

## **APPROVAL OF HONORS PROGRAM SENIOR PROJECT**

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### **Project Title**

*Starters Versus Non-Starters: Countermovement Jump Derived Neuromuscular Performance in Female Collegiate Volleyball Players*

**This Senior Project is approved as acceptable**

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Starters Versus Non-Starters: Countermovement Jump Derived Neuromuscular Performance in  
Female Collegiate Volleyball Players

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**ABSTRACT**

**BACKGROUND:** Several studies from our laboratory demonstrated that NCAA Division III soccer players underperform anaerobically at the beginning of the playing season. Further examination of the data shows a large variability in performance measures between players. Such data has not been examined in NCAA Division III women's volleyball players. Therefore, this study aimed to utilize countermovement jump (CMJ) to provide insight into neuromuscular function and to compare starters and non-starters' performance. **METHODS:** Seventeen NCAA Division III women's volleyball team members (mean  $\pm$  SD; age =  $19.0 \pm 0.4$  years) volunteered to participate in this study. CMJ neuromuscular performance testing included jump height, peak eccentric and concentric force, peak eccentric and concentric power, and eccentric and concentric impulse. All performance testing occurred before the start of the regular season. The athletes were divided into starters (S) and non-starters (NS). **RESULTS:** Participants height (S:  $1.73 \pm 0.84$ ; NS:  $1.68 \pm 0.73$  m), weight (S:  $71.31 \pm 16.84$ ; NS:  $70.40 \pm 9.65$  kg), BMI (S:  $23.85 \pm 5.80$ ; NS:  $24.91 \pm 3.59$  kg·m<sup>2</sup>), CMJ height (S:  $28.28 \pm 5.36$ ; NS:  $27.10 \pm 5.24$  cm), peak eccentric force (S:  $21.98 \pm 2.32$ ; NS:  $22.50 \pm 2.10$  N·kg<sup>-1</sup>) peak concentric force (S:  $22.12 \pm 2.01$ ; NS:  $22.43 \pm 3.25$  N·kg<sup>-1</sup>), peak eccentric power (S:  $15.61 \pm 4.57$ ; NS:  $15.54 \pm 4.12$  W·kg<sup>-1</sup>) peak concentric power (S:  $44.36 \pm 5.46$ ; NS:  $43.17 \pm 7.04$  W·kg<sup>-1</sup>), eccentric impulse (S:  $204.36 \pm 71.67$ ; NS:  $201.05 \pm 37.47$  Ns) and concentric impulse (S:  $367.74 \pm 92.30$ ; NS:  $371.66 \pm 63.50$  Ns) were not significantly different ( $p > 0.05$ ) between S and NS, and displayed medium, medium, small, small, trivial, trivial, trivial, trivial, small and small effect sizes ( $d$ ), respectively, and between the groups. **CONCLUSIONS:** The study's results suggest that differentiating between starters and non-starters is not attributed to jump performance, but more likely to other factors such as sport specific skill, communication, and teamwork.

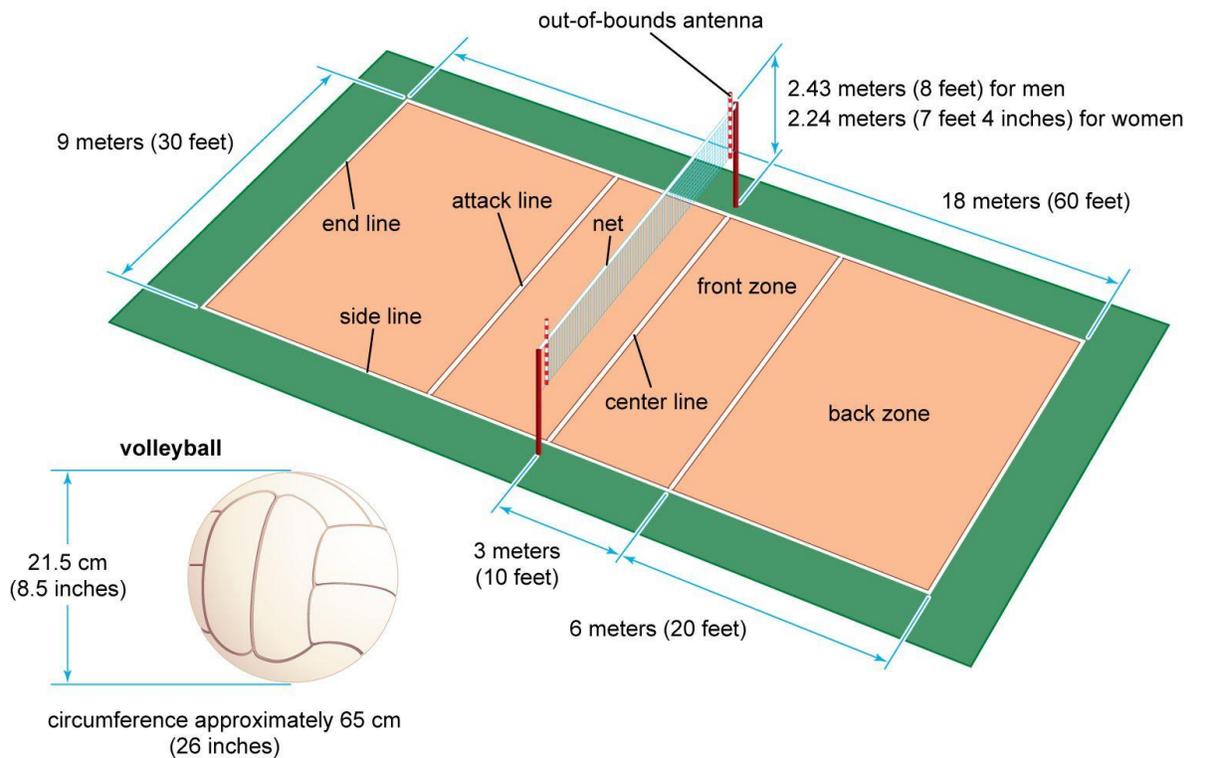
## INTRODUCTION

Volleyball is a fast-paced sport played primarily in the anaerobic energy systems (Akarçesme et al., 2022). While volleyball is a common collegiate sport for both males and females, little research has been conducted on the anaerobic performance of collegiate female volleyball players at the NCAA Division III level. For any primarily anaerobic athlete, force plates can be utilized to measure anaerobic components such as eccentric and concentric power, force, and impulse. Force plates can also be utilized to show any deficiencies an athlete may possess. There are many tests that can be conducted on force plates, however the test conducted in this study was the countermovement jump test (CMJ). The CMJ is a maximal anaerobic test that requires the athlete to perform a countermovement before jumping as high as they can. The athletes were put into two groups, starters and non-starters. When determining the categories of starters and non-starters, we utilized the athlete's usage percentages which for the starter group; were around 80% usage. With the data from the CMJ test, the primary goal was to identify the differences in neuromuscular performance between starters and non-starters.

## VOLLEYBALL

Volleyball is a sport that involves many different aspects of movement. It contains a unique blend of sprinting, jumping, lateral movement, diving, and arm movements such as extension, flexion, internal and external rotation, pronation and supination. Volleyball is played by both males and females. As mentioned in the introduction, collegiate female volleyball players will be the focus of this study. The main difference between men's and women's volleyball is the net height; for men the net height is 2.43m tall, while for women, the net is 2.24m. The court dimensions remain the same regardless of sex (USA Volleyball, 2021).

### Volleyball court



**Figure 1.** Volleyball court dimensions (Encyclopædia Britannica, 2024)

In a volleyball match, each “game” is played until one team scores 25 points; however, for a team to win the game, they must have two more points than the opponent. Therefore, if the score is 25-24, the team must score again to win the game. Each match is the best of five games,

meaning you must win three games to win the match. If both teams win two games through the first four sets, then the fifth set is played to 15 instead of 25 but the winning team still must win by two. Each point begins with a serve, which leads to a rally; the objective is to get the ball to touch the opposing teams' floor within the boundaries of the court. To do this, volleyball players mostly utilize a "spike," which involves a player jumping above the net and hitting the ball downwards with force. This movement takes ample practice to perfect as the upper and lower halves of the body must be working in unison. Rotational sequences are key in generating optimal power for a spike. Rotation of different joints simultaneously has been found to be the least effective rotational pattern. A 2024 study by Barrett et al., looking into the biomechanics and rotational patterning of volleyball spikes by using variables x, y, and z to describe different joints. They found that an x, y, and x rotational pattern is very effective for generating maximum power. However, an x, y, z rotational pattern is also effective. An example of a y, x, y would be y is the shoulder, rotating externally, x is the torso rotating, and y is the shoulder internally rotating. x, y, and z rotations would be three different joints rotating at different times (Barrett, 2024).

	Z		X		Y	
	Min	Max	Min	Max	Min	Max
XYZ	-37.47	152.99	-150.58	28.07	-89.56	67.62
YXY*	-107.14	138.60	-152.70	9.87	-107.04	53.53
XZY	-37.23	89.35	-399.76	414.34	-361.73	470.20
ZYX	-351.89	461.37	-374.78	398.89	-17.30	87.36
ZXY	-44.13	229.61	-84.65	40.83	-19.19	199.85
YXZ	-353.77	416.42	-87.02	15.57	-353.36	445.28

**Figure 2.** Rotational sequence calculated shoulder angles in degrees from “Rotation Sequences for the Calculation of Shoulder Kinematics of the Volleyball Attack” (Barrett, 2024)

A spike is not the only way to score; sometimes a player will utilize a “set,” which is mostly used to set up a spike but can also be used to get the ball over the net and score. The most common strategy to defend is called a “dig”, which involves a player diving or squatting to hit the ball back up into the air. This move requires quick reaction times as spikes are hit at high velocities from very short distances; in fact, a study found when looking at ball-to-hand contact forces in female collegiate volleyball players, that the velocities of spikes ranged from 8.6 m/s – 18.2 m/s (Howard et al., 2023).

The positions played in volleyball are outside hitter, right-side hitter, opposite hitter, setter, middle blocker, and libero. However, players often perform other actions than what is asked of their position, such as hitters are the players performing spikes; however, they might be asked to block or dig when the opposing team spikes. Because of this versatility, players must be very durable and in peak athletic shape to perform at their best. However, injuries still occur despite collegiate volleyball players being in peak athletic fitness. The most impacted body areas for volleyball players include the ankle, knee, and shoulder. Quick cuts and constant impact from jumping on a hard surface put the knee and ankle at increased risk of injury; in contrast, constant internal and external rotation of the shoulder during spikes makes the shoulder more vulnerable. There are other factors, in female athletes, which could also impact performance and/or injury in volleyball and other sports. One such factor is the female athlete triad. The female athlete triad consists of three factors: bone density, menstrual function, and low energy availability. Each of these factors increases risk of dysfunction or injury for females playing sports, along with the larger female Q angle of the knee and hip. The female athlete triad and larger Q angle contribute to the increased risk of knee injuries, especially ACL injuries; along with many other musculoskeletal injuries generally impacting the lower body (Young et al., 2023).

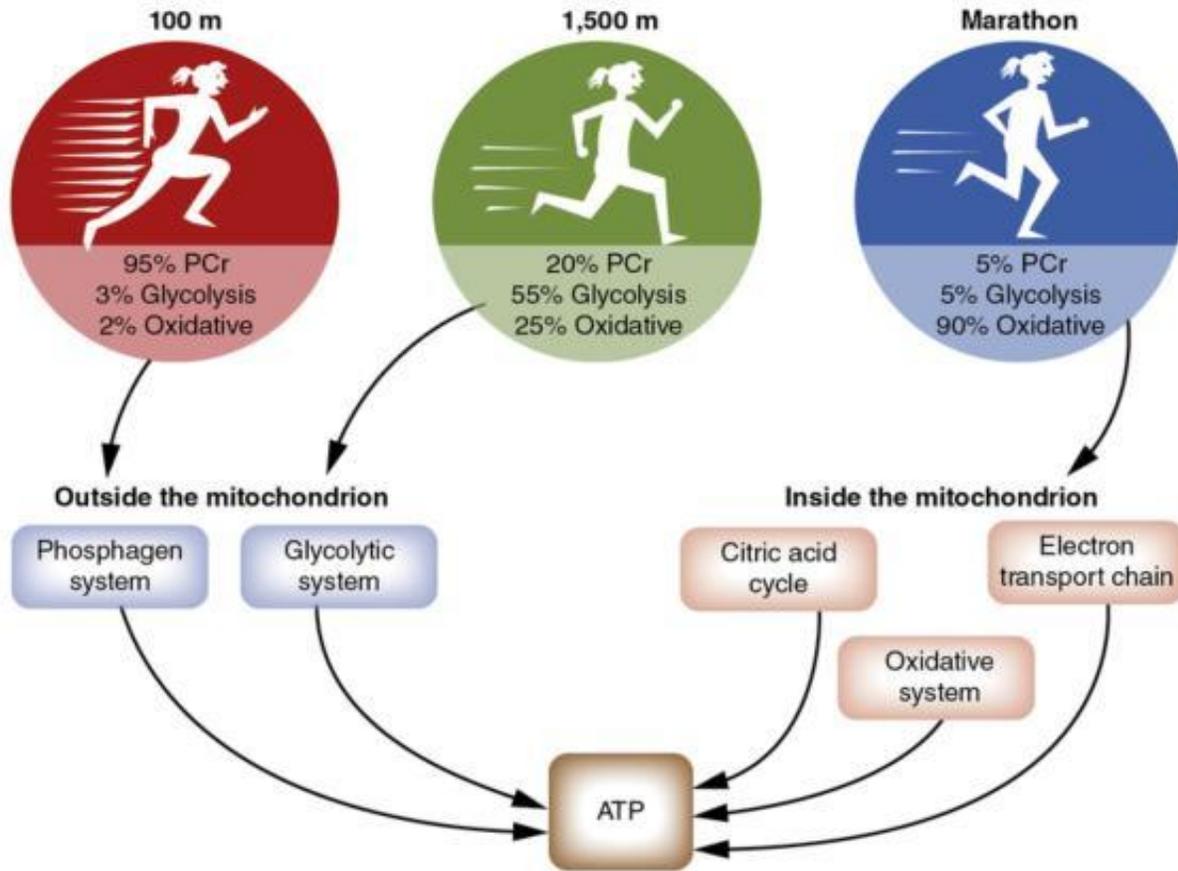
Volleyball players utilize both anaerobic and aerobic energy systems; however, they are primarily anaerobic athletes. In a volleyball match, a player makes quick cuts and sprints constantly around the court. These actions are supplied by the adenosine triphosphate-phosphocreatine (ATP-PCr) system, but the glycolytic system supplies the continuation of these movements. Movements like jumping, spiking, and diving, which are often not done in rapid succession are supplied by the ATP-PCr system. Despite the main actions of volleyball being

supplied by the ATP-PCr system, the sport itself is primarily played in the glycolytic system. Rapid successions of these movements require glycogen as the fuel source rather than phosphate. Glycogen is the primary fuel source gathered from food and is the body's preferred fuel source. The utilization of the aerobic system comes from the duration of a volleyball match. Matches can have very long durations in which the aerobic system would start to contribute to energy output. Ideally, a volleyball player does not want to utilize the aerobic system, as anaerobic power is critical to the game of volleyball (Akarçesme et al., 2022).

## ENERGY SYSTEMS

The energy systems of the body are what produce ATP which is the fuel for the human body and all movements. There is not one uniform method for the body producing ATP; rather, usages of different substrates, durations, and by-products keep ATP generation continuous regardless of what is asked of the body. Even the simplest of movements require energy as every movement is a muscular contraction. During a muscular contraction, ATP is converted to adenosine diphosphate (ADP) with the assistance of an enzyme ATPase, which is combined with phosphate and energy to result in a muscular contraction (Magida, 2017).

The body's energy systems are broken up into two categories, anaerobic and aerobic. The anaerobic energy system consists of two different systems: the ATP-PCr and glycolytic systems. The ATP-PCr, also referred to as the phosphagen system, is what supplies the body with ATP during short duration bouts lasting a maximum of around 10 seconds. In sudden movements such as cutting or sprinting, the body will utilize the ATP-PCr system to perform those movements. The glycolytic system is also utilized during short, explosive movements but sustains the body with energy for longer durations, typically 1 minute but it can be around 3 to 4 minutes. The aerobic energy system is only one system, the oxidative system. The oxidative system uses oxygen to convert ADP into ATP. Still this process is very slow, which is why the oxidative system is a very slow-acting system and is utilized during long bouts of exercise. However, it will supply the body with energy for far longer than either anaerobic system (Baker et al., 2010).



**Figure 3.** General energy system contribution during a 100m sprint, 1,500m run, and a 42.2km marathon (Magida, 2017).

## ATP-PCr System

Phosphocreatine was discovered in muscular tissue in 1927; however, it wasn't until 1962 that researchers found how it was utilized in the body. (Guimarães-Ferreira, 2014).

Phosphocreatine is stored in muscular tissue but isn't utilized until an enzyme called creatine kinase turns phosphocreatine into creatine which is now known to be a large contributor to muscular growth, but in the ATP-PCr system creatine is also utilized in the production of ATP.



**Formula 1.** Conversion of phosphocreatine and ADP into creatine and ATP (Guimarães-Ferreira, 2014).

Because of the rapid production of ATP, the ATP-PCr system is critical for homeostasis. While very little ATP is produced per cycle, the cycle is rapid so for those quick bursts utilizing the ATP-PCr system, ATP will constantly be supplied to the muscles for contractions. The most common example of the usage of the ATP-PCr system is sprinting. In a sprint, the initial explosive takeoff to begin the sprint is supplied by stored ATP in the body. Still, as the sprint duration continues for only just a few seconds, the ATP-PCr system will begin the breakdown of phosphocreatine to replenish the utilized ATP from the initial takeoff (Guimarães-Ferreira, 2017).

## Glycolytic System

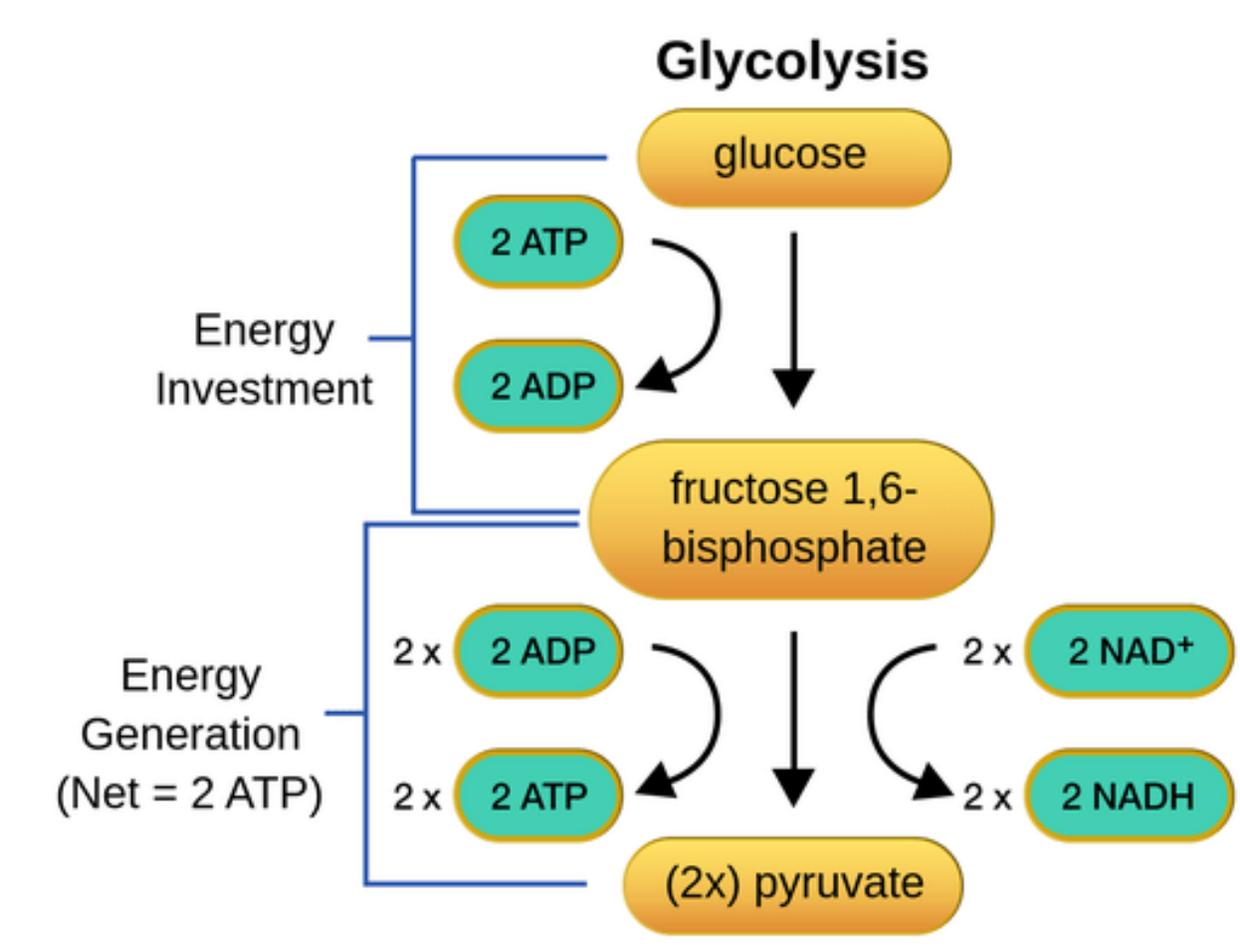
Similarly to the ATP-PCr system, the glycolytic system provides the body ATP during shorter duration movements. However, the process of generating ATP is completely different during utilization of the glycolytic system. The production of ATP comes from a metabolic pathway known as glycolysis, this process begins with a rather simple substance, glucose.

Glucose is also known as blood sugar and is the body's preferred fuel source. Stored glucose is

known as glycogen, and this is what the body uses for fuel. Breakdown of glycogen begins the glycolytic cycle, which can be described in two phases: the investment phase and payoff phase (Chaudhry, 2023). During the investment phase, the glucose molecules have an added phosphagen group, which forms the molecule glucose-6 phosphate. The glucose-6 phosphate molecule then has another phosphagen group added to it by way of the enzyme phosphofructokinase (PFK). This turns the glucose molecule into fructose-6 phosphate. The fructose-6 phosphate molecule then undergoes lysis and splits into two cells which are within equilibrium. After the lysis of the molecules, the payoff phase begins. The enzyme glyceraldehyde-3-phosphate dehydrogenase metabolizes the two molecules, and generates one ATP from each molecule, along with one pyruvate. The ATP generated is used as energy, while the pyruvate is stored away and utilized when needed (Chaudhry, 2023).



**Formula 2.** Equation of the glycolytic pathway.



**Figure 4.** Basic diagram of the glycolytic pathway. Adapted from

<https://www.biologyonline.com/dictionary/glycolysis>.

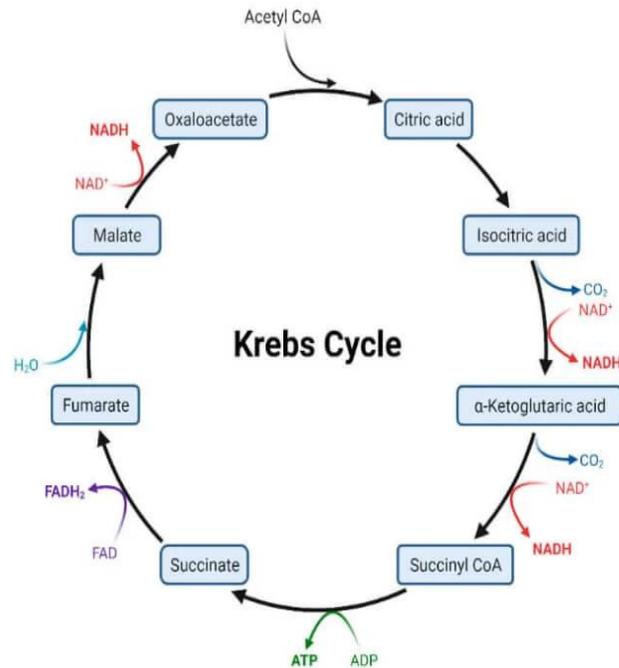
Pyruvate is utilized in the oxidative system but also has a function within glycolysis. If there is excess pyruvate after the glycolytic cycle, the pyruvate will be converted to lactate via the enzyme lactate dehydrogenase. When hydrogen ions are combined with lactate; lactic acid is formed. Thought to be a detriment to muscular health, lactic acid has been found to be benign at rest as it exits the body quickly via the filtration through the liver and kidneys. However, lactic acid can cause damage to the muscle fibers if build-up continues during energy output. When pyruvate is converted into lactic acid, this occurs because there is no oxygen available to begin ATP production from pyruvate. This prevents oxidative phosphorylation from occurring in the

mitochondria, rather the pyruvate stays in the cytoplasm which is ultimately where lactate is formed (Comana, 2016).

The glycolytic system is used in most anaerobic sports and higher intensity activities. While the ATP-PCr system is still often used, the glycolytic system generates most of the bodies energy anaerobically. A good way to distinguish between the ATP-PCr system and the glycolytic system in lay terms would be to look at the glycolytic system as reinforcement for the ATP-PCr system. An example could be an individual doing deadlifts. The first rep they do will likely be easy and won't put much strain on the body. Therefore, they will not be utilizing much energy; same with second rep, likely won't be too much strain on the body so, the ATP-PCr system will produce enough energy to suffice. However, once rep number 5 comes around, the strain on the body will increase significantly. Therefore, the body will need more energy to perform the deadlift, supplied through the glycolytic system (Chaudhry, 2023).

### **Oxidative System**

The oxidative system is the only aerobic energy system in the body; the name oxidative means that oxygen will be utilized. Unlike the anaerobic energy systems, the oxidative system produces ATP very slowly but ultimately produces the most out of one cycle. The oxidative system utilizes one of the products of glycolysis, pyruvate, to begin its cycle. Pyruvate is oxidized and converted into the enzyme acetyl-CoA, which enters what is known as the Krebs Cycle. The Krebs Cycle utilizes eight different compounds and molecules to generate ATP. This cycle is very slow but is worth the process for the payout of ATP (Irene, 2022).



**Figure 5.** Diagram of Krebs Cycle. Adapted from

<https://scienceinfo.com/krebs-cycle-reactions-steps/>

Unlike the anaerobic energy systems, all three macronutrients: carbohydrates, lipids, and proteins, are utilized. Carbohydrates are stored as glycogen which is the primary and preferred energy source of the body. But by the time the oxidative system is utilized, if glycogen stores have been depleted and there is an insufficient amount of pyruvate, energy production from fat is next in line. The body does not prefer to utilize fats and proteins as energy sources because fat takes a long time to metabolize, and proteins are used to build muscle fibers rather than supply energy for contractions. However, if the body has no other option, it will utilize these macronutrients. For fat, the body utilizes beta-oxidation to convert stored triglycerides into free fatty acids, which, when oxidized become Acetal CoA and thus begin the Krebs cycle. For protein, a process known as deamination involves removing a nitrogen group and the carbon

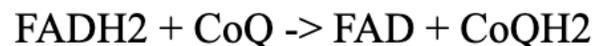
from an amino acid which allows this form of the protein to begin the Krebs cycle (Dunford, 2015).

The electron transport chain (ETC) is the last step in energy production for the oxidative system. The overall goal of the ETC is to generate the amount of energy needed for an action. This occurs within the following proteins: Complex I, Complex II, Complex III, and Complex IV. Complex I begins with the NADH molecule created during glycolysis. The NADH molecule acts as an electron acceptor and gains hydrogen ions allowing the NADH molecule to enter the intermembrane space. Complex I is where cells will decide if they need to conduct apoptosis or programmed cell death, because once the cell has crossed into intermembrane space, it must complete the cycle (Ahmad, 2023).



**Formula 3.** Chemical equation for complex I (Ahmad, 2023).

Complex II will not cross electrons through the cell membrane; rather, the NADH molecule accepts two more electrons within the intermembrane space and prepares to be transported by coenzyme Q which is the carrier protein for complex II.



**Formula 4.** Addition of electrons and coenzyme Q (Ahmad, 2023).

Complex III begins with cytochrome c and b proteins, which take the molecule and allows for the addition of another electron. Cytochrome proteins can only accept one electron at a time so therefore this process is referred to as the Q-cycle which is a two-step process that

allows for not only an electron to be accepted but also allows protons to be released into the membrane.

Complex IV is the end of the chain and starts with cytochrome c being oxidated and transferring the electrons to the oxygen molecule. The oxygen molecule is now ready for ATP synthase which some call Complex V; others refer to it as ATP synthase. During the ATP synthase, hydrogen bonds with the oxygen molecule and forms water, however, shortly after, every four hydrogen ions are used to produce one ATP. In lay terms, the ETC involves a molecule of NADH donating and receiving electrons to allow it to travel across the cell membrane, ultimately leading to ATP production once oxidized (Ahmad, 2023).

The oxidative system will be used only for aerobic activities such as jogging, running, or swimming. The oxidative system will often utilize fat to produce energy. This is why people who want to lose body fat will often utilize aerobic exercise, which will burn fat more than the anaerobic energy systems. Distance runners and swimmers will be the athletes that mainly use the oxidative system. However, depending on duration, basketball, football, volleyball and other primarily anaerobic sports can also tap into the oxidative system. The significant difference between the anaerobic systems, and the oxidative system is there is little production of power coming from the oxidative system. Powerful muscular contractions occur very quickly, and the muscle only has so many contractions consistently before it fatigues. By the time the oxidative system takes over, power will likely not be easy to come by (Wilson, 2017).

### **FORCE PLATES**

One of the most used tools for measurement of neuromuscular function is the force plate. While force plates have been around since 1969, since the 2010s, innovations have been made to the technology. Originally, force plates had to be plugged into a power source and into the

computer to get the data; now, there are wireless force plates that allow for data collection in various settings. The basis of force plates is they use sensors to determine numerous amounts of data about the action that was performed on them. The most common data obtained from force plates are velocity, power, displacement, time, and symmetry. Symmetry is measured by bilateral force plates, which are two different force plates linked together. While unilateral force plates are still sufficient in obtaining much of the same data, bilateral force plates have allowed for further research and data collection. While many movements, even sport-specific movements, can be performed on force plates, most movements are used for testing (Hawkin, 2023).

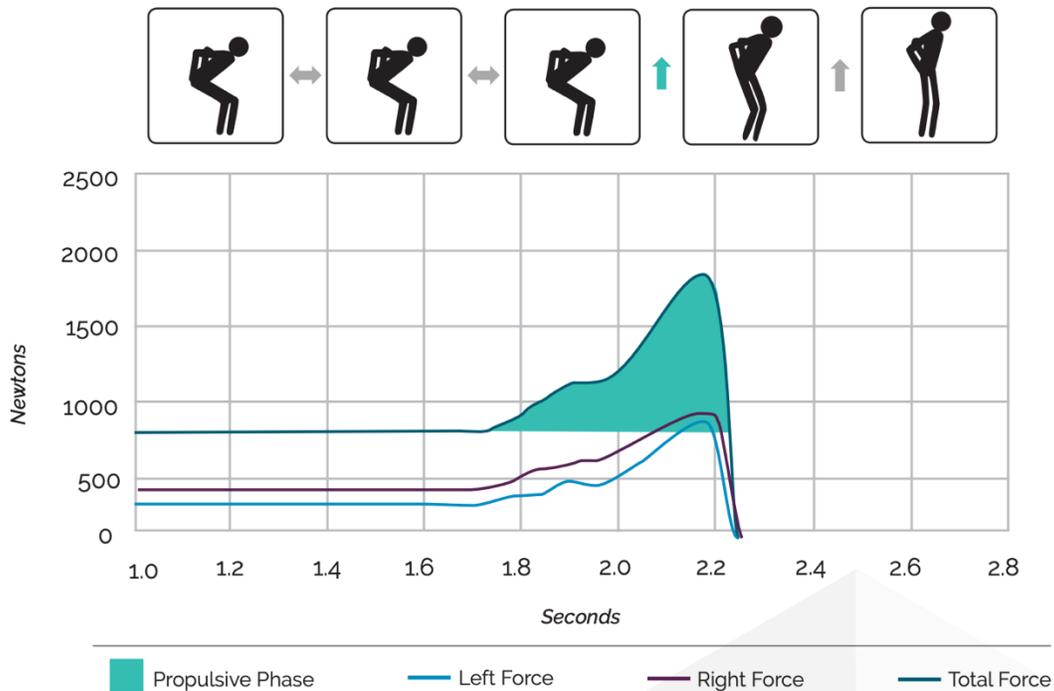


**Figure 6.** Bilateral force plate on the left and unilateral force plate on the right.

(Hawkin, 2023)

### **Squat Jump Test**

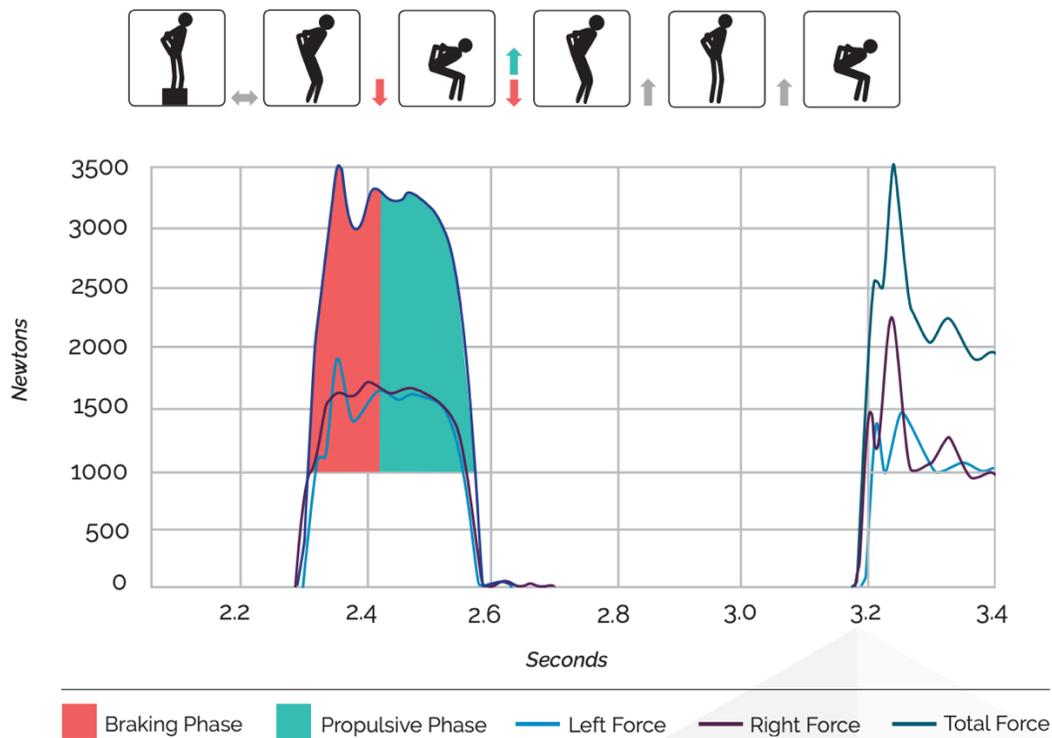
Squat jumps are a test used to measure the concentric abilities of the individual. During a squat jump test, the individual will jump with as minimal countermovement as possible. It is important for them to land firmly on the force plate(s) to ensure proper readings of the landing. The main purpose of the squat jump is to isolate the individual's concentric movement if done correctly, there will be no eccentric loading at the beginning of the jump (Hawkin, 2023).



**Figure 7.** Squat jump test diagram with bilateral force plate data. Adapted from [HawkinDynamics.com](http://HawkinDynamics.com)

### Drop Jump Tests

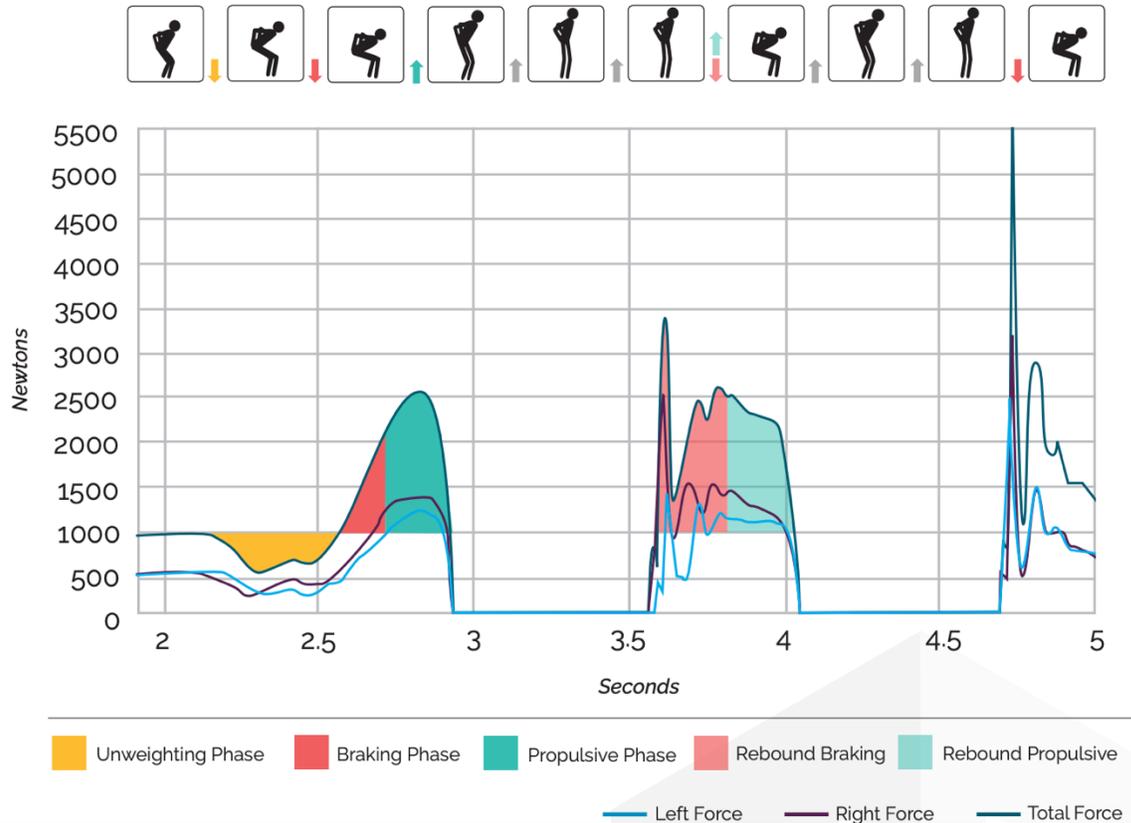
Drop jump tests are an aggressive eccentric and concentric action. The drop jump test involves an individual dropping onto the force plate and immediately entering the braking phase. Once they land from the drop, they immediately jump back up, this puts them in the propulsion phase, which can be measured independently or with the braking phase to determine the relationship between the two phases. The relationship between the braking and propulsion phases is the time it takes for the individual to absorb the landing from the initial drop, versus the time it takes for them to get back in the air (Hawkin, 2023).



**Figure 8.** Drop jump test diagram with bilateral force plate data. Adapted from [HawkinDynamics.com](http://HawkinDynamics.com)

### Countermovement Rebound Jumps

Countermovement rebound jumps begin with a countermovement jump (CMJ), however, once the individual lands from the initial CMJ, they perform a second CMJ. This test is used to test both type I and II muscle fibers and is broken down into five phases: unweighting, braking, propulsive, rebound braking, and rebound propulsive. The unweighting phase shows the individual leaving the force plate on the initial CMJ, the braking phase is the initial landing, the propulsive phase is the beginning of the second CMJ, and the rebound braking and propulsive phases are the same as the initial, just for the second CMJ. The countermovement rebound jump test will show an individual's reactivity along with their overall jumping capabilities (Hawkin, 2023).

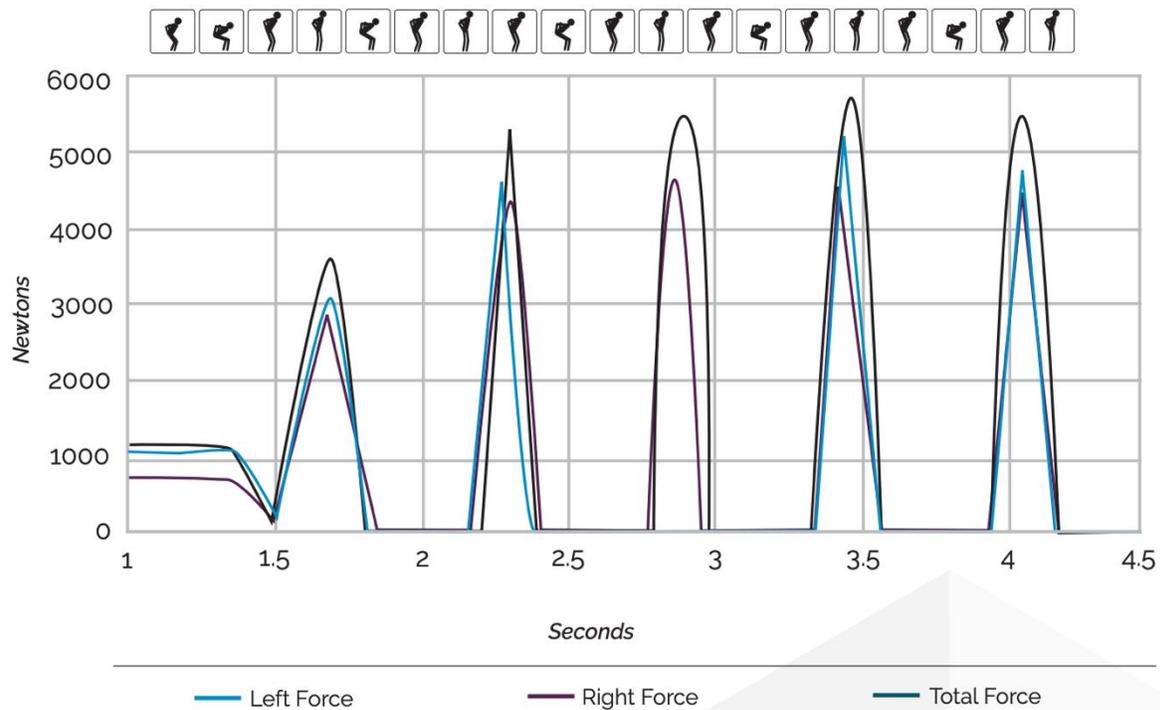


**Figure 9.** Countermovement rebound jump diagram with bilateral force plate data. Adapted from HawkinDynamics.com

### Multi-Rebound Test

The multi-rebound test is like the CMJ rebound test in that it tests an individual's reactivity, and performance associated with fatigue. The premise of the multi-rebound test is an individual jumping as high as they can, as many times as they can within the test's duration; the test's duration is up to the person running it as they can set the timer based on the individual. The key measurements gathered during this test along with the jump height, are the flight time

and contact time, which are referred to as the refractive strength index (RSI). The RSI is a great metric to use when measuring quick explosive movements (Hawkin, 2023).



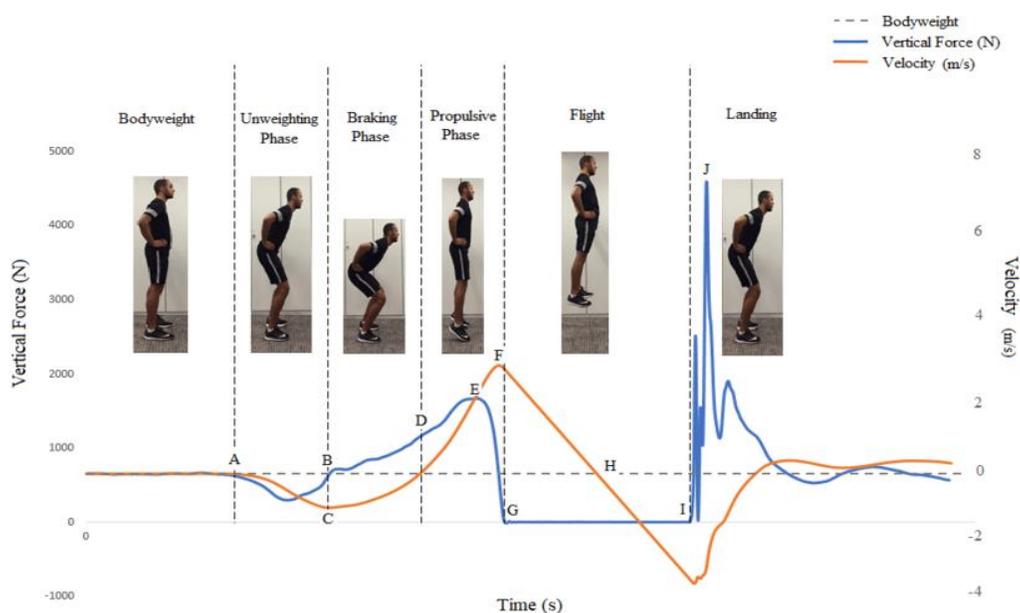
**Figure 10.** Multi-rebound jump diagram with bilateral force plate data. Adapted from [HawkinDynamics.com](http://HawkinDynamics.com)

Each test is useful for different categories; however, this study focused on two tests: the countermovement jump, and the isometric mid-thigh pull.

### Countermovement Jump Test

The CMJ is a beneficial movement for testing regardless of sport or activity. A CMJ is a maximal anaerobic movement for the lower body. Therefore, the test is a maximal anaerobic test. The premise of a CMJ is jumping vertically as high as possible while utilizing triple extension, which is a synchronized extension of the hip, knee, and ankle. While the CMJ is great

for measuring anaerobic power, it is also helpful in measuring neuromuscular ability, as triple extension requires all muscles involved to work in unison. When the CMJ is performed, the force plate will read how much force was used to jump up and how long the individual was in the air, which correlates to the jump height, the force created when landing, and many other measurements such as movement time, refractive strength index, and velocity. Ideally, a CMJ test is conducted on a bilateral force plate, which allows for any asymmetry in the limbs to be exposed (Mao et al., 2024).



**Figure 11.** CMJ diagram with two force plate readings. Adapted from

<https://www.scienceforsport.com/countermovement-jump-cmj/>

When understanding force plate data during a CMJ test, the force-time curve is the most influential portion to understand. On the graph of the force-time curve, the y-axes contain vertical force (N) and vertical velocity ( $\text{m}\cdot\text{s}^{-1}$ ). The force-time curve allows for each phase to be identified in a CMJ, the first phase is the weighing phase, where the individual will stand as still as possible on the platform so that their body weight can be measured. This is important because

body weight will allow the system to know when the CMJ has begun. The second phase is the unweighting phase, when the individual performs the CMJ. When analyzing the force-time curve, this phase will be noticeable as there will be a large dip in the curve after the steady reading of the weighing phase. The third phase is the braking phase, which is when the individual decelerates. During this phase, the maximal vertical force will be shown on the force-time curve, and the graph reading will show a large jump in the curve from the unweighted phase. The fourth phase is the propulsion phase, also referred to as the concentric phase, this phase measures the individual's triple extension. On the graph, the propulsion phase will show a substantial dip before showing a minor jump, then the line dives substantially. The fifth phase is the flight phase, which is very simple as it is the amount of time the individual is in the air. This phase will show a dotted line that decreases gradually. The sixth and final phase is the landing phase, which shows the maximal vertical force created by the CMJ (McMahon et al., 2018).

### **Isometric Mid-Thigh Pull Test**

The isometric mid-thigh pull (IMTP) is a maximal anaerobic test that determines full body strength and power. The premise of an IMTP is pulling what is commonly a stationary barbell, simulating a deadlift that concludes at the mid-thigh. Because the bar is stationary, maximal tension is generated using the force plate, and the maximal force of the individual will be measured. Generally, an individual will hold the movement for a few seconds to ensure maximal tension, thus generating the maximum amount of force into the force plate. The IMTP test can also be used as a predictive measure for maximal resistance testing as research has shown that there is a correlation between force and power production and performance. Like the

CMJ test, ideally, the IMTP test is conducted on a bilateral force plate so any asymmetry or imbalances can be presented (Pasfield et al., 2024).



**Figure 12.** Isometric mid-thigh pull test conducted on a bilateral force plate adapted from:

<https://www.hawkindynamics.com/blog/upper-limb-force-plate-testing>

### **STARTERS VERSUS NON-STARTERS**

In sports, starters are generally the best-performing players on the team. While there can be exceptions, such as in basketball, where a team could have two of their top performers play the same position, such as one starts and the other is a non-starter or reserve, generally, the highest performing players are the starters. (Morrison et al., 2022). While the current study is focused on collegiate volleyball, the performance of starters and non-starters in gymnasts has been researched. This research was on the well-being and strain of elite rhythmic gymnasts and found that there was a discrepancy between the training loads for starters and non-starters. This

discrepancy occurred during the preparatory phase of their training cycle, meaning that the starters were doing significantly more than the reserves. This led to an increased strain on the starters. However, no differences in well-being were found between the two groups (Fernandes et al., 2022).

A collegiate athlete's playing career spans over four years. While the COVID-19 pandemic recently allowed all athletes who played during the 2019-2020 season a 5<sup>th</sup> year of eligibility, the 2023-2024 sports seasons were the last of the athletes who were granted the "COVID year". While the development of players from their freshman to senior years is specific to the individual, the consensus is that an athlete's best performing year should be their senior year. This consensus was encouraged in a 2024 study conducted to observe the age-related differences in motor ability of volleyball players. It was discovered that lower body anaerobic power develops most between the ages 13 and 14, then again at ages 19 and 20. For most collegiate athletes, their age 19-20 year is their sophomore year, so combined with continued sport-specific development, generally, athletes should be performing their best by their senior year. Therefore, starters in volleyball are usually juniors and seniors, or upperclassmen. This does not mean that underclassmen, freshmen and sophomores automatically aren't starters, just that juniors and seniors are more likely to be starters (Peev et al., 2024).

Not only are starters generally the most talented players on their perspective teams, but they often also have better anthropometric measures than non-starters as well. While significantly more physical than volleyball, rugby is a sport that combines anaerobic and aerobic energy system usage like volleyball. In rugby, jumping, change of direction or cutting, and sprinting are all utilized, and not only has research found that starters in rugby performed better in all these categories, but they also found that starters were taller and heavier, yet still had

higher VO2 max scores than non-starters. Also, to reinforce the discussion above, the rugby starters observed during this research were also found to have greater playing experience, indicating that they were mostly older than the non-starters (Gabbett et al., 2009).

Communication is very important in sports. Not only from the coaches and support staff communicating with players, but also the communication between athletes during competition. In volleyball, a very effective way to score is by passing the ball back and forth a few times before setting up a spike; this requires a lot of unspoken communication as they don't want to give the other team any indication of who is spiking the ball. Communication skills vary amongst individuals, extroverts have very little problem communicating, while introverts often do have issues communicating. However, recent research has shown that there is a positive correlation between playing sports and enhancing communication skills and overall mental health. This increase can come from many different areas in sports; if coaches show empathy and support to their athletes, studies show that athletes self-efficacy increases, along with ongoing research that has already begun to prove that exercise in general helps to promote self-efficacy. Self-efficacy is very important in developing communication skills, as an individual with high self-efficacy are confident in themselves and thus makes communicating with others easier (Kurova et al., 2024).

Unfortunately, there is a trend in sports in which the starters are generally treated better than the non-starters. Research has shown that many non-starters not only report higher levels of training in-season than non-starters but there is also a feeling of inferiority for non-starters. However, this perceived increase in training could be attributed to load management by the coaches. Because non-starters will not be exerted at the same level as starters during competition, the increased training load could be done to keep them in similar shape as the non-

starters in case a change is needed in the starting lineup. This is not universal; however, it is not uncommon for non-starters to feel like they are not on the same level as the starters, thus lowering their self-efficacy. Lowering self-efficacy, as discussed previously has been found to inhibit some communication skills. This is a possible explanation as to why starters generally have better communication skills (Oliveira et al., 2023).

## **METHODOLOGY**

### **Participants**

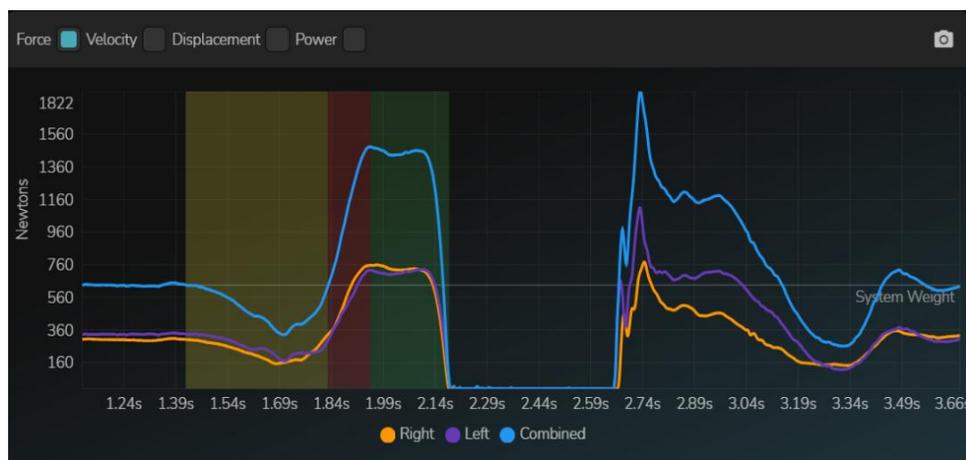
Seventeen members of the NCAA Division III North Carolina Wesleyan University women's volleyball team with an average age of 19 years old, average body weight of 70.82 kg, average height of 1.77 m, and an average BMI of 22.46 kg·m<sup>-2</sup>; volunteered to participate in this study. Participants completed a medical history form and gave their written consent before their participation in the study. All experimental procedures were conducted in the Lab of Applied Physiology (LAP) at North Carolina Wesleyan College (NCWC) and were approved by the NCWC Institutional Review Board for Human Participants Experimentation.

### **Procedures**

At the beginning of the playing season, each participant completed an informed consent process, which allowed the data for this study to be collected. Each participant was asked to attend and complete two separate lab sessions: a “dry run” and a data collection session. Both sessions used a bilateral force platform and Hawk Dynamics software (Hawk Dynamics, Westbrook, ME) for countermovement jump (CMJ) data collection and analysis.

#### *Countermovement Jump Test (CMJ)*

The Countermovement jump test (CMJ) required the participants to complete one jump, jumping as high as they could. Each athlete was given three tries to jump the highest that they could, the best score from the three jumps was the score used in the data analysis. To start the test, the participants were asked to step on plates. Then, the tester counted down from 3; once the beep was heard, the participants were asked to jump as high as they can with their hands placed on the hips. Once the jump test was completed, participants were asked to step off the plates.



**Figure 13.** Final results from one participant during CMJ testing

### Statistical Analysis

The athletes were divided into starters (S) and non-starters (NS). Means and standard deviation (SD) were used to describe the physical characteristics of the participants. Independent sample t-tests were used to compare S and NS in respect to anthropometric measures, CMJ jump height, peak eccentric and concentric force, peak eccentric and concentric power and eccentric and concentric impulse. A Bonferroni correction was used to eliminate the possibility of type I errors in the consequent pairwise comparisons. For the Individual dependent t-tests Cohen's d effect sizes statistics (1) were calculated and corrected for the small sample size (<20

participants) using Hedges's  $g$ s (3). The values were interpreted as 0–0.2, 0.2–0.6, 0.6–1.2, and 1.2–2.0 to be considered trivial, small, medium, and large effects, respectively (2). Statistical analyses were performed using statistical software (SPSS, Version 30.0, SPSS, Inc., Chicago, IL, USA).

## RESULTS

S and NS descriptive statistics are presented in the form of means and standard deviation (Table 1). Differences between the S and NS are presented in table 2, below.

Table 1. S and NS Anthropometric Measures

Measure	S (n=8)	NS (n=9)	Size Effect
Wt (kg)	71.31 ± 16.84	70.40 ± 9.65	-0.06
Ht (m)	1.73 ± 0.84	1.68 ± 0.73	0.59
BMI (kg·m <sup>-2</sup> )	23.85 ± 5.80	24.91 ± 4.28	-0.21

S = starters; NS = non-starters; Wt = weight; Ht = height; BMI = Body Mass Index  
Values are expressed as mean ± standard deviation (SD)

Table 2. S and NS CMJ Performance Measures

Variable	S (n=8)	NS (n=9)	Size Effect
CMJ Jump Height (cm)	28.28 ± 5.36	27.10 ± 5.24	0.21
CMJ Peak Eccentric Force (N·Kg <sup>-1</sup> )	21.98 ± 2.32	22.50 ± 2.10	-0.12
CMJ Peak Concentric Force (N Kg <sup>-1</sup> )	22.12 ± 2.01	22.43 ± 3.25	-0.06
CMJ Peak Eccentric Power (N·Kg <sup>-1</sup> )	15.61 ± 4.57	15.54 ± 4.12	0.06
CMJ Peak Concentric Power (N·Kg <sup>-1</sup> )	44.36 ± 5.46	43.17 ± 7.04	0.17
CMJ Eccentric Impulse (Ns)	204.36 ± 71.67	201.05 ± 37.47	-0.06
CMJ Concentric Impulse (Ns)	367.74 ± 92.30	371.66 ± 63.50	-0.05

Values are expressed as mean ± standard deviation (SD)

## DISCUSSION

The study's results suggest that differentiating between starters and non-starters is not attributed to jump performance but could be attributed to other factors such as sport specific skill, communication, and teamwork. Sport specific skills in volleyball include hitting, which constitutes passing, setting, spiking, and blocking, along with positioning and an understanding of the game (Barrett, 2024). Communication in volleyball, is very important, however, in team sports, often the players that communicate the most on and off the court are the best players. This is because research has shown that starters in sports often have a higher self-efficacy than the non-starters, therefore they will be more confident to speak up and be a leader of the team (Kurova, 2024). Teamwork and communication are similar, however the difference in teamwork is that it is role based. A big part of communication is leadership; however, teamwork requires everyone to play a certain role, whether the athlete is a leader or not. Research has shown that teamwork has a positive effect on overall team success, therefore the starters often work best as a team (Yang, 2022).

When comparing the neuromuscular performance between starters and non-starters in volleyball, the starters, on average, were slightly taller and weighed more yet had a lower average BMI than the non-starters. Height is important for those playing on the frontline as they are the players who will spike the ball and attempt to block the opposing teams' spikes. However, height is not as important for the backline as they will mainly be diving and making quick cuts to ensure the other team does not score. Therefore, the heights were similar on average due to only a few of the starters being taller. The weights of the starters were also higher than the non-starters. While this could be attributed to the starters being taller, it is known that muscle weighs more than fat. This is consistent with previous research, as in a previous study

mentioned about rugby players, it was found that starters were taller and heavier on average than non-starters (Gabbett et al., 2009).

Starters are generally going to be the best-performing athletes. A higher percentage of muscular body weight does not always equate to better athletic performance; mostly due to the dominant muscle fiber type the athlete possesses, in general, someone who is stronger and can generate more power. BMI is a measurement of body composition based on height and weight. While BMI is not always the most accurate measurement of body composition, but it provides a general baseline due to muscle weighing more than fat. The fact that the starters were taller than non-starters, would explain why the non-starters had a higher BMI (Battista et al., 2025)

The starters slightly outperformed the non-starters in average jump height, peak eccentric and concentric power, and eccentric impulse, in contrast, the non-starters slightly outperformed the starters in peak eccentric and concentric force and concentric impulse. Jump height is simple, as the starters jumped higher on average than the non-starters. However, the eccentric and concentric measurements give a better indication of the neuromuscular performance of the athletes. The term eccentric means lengthening while the term concentric refers to shortening. During a CMJ, eccentric and concentric power is measured during the countermovement. Concentric power is measured right when the athlete jumps, as forming their knees from a 90-degree angle, thus shortening the muscle fibers. Eccentric power is measured as the athlete reaches triple extension, which is the extension of the ankle, knee, and hip joints. The eccentric and concentric impulses are how quickly the athletes were able to decelerate, and the same is true of power; deceleration occurs during both the lengthening and shortening phases. The eccentric and concentric force is measured as the athlete returned to the force plate, again, both during the lengthening and shortening phases. While power and force do often correlate, during

a jump, the heavier the athlete's body weight, the more gravity will impact them. Therefore, more force will be generated (Faivre-Rampant et al., 2024).

The CMJ is an anaerobic test. Each component tested during the CMJ correlates to anaerobic power production. Returning to the discussion on starters and non-starters, research has shown that starters are generally the highest performing in their sports energy system. While eccentric and concentric power results did edge slightly to the starters, there was no significant difference between starters and non-starters. However, as stated previously, this could be attributed to the backline not needing to generate as much anaerobic power as the frontline. Despite the results, it can be conferred that regardless of neuromuscular performance, starters will be better with their sport-specific skills, communication, and teamwork. While a CMJ test is a great tool to measure an athlete's anaerobic abilities, an athlete that performs well on a CMJ test, does not mean they will perform the highest in their sport (Morrison et al., 2022).

These results tie back to the previous discussion about starters and non-starters. Individuals have been found to develop anaerobically the most around the ages of 19 to 20. With collegiate athletes' ages ranging traditionally from 18 to 22, this means some athletes will not be fully developed anaerobically until their sophomore years. However, while often upperclassmen, juniors and seniors, are more likely to be starters, it is not uncommon for freshmen to be starters. This means that regardless of the athlete's anaerobic performance, more emphasis is on sport-specific skill when determining if an athlete should be a starter or non-starter (Peev et al., 2024).

Limitations that were faced during this study included not dividing the starters and non-starters into their specific positions. As stated, depending on the position the athlete plays, different movements and tasks will be required, this could've potentially allowed for more significant results for the CMJ measurements. Another limitation was that there was no

measurement for sport-specific skills, communication, and teamwork. While ultimately the conclusion was that starters are better at these three categories, there was no specific measurement available to provide quantitative proof.

Future research includes splitting the athletes by position as the front line jumps more than the back line. The back line will primarily be doing quick cuts and diving. With dividing up the athletes by position, this would lessen an already smaller sample size, so with this idea, it would need to be conducted over multiple seasons to see the differences in the larger sample size. Another idea for future research is to use other tests such as an isometric mid-thigh pull, or countermovement rebound test. These tests are like the CMJ test in that they test maximal anaerobic power, but they also add other components such as muscular endurance and some upper body components.

## **CONCLUSION**

In this study, starters and non-starters were compared by their anthropometric measurements and CMJ test results. The study's results suggest that differentiating between starters and non-starters is not attributed to jump performance, but more likely to other factors such as sport specific skill, communication, and teamwork. The anaerobic components of volleyball are very important, however, anaerobic performance and performance in the sport do not always correlate. The results did not show a significant difference between starters and non-starters, however what separates starters from non-starters are their sport-specific skills, teamwork, and communication. In volleyball, the sport-specific skills go past hitting the ball, but rather understanding where they should be positioned and how to effectively score and defend based on what the other team is doing. Volleyball is a team sport, in any team sport athletes

need to be able to work together to be effective. Starters are generally going to work together better than non-starters and this is due to starters being older and playing alongside their teammates for longer than the non-starters. Communication ties into teamwork as far as communicating on the court, but communication is also important off the court. Starters will often be the voices and leaders of the team often due to the psychological hierarchy of a team. The starters will often have higher self-efficacy than the non-starters and thus, have more confidence to speak up and lead the team. Despite there being insignificant results between the starters and non-starters, all athletes should still strive to perform their best either anaerobically or aerobically depending on their sports primary energy system.

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