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APPROVAL OF HONORS PROGRAM SENIOR PROJECT

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High and Low Performer Differences in Force Plate Derived Neuromuscular Performance in Female NCAA Division III Soccer Player

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High and Low Performer Differences in Force Plate Derived Neuromuscular Performance in Female NCAA Division III Soccer Players

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INTRODUCTION: Several studies from our Laboratory of Applied Physiology at North Carolina Wesleyan University (NCWU) have demonstrated that NCAA Division III female soccer players may not be at peak anaerobic condition at the onset of the competitive season. It has also been demonstrated that there is a fair amount of countermovement jump (CMJ) performance variability between these players. **PURPOSE:** To examine the relationship between countermovement jump (CMJ) performance, isometric mid-thigh pull (IMTP), and the 10/5 reactive strength index (10/5 RSI) in NCAA Division III women's soccer players. **METHODS:** Sixteen members of a NCAA Division III women's soccer team (mean ± SD): age (19 ± 1.0 y); body weight (65.76 ± 15.55 kg); height (1.64 ± 7.26 m); BMI (24.19 ± 4.39 kg·m^{-2}) volunteered to participate in the study. Assessments included CMJ jump height; IMTP peak force, relative peak force; the 10/5 RSI score and the average top 5 jumps RSI score. All performance tests occurred prior to the start of the regular season. A median split was applied to divide the athletes into low (LP) and high (HP) performing groups based on CMJ height. **RESULTS:** The median split procedure divided the group to eight LP players (CMJ ≤ 22 cm) and eight HP players (CMJ > 22 cm). Significant and large effect size differences were observed between the groups for IMTP peak force relative to body weight (LP: 246.54 ± 30.92; HP: 294.15 ± 39.77 %, $p < 0.01$, $d = -1.26$) and peak RSI score (LP: 1.67 ± 0.4; HP: 2.10 ± 0.19, $p < 0.01$, $d = -1.27$). Peak force, relative peak force and the average top 5 jumps RSI score were not significantly different ($p > 0.01$) between LP and HP, and displayed trivial, medium and medium effect size (d), respectively. **CONCLUSIONS:** Results of the study suggest that regardless of CMJ jump height performance, IMTP performance may be body weight dependent. In addition, athletes who produce higher body explosive power are likely to produce higher relative peak isometric force and higher reactive strength scores.

Introduction

Soccer is a popular and well-known sport played all around the world (Bloomfield et al., 2007). This sport requires athletes to have adequate and reliable aerobic and anaerobic fitness, paired with abilities to reach higher levels of speed and overall fitness as the needs for soccer constantly change. It is commonly known that soccer requires athletes to run large distances, perform large amounts of agility, and exert large amounts of energy (Bloomfield et al., 2007). In recent years, neuromuscular testing has become a popular and dominant way of determining strength, expected performance, and areas that could use improvement (Hewett et al., 1999). The use of this testing has been shown to be beneficial for soccer performance, however, data is still quite limited, specifically for women's soccer players in the National Collegiate Athletic Association (NCAA). Therefore, the purpose of this study is to examine the relationship between countermovement jump (CMJ) performance, isometric mid-thigh pull (IMTP), and the 10/5 reactive strength index (10/5 RSI) in NCAA Division III women's soccer players.

REVIEW OF LITERATURE

The Game of Soccer

The game of soccer involves eleven players per team, while each team's goal is to move the ball up the field into their opponent's goal, there are also specific jobs for each teammate. This sport involves short, explosive activity paired with a more constant lower-moderate intensity level movement. Soccer requires the athletes' aerobic and anaerobic systems to work within the needs of the athlete and be reliable, meaning the systems will allow the athlete to reach high and constant speeds. For example, during an average game at the higher level, players tend to cover distances ranging anywhere from two miles, typically the goalkeeping position, to eleven miles per game; this does not include the warm-up for most players (Bloomfield et al., 2007). The lower-moderate distance, along with the tops speeds reached by the player, are based on the abilities of the Glycolytic (anaerobic) and Oxidative (aerobic) system working together. As all the systems are used to create the energy one needs to endure an energy taxing sport, one of the systems is used more during certain situations. For example, the glycolytic (anaerobic) system creates lesser amounts of ATP, but at a faster rate, therefore this system is most often used during a short, yet fast, sprint. As soccer is an intermittent intensity sport, these two systems will work interchangeably throughout an entire game (Hart et al., 2020). In addition, there are also other physical demands on the player's body. It is often that players are knocked off their feet, shoved to the ground, or are outran by their opponent (Silva et al.; 2015).

Positioning on the Soccer Field

There are eleven different players on the field, each responsible for a different position. These positions include the striker, the left and right winger, the center attacking midfielder, the midfielder, the defensive midfielder, the right and left outside defender, the center defenders, and lastly the goalkeeper. Each of these positions require different aerobic and anaerobic capabilities.

Table 1. Soccer positions and roles

Striker	Striker's key role is to score the goals but to also help generate set pieces with the other players. This position is known to obtain the highest distance of maximal sprints throughout the entirety of a game (Bloomfield et al.; 2007). Therefore, the striker needs to be strategic in their technical skills, such as having the ability to maneuver the ball through opponents, along with having the capability of sprinting, and being able to do that sprint countless times, at a quick pace.
Wingers	The left and right wingers' roles are like that of the striker; however, they are relied more on for crossing the ball to provide goal-scoring opportunities. It is beneficial for a winger to move fast paced with and without control of the ball.
Midfielders	The center midfielder center attacking midfielder, and the defensive midfielder's role is to work as a unified team. They tend to connect in a triangle shape to pass around other opponents, to then pass on to their scoring teammates. In soccer, a triangle shape can be beneficial for creating passing patterns that help create scoring opportunities. The midfield position tends to maintain a low-moderate intensity for a long duration than other positions on the field (Bloomfield et al.; 2007). Therefore, their abilities are more based on precise technique, quick

	decision making, cardiovascular fitness, and agility. Precise techniques for a midfielder can be defined as accurately passing the ball, having strong motor skills such as acceleration and change of direction, and goal scoring accuracy (Sermaxhaj et al.; 2015).
Defenders	The left and right outside defenders' role is to defend incoming balls from the opponents. A soccer team's set piece can begin with the defender and from there, passed into the center or out to the wingers, then lastly advanced up the field. This position tends to be one that covers one of the highest distances on the field, as they can be used in defense and attack. In return, outside defenders must be very quick in speed, agile, and muscularly strong. The player must have control of their bodily movements to produce the power needed for kicking the ball, the strength to create explosive speeds, and the muscle to defend an opponent. Center defenders' jobs are like the outside defenders; however, they must focus on preventing any opponents from getting through their defensive line and helping advance the ball up the field. This position is known to be in situations where jumping and tackling are common (Bloomfield et al.; 2007).
Goalkeepers	Goalkeeper seldom engages in high intensity activity during a given game. However, their role will still have specific energy demands. For example, the goalkeeper will often have short sprints when defending a goal, therefore their aerobic and anerobic systems will both be used often.

Energy Systems

An athlete's body will use multiple energy systems throughout a game, including the ATP-creatine phosphate system, Glycolysis (anaerobic), and the Oxidative (aerobic) energy system. All of these are used at the specific time that the athlete needs, although all systems will be used at the same time, only one will be the dominant system in use (Hart et al.,2020).

There is not one dominant energy system at any given time, but dominance will vary based on the intensity of the exercise the athlete is doing. Following the use of stored ATP, the creatine phosphate system (ATP-CP) and glycolytic system (anaerobic) will be utilized. However, when the athlete reaches longer periods of endurance activity during a soccer game, the energy source will come mostly from the oxidative system. When an athlete is working through intense levels of exercise, the body will use glucose for fuel, therefore the ATP-PCr system and oxidative system will work together as one. The process of when the body produces ATP from glucose or glycogen is known as anaerobic glycolysis (Comana, 2022).

Adenosine Triphosphate storage is limited in our muscles, therefore, the three working systems named above must produce the additional ATP.

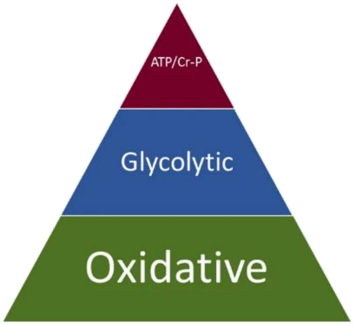


Figure 1. Diagram of Energy Systems (Quall, 2019)

ATP-Creatine Phosphate System

This system includes storage of ADP and creatine phosphate. As muscles are not able to make their own ATP, the body must use rephosphorylation of ADP to create the ATP needed. To do this, we need ADP and Pi (inorganic phosphate) to combine to create ATP.

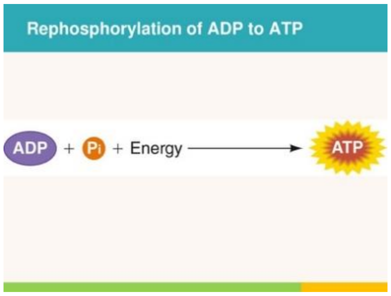


Figure 2. Diagram of Rephosphorylation of ADP to ATP (Payne, 2014)

The ATP-Creatine Phosphate system is known as an "immediate source of energy" (Morton et al.; 2008). This is because the use of this system, although short, is used immediately without the need for oxygen. However, it does need time to completely restore what had been used. This system can replenish all that was lost within 3 to 5 minutes and can do so while doing smaller amounts of activity or during full rest periods. Therefore, this system can be used repeatedly until total fatigue sets in. The energy is provided by combining ADP and phosphate from phosphocreatine to create a short, yet intense bout of energy.

Glycolytic System-anaerobic glycolysis

The glycolytic system is the system that generates Adenosine Triphosphate (ATP) from glucose/glycogen, for energy for exercise, through the process of glycolysis. This process can function with and without oxygen, depending on the needs of the body. For ATP to continue to be generated, glucose must first be synthesized from glycogen (the stored form) through the process called glycogenolysis. Glycogenolysis is the breakdown of glycogen to form glucose to use as an energy source. Once the glucose is needed, it will be converted into a compound called glucose-6-phosphate (Kenney et al. 2022).

During this process of glycolysis, 3 moles of ATP will be created per mole of glycogen that is broken down. However, if glucose is used at the beginning, instead of glycogen, only 2 moles of ATP will be created per mole of glucose. The reason for this difference is because in the process of phosphorylation of *glucose,* glucose was converted to glucose-6-phosphate, so 1 mole was used for the phosphorylation and 2 net ATP are generated (Kenny et al., 2022).

The glycolytic system does not require oxygen to be able to function, therefore the other section of this system is called *anaerobic glycolysis*. As this system does not generate large amounts of ATP, the glycolytic system and the ATP-PCr system work together as one, to help the body's muscles create the force needed with a limited oxygen supply.

When the body relies on anaerobic glycolysis, the increased production of ATP will lead to the buildup of lactic acid. This build up will reduce the production of ATP causing a limitation (Kenney et al. 2022). More specifically, lactate build-up can lead to extreme fatigue, impairment of muscle contractibility, and reduction in physical performance.

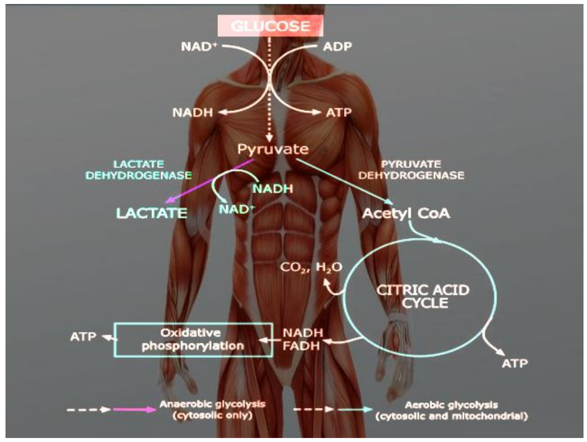


Figure 4. Anaerobic Glycolysis (Chaigasame, 2023)

Oxidative Energy System

This energy system is known as the most complex of the energy systems. It is slow to activate yet has the better ability of creating large amounts of energy. As it can create larger amounts of energy it is used during higher endurance exercises, making this energy system an aerobic process.

There are three different sources of oxidation using substrates including carbohydrates, fats (preferred), and proteins.

- **Oxidation of Carbohydrates**- when oxygen is present, the pyruvic acid (derived from glucose or glycogen) from glycolysis, enters the mitochondria and is converted to acetyl CoA. Once it becomes acetyl CoA, it will enter the Krebs Cycle (Youdim, 2022).

- **Oxidation of Fat-** fat in the human body is stored inside the adipose tissue as triglyceride (TG's) which may provide around 70,000 kcal in adults. TGs are stored inside fat cells within muscle fibers and to be used they must be broken down into one molecule of glycerol and 3 free fatty acid molecules through the process of lipolysis. Glycerol will be converted to glucose through the process of gluconeogenesis. Fatty acids will be broken down through the process of β oxidation and enter as acetyl-CoA to the Krebs cycle (Tocris Bioscience, 2022).

- **Oxidation of Proteins-** Proteins are not the body's preferred source for fuel. When the body does use protein, it is rather used for synthesizing enzymes/hormones, and repairing/maintaining the body tissues (Human Kinetics, 2022). The use of proteins can be related to a limited intake of nutrients, therefore, when one is on a restricted diet or not obtaining enough nutrients through their diet, protein will become the body's source of fuel (Youdim, 2021). There are two ways of using proteins, through gluconeogenesis (the process of converting amino acids to glucose) or converting amino acids into pyruvate or acetyl CoA. Proteins are deemed more complicated than the oxidation of carbohydrates or fats because of their structure complexity. They contain Nitrogen, which causes the nitrogen from proteins to create new amino acids when the old amino acids are converted. However, when there is left over nitrogen in the body, it cannot be used in oxidation, therefore, the body will convert it to urea (a waste product) and then will be excreted from the body. Although the extra nitrogen has been excreted, this process requires some ATP, causing the energy once produced from the proteins, proteins to be used in excretion too. In this form of oxidation, it creates very little amounts of energy, used only during extreme situations such as starvation and therefore is not dominant for exercising (Human Kinetics, 2022).

- **Krebs Cycle-** This cycle is the main source of energy for cells in the body. Primarily, its function is to produce NADH (Nicotinamide Adenine Dinucleotide) and FADH (Flavin Adenine Dinucleotide) which are electron carriers. This cycle begins with acetyl-CoA inside the mitochondria. There are 8 overall steps to this cycle, first Acetyl-Coa will bind with 4-carbon molecules (oxaloacetate) to form citrate, second citrate will be converted to isocitrate, third isocitrate will be oxidized to alpha-ketoglutarate (6 carbon molecule), which will release carbon dioxide. As a result, NADH will form. Fourth, Succinyl CoA is produced via Alpha-ketoglutarate, forming a 2nd molecule of NADH and another carbon dioxide molecule. Fifth, Succinyl CoA is converted to fumarate (4-carbond molecule) and a FADH molecule is produced. Seventh, Fumarate is converted to malate, and lastly Malate is converted into oxaloacetate, then producing the third molecule of NADH (Millipore Sigma, 2022). Therefore, 6 NADH molecules are generated and 2 FADH molecules are produced.

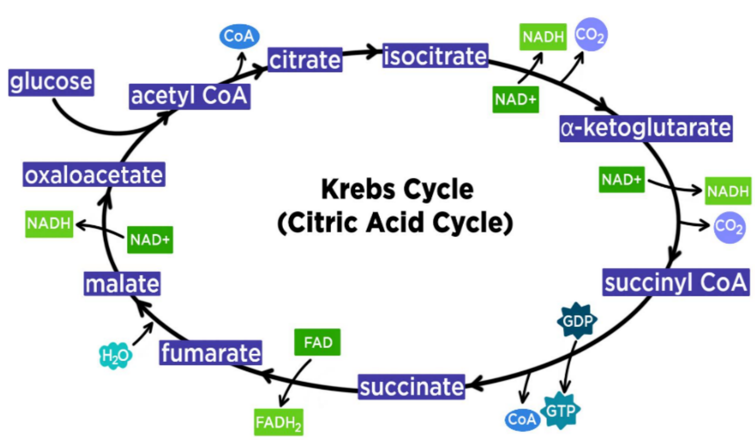
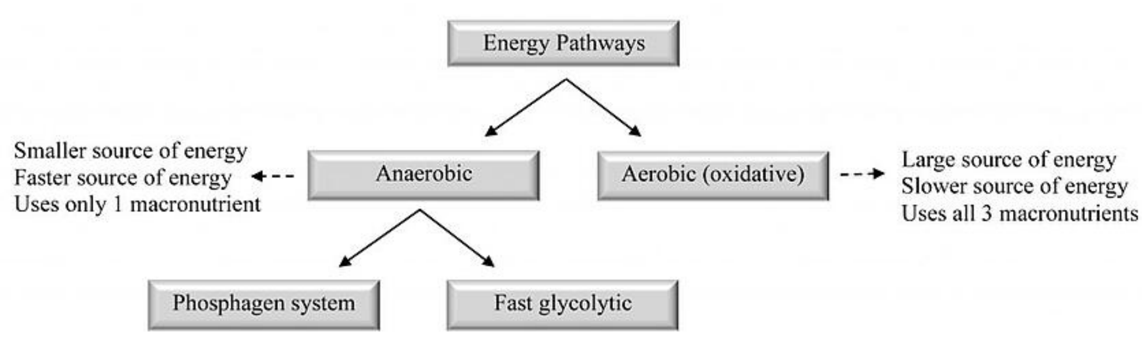


Figure 5: Diagram of Krebs Cycle

(Slizewska, 2019)

- **Electron Transport Chain-** This is the main source of ATP production in the human body. The Electron Transport Chain (ETC), also inside the mitochondria, consists of 5 main complexes labeled as I, II, III, IV, and V. Both NADH and FADH will begin the ETC by providing electrons to complexes I and II, and from there electrons will be passed down the chain. After this is complete, an energy is created that will pump hydrogen ions into the intermembrane space, causing a proton motive force to be created. This proton motive force can be re-entered into matrix via complex V (ATP Synthase). When the Hydrogen ions are re-entered into the matrix, ATP is produced from ADP and inorganic phosphate. As this occurs, electrons will bind with hydrogen and oxygen to form water via Complex IV (Ahmad et al., 2022).

Figure 6: Diagram of Electron Transport Chain (OpenStax College)



<u>Neuromuscular Testing Benefits</u>

Neuromuscular testing (NMT) is defined as the measurement of muscular strength, strength, and overall muscular ability (Hewett et al., 1999). NMT is beneficial for all athletes, however, for soccer it can determine the level of strength and ability the athlete is at. More specifically, neuromuscular testing can provide insight on what motors skills and strengths each athlete needs to work on individually (Akbar et al., 2022). As opposed to testing for skill and strength, this form of testing is also helpful with preventative measures for low extremity injuries such as the Anterior- Cruciate Ligament (ACL), along with insight on rehabilitation progress post injury (Hewett et al., 1999).

Neuromuscular Testing and Protocols

As soccer is considered a high intensity sport accompanied with sprints, jumps, sudden change of direction, and acceleration, it can be the repetitiveness of these fitness skills, when fatigued, that cause injuries (Roso-Moliner et al., 2022). A reliable way to assess these skills and fitness abilities is to use force plates. Force plates are used to determine ground reaction forces one endures when running, walking, jumping, and other movements (Test Types, 2022). Force plates contain multiple strain gauges or load cells sensors that allow them to measure force. Although there are several NMR testing protocols, the ones that we utilized were the Countermovement Jump (CMJ) Test, the Multi Rebound Test, also known as Repeated Jump Test (RJT) and the Isometric Mid-Thigh Pull (IMTP) Tests.

The CMJ is an anaerobic test that is especially studied as it is the most common motion that is often incorporated into sports (Thomas et al., 2022). Specifically, the CMJ is used to determine how high one jumps and how efficiently they were conducting the jump. To perform a CMJ test, the participant is asked to first step onto the force plates, stand motionless with their hands on their hips to allow the force plates to measure bodyweight, once the participant is given a que, they are to squat down and jump up as high and powerful as they can. Finally, as the athlete lands, they should focus on a stable and soft landing, while ensuring to stay on the force plates until the test has officially ended.

The RJT is also an anaerobic test that is often used to determine how high one can jump, and how fast they can jump back up once they land. Commonly, this test requires 11 consecutive jumps. To set-up for this test, the participant is asked to step onto the force plates with their hands on their hips, remain still to allow the force plates to measure their body weight. Once they hear the queue, they should jump up as high as they can, but when they come down, they should rebound back up 11 consecutive times. Again, once the jumps are completed, the participant should stick the landing and hold until the test completes (Hawkins Dynamic, 2018). The RJT is beneficial in determining muscle fatigue and training readiness. In conclusion, the use of the RJT and the CMJ tests can help determine levels of fatigue which can prevent overtraining that could lead to injury.

The IMTP is an isometric strength testing that is performed with the use of force plates and a bar. The purpose of this test is to measure the maximum isometric force an athlete can produce. Studies show that this test is the true measure to show an athlete's maximum force generation abilities (Thomas et al., 2022). The ability to develop a rapid rate of force is a necessity when it pertains to athletes. To conduct this test, the participant is asked to step onto the force plates, next the bar will be adjusted to the proper height according to the length of their lower body. To determine proper height, a goniometer should be used to measure a knee angle of 125-145 degrees, and a hip angle of 140-150 degrees (Dobbs, 2018). Once the bar height is adjusted, the participant can grip the bar and stand in the proper position. Once they are given the que, they should pull up on the bar causing their legs to push into the force plates; this test will last 3-5 seconds be based on the participant. In between each test, there should be a 60 second rest to provide optimal recovery for true measurements. Like the CMJ and RJT, the participant should remain still on the force plates until the test is fully complete.

Figure 8: Image of Force Plates Used for Neuromuscular Testing (Hawkins Dynamic, 2018)

Neuromuscular Testing in Soccer

Neuromuscular testing has become the new way to determine true readiness for training and competition. Coaches can benefit from this form of testing and use it to properly create a training session that will be effective (Armada-Cortés et al., 2022). Although it is common for athletes to become injured, sore, and fatigued, the use of neuromuscular testing, coaches/trainers can build their training/practice sessions that will optimize the players' performance. Once Neuromuscular testing has been completed, the next step is continuing with neuromuscular training.

The Countermovement jump (CMJ) test is utilized with soccer athletes at different levels. Specifically, this neuromuscular test is beneficial for determining an athlete's strength and power (Wilkins, 2020). However, to be noted this neuromuscular test is more accurate when measuring an athlete's strength and power progression, rather than regression. Impulse, a product of force and time, is what is needed most to perform well on this test. Therefore, a greater force equals a greater impulse which points to why some perform better than others (Thomas et al., 2022). This test is also often being used to provide insight on when an athlete can return to play. Athletes are often more at risk for injuries, such as an Anterior Cruciate Ligament (ACL) tear, because of the effects of fatigue caused by lack of rest after a full game or intense practice (Wilkins, 2020). When a soccer player, or any athlete, experiences excessive fatigue due to over training or not obtaining optimal recovery, they begin to limit their strength/reaction abilities subconsciously. As a result of this, non-contact ACL tears become more prevalent. However, using neuromuscular tests, such as the CMJ, can provide enough information to determine who is recovered enough and who may not be, and perhaps limit the prevalence/risk of injury (Wilkins, 2020). According to the study by Wilkins, twenty-two Division I female soccer players were tested on their countermovement jump abilities before competing in 2 soccer matches. Then, 72 hours after the matches had concluded, they were tested again. Interestingly, the countermovement jump measures never returned to baselines, meaning their overall jump heights were unable to reach their prior baseline scores, even after 72 hours rest. Therefore, it can be inferenced that optimal recovery is needed to perform maximum abilities.

A study using 26 Division I male soccer players showed strong correlations between jump height and their reactive strength index. As previously mentioned, when an athlete has a higher RSI and jump height, it is suggested that their performance on the field is higher as well. Specifically, their abilities such as sprinting and changing direction (Leland et al, 2018).

Another study using 51 English Premier League Soccer players were tested on bilateral and unilateral countermovement jumps. Significant correlations were found between leg asymmetry and physical performance. The study suggested that the higher the asymmetry, the lower their physical performance was in areas including sprinting, jumping, and change of direction at high speeds. Therefore, players with higher leg asymmetries often performed lower during games and in performance testing (Bishop et al., 2021).

The Multi-rebound jump test (RJT), as previously mentioned, is a neuromuscular test used to determine levels of muscle fatigue. This test is very reliable when determining an athlete's reactive strength index (RSI). Reactive strength index’s value represents explosive strength, derived from the relationship between jump height and ground contact time (Ebben and Petushek, 2010). The value of the RSI is the reactive jump capacity (Kinsella-Kent, 2020). This value varied from <1.5 and >3.0 and represents reactive strength ability (Flanagan, 2016). This index often does not correlate with performance in the weight room, because the RSI requires ankle strength dominance, whereas weightlifting requires knee/hip strength dominance (Flanagan, 2016). There have been numerous research studies that show a correlation between maximal strength and reactive strength in stronger athletes. Specific to the RJT test, the RSI in athletes is measured and provides coaches with quick information on their reactive strength. Soccer players encounter a stretch shortening cycle (SSC) throughout a game. Specifically with movements such as cutting, jumping, and sprinting. The SSC is a muscle function where the muscle stretches right before it is contracted (Flanagan, 2016). This is a common and useful tool used often within soccer teams. Coaches will use the results of this test to determine proper training loads that will result in less injuries across the board (Gustafsson, 2019). This is beneficial to soccer players, as injury prevention is one of the most common areas that need work as a sport. Although there is limited research with women and college soccer using the RJT, there are studies of youth male soccer athletes who have benefited from this neuromuscular test. Fatigue is, as previously mentioned, a common cause of injury in soccer players. It is described as a multifactorial phenomenon that causes an inability to sustain a required or optimal work rate (Gustafsson, 2019). A study of 46 youth male soccer athletes, mean average of 17 years old, was conducted to determine if results of the RJT show true levels of fatigue. The athletes performed this neuromuscular test prior to their team training, and then again after their training. Results of this study show that the scores of the RJT were much lower after team training. Therefore, they noted that this neuromuscular test provides adequate results that show true levels of fatigue (Gustafsson, 2019).

The Isometric Mid-thigh pull (IMTP) is another neuromuscular test that is commonly used when assessing soccer players. Most importantly, this test can determine the maximal strength, power, and force the athlete has. The use of this software provides in-depth detail in what areas the athlete is and if any room for improvement is needed. These details include measures such as when the athletes' produced force began to decline during the test, the maximum force they were able to reach, and perhaps their ability to maintain that force (Kuki et al., 2017). Correlations have been suggested between measures in this test and sprint speed. Most often, the athlete that produces a high force during the IMTP will also perform well with sprint speeds (Dobbs, 2018).

Mason et al., (2020) research on 11 professional female soccer players, demonstrated that the IMTP is reliable in providing insight on an athlete’s capability (Mason et al, 2020). They determined this as there were correlations between maximal sprint tests and peak force that were measured during the IMTP. More specifically, the higher the peak force score the athlete had, the faster their maximum sprint speed was.

Further, Mason et al., (2021) also mentioned that the study using 11 professional developmental soccer players was completed to determine if there were true correlations between the IMTP and athletic performance. Like the study by Thomas et al, the participants conducted the Isometric Mid-thigh pull test, along with a 5 meter to 10-meter sprint test. Relative and absolute peak force was measured at 50, 100, 150, and 200ms values during the IMTP. This means that the maximal force the athlete can produce was measured at 50, 100, 150, and 200 milliseconds. Results of this research study suggest that there are high correlations between IMTP performance, sprint performance, and overall soccer performance. More specifically, it was concluded that the IMTP and sprint performances were strong indicators of high athletic performance in the studied soccer players (Mason et al., 2021).

Similarly, Thomas et al., (2015) conducted a study on 14 male collegiate soccer players to determine if the Isometric Mid-thigh pull was a determinant of sprint and change of direction performance in soccer players. Male soccer players completed trials of the IMTP that involved peak force, maximum rate of force development, and impulse. Athletes also conducted other testing using the 5 meter and 20-meter sprint test. Results of the IMTP and sprint tests showed that the higher performances on the IMTP, also performed better on the sprint tests as well. It was concluded that the Isometric Mid-thigh pull test can be used to determine athletic performance and is recommended for athlete monitoring and assessment (Thomas et al., 2015).

Pre-Season Testing in NCAA Division III Man and Women Soccer

Soccer players must be aerobically fit as they need to sprint high mileage at a time. However, studies show that early in a competitive season, Division III athletes are not as fit as they need to be. A study involving 12 NCAA Division III male soccer players suggest just that.

In that study the researchers measured aerobic capacity, 30m and 40m sprints times, agility tests performance, and anaerobic performance (Magal et al., 2009). Results showed that, unlike most NCAA Division I, Division II, and professional soccer players (Magal et al., 2009), performance improved over the playing season.

Similar results were also demonstrated in another study from the same academic institution. In this study the researchers tested 14 starting Division III female soccer players using similar tests (Valladarez-Cuestas, 2020). Similar to the study Magal and colleagues (2009), there was an overall improvement in anaerobic and aerobic abilities during the playing season. The cause of players performing poorly at the beginning of the season but increasing at the end is likely due to deloading. Deloading occurs during an off-season when players are no longer working out at the same intensity as they were in season (Thermohuman, 2022). In other words, the Division III female soccer athletes came into the season with room for improvement (Valladarez-Cuestas, 2020).

These findings mentioned before are unlike those of professionals, NCAA Division I or Division II players (Miller et al, 2007). It is common to see a plateau or a decline in athletes in Division I, Division II, or Professional. This was attributed to possibly overtraining (Oliveira et al., 2021). In comparison to the studied DIII soccer athletes, a study using 26 Division IA female soccer players from Texas A&M University was conducted to determine body composition and aerobic capacity (Miller et el., 2007). The players were tested during their preseason, postseason, and the end of their off season. Results suggested that a decrease in muscle mass throughout a competitive season (August-December) contributes to a decrease in aerobic capacity as well. Body fat, however, showed an increase from the beginning of the season to the end. However, Miller et al., 2007 did not determine if this decline in muscle mass and increase in percent body fat, was due to overtraining or limited training. The results of this study suggest that the Division 1A female soccer players came into their season at maximum performance, but as the season continued, their abilities began to decrease, likely due to overtraining.

A team of Division II female soccer players were evaluated based on their aerobic fitness, anaerobic fitness, and body composition changes (Peart et al., 2018). The researchers used the CMJ, the Wingate Anaerobic Test (WAnT), and peak oxygen uptake testing to determine the aerobic and anaerobic measures. These tests were conducted 5 times, at the end of competition season, beginning of the season, end of off season, and preseason. Results showed that the players aerobic/anaerobic abilities remained relatively consistent based on the CMJ, WAnT, and oxygen uptake tests. Although, their body composition, specifically fat free mass and hip circumferences, decreased (Peart et al, 2018). In comparison to the previously mentioned DIII study by Valladarez-Cuestas, 2020, the DII female athletes showed a decrease of body composition and increase in aerobic fitness and anaerobic fitness, whereas the DIII female athletes also showed an increase in aerobic/anaerobic fitness along with a decrease in body composition. This finding may suggest that NCAA DII women soccer players are coming into competitive seasons somewhat similar to Division III female soccer players. Specifically, research studies are showing both Division II and Division III female soccer players are improving over a season, however, Division III female athletes show a better improvement that may suggest a lower starting condition.

There are a limited number of studies that examine professional soccer players comparing preseason neuromuscular testing to postseason. However, there is one study worth mentioning that highlights the negative effects of overtraining seen in professional soccer settings. Professional soccer players usually have higher aerobic capacity, agility abilities, and speed as compared to the NCAA DI, DII, or DIII college teams. However, they are also expected to train countless hours in-season and off-season while competing in multiple games. Although all collegiate competitive teams are required to train and compete for countless hours, professional teams show to have a higher number of trainings and more intense exercise monitoring, throughout an entire year (Amplified Soccer, 2015).

A study was conducted to determine if there was a relationship between amotivation and overtraining in a Brazilian Male soccer team. 32 Brazilian male professional soccer players participated in this study (Fagundes et al, 2021). Each player participated in 7 evaluations, 2 in the pre-season, and 5 during competition season. Researchers used a recovery-stress questionnaire that asked about how they felt their performance was in training and in games. Amotivation is known as a reduction in motivation in someone (Lee et al., 2015). It was concluded that athletes who began their competitive season amotivated, were not recovering properly, and they were suffering from sport-related stress more than others. Therefore, overtraining and players with amotivation proved to have a direct relationship (Fagundes et al.,2021). It was noted that stress factors in season consisted of competitiveness with teammates, interpersonal relationships with teammates and coaches, and the increase of frequent demands for positive results physically for performance.

Methods

Participants

Sixteen female participants who are members of a National Collegiate Athletic Association (NCAA) Division III Women's soccer team at North Carolina Wesleyan University volunteered and were recruited for this study. The participants ranged from the age of 18 to 22 and each participant participated in a set of tests during the preseason of August 2022. An informed consent form explaining the study and its purpose was provided and explained to each of the participants. The participants were informed that their participation was completely voluntary, and they could withdraw from the study at any time throughout testing. They were allotted time to read and ask questions about the form should they have any.

Performance Testing

Prior to the participants arriving at the Lab of Applied Physiology (LAP) on the campus of North Carolina Wesleyan University, the height and weight of each participant were taken and recorded. Next, athletes were split into 4-5 groups and completed each jump test in a rotation to allow rest in between each test. Each participant completed the Countermovement Jump test (CMJ), the Multi-rebound Jumps test (RJT), and the Isometric Mid-Thigh Pull (IMTP) using the Hawkins Dynamic force plates (Westbrook, ME).

Countermovement Jump Test

The countermovement jump required the athlete to perform three jumps, as high as they could. Out of the three jumps, the best score was taken from one of them and used for analysis. Before each jump, the participant was told to step onto the force plates, place their hands on their hips, and wait for the beep. Once the beep was heard, the athlete would jump as high as they could, and as they landed, they were told to stick the landing while keeping their hands on their hips. Next, they were to remain on the force plates until the jump test was completed. Once it was completed, participants were asked to step off the force plates and take a 1-minute rest. This process was used for all 3 jump trials. With the completion of each trial, the data was saved to the computer and exported to an Excel spreadsheet.

Multi-Rebound Jump Test

The Multi-Rebound Jump Test (RJT) consisted of eleven jumps performed as high and as quickly as possible. Each group were given the same, short demonstration on how to properly perform the test. To begin the test, participants were told to step onto the force plates, and place their hands on their hips. Next, they were told to remain still and wait for the beep, once the beep was heard they would complete the 11 jumps. For the eleven jumps, the participants were to jump as high as they could and do so as fast as possible. To ensure the proper number of jumpers were completed, each jump was counted out loud by one of the researchers. Like the CMJ, participants were given three trials to complete their best set of jumps. Each trial was saved to the computer and later exported to Excel for analysis. The reactive strength index (RSI) was determined for each athlete based on the RJT. A top RSI score and an average top 5 RSI score were determined. The reactive strength index is calculated by dividing the athlete's flight time by their ground contact time ("What is the different between RSI", n.d.). Experts have proposed that RSI is an effective method to assess the stretch shortening cycle (Healy et al., 2018).

Isometric Mid-Thigh Pull

The Isometric Mid-Thigh Pull (IMTP) consisted of one pull by the participant for five seconds. The second test was performed using an alternate grip. Each athlete was given demonstrations on how to properly perform both tests. Proper positioning includes the athletes holding their torso upright, placing their feet and knees underneath the bar, and ensuring their thighs were in contact with the bar. The height of the bar was adjusted for each athlete based on their height. To do this, knee and hip angles were measured using a goniometer. Knee angles were maintained between 125-145 degrees and hip angles were maintained between 140-150 degrees (Comfort et al., 2019). Once the athlete was in proper positioning, they were instructed to wait for the beep that was the notion that they could begin pulling. During the test, encouragement and cues from the researchers were provided to ensure the athletes gave their best abilities. Researchers pointed out that the athlete should focus on pushing their feet into the ground as hard as they could.

Statistical Analysis

A median split was applied to divide the athletes into low (LP) and high (HP) performing groups based on CMJ heights. Means and standard deviation (SD) were used to describe the physical characteristics of the participants. Paired sample t-tests were used to compare LP and HP in respect to anthropometric measures, CMJ jump height; IMTP peak force, relative peak force; the 10/5 RSI score and the average top 5 jumps RSI score. 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 were calculated and corrected for the small sample size (<20 participants) using Hedges's gs (Lakens, 2013; Cohen, 1988). 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 (Hopkins, 2022). All statistical analyses were performed using a statistical software package (SPSS, Version 28.0, SPSS, Inc., Chicago, IL).

Results

LP and HP anthropometric measurements (Table 1) including weight ranged from 70 kg (LP) to ~62 kg (HP), height 1.63 m (LP) and 1.64 m (HP), and BMI ~26 kg·m^{-2} (LP) and 22 (HP). LP and HP CMJ performance ranged for IMTP Peak Force (N) from ~1625 to ~1660, IMTP Relative Peak Force (N·Kg^{-1}) from ~24 to 27, Peak RSI Score from 1.67 to 2.1, and average Top 5 Jump RSI Score 1.55 to 1.90 respectively (Table 2). Overall, HP group was 13.78% lighter than the LP group, HP was 0.6% taller than LP, BMI for HP was 14.13% smaller than LP (Table 1). HP group outperformed LP groups by 2.14% for IMTP Peak Force, 14.21% for IMTP Relative Peak Force, 25.75% for Peak RSI Score, and 22.58% for average top 5 jump RSI Score (Table 2).

Physical and anthropometric characteristics are presented in Table 1. Neuromuscular and performance measures of the participants are presented in Table 2. The median split procedure divided the group to eight LP players (CMJ ≤ 22 cm) and eight HP players (CMJ > 22 cm).

Table 1. LP and HP Anthropometric Measures

Measure	LP	HP	Size Effect
Wt (kg)	70.00 ± 19.53	61.52 ± 9.78	.54
Ht (m)	1.63 ± 0.94	1.64 ± 0.49	-.09
BMI (kg·m^{-2})	25.62 ± 4.58	22.00 ± 3.95	.63

Values are expressed as mean ± standard deviation (SD)

Table 2. LP and HP CMJ Performance Measures

Variable	LP	HP	Size Effect
IMTP Peak Force (N)	1624.92 ± 322.70	1659.72 ± 218.99	-0.11
IMTP Relative Peak Force (N·Kg^{-1})	23.77 ± 3.30	27.15 ± 2.63	-1.07
IMTP Relative Peak Force (%)	246.54 ± 30.92	294.15 ± 39.77*	-.126
Peak RSI Score	1.67 ± 0.41	2.10 ± 0.19*	-1.27
Average Top 5 Jump RSI Score	1.55 ± 0.38	1.90 ± 0.21	-1.09

Values are expressed as mean ± standard deviation (SD)
* $p \leq 0.01$ between the methods

Discussion

The purpose of this study was to examine the relationship between countermovement jump (CMJ) performance, isometric mid-thigh pull (IMTP), and the 10/5 reactive strength index (10/5 RSI) in NCAA Division III women's soccer players. The median split procedure divided the group to eight LP players (CMJ < 22 cm) and eight HP players (CMJ > 22 cm). Significant ($p < 0.01$) and large effect size (> 1.2) differences were observed between the groups for IMTP peak force relative to body weight and peak RSI score (Table 2). Peak force, relative peak force and the average top 5 jumps RSI score were not significantly different ($p > 0.01$) between LP and HP, and displayed trivial, medium, and medium effect size (d), respectively (Table 2).

The results of this current study suggest that there may be a relationship between body mass and IMTP. Although body mass was not significant ($p > 0.05$) between the HP and LP groups, it was substantial with a difference of ~ 9 kg. However, IMTP performance was significantly different between HP and LP groups. As White (White, 2020) stated, it is possible that lower performances could be related to the extra weight being carried. Another study conducted by Thomas et al., 2015, suggested that the IMTP results will be like the results of sprint performance and relation to body mass. More specifically, in the study, researchers wanted to determine if there was a relationship between IMTP and sprint performance, and if there was, what was the commonality. In the study, individuals with a higher amount of strength and lower body mass performed better in the sprint tests. This was the same for a higher performance on the IMTP. Therefore, researchers concluded that body mass could have a role in a higher performance for the IMTP as a lower body mass made acceleration and force production better (Thomas et al., 2015).

Similar to the IMTP findings (Table 2), the results of this current study suggest that there may be a relationship between body mass and RSI score. Although body mass was not significant ($p > 0.05$) between the HP and LP groups, it was substantial with a difference of ~ 9 kg. However, RSI scores were significantly different between HP and LP groups. The RSI also measures force production, as Thomas et al., 2015, mentioned above stated, when body mass is generally lower, force production is enhanced overall. As with the IMTP, the RSI of this study also showed a difference based on BM and performance. An RSI score is often related to the performance of the neuromuscular system, meaning that when one performs well on the neuromuscular test, such as the IMTP, then their RSI score is likely to be high as well (Dossantos et al., 2017). Resembling this study, research with elite futsal players determined that the athletes with a higher BM also performed lower on the Peak Reactive Strength Index (Konstantinos et al., 2023). This finding is likely related to the relationship between jump height and the frequency of jumping, and body mass.

Conclusion

In conclusion, neuromuscular testing can provide the information needed for coaches and athletes to understand their strengths and weaknesses in their sport and be used for injury prevention. There have been more studies within the NCAA women's soccer population over the last few years, however information regarding the Division III women's level remains slim. To our knowledge, there is limited research using the IMTP in the DIII women's soccer population. The findings of this study suggest that there were substantial differences between low performers and high performers in the Isometric Mid-thigh Pull and the Peak Reactive Strength Index, with relation to BMI. With the results of this study, a high neuromuscular test performance is correlated with a higher peak RSI, sprint speed, and overall strength. The information of this study should be used as preliminary as further research needs to be conducted in this population of Division III female soccer players.

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