of glucose in the muscle, which is used as an energy source during high-intensity, long-duration exercise.

Strength training increases phosphocreatine and glycogen storage capacity in muscle through several mechanisms. On the one hand, strength training increases the activity of enzymes involved in the synthesis and storage of phosphocreatine and glycogen, resulting in a greater amount of these molecules available for use during exercise. Additionally, strength training improves muscle glucose uptake and glycogen storage capacity, increasing the availability of glucose as an energy substrate during high-intensity exercise. Examples of enzymes that play an important role in these synthesis and storage processes:

Creatine kinase (CK): Creatine kinase is an enzyme that catalyzes the transfer of a phosphate group from phosphocreatine (PCr) to ADP (adenosine diphosphate), regenerating ATP (adenosine triphosphate), which is the main source of energy for contraction muscular. CK is essential for maintaining energy homeostasis in muscle, especially during high-intensity exercise.

- Glycogen synthase: a key enzyme in glycogen biosynthesis, catalyzing the joining of glucose units to form glycogen chains. This enzyme is responsible for the synthesis and storage of glycogen in skeletal muscle, providing a reserve of energy available for use during exercise.
- Glycogen phosphorylase: Glycogen phosphorylase is an enzyme that catalyzes the breakdown of glycogen into glucose units, releasing glucose-1-phosphate. This enzyme is essential for the mobilization and release of glucose stored as glycogen.
- Phosphoglucomutase: Phosphoglucomutase is an enzyme that catalyzes the conversion between glucose-1-phosphate and glucose-6-phosphate. This enzyme plays a crucial role in the regulation of glucose metabolism and in the entry of glucose into the glycolytic pathway for subsequent use as an energy source.

In addition to increasing phosphocreatine and glycogen storage capacity, strength training also improves the efficiency with which the muscle uses these substrates during exercise. This is due in part to a series of metabolic adaptations that occur in muscle in response to strength training, such as increased activity of enzymes involved in fatty acid oxidation and improved acid utilization capacity. fats as a source of energy during long-duration exercise. (Hoppeler H, Klossner S (2008). So not only creatine phosphate and glycogen play an important role, but also the use of aerobic pathways (oxidation of compounds), once the main effectors have been exhausted. It is here where we can contemplate the relationship between fatigue and oxygen-dependent energy expenditure; where the percentage or concentration of oxygen that is limited during maximum lifting directly affects the body's ability to deal with the effects of hypoxia (low oxygen concentration).

Oxygen is limited not because the body cannot absorb large quantities, on the contrary, the body is quite efficient in using this solute, but because in the lifting technique a specific type of breathing and abdominal contraction must be carried out. which forces air to be held inside the abdominal cavity. Bracing is the best used method to lift large loads in a safer and more effective way. It consists of first taking wave breaths to release as much CO2 as possible before taking in as much air as possible quickly. This air will be used by all body systems, but being in a state of maximum muscular stress, the muscles will receive much of it. Once the air enters the abdominal cavity, not the thoracic cavity (contrary to normal breathing), a three-dimensional abdominal contraction is performed, creating internal pressure against the walls of the core; This is called diaphragmatic breathing.

Proceeding with the lift, the athlete will not allow air to escape, in order to maintain the internal pressure as long as possible and thus complete the lift. This period where air is not released is when the body begins its state of hypoxia. In hypoxia, the body suffers from a lack of oxygen and its ability to function deteriorates. This situation is not ideal; however, the stress generated develops cardiorespiratory adaptations suitable for its containment.

During lifting, the respiratory system undergoes crucial adaptations to ensure adequate oxygenation and carbon dioxide removal, allowing optimal metabolic balance and physical performance to be maintained.

- Increased pulmonary ventilation: In response to hypoxia, the body can trigger an increase in pulmonary ventilation, both in respiratory rate and in inspiratory and expiratory volume. This increase in the frequency and depth of breathing is intended to improve oxygen uptake and removal of carbon dioxide from the lungs, thereby facilitating the diffusion of oxygen into the blood and the removal of metabolic waste products.
- Increase in tidal volume: Hypoxia can cause an increase in tidal volume, that is, the amount of air that is inhaled and exhaled in each respiratory cycle. This increase in tidal volume allows for greater entry of oxygen into the lungs and greater removal of carbon dioxide, thus optimizing gas exchange in the lung alveoli and ensuring adequate oxygen supply to active tissues. Hypoxia also induces metabolic adaptations that affect energy production and muscle performance, allowing the body to maintain energy homeostasis under conditions of low oxygen availability.
- Greater use of anaerobic glycolysis: In conditions of hypoxia, the body increases its dependence as a main source of energy. (Hoppeler H, Klossner S (2008).It is a metabolic process that does not require oxygen and can quickly generate ATP from glucose, providing a fast and efficient source of energy for active muscles.
- Activation of the lactacydemic system: Hypoxia can promote the accumulation of lactate in the muscle as a result of the increase in anaerobic glycolysis. Lactate is a metabolic by-product produced when glucose is broken down for energy in the absence of oxygen. Lactate buildup can contribute to muscle fatigue and decreased performance, although it can also serve as an alternative source of energy for muscles.

- Changes in fatty acid oxidation: Hypoxia can affect the body's ability to oxidize fatty acids as a source of energy during weight lifting. Since the oxidation of fatty acids requires oxygen for its metabolism, the body can reduce its dependence on fatty acids as an energy substrate in conditions of low oxygen availability, favoring instead the use of glucose as the main source of energy.

These adaptations are designed to ensure an adequate supply of oxygen and energy to active muscles, allowing optimal physical performance to be maintained in conditions of low oxygen availability. However, it is important to note that hypoxia can also increase the risk of fatigue and muscle injury. Apart from the adaptations related to energy metabolism in the muscle, there are also systematic adaptations in terms of oxygen uptake and transport. For the specific case of hypoxia, the following are highlighted:

- Production of Hemoglobin and Red Blood Cells: Chronic hypoxia stimulates the production of erythropoietin (EPO) in the kidneys. EPO travels to the bone marrow and stimulates the production of more red blood cells (erythropoiesis) and therefore hemoglobin, which increases the oxygen-carrying capacity of the blood. (Friedmann B, Frese F, 2007)This process is known as erythrocyte hypertrophy and helps improve the body's ability to transport oxygen in conditions of low availability of this gas. Hypoxia induces the production of EPO mainly in the kidneys, although it can also be produced in the liver. EPO stimulates erythropoiesis in the bone marrow, resulting in increased red blood cell production. This adaptation is essential to increase oxygen transport to tissues under hypoxic conditions.
- Production of Vascular Growth Factor (VEGF): Hypoxia can also induce the expression of growth factors such as VEGF. VEGF promotes the formation of new blood vessels (angiogenesis) and improves oxygen perfusion to tissues. This adaptation is crucial for increasing oxygen-carrying capacity in tissues and can improve exercise endurance and recovery capacity.

Together, these adaptations are critical to improving the body's ability to cope with conditions of low oxygen availability, such as those experienced during exercise at high altitudes or in hypoxic environments, such as lifting weights in hypoxia. Since they are not long-lasting and constant, these adaptations usually take longer to develop, which is essential to understand why athletes with little training tend to leave aside the training of these systems and therefore one of the reasons behind the experiment design.

The employment respiratory and muscle capacity stress tests are the solution proposed to analyze athletes in conditions as similar as possible to critical points achieved in competition deadlifting, to then run them through a 4-week hybrid training program and then evaluating their cardiorespiratory capacity again as well about their epigenetic individual adaptation to oxygen systemic deprivation. The study will incorporate spirometry (measured of inhaled and exhaled gases) (Adhikari et al., 2017), EMG (Electromyography – muscle activity) as primary measurements, and Blood Lactate level, heart rate monitoring (rate of heart beats per minute) and pulse-oximetry (Blood O_2Sat (mol/mL))(Mahmud & Bashir, 2023) as contrast measurements.

The research framework is substantiated by a compendium of peer-reviewed articles. These studies emphasize the pivotal role of hybrid training in enhancing respiratory efficiency the correlation between aerobic and anaerobic effects on the body during maximal effort and its compatibility as a conjoined mechanism.

Methods

Tools and Measurements:

Equipment	Test	Type of measurement	Variables
Spirometer	Spirometry	Direct	Ventilation (VE – Lt/min)
Pulse-oximeter	O_2Sat monitoring	Control	O_2Sat (mol/mL)
Lactate Acid (LA) Analyzer	LA monitoring	Control	$LA\ Level$ (mol/mL)

Taking into account the information contemplated regarding the physiology of the body's effects on sports wear and tear, an experiment was designed to observe the effects of weight lifting in terms of metabolic capacity. The idea is to subject a test subject for performing deadlifts.

The proposed procedure is as follows:

1. First, you must choose an athlete with an advanced level, who has satisfactory technique, and who is accustomed to moderate levels of fatigue. The criteria for selection were their own, simply judging basic sports skills such as shot put, 20 m sprint, etc; as well as creating a basic profile of who this person is in terms of body measurements, age, gender, height, among others.
2. Once the test subject has been confirmed, he or she must receive and sign a consent form that clearly indicates the tests to which he or she will be subjected and the measurement systems that will be used during them.
3. Logistically, at this point the experiment can begin. It should be noted that in order to improve the overall data and its analysis, a second test subject was sought, who acts as a control, since the data are considered too specific to normalize in the first station.
4. A single test will then be carried out, at two different times, separated by a hybrid training meso-cycle that is believed to induce the aforementioned adaptations in the test subject:

   4.1. Test: The athlete must warm up following his own process, ensuring the least possible intervention so as not to taint the data collection with variables not included, and then prepare to perform a single series of indefinite number of repetitions of deadlift with barbell, in 100% RPE (Rate of perceived effort); while spirometry equipment is connected that will measure gas exchange during these lifts, simulating the "hypoxic" or hyperbaric environment that an athlete undergoes during a maximum attempt. In addition to the measurement of %O2 and %CO2 through spirometry, control measurements will be carried out that will help interpret the gas exchange behavior of the test: 4 measurements of blood lactate and 2 pulse-oximetry measurements.

4.2. As for lactate measurements, they will be spaced out temporally, and totally dependent on the athlete's capacity; The first lactate acid measurement will be done initially before the test as a starting value or artificial zero, then a second measurement will be carried out at the end of a fifth repetition, ensuring a moderate level of fatigue. To continue with a third measure, as the athlete continues lifting until reaching failure, the number of repetitions is solely linked to the athlete's ability; But once it is taken, the next step is to wait for complete rest by sitting for 5 minutes, during the refractory period, to be able to measure the lactate in the blood the last time, and thus see how developed the athlete's physiological capacity is to metabolize waste. which entails the high concentration and use of lactate in the blood.

4.3. Oxygen saturation measurements are less invasive and are only carried out at the beginning of the test, together with the first lactate measurement and at the end of the third lactate measurement, enclosing all the physical effort between the values and observing whether had no effect on the amount of oxygen maintained in the blood, even when the body experienced oxygen deprivation and changes in perfusion pressure.

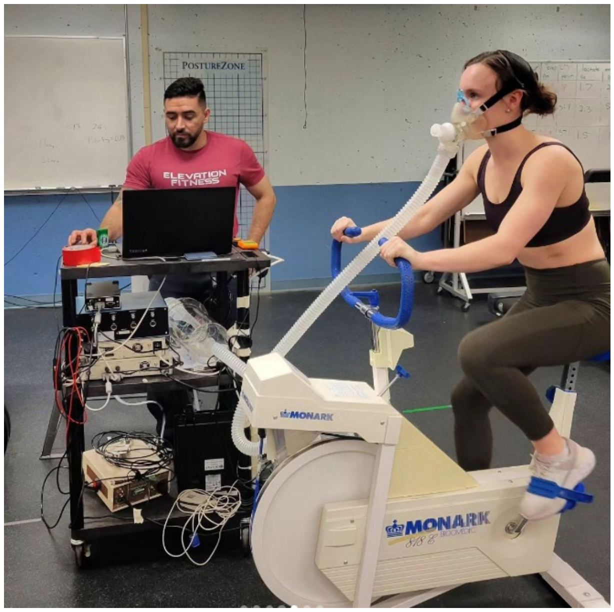
4.4. For each measurement, it will be specified how it should be taken and what steps to follow in the laboratory.

5. Once the rest period or refractory period is over, and the last lactate measurement is taken; the experiment is terminated. The athlete will be able to do his own cool down and stretching, to be able to rest completely.
6. The athlete will then receive from the investigator the program that was designed for the interlude between one test and the other. This program is designed based on the theory of weight lifting meso-cycle programming, with the addition of small components of aerobic conditioning, which is suggested by the researchers, is the factor that will trigger the adaptations that they want to observe in the second test. This program will only be seen and used by the active subject of the tests, the control subject will simply perform the tests, but will continue their weightlifting training in an ordinary way.
7. The program designed by the research team was previously designed to increase difficulty and RPE during a month of training (4 weeks), triggering changes in breathing ability when lifting the bar.
8. Once the training cycle period has elapsed, the second test will be carried out with the same equipment layout used previously, and the same order of samples. It is then expected to have two datasets with similar behavior, which can be compared.

Spirometry measurement (VO 2 max)

Equipment functioning:

Spirometry equipment, used to measure VO2 max, operates by capturing and analyzing respiratory gases during exercise. It uses a system of sensors connected to a face mask while performing physical activity. These sensors detect the composition of respiratory gases, including oxygen (O2) and carbon dioxide (CO2).



The process begins when the subject breathes through the mask or mouthpiece, inhaling oxygen and exhaling carbon dioxide, along with other gases. The equipment's sensors continuously record the concentration of O2 and CO2 with each breath.

This data is sent to analysis software, such as LabChart, which records and graphs O2 and CO2 values over time. The software can automatically calculate the respiratory quotient (RQ), which is the ratio between the amount of CO2 produced and the amount of O2 consumed. But for the purposes of this experiment, the data was filtered manually.

The spirometry equipment uses a sensor and gas analyzer to measure the levels of oxygen (%O2) and carbon dioxide (%CO2) in the air inhaled and exhaled by the subject during the stress test. The gas analyzer uses infrared spectroscopy principles to detect and quantify the concentration of gases in the air sample.

Subject Preparation:

- Place the subject in a comfortable position to perform the stress test.
- Place the mask connected to the gas analysis system on the subject's face and secure it properly to prevent air leaks.

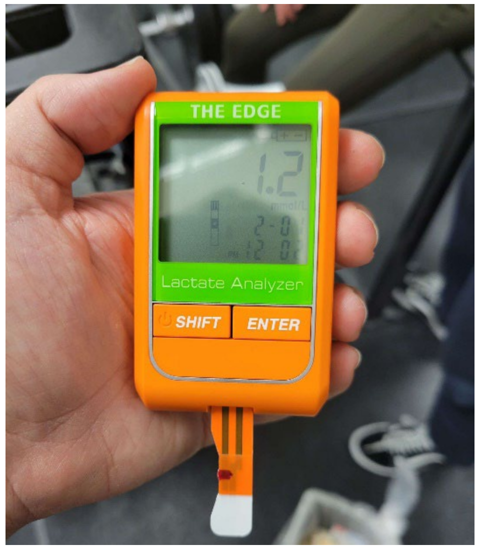
Equipment Calibration:

- Before starting the test, make sure to correctly calibrate the gas analyzer according to the manufacturer's instructions. Either with an injection of atmospheric pressure or with a bag with oxygen at room pressure.
- Calibration ensures accurate and reliable measurements of respiratory gas levels during testing.

Interpretation of results:

After completing the stress test, it analyzes the data recorded in LabChart to calculate physiological parameters, such as oxygen consumption and carbon dioxide production. This way, the results of your analysis are then presented.

Measurement of Blood Lactate Levels (mmol/ml)



Measurement of blood lactate levels is performed using biochemical analysis equipment, such as a lactate analyzer. The process involves taking a blood sample from the subject, usually through a finger stick or vein, and placing it into testing equipment.

The lactate analyzer uses specific methods to measure the concentration of lactate in the blood sample. This may involve enzymatic reactions that produce a color change or an electrical signal proportional to the amount of lactate present. The device automatically calibrates measurements and displays results in units of lactate concentration, such as millimoles per milliliter (mmol/ml) or milligrams per deciliter (mg/dl).

Once the measurement is made, the blood lactate concentration is recorded and used to evaluate the subject's metabolic response during exercise or physical activity. Blood lactate levels can indicate the intensity of the effort exerted and the body's ability to metabolize the lactate produced during exercise. This is especially relevant to evaluate the individual's aerobic and anaerobic capacity, as well as to monitor muscle fatigue and performance during sports training.

Measurement of blood oxygen saturation (%Spo2)

Pulse oximetry is a non-invasive method to measure oxygen saturation in the blood. Pulse oximetry equipment uses a sensor that is placed on a vascularized area of the body, such as the finger, ear, or nose. The sensor emits two types of light through the tissue, red light and infrared light. These lights are absorbed by hemoglobin in the blood, and the sensor detects the amount of light that passes through the tissue.

Pulse oximetry equipment generally does not require calibration as it uses optical principles to measure oxygen saturation in the blood. However, it is important to ensure that the sensor is positioned correctly and that there are no external interferences that could affect the readings.

The value will be a percentage, which indicates the amount of hemoglobin that is bound to oxygen in relation to the total amount of hemoglobin available. A normal resting blood oxygen saturation reading is typically between 95% and 100%. Lower readings may indicate oxygenation problems, such as respiratory distress or hypoxemia. Oxygen saturation readings are interpreted in conjunction with other vital signs and clinical symptoms to evaluate the patient's respiratory status.

Descriptive Approach:

Research methodology involves subjecting participants to both aerobic and anaerobic exercise regimens while meticulously monitoring the physiological responses.

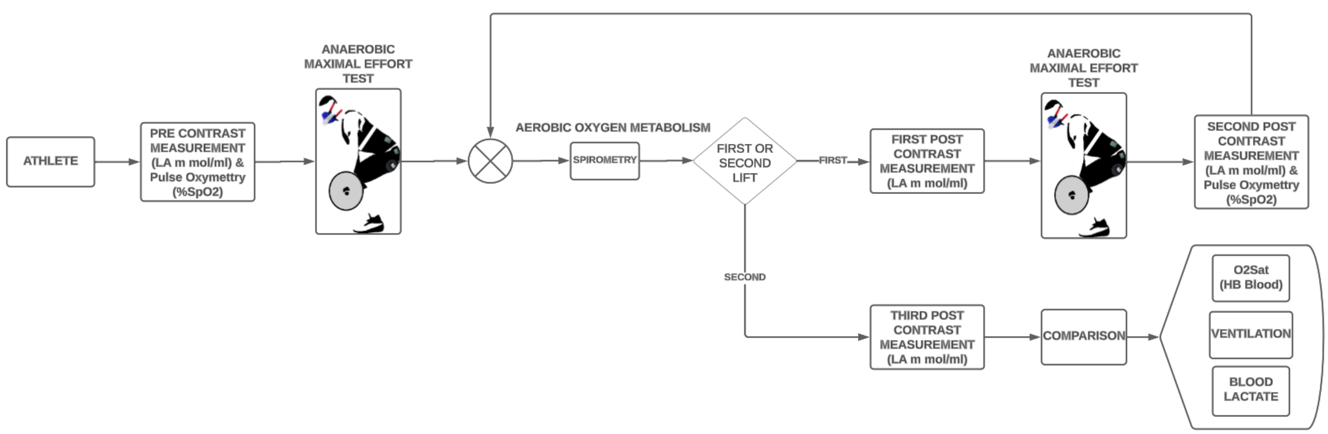
- Warm up: Short warm up an activation complex will be executed by the athlete, this section will be independent so the subject can manage their own RPE (Rate of perceive Effort), and there is not disturbance to their usual routine.

- Anaerobic Test: The athlete will rest completely and recover from the warm up, to then perform the anaerobic effort, which consist in 1 set attempt for reps (repetitions) with 80-90% RM (Maximum Record) Barbell Deadlifts; projected RPE of 10 while holding inhalation with each pull, as described on bracing in advance lifting. Spirometer will be calibrated to atmospheric pressure and set to measure oxygen intake (%O2/%CO2), the athlete will wear the mask during the lift, to register breathing patterns and concentrations through out the fatigue process. This equipment will also be connected to LABCHART studio. In the case of the barbell, once loaded to the resistance needed, athlete will proceed and will undergo an oximetry and lactate measurement prior the test, and posterior to the conclusion of the attempt. The post work test are one at the exact end of the lift and a second delayed by 5 min of refractory period (Rios et al., 2024).

- Timeframe: The main idea was to have 2 testing sessions, to see the adaptation to hypoxic stress over time, an determine if adding conditioning training to elevate respiratory capacity increase performance. One prior to the training protocol and one after, separated by the period of 4 weeks. Also, the athletes will test their basic athletic capacity with control tests before the experiment begins.

- Control tests: By discretion of the investigator, the initial testing will consist of (No data is taken from this section, is just a justification for athlete selection for the test):
  - Vertical static jump (Height)
  - Grip max (Over All Force)
  - Deadlift Max (1 RM)
  - Basic personal measurements (weight, height, age, gender).

Flow diagram



WORKOUT SPREAD			MARCH							
DAYS	SPREAD	EXERCISES	RPE 7		RPE 8		RPE 9		RPE 10	
			W7		W8		W9		W10	
MONDAY	SQUAT LEGS	LOW BAR SQUAT	4	3	3	3	3	3	3	2
		LOW BAR GOOD MORNING	4	3	3	3	3	3	3	2
		DEFICIT DEADLIFT	4	3	3	3	3	3	3	2
		HEX BAR DL	4	3	3	3	3	3	3	2
		GHD EXT	4	10	3	10	3	10	3	10
WEDNESDAY	BENCH UPPER	PAUSE BENCH PRESS	4	3	3	3	3	3	3	2
		BLOCK BENCH PRESS	4	3	3	3	3	3	3	2
		BANDED BENCH PRESS	4	3	3	3	3	3	3	2
		WIDE PRESS	4	3	3	3	3	3	3	2
		WEIGTHED PULL UPS	4	3	3	3	3	3	3	2
		SKULL CRUSHER	4	10	3	10	3	10	3	10
		WRIST EXT/FLEX	4	10	3	10	3	10	3	10
FRIDAY	DEADLIFT LEGS	COMP DEADLIFT	4	3	3	3	3	3	3	2
		HIGH BAR SQUAT	4	3	3	3	3	3	3	2
		SUMO SQUAT	4	3	3	3	3	3	3	2
		RDL	4	3	3	3	3	3	3	2
		PULL DOWN	4	10	3	10	3	10	3	10
		SEATED GM	4	10	3	10	3	10	3	10
SUNDAY	ENDURANCE (OPEN)									
LOADING			S	60	S	64	S	72	S	80
			B	45	B	48	B	54	B	60
			D	60	D	64	D	72	D	80

ATHLETIC DATA		
CURRENT LIFTS - APRIL 2024		
LIFT	KG	LBS
S	80	176
B	60	132
D	80	176
TL	220	485

This is proposed program, but the actual constriction of it varies within the athlete, this cycle of power output and hybrid training might not be efficiency within repetition of this experiment protocol.

Results

After performing the experiment with one test subject and one control, following data was summarized and analyzed:

Basic Measurements (ATHLETES PROFILE)

BASIC PROFILE		
NAME	ANDREA FEERE (A1)	ALEJANDRA (C1)
AGE	29	22
HEIGHT	1.65cm	1.67cm
WEIGTH	63kg	61 kg
GENDER	FEMALE	FEMALE
ATHLETIC PROFILE		
VERTICAL JUMP	45cm	40cm
GRIP STRENGTH	37kg~	40kg~
DEADLIFT MAX	95kg	100kg

This profile suffices as prove of advance level in WeigthLifting training; more than enough to take the test and excel at it. Both subjects have outstanding values that increases the chances of seeing better development of the exercise during the test, better struggle and fatigue to performance ratio aswell.

Next, is the general description of the experiment graphic. This conglomerate of data is shown for the way the tendency line by mean regression, highlight the behavior of RQ (Respiratory Quotient).

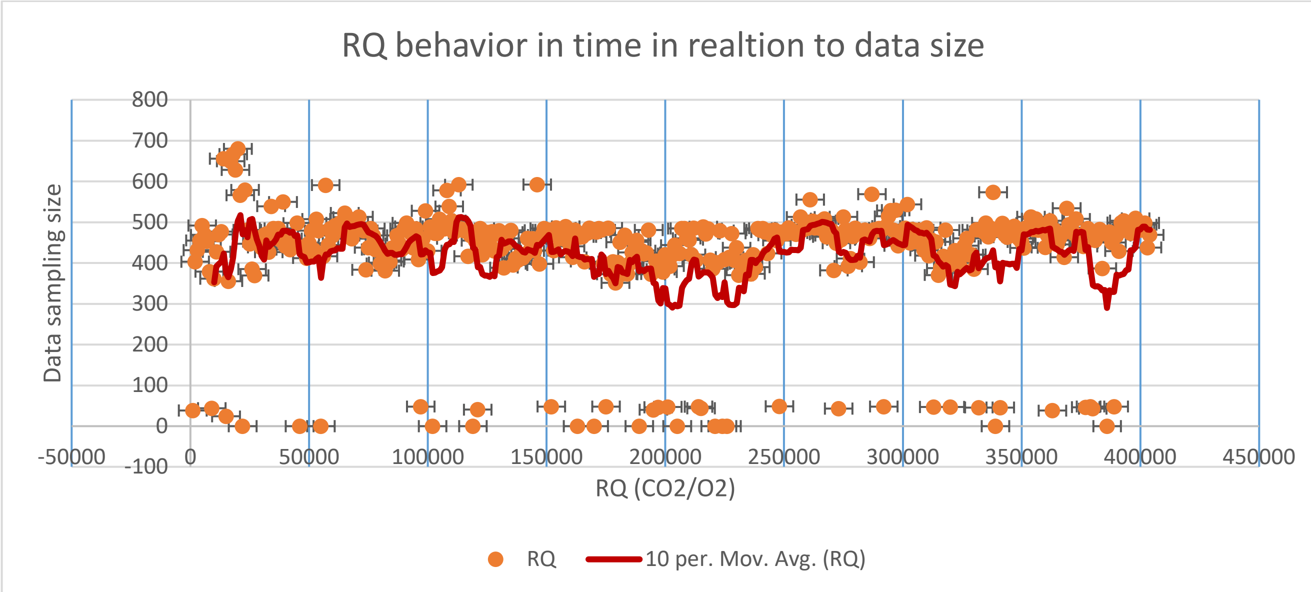
The Respiratory Quotient (RQ) is a fundamental physiological parameter used to assess the type of fuel being metabolized for energy production within the body. It reflects the ratio of carbon dioxide (CO_2) produced to oxygen (O_2) consumed during metabolism, providing insights into the metabolic pathways and substrates utilized by cells.

The RQ is calculated by dividing the volume or percentage of CO_2 produced (VCO_2/%CO_2) by the volume of O_2 consumed (VO_2/%O_2) over a specific period, typically measured in liters per minute. This ratio indicates the relative proportions of different macronutrients (carbohydrates, fats, and proteins) being oxidized to meet energy demands. Understanding RQ values is crucial for assessing metabolic efficiency and substrate utilization during various physiological states, such as rest, exercise, fasting, or feeding. Here's a breakdown of RQ interpretations:

Interpretation:

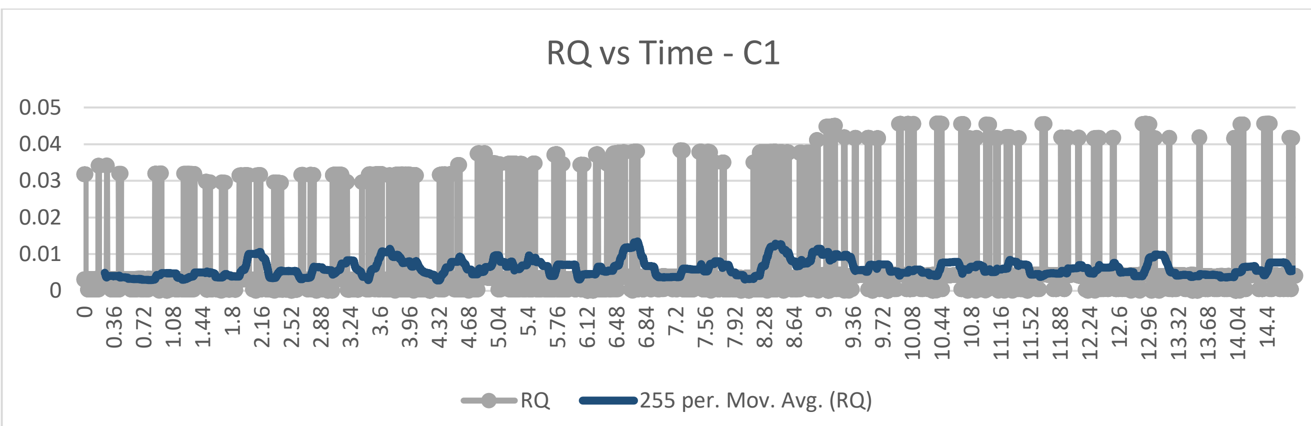
- RQ < 0.7: This indicates a predominance of fat metabolism, suggesting that fatty acids are the primary fuel source. This scenario often occurs during prolonged fasting or low-intensity aerobic activities when the body relies on stored fat for energy.
- RQ ≈ 0.8: This value suggests a mixed fuel utilization, where both fats and carbohydrates are being oxidized. It's commonly observed during moderate-intensity exercise or in the post-absorptive state.
- RQ ≈ 1.0: An RQ close to 1 indicates predominant carbohydrate metabolism, with glucose being the primary fuel source. This occurs during high-intensity exercise or when the body is relying on readily available glucose stores for energy.
- RQ > 1.0: While rare during normal physiological conditions, an RQ greater than 1 suggests non-carbohydrate substrates, such as proteins, are being metabolized for energy. This may occur during extreme metabolic states or in certain disease conditions.

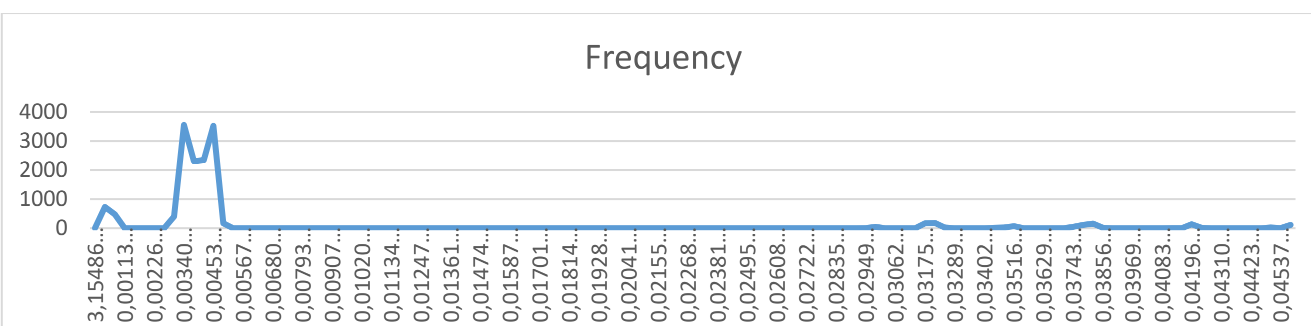
In the case of the study, the RQ is interpreted by percentages, so unscaled RQ values may offer insights into the variability and sensitivity of the measurements, particularly if there are fluctuations or trends in the data that could be obscured by scaling. Analyzing the raw values, allows to identify patterns or outliers that might be relevant and it also provides flexibility for future analyses or alternative interpretations. Researchers with different analytical preferences or hypotheses may prefer to work with raw data to apply their own scaling methods or algorithms.



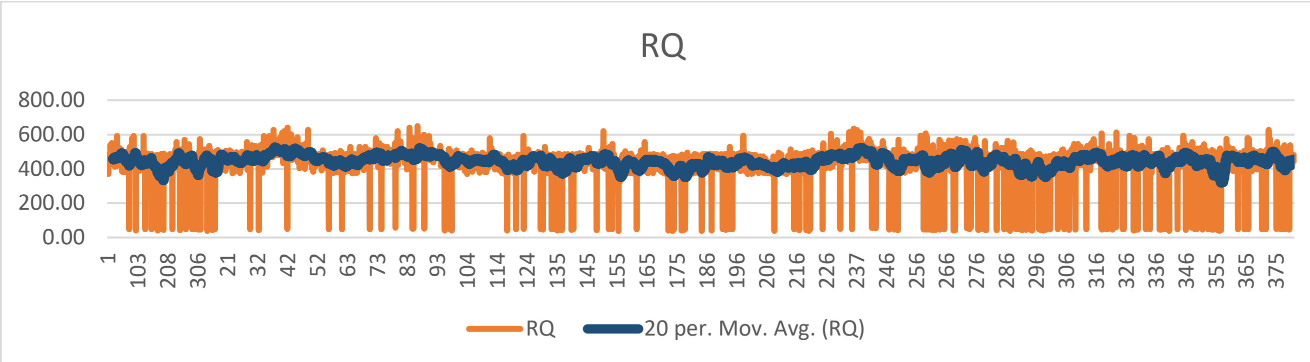
The constitutes an unfiltered version of the data collection, for a full attempt of maximum amount of reps, as with the RQ, the data is not scale to allow for better visualization and analysis. The graph is showing both A1 and C1 second test in time, using the same load. Although the data is raw, the sampling rate was adjusted to create a visible graph, change from 0.0001 s to 1 s. Due to the size of the dataset, the mean tendency line was done by 10.

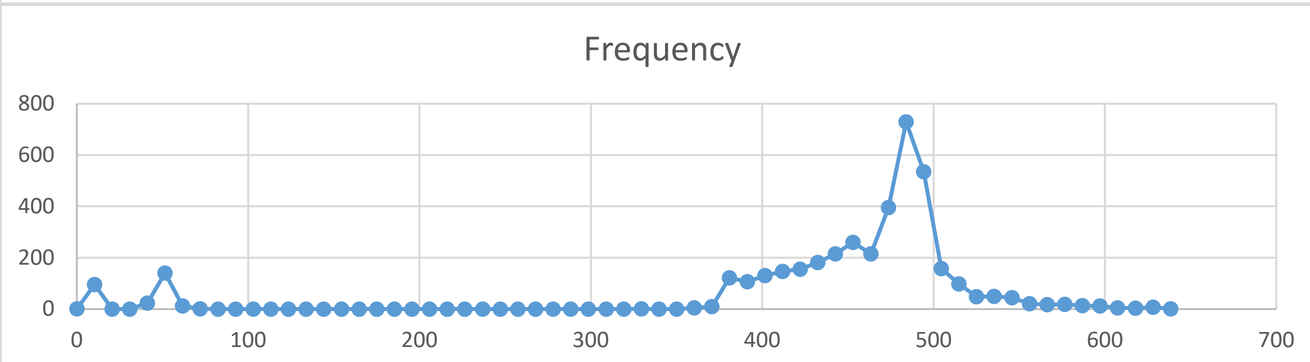
The filter as discuss was a frequency histogram, so the dispersion of the data was settle by the mean and mode, as well as the tendency line, that describes the signal's behavior by an adjustment of the mean values by 255 (max value for filter). Below, the filtered version of both test, using histogram to filter in the frequency domain to display RQ vs Time for C1.



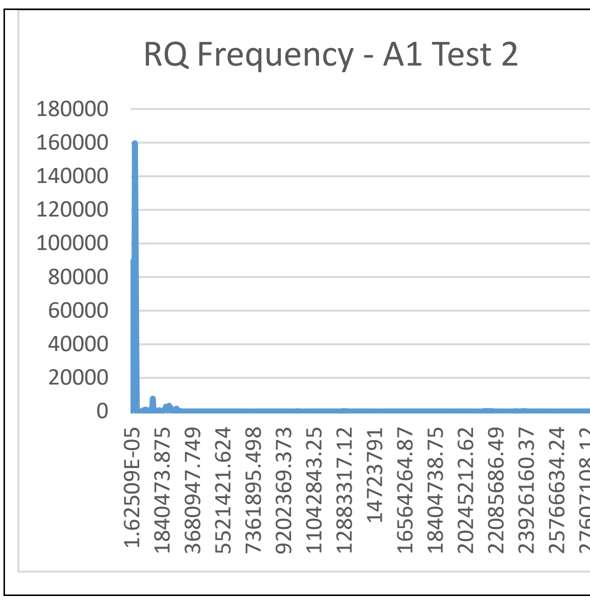


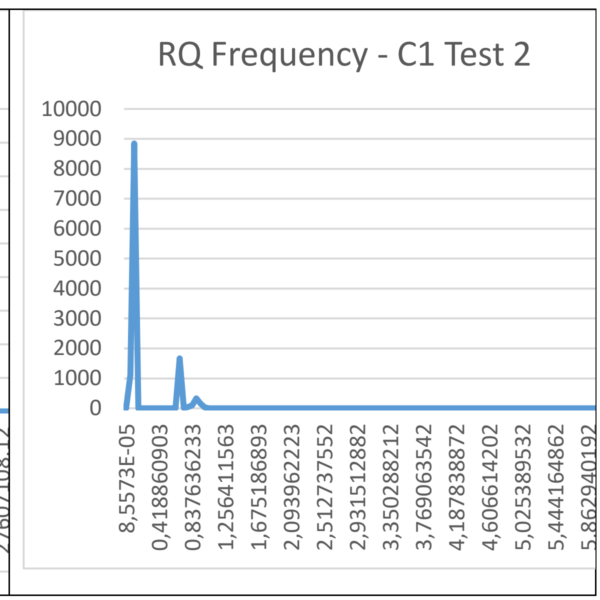
Following, is the filtered version of both test, using histogram to filter in the frequency domain to display RQ vs Time for A1.

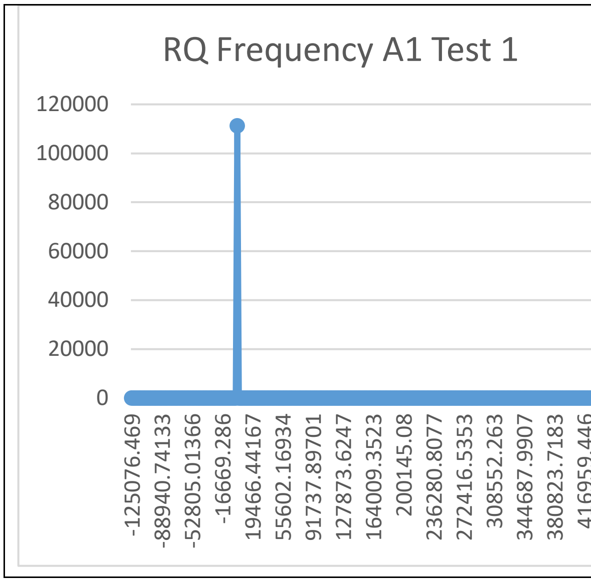


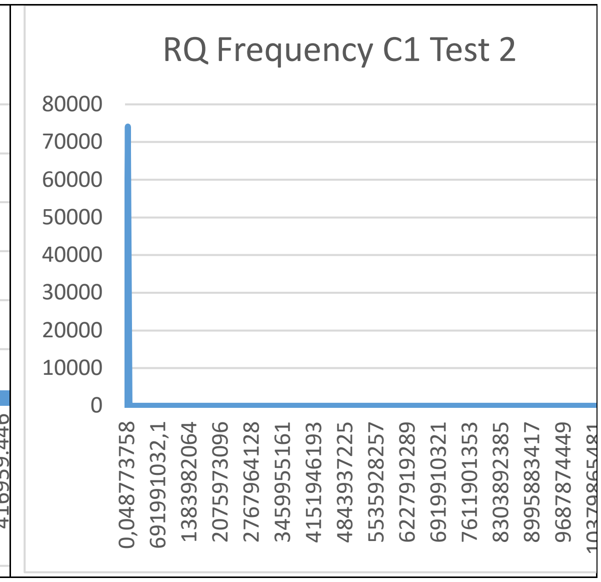


Same filter with the histogram data analysis tool was used but for individual tests, all in terms of frequency and data gathering (class).





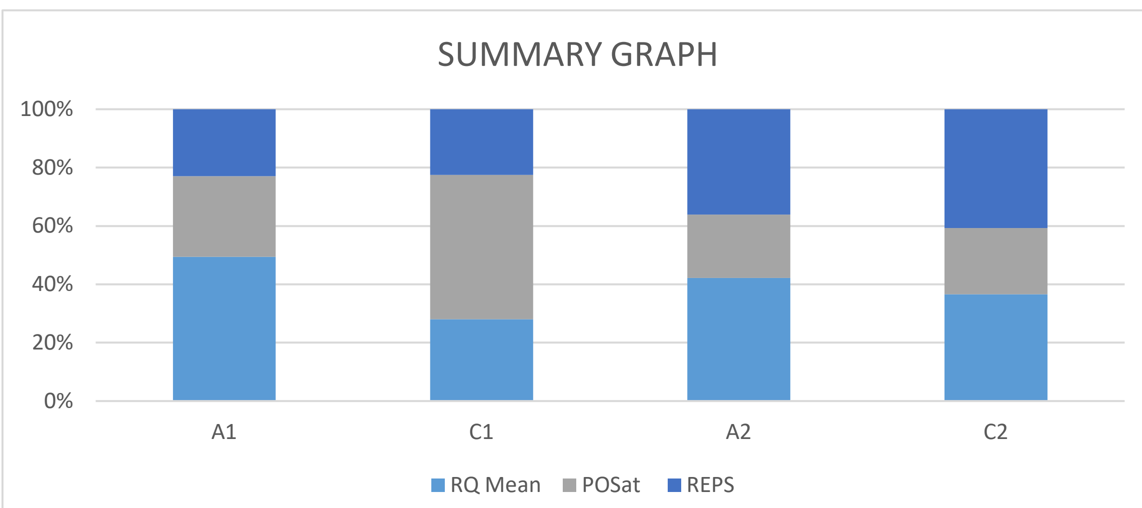




This table shows the comparison between first and second test for both A1 and C1. The data is unscaled as well, but it is filtered by histotrophic tool too.

Extrapolating the most relevant data form the entire data collection, the next table summarizes the data points that mark the behavior of the oxygen metabolism and interchange during the lifts.

SUBJECT		RQ Mean	Δ PO2Sat	V Lactate $\left[\frac{L3-L2}{\Delta t}\right]$	REPS	LOAD
TEST 1	A1	15696	~2	0.05 mmol/lt/s	11	80 kg
	C1	8847	~3	0.043 mmol/lt/s	18	84 kg
TEST 2	A1	111157	~1	0.073 mmol/lt/s	14	84 kg
	C1	74111	~4	0.046 mmol/lt/s	15	84 kg



Last graph shows how the data points relate in change in percentage, with the tendencies of improvement depending on the size of the box.

Discussion

All the graphs were surrounding on value and was RQ, the main variable in relation with the oxygen consumption or lack dependency on it. Following the trend, the first problem found on the signals is the consistency of the values, not the error marginal points that scattered around but the central tendencies close to the mean line. All those values were in general terms very constant, even with the difficulty increase, the RQ was not affected greatly, this suppose an issue against the hypothesis, because it was thought possible that aerobic studies could be directed to weightlifting and strength training more dependently than is based on now. But it is confirming that the values are very close, and the biggest changes are not seen within data point, moments in time specific, but in trends; like seen after filtering the frequencies.

After filtering the data, it was clear the frequency domain was the best way to analyze de data. Based on the first graphic of comparison of the full signal, the frequencies shown clustering close to the beginning, which indicates that both athletes have a tendency to follow the right brazing technique, with big inhalation toward the start of the lift and holding of breath for as many reps as possible to maximize speed and power output. Breathing again will be beneficial in fatigue, but it will not help the prompt movement yet to be realize

Another tendency that created issue was the PO2 saturation, because as seen on the constant attempts, there was not negative change whatsoever. Instead a slight increase in the athlete's capacities to gather oxygen which makes complete sense, due to the body being able to react to the environment and correct in multiples ways with homeostasis.

Lactate is the last variable that was taken, although multiple measurements were made the most relevant were the changes between sample 2 and 3, where real fatigue settled in and the RQ showed how dependable the system was on creatine phosphate and glucose for the most of the test, leaving less room to see how the oxygen could maybe interact better in greater levels of stress.

Conclusion

Aerobic measurement remains most likely to be used for efforts that mostly rely on them to last long terms of time as is expected, but the overall analysis did allow to grasp small improvements in the overall performance thanks to hybrid training, moving forward, the projects next step is to use a longer period of time for the training cycle, as well as weekly data intakes, more data could bring light to tendencies lost mostly in the filtering due to lack of repetition.

Some other variable from spirometry like the volumes of air of the rate of respiration should also be included, seems according the RQ's behavior that CO2 builds up exponentially after the first 20 seconds almost, which should be better explain in relation of the lactate with the actual volumes of CO2 exhaled.

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