APPROVAL OF HONORS PROGRAM SENIOR PROJECT

Candidate

Thiago Gianico

Project Title

The Association Between Isometric Mid-Thigh Pull and Deadlift Performance in Female NCAA Division III Basketball Players

This Senior Project is approved as acceptable

Project Director

Dr. Meir Magal

Committee Member

Dr. Timothy Dornemann

Committee Member

Dr. Emily Weber

Honors Program Co-Director

Dr. Bill Yankosky

Honors Program Co-Director

Dr. Fred Sanborn

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THE ASSOCIATION BETWEEN ISOMETRIC MID-THIGH PULL AND DEADLIFT PERFORMANCE IN FEMALE NCAA DIVISION III BASKETBALL PLAYERS

HONORS THESIS PROJECT

THIAGO GIANICO

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Abstract

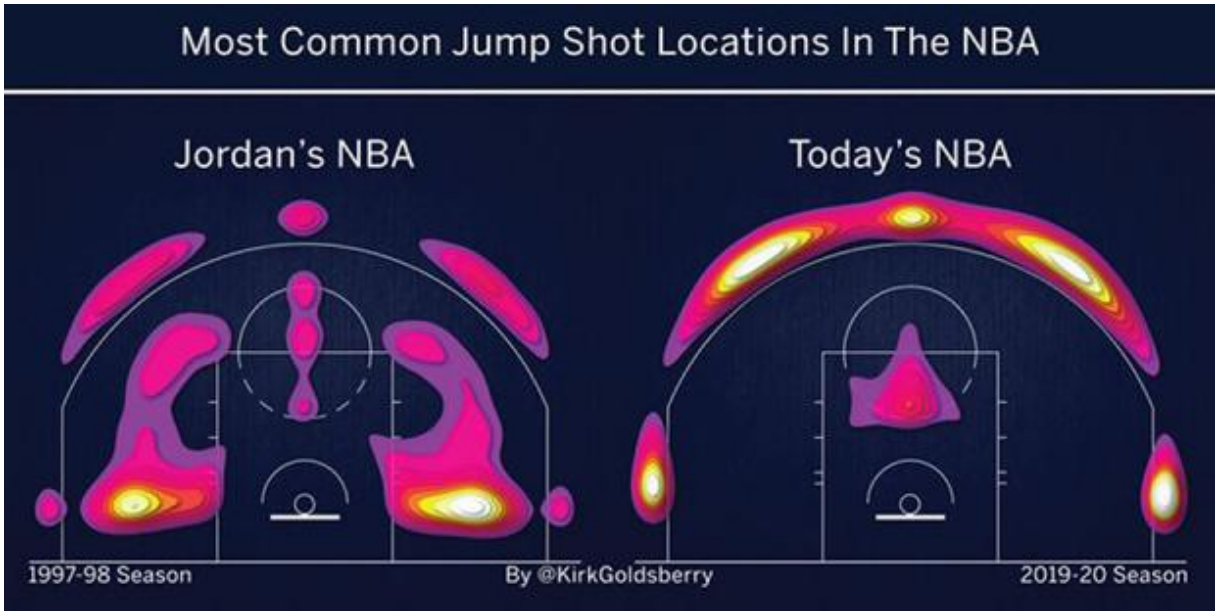
The purpose of this study was to look at the association between female NCAA Division III basketball players isometric strength assessments, done by the Isometric Mid-Thigh Pull (IMTP), and their dynamic strength performance when assessed by the one-repetition maximum (1RM) trap-bar deadlift. Twelve female collegiate basketball players (body mass: 73.52 ± 13.27 kg; age: 19.42 ± 1.16 years) participated in the study. To perform this study, a force-plate device was used to assess peak force, rate of force development (RFD), and force-time characteristics during IMTP testing. Therefore, participants executed a 1RM trap-bar deadlift on a different day. Furthermore, to assess the associations between IMTP characteristics and deadlift performance, we utilized the Pearson product-moment correlation coefficients. Our findings showed that IMTP peak force and 1RM trap-bar deadlift performance were significantly positively correlated ($r = 0.75$, $p < 0.05$). Nonetheless, although they did not approach statistical significance, other IMTP variables, such as numerous RFD measurements and relative peak force, showed moderate-to-large relationships with deadlift performance. In the current cohort, dynamic strength performance is highly correlated with maximal isometric force generation. This information should be further studied to assess potential uses in athlete monitoring and performance assessment, as the IMTP can be a useful and less dangerous alternative to conventional maximum strength testing.

Basketball

History

Basketball is a sport that combines athleticism, strategy, and technical demands into a fast-paced game. Basketball was first created as an indoor sport to keep students active throughout the winter, since they could no longer play football or lacrosse. It was created by Dr. James Naismith at Springfield College in 1891, using a soccer ball and two baskets to play (Where Basketball was Invented: The History of Basketball). Played at professional, collegiate, and recreational levels worldwide, the sport has now grown into a significant global phenomenon. It is now a universal sport with a defined structure, thanks to standardized rules established by governing bodies such as the International Basketball Federation (FIBA) and the National Basketball Association (NBA). There are five positions in basketball: center, shooting guard, small forward, power forward, and point guard, and each has a specific function that helps the team win. First, the point guard is responsible for leading the offense and distributing the ball efficiently. On the other hand, the shooting guard is usually the team's leading scorer, who will specialize in both off-ball movement to find spaces and long-distance shots. Then, the small forward is known for combining mid-range scoring, defense, and quickness, making them a jack-of-all-trades. Lastly, the center and power forward control the paint area and focus on setting screens, getting rebounds, and scoring close to the basket. Nowadays, athletes are expected to perform a variety of roles beyond their traditional duties, as modern basketball has shifted towards a positionless style in which players can do everything for the team. This shift is evident in the trend of jump shot locations over the decades. Nowadays, every player must be able to shoot from

long distance, as teams are increasingly shooting more three-pointers than two-pointers (Leopold, 2020).



(Leopold, 2020)

In this graphic, two centuries are compared for jump shot locations. The first one, from the 1997-1998 season, when the famous Michael Jordan played, had a higher incidence of jump shots at mid-range distances and closer to the paint. This meant that two-pointers were the main way for most teams to score; however, in the second one, we can see the difference compared to how the game looked in the 2019-2020 NBA season. This graphic demonstrated that nowadays, the long-distance shots have increased considerably, prioritizing three-pointers and players who can shoot from this distance. This leaves mid-range shooters and players that can only play close to the rim out of the equation, forcing them to adapt or be left behind. Players like power forwards and centers that play close to the rim, scoring two-pointers, pivoting, and blocking, are still necessary, but now they are asked to shoot from long distance as well. Therefore, this shows that players in every position, even bigger guys like the

point guards, need to be able to shoot from long distance, shifting the game away from what it used to be a few decades ago.

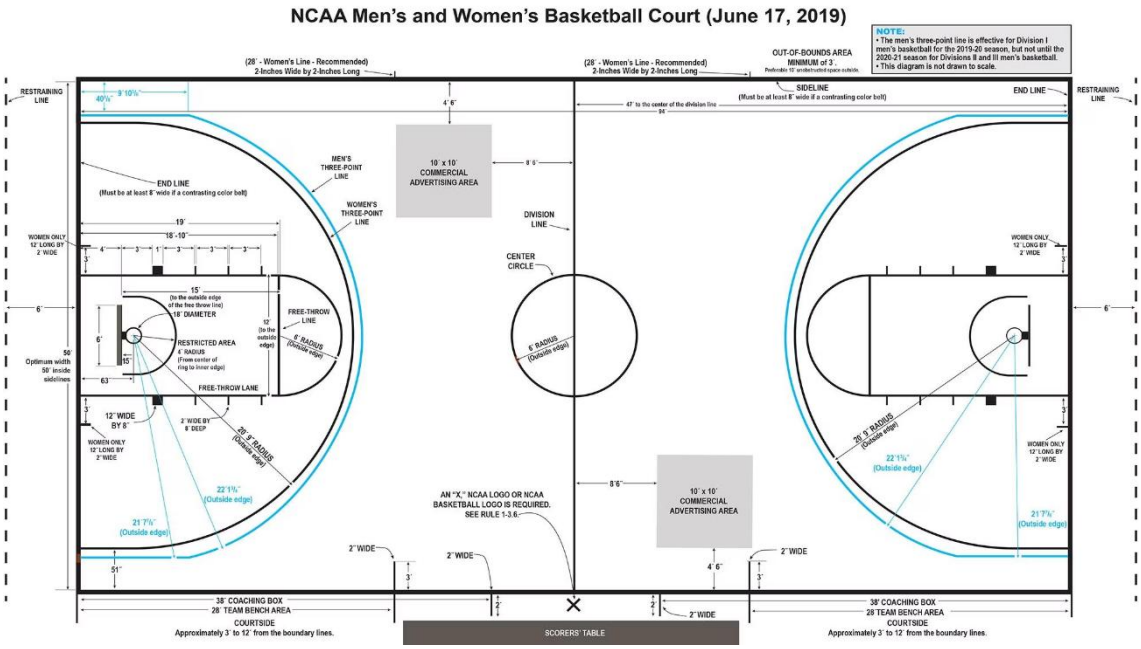
This is not the only change one can see in basketball from the last century to today, since the shift in how teams score has drastically affected the number of points per team. Up to now, the average points scored in a game per team in the 2025-2026 season is 116.9 points per game. In the 1998-1999 season, part of the Michael Jordan era, the average points per team were 91.6, a difference of 25.3 points per game compared to today. This drastic change stems from a combination of factors, not just players shooting more three-pointers, but also a higher pace, which translates into more possessions per team per game. To support this point, I analyzed the 1998-1999 and 2025-2026 seasons once again. Looking at statistics, in the 1998-1999 season, teams averaged 88.9 possessions per game. On the other hand, the ongoing season averages 104.5 possessions per game. This means an increase of 15.6 possessions per team and per game, which will naturally increase the number of scoring opportunities for each team and, therefore, the scored points per game (Imbo, 2025). This phenomenon occurred in the WNBA as well, when comparing the 1997 inaugural season with the ongoing season there is a big difference. In the 1997 season, the highest scoring team averaged 74 points per game, while on the other hand the highest scoring team in the 2026 season is averaging 86.1 points per game (ESPN, n.d.). This is a clear sign that basketball is constantly evolving, rewarding those who adapt and punishing those who cannot keep up.

Scoring

The way to win in basketball is by shooting the ball through the elevated hoop to score more points than the other team, and a shot is worth two points if made from

within the three-point line distance, and anything outside that is worth three points. Also, under certain conditions, such as fouls, players can take a free throw, which is worth one point. In basketball, there are four quarters, each lasting 10 minutes under FIBA regulations and WNBA, or 12 minutes under NBA regulations (FIBA, 2024). In the NCAA, men's teams play two twenty-minute halves, while the women's teams play four ten-minute quarters. Each team has five players on the court at any given time, and substitutions are permitted during stoppages. If the score is tied, five-minute extra periods are played until one team wins. Another important feature in basketball is the shot clock, a 24-second timer that drives teams to make a shot within that window, resulting in a fast-paced, constant game and avoiding strategies that might slow it down. When combined, these regulations ensure the sport remains strategic, dynamic, and equitable for both teams.

Court and Ball



(Wilco, 2019)

It is fundamental to discuss the importance of knowing the court and ball characteristics. To better understand and analyze basketball's physiological needs, it is essential to first delve deeply into its structure. Therefore, to preserve fairness across various playing levels, standardized court and equipment measures were created worldwide. An official basketball court is 28 meters long by 15 meters wide, or around 91.9 feet by 49.2 feet, and these measurements are also utilized in the NCAA for both men's and women's teams (FIBA, 2024). The only difference between men's and women's is the three-point line: for men, it is 23 feet and 9 inches, while for women, it is 22 feet and 1.75 inches, reflecting physical differences between the sexes to create a more even and fair court for both genders. Afterward, everything is the same: a center line separates the two halves of the court, each of which has a restricted area close to the basket, a three-point arc, and a free-throw semi-circle and lane. These are supported by a backboard that is 1.8 meters wide and 1.05 meters tall; the basket itself is positioned 3.05 meters, or 10 feet, above the playing field. Furthermore, these lines and circles must follow specific rules, for example, from the midpoint of the sidelines, the center line must be drawn parallel to the end lines, going 0.15 meters past each sideline. Also, the center circle, which has a radius of 1.80 meters measured to the outer border of the circumference, must be marked in the middle of the court. The free-throw semicircles must be marked on the court, with their centers at the midpoint of the free-throw lines and a radius of 1.80 meters measured to the outer edge of the circumference. Lastly, each endline must be marked parallel to the free-throw line; it will be 3.60 meters long, with its furthest edge 5.80 meters from the inner edge of the endline. Its midpoint will lie on the imaginary line connecting the two end lines' midpoints. The endlines, the extended free-throw lines, and the lines that start at the

endlines and end at the outer edge of the extended free-throw lines, which are 2.45 meters from the midpoint of the endlines, are the rectangular areas on the court that are designated as restricted areas. Lastly, outside the court, each team needs a bench for the other substitute players who may come in at any moment, for the coaching staff, such as the head coach or assistant coaches, and for medical staff and athletic trainers. Each bench for each team must have two designated spaces, each with two lines, separated by two meters from the court sidelines. Each team bench area must have 16 seats accessible to all its crucial members, but any additional individuals must be at least 2 meters behind the team bench. Lastly, all of these lines must be the same color and marked in white, or in any color that contrasts with the court, with a width of 5 cm, and be clearly visible.

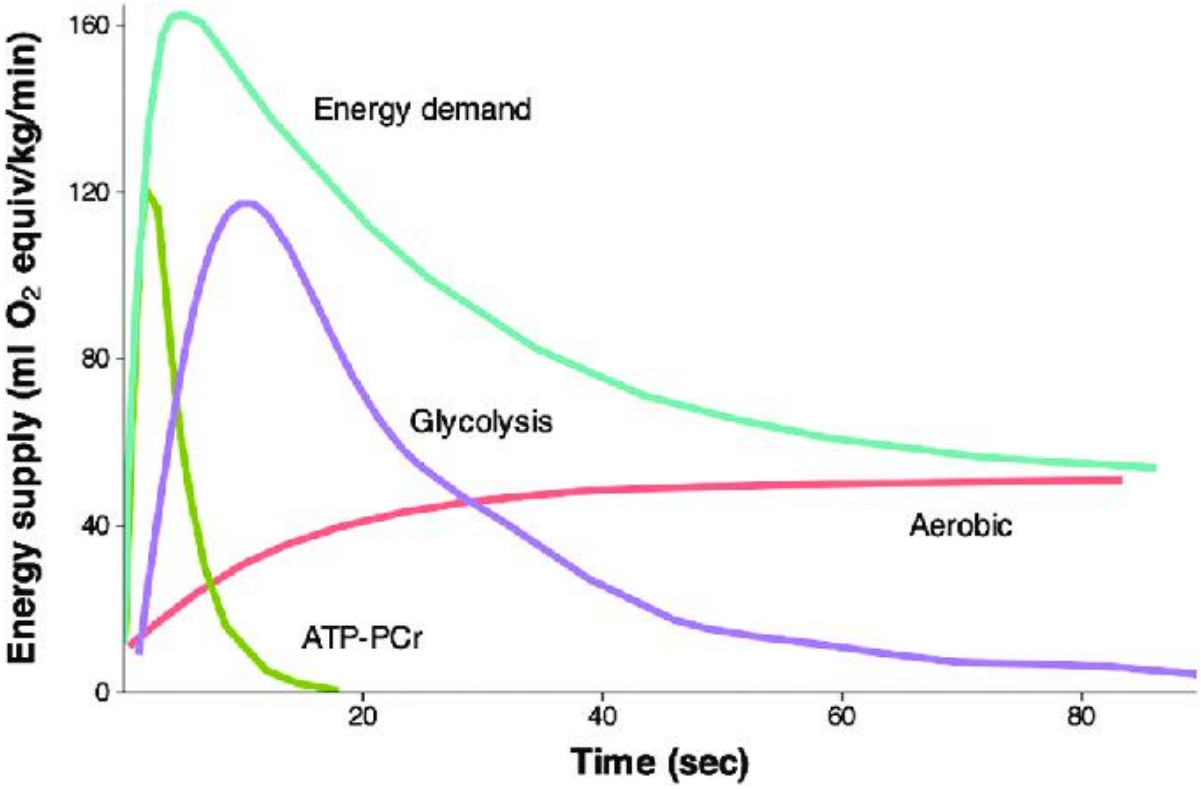
When analyzing basketballs, one finds a few differences between those used in men's basketball and those used in women’s basketball. A size 7 basketball, which weighs between 600 and 650 grams (1.3-1.4 pounds) and has a circumference of roughly 75 cm (about 29.5 inches), is used in men's events for the NBA and NCAA (FIBA, 2024). On the other hand, in women’s events for the WNBA and NCAA, they use a size 6 ball, which is marginally lighter and smaller to fit hand size and maximize control, again reflecting the normal physical differences between the sexes. In addition, to ensure consistency in the game, the ball must be spherical, composed of leather or a composite material, and inflated to 7.5-8.5 psi (FIBA, 2024). Thanks to this, players can readily switch between leagues and tournaments because these standardized metrics provide a consistent experience wherever they play. It is crucial to maintain a balance and standard across court size, basket height, and ball weight, as this pushes players to improve their strength, coordination, and shooting accuracy within these exact

measurements. Also, these differences between the sexes just show once again why the game is intended to be fair, giving everyone equal opportunities to perform at the highest level.

Energy systems

When it comes to basketball, one finds that it is a high-intensity, intermittent activity that needs quick transitions between explosive movements and short rest intervals, but also is an activity that players must be able to perform during 48 minutes on the court. This means that from a physiological standpoint, there will be multiple processes occurring at the same time, and to deeply understand how basketball players perform, first we need to analyze these processes. These will take place through the aerobic glycolysis, the aerobic system, and the phosphagen system, also called the Adenosine Triphosphate-Phosphocreatine, or ATP-PC system, the three main energy systems that will be present in the game of basketball (Shalom et al., 2023). When assessing players' performance, it is critical to examine their strengths and weaknesses and identify ways to improve them; all of these are crucial factors if optimizing performance is the goal. This is why it has been proven that elite basketball players have hybrid energy demands and must train their overall fitness capacity. In a game, there may be many moments of low or moderate aerobic activity, prioritizing the aerobic system and cardiovascular fitness, alternated with quick transitions and a fast-paced game that will test their anaerobic energy system (Shalom et al., 2023). Therefore, the game could come down to which team can manipulate these variables better, being ready to perform these different tasks under fatigue and pressure, and able to adapt to what the team needs from those specific players at that moment in the game.

To further explain the demands placed on these different energy systems, a graphic perfectly illustrates them. In the figure below, the energy demand is shown on the Y vertical axis, and the time, in seconds, on the X horizontal axis. Therefore, we can analyze how large these energy demands are at different times during the movement and which energy system is most involved.

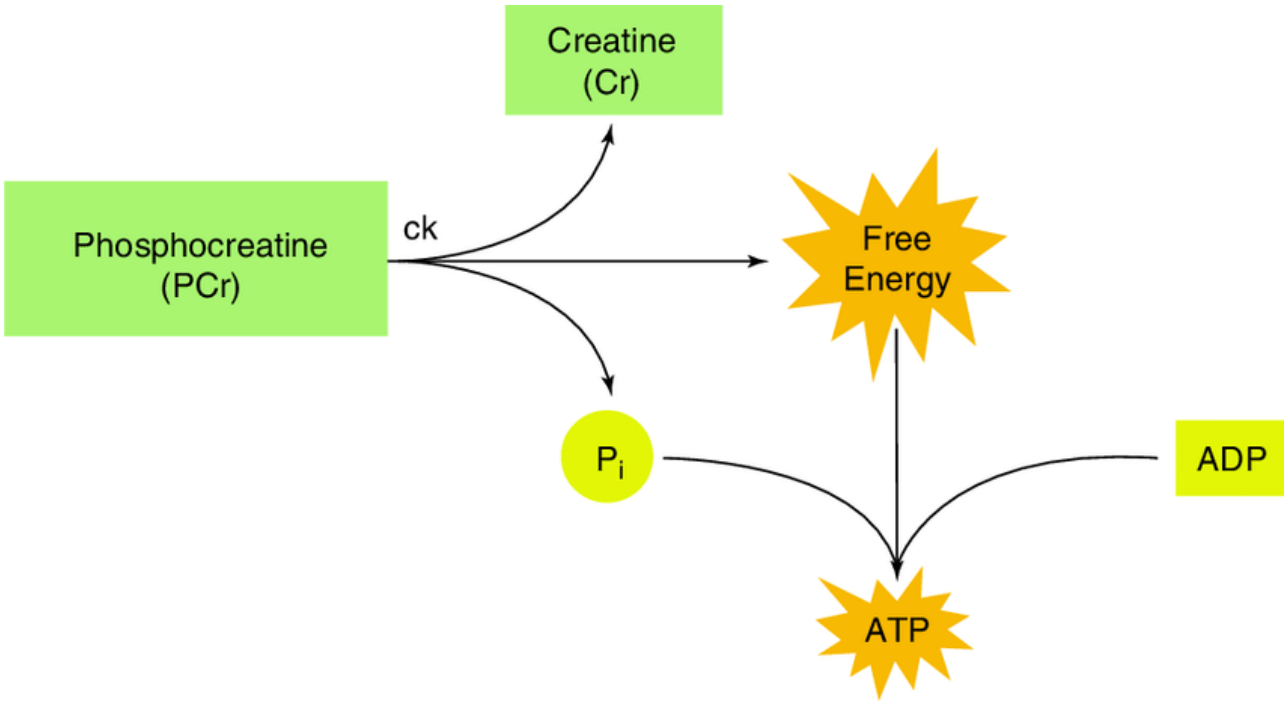


(Leaf et al., 2024)

ATP-PC System

First of all, it is important to understand that in a 48-minute game, there will be many short, explosive movements lasting less than 10 seconds, powered by the ATP-PC system. In the game of basketball, these quick movements can include everything from sprints from one side of the court to the other for a quick attack/defense transition, a vertical jump to grab a rebound, score a point from a layup or an alley-oop, or blocking a point, as well as rapid direction changes that will test their agility to the extreme.

These movements may seem simple or not have much impact, but in a game as intense as basketball, they can define possessions, points, and even games. From a physiological standpoint, the adenosine triphosphate and phosphocreatine system will be essential for these movements, since phosphocreatine is stored in muscles and depletes quickly but recovers rapidly. In fact, lower-intensity movement will promote its recovery, since the aerobic system helps restore phosphocreatine to about 50% of its pre-exercise level after only 20 seconds of active rest and to about 90% after 60 seconds of rest. Because of this fast recovery system, it makes it a very efficient energy source for these quick scenarios in basketball (Gottlieb et al., 2021).



(Sousa et al., 2019)

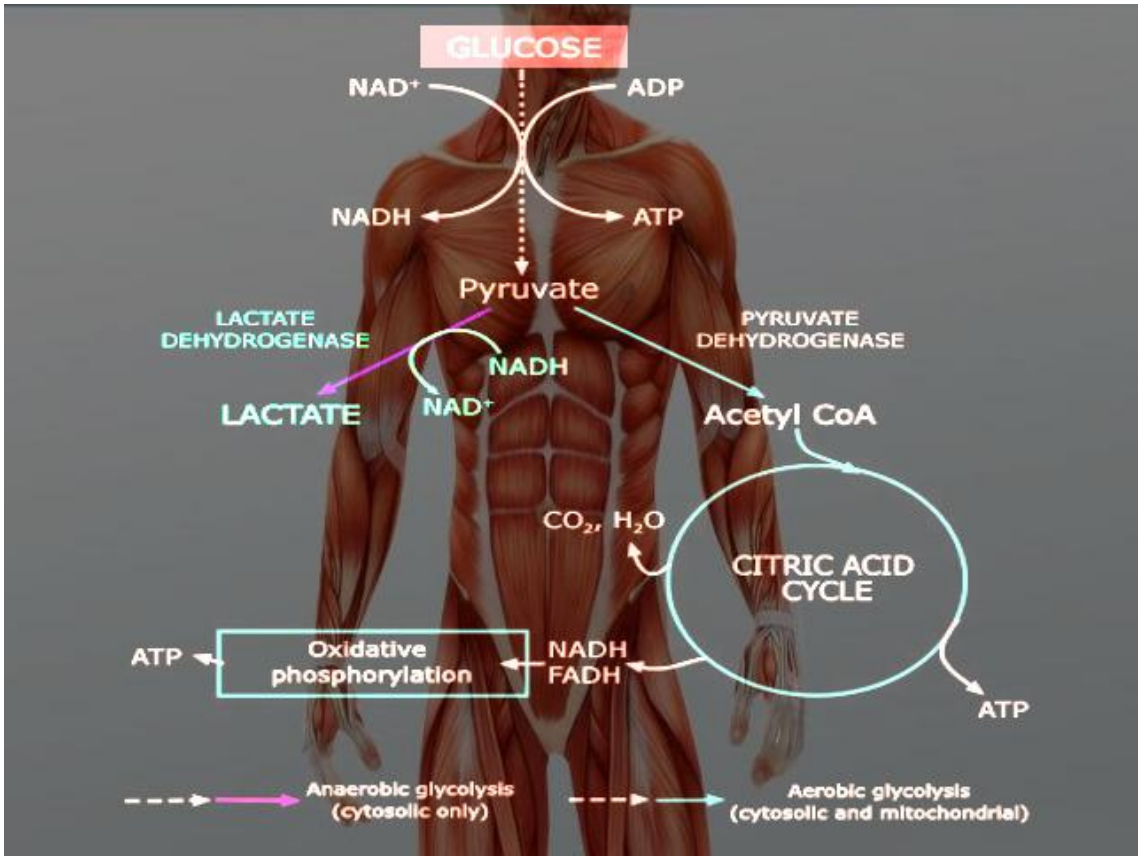
In the figure above, one can see how, through the ATP-PC energy system, energy released from phosphocreatine hydrolysis is used to synthesize ATP by binding inorganic phosphate (Pi) to ADP or adenosine phosphate (Sousa et al., 2019).

Glycolytic system

Afterwards, when these efforts go beyond the ATP-PC availability and last longer, the anaerobic glycolytic system will play a massive role. The glycolytic system will be the primary fuel for situations like extended defensive possessions that involve constant switching and help rotations, or fast-break plays that involve many accelerations throughout the court. Also, there are moments when a team needs to maintain power production across different movements from different players at the same time, within a single possession, either to attack or defend a basket. These situations may come as a last-minute play that can define the outcome of the game, applying pressure throughout the court to defend, or attacking the basket from different angles with different plays. This is where this system will become crucial due to the glycolysis process that will occur. The process of glycolysis is the start of breaking down muscle glycogen, occurring during prolonged high-intensity play or anything lasting longer than 10 seconds, eventually leading to lactate accumulation and increased fatigue. Consequently, the oxidative system may take a bigger role later on, since a lot of the time during a game the players will be walking or standing, and this means that during these lower intensity activities their capacity to recover from one fast play to another must be efficient, making the aerobic system as important as the rest.

Although this is true, and the oxidative system is important, the glycolytic system has the advantage of quickly providing ATP energy without oxygen, making it very efficient during basketball possessions. This is because these possessions may last up to 24 seconds in the professional NBA or WNBA, and up to 30 seconds in NCAA college games.

Lastly, in the figure below, one can see the process of glycolysis that occurs through the glycolytic system. This is a process that occurs in the cytoplasm of a cell. After 10 enzymatic reactions that break down the glucose molecule, it ends up being converted to pyruvate. Therefore, lactic acid fermentation, which is the form of anaerobic respiration carried out by yogurt bacteria and your own muscle cells when you train, will allow glycolysis to continue producing ATP in low-oxygen environments by converting the 3-carbon pyruvate to the 3-carbon lactate and regenerating NAD+. Therefore, because each cell has a certain supply of NAD+, this oxidizing agent must be renewed in order to continue producing ATP. To accomplish this, NADH functions as a reducing agent, renewing NAD+, and lactate is produced via the reduction of pyruvate (Roy, 2024).

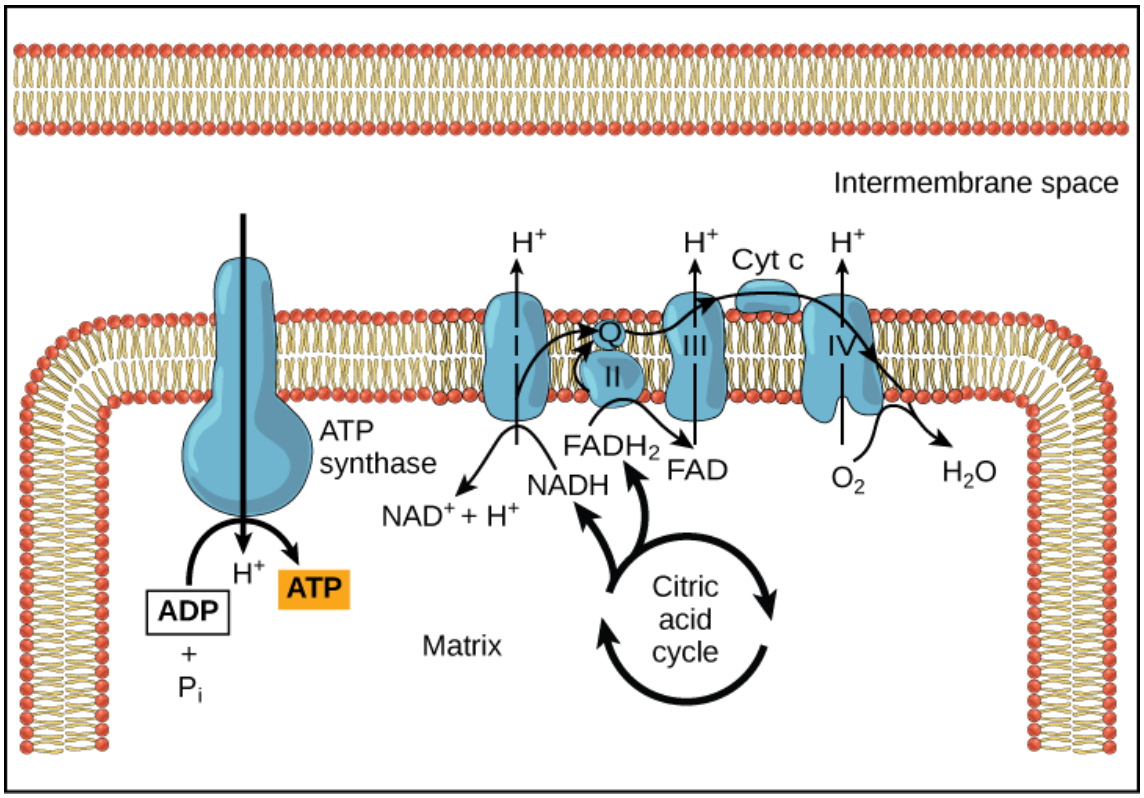


(Melkonian, Schury, 2023.)

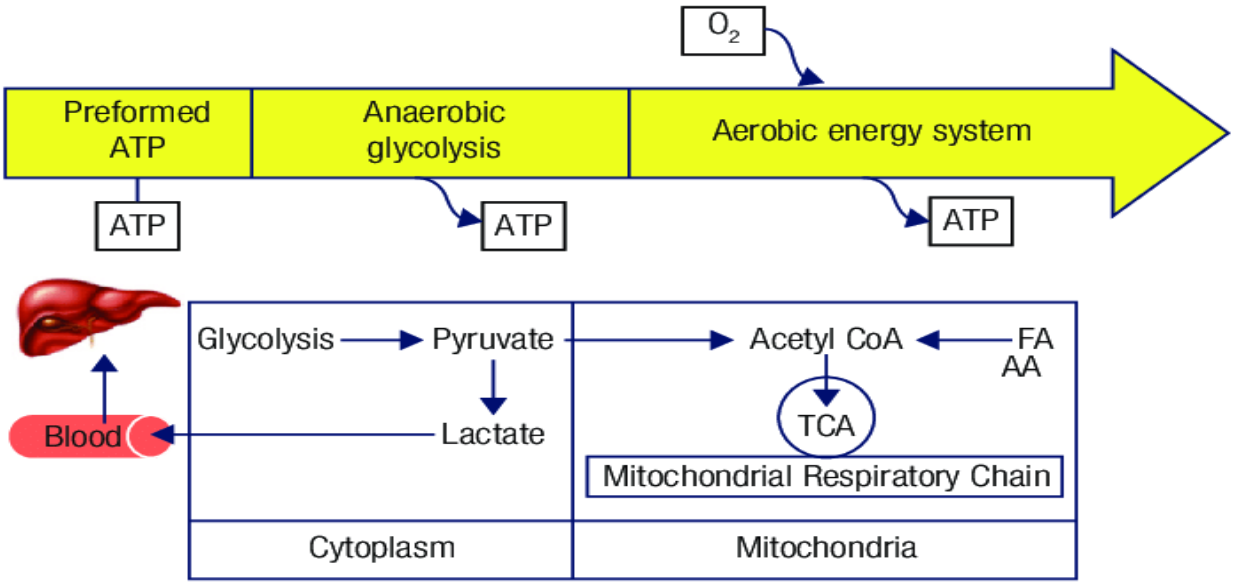
Aerobic system

Lastly, as mentioned before, the aerobic or oxidative system will play a crucial role, since fatigue accumulation from the glycolytic system will begin to set in after a few minutes into the game, and players need to be well-conditioned to endure it. In this system, oxidation will occur, a process in which acetyl-CoA initiates a chain of chemical reactions that allow the Krebs cycle to end with the production of CO2 and 1 ATP molecule per cycle. Therefore, the released hydrogen ions will bind to two coenzymes, the Nicotinamide Adenine Dinucleotide, or NADH, and the Flavin Adenine Dinucleotide, or FADH. These will transport the hydrogen atoms into the inner membrane of the mitochondria, the part of the cell where all of this process occurs. In the electron transport chain, FADH and NADH act as electron carriers. Here, the electrons will undergo a process of reduction-oxidation (redox) reactions. This is a chemical reaction that simultaneously transfers electrons between two substances: one loses electrons (oxidizes) and the other gains electrons (reduces). Consequently, when each protein complex receives an electron, it releases energy to form a proton gradient. For that reason, when the electrons reach the end of the chain, there will be a lot of stored potential energy, which will then be used during chemiosmosis to create

ATP (Ahmad et al., 2023).



This happens because the protons flow back down their concentration gradient into the matrix through a specialized channel protein called ATP synthase. Therefore, once these hydrogen ions go down their concentration gradient, they will cross the membrane and be used by the ATP synthase enzyme to generate ATP by phosphorylating ADP with inorganic phosphate (Sousa et al., 2019).



(Ho, 2019)

In conclusion, this image from Ho's 2019 study, along with the proton gradient explanation image, provides a general overview of the processes we explained before across the different systems, as well as their primary metabolic products and byproducts. First of all, the ATP-PC system uses preformed ATP to release a large amount quickly, producing heat and a byproduct during these explosive movements performed in less than ten seconds. Secondly, the anaerobic glycolytic system proceeds via cytoplasmic glycolysis, generating pyruvate, which can then be converted to lactate. Lastly, the aerobic or oxidative energy system generates the biggest amount of ATP molecules between all three energy systems. This process occurs in the mitochondria, where pyruvate is transported and transformed into acetyl-CoA. Therefore, acetyl-CoA enters the Krebs cycle (tricarboxylic acid cycle, TCA) and generates NADH, $FADH_2$, and CO_2, fueling the electron transport chain, synthesizing more ATP, and releasing H_2O and heat as byproducts.

Testing Modalities

Isometric Mid Tight Pull

The isometric mid-thigh pull (IMTP) is a multi-joint exercise used to evaluate overall strength and force-generating capacities. In this exercise, a stationary barbell is used to simulate a deadlift, with the only difference that it is isometric at mid-thigh. Because the bar is in an isometric position, maximal tension will be generated using the force plate below it, and therefore, the athlete's maximum force, as well as their power, can be measured. This is why the IMTP test can be used to calculate peak force development, rate of force development (RFD), and other time-constrained strength or power variables, for example, force applied 100 milliseconds after the pull started. Nonetheless, we can also assess asymmetries with this test, since the system shows the applied force on each side at each moment, serving as a tool to correct them and prevent future injuries. This information is very difficult to obtain using typical muscle-strength testing methods, such as the barbell back squat or the conventional deadlift 1RM. Other benefits of the IMTP test include time efficiency, since it does not take long to perform, it has less disruption to training, it has a reduced risk of injury, and it requires less technical instruction as an exercise compared to full range of motion core lifts such as squats or any of the Olympic lifts.

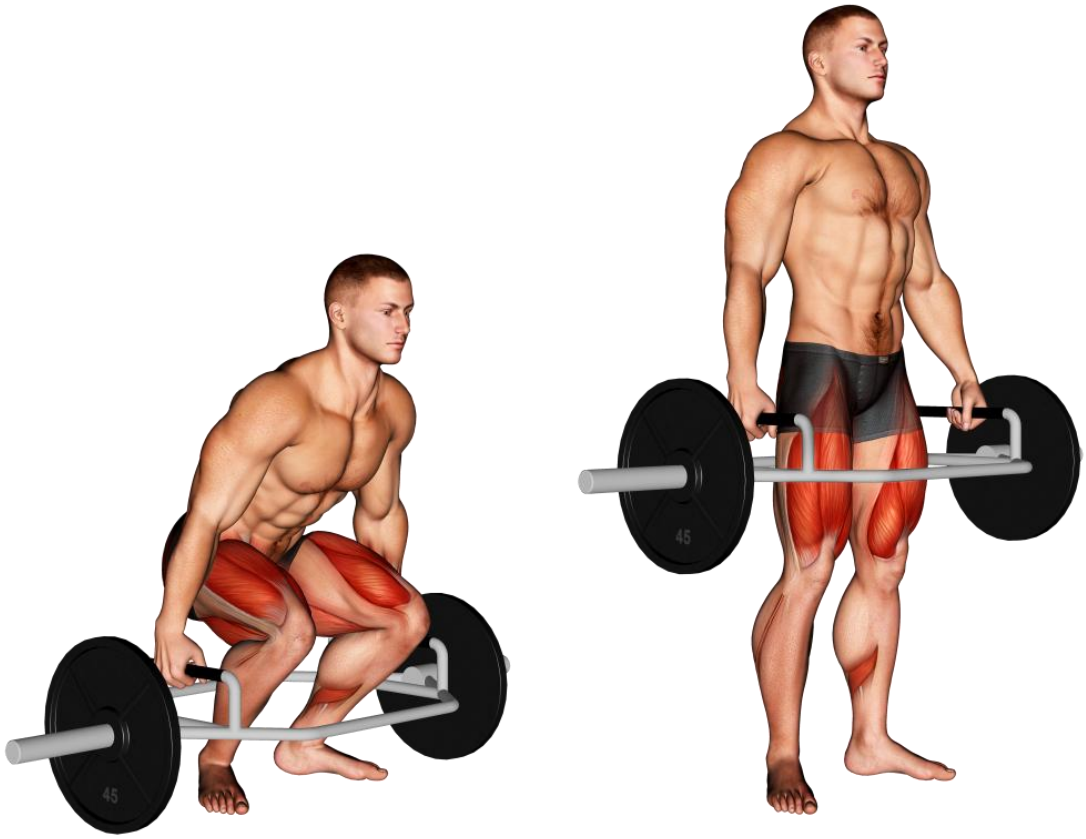


(Stien et al., 2025)

Trap Bar Deadlift

Apart from the IMTP, the three-rep max test on trap bar deadlifts was tested to compare the strength of D3 women's basketball athletes pre- and post-season. The trap bar deadlift, which is also known as the hex bar deadlift, is an exercise that will be performed with a hexagon barbell. Using the hexagon barbell allows athletes to stand inside the load rather than behind it, as in the most popular variation, the conventional deadlift. When the trap bar's structure was analyzed, it was observed that the handles on the sides better align the load with the athlete's center of mass. Therefore, this allowed athletes to maintain a more upright torso, creating a safer, easier movement pattern to learn. Since it was easier to learn and safer in general, this created a better environment for athletes to generate greater power and strength. In addition, strength and power output in the 3RM trap bar deadlift test are directly correlated with their

performance on the court. This can be seen in the movements athletes must perform, such as sprinting from one side of the court to the other, jumping to grab a rebound or block a shot, and changing direction quickly. In all of these movements, there will be triple extension, ankle, hip, and knee, and an increase of strength and power output in the trap bar deadlift test, consequently demonstrating an improvement in the court.



IMTP in female basketball players

This section will review the available literature on the use of the IMTP test with collegiate basketball players to measure peak force production and rate of force development, as well as its accuracy in predicting performance on the court. Understanding the science behind the IMTP test is essential, since it has proven reliable for assessing athletes' physical readiness and predicting their performance on the

court. A study conducted by Townsend et al. (2019), examined 23 male and female collegiate D1 basketball players, asking them to perform multiple tests. They performed the IMTP, a front squat 1RM, a hang clean 1RM, and vertical jump and agility tests. When conducting these tests, they found that the IMTP has a strong relationship with 20-m sprint time, dynamic strength and power, and agility. These findings show that the athletes who performed well on the IMTP test, producing a high peak isometric force, also performed better in the other tests.

Table 1. Descriptive statistics for performance and isometric midthigh pull (IMTP) results.*

	Men's basketball team ($n = 8$)	Women's basketball team ($n = 15$)
Front Squat 1 Repetition Maximum 1RM (kg)	126.1 ± 17.7	83.6 ± 12.5
Hang Clean 1RM (kg)	44.0 ± 6.1	23.7 ± 2.7
Vertical Jump (cm)	77.4 ± 6.4	50.0 ± 5.4
Proagility (s)	4.54 ± 0.21	5.05 ± 0.22
Lane Agility (s)	11.80 ± 0.90	13.68 ± 0.86
1,080 20 m Sprint (s)	3.31 ± 0.15	3.79 ± 0.13
Peak Force (N)	2,534.1 ± 368.0	1,248.0 ± 377.2
Rate of Force Development (RFD) 0–50 ms ($N \cdot s^{-1}$)	5,643.1 ± 6,459.8	2,778.7 ± 1708.0
RFD 0–100 ms ($N \cdot s^{-1}$)	6,161.4 ± 4,694.8	2,988.1 ± 1831.1
RFD 0–150 ms ($N \cdot s^{-1}$)	5,811.0 ± 3,995.0	2,664.6 ± 1,439.0
RFD 0–200 ms ($N \cdot s^{-1}$)	6,015.8 ± 2,678.0	2,736.0 ± 1,176.5
RFD 0–250 ms ($N \cdot s^{-1}$)	5,603.0 ± 2,272.6	2,882.2 ± 1,105.2

*Data presented as mean ± *SD*.

(Townsend et al. 2019)

Furthermore, the IMTP test has been widely used as a strength assessment to evaluate basketball players' physical capabilities. Faulks et al. (2024) conducted a systematic review that analyzed 12 additional studies examining the physical abilities of players at different levels. Their findings showed that the most utilized strength assessments among basketball players are the back squat 1RM and the IMTP. The continued use of this testing method across different studies and levels demonstrates its reliability. In a sport like basketball, where jumping, sprinting, and rapid changes of direction occur frequently, the IMTP assessment easily allows coaches to measure the peak force and RFD required for these movements. In conclusion, this method is

supported not only by science but also by practical application. It is not only easier to learn and perform, but also safer and less fatiguing.

Relationship between IMTP and Deadlift performance

When analyzing the relationship between IMTP and deadlift performance, the evidence suggests a strong relationship between produced peak force and one-rep max deadlift performance. De Witt et al. (2018) tested a group of nine subjects; during this study, the subjects performed a deadlift 1RM and the IMTP test on two separate sessions. Therefore, the results showed a significant correlation between IMTP peak force and one-rep max deadlift performance ($r = 0.88$, $p \leq 0.05$). Nonetheless, the rate of force development did not correlate with deadlift 1RM performance. These findings suggest that the ability to produce a high peak of maximal force is strongly related to the 1RM test; however, the ability to produce force as fast as possible, known as RFD, does not seem to correlate as much. Furthermore, Miller et al. (2021) conducted a study analyzing the relationship between deadlift performance and isometric pulls. During this study, twenty-three healthy adults performed a session consisting of a 1RM deadlift test on the hex-bar and another session of maximal-effort isometric pulls. Results showed that the correlation coefficients between 1RM and force-time characteristics at all positions were strongly associated with peak force. These findings show that isometric pulls can be as efficient, if not more so, than 1RM deadlift tests because they are safer and easier to apply during team evaluations.

Moreover, there is substantial evidence supporting the connection between isometric and dynamic strength. McGuigan and Winchester (2008) conducted a study examining the relationship between isometric and dynamic strength in collegiate Division I football athletes. Peak force, RFD, and strength were measured using the

IMTP and 1RM tests across different lifts. Once again, no correlation was found with RFD, but strong correlations were observed between PF measures and 1RM. This concluded that the isometric mid-thigh pull test provides a strong indication of dynamic performance in these athletes.

Nonetheless, McGuigan et al. (2010) also found a strong correlation among recreationally trained men. During this study, 26 recreationally trained men performed IMTP and 1RM tests, revealing a strong correlation between isometric strength measurements and dynamic strength performance during 1RM lifts. These findings led to the conclusion that isometric midthigh pulls are an efficient method for assessing strength, even in recreationally trained individuals, not only in professional populations.

In addition, the IMTP test is not only related to strength measurements; it is also significantly correlated with agility and sprint performance. Wang et al. (2016) tested athletes and found that the IMTP force is significantly associated with these physical abilities, which are extremely important in basketball. Likewise, Scanlan et al. (2020) conducted a study on this topic by examining a group of basketball players who performed an IMTP test, a 20-m sprint, a countermovement jump (CMJ), a standing long jump, and a repeated lateral bound. During this study, they found an almost perfect correlation between the absolute peak force attained during the IMTP and CMJ, and a strong correlation with the jumps and sprints as well. In conclusion, these findings indicate that the IMTP is a strong tool to assess maximal and rapid force expression, as well as sprinting and jumping abilities, which are essential across a range of basketball-specific movements.

Methods

Participants

Twelve individuals who are members of a National Collegiate Athletic Association (NCAA) Division III Women's Basketball team at North Carolina Wesleyan University were recruited for this study. All participants (mean ± SD): age (19.42 ± 1.16 yrs); body weight (73.52 ± 13.27 kg); height (1.68 ± 0.07 m); BMI (26.21 ± 4.53 kg×m-2) volunteered to participate in the study performed during the off-season of the 25/26 season. Each participant received an informed consent form outlining the study's goals before engaging in any physical activity. Further, participants were informed that their involvement in the study was entirely voluntary and that they could withdraw at any time. Lastly, the participants had time to read the form and ask any questions they might have.

Performance Testing

Participants' height and weight were measured and recorded upon arrival at the Lab of Applied Physiology (LAP) on the North Carolina Wesleyan University campus in Rocky Mount, North Carolina. Afterwards, the athletes performed a dynamic warm-up that progressively increased movement intensity to elevate core temperature and stimulate neuromuscular activation, preparing them for maximal force production. The warm-up was standardized across all participants and designed to prepare the major muscle groups and movement patterns required for the testing protocol. This warming-up protocol was used in two separate testing days. On day one, right after participants signed the informed consent, each subject performed the Isometric Mid-Thigh Pull Test on the Hawkins Dynamics force plate system (Hawkin Dynamics, 2024). On day two, participants performed a one-rep max in the trap-bar deadlift.

Isometric Mid-Thigh Pull Test (IMTP)

For the IMTP test, all force values were corrected, and only the force produced by the movement (net force) was counted. Therefore, during this test, participants had to hold one pull for 5 seconds, testing whether they could maintain peak force throughout. Before beginning three trials, each athlete received a brief demonstration of the test using an alternate grip. Athletes were told to maintain an upright torso, position their knees and feet beneath the bar, and make sure their thighs touched the bar. Before beginning the IMTP, each athlete's bar height was changed to ensure proper body alignment. Both knee and hip angles were assessed to ensure uniform form. Hip angles were kept between 140 and 150 degrees, whereas knee angles were kept between 125 and 145 degrees (Comfort et al., 2019). The athletes were told to wait for the beep after positioning themselves before starting to pull. Lastly, the players received guidance and encouragement from the researchers to help them give their best effort. During the five seconds, the athletes were instructed by the researchers to pull as hard as they could, directing their force upwards, and considering driving their feet into the ground.

Trap-Bar Deadlift

Before performing this exercise, participants were given a set of instructions and demonstrations set forth by the National Strength and Conditioning Association (NSCA) guidelines (Lockie & Adrina, 2017).



(Lockie & Adrina 2017)

To begin with, participants were advised to point their toes forward or slightly outwards. Therefore, individuals had to squat down by flexing at the hips, knees, and ankles to grasp the high handles with a closed, neutral grip. During this position, their hips had to be lower than their shoulders because of flexion at the hips and knees. Therefore, they had to initiate the lift by driving down into the floor and extending at the hips and knees. The extension in these joints occurs simultaneously, and the torso angle with the floor should remain constant. To achieve this, they were told to keep their head and chest up, with their back muscles contracted to retract the shoulder blades. The participants had to simultaneously extend at the hips and knees until a standing position was achieved, ideally while looking forward, to have a more natural spine alignment. Then, the descent had to be done by simultaneous flexion of the hips and knees, keeping the back in a neutral position. Their arms had to remain extended at the elbows and held to the sides of the body throughout the descent and the ascent. Lastly, for the descent, they were advised to flex their hips and knees until the weight plates contact the floor, then return to the starting position (Lockie & Adrina, 2017). Once these instructions were given, athletes began warming up using the following

protocol designed by NCWU's strength and conditioning coach, Ms. Vanessa Batchelor, with guidance from the NSCA protocol (Haff & Triplett, 2016).

SET	**REPS**	**1RM %**	**WEIGHT**
1	10	EMPTY BAR	45 LB
2	5-8	50%	
3	3-5	60%	
4	2-3	70%	
5	1	80%	
6	1	90-95%	
7	1	95-100%	
8	1	100-105%	

(Haff & Triplett, 2016)

This protocol used an ascending approach, with participants starting with more reps with just the bar; a 45lb bar or a 33lb (15kg) bar was offered as an option for athletes who needed it. This approach promotes a gradual increase in weight and a decrease in repetitions, optimizing the probability of achieving as much weight as possible for a one-repetition maximum. During this protocol, it was expected that

athletes hit their 1RM on the last two attempts; if they needed to take another attempt, they were allowed to do so. Likewise, if athletes had reached their 1RM before attempts 7 or 8, they were allowed to stop the protocol before the planned number of attempts.

Statistical Analysis

Means and standard deviation were used to describe the physical and anthropometric characteristics, and neuromuscular and performance measures of the participants. Pearson product–moment correlation coefficients were used to examine any significant correlations IMTP neuromuscular performance and deadlift performance. Associations were defined as small, 0.1-0.3 (positive or negative); medium, 0.3-0.5 (positive or negative); large, 0.5-1.0 (positive or negative). Statistical significance was set at $P < .05$ for this investigation. All statistical analyses were performed using a statistical software package (SPSS, Version 28.0, SPSS, Inc., Chicago, IL).

Results

Physical and anthropometric characteristics are presented in Table 1. Normative IMTP neuromuscular performance data and 1RM hexagonal bar deadlift performance are presented in Table 2. Pearson Product-Moment Correlations ® between IMTP neuromuscular performance and 1RM hexagonal bar deadlift performance are presented in Table 3.

Table 1. Physical and anthropometric characteristics (n = 12) data.

Variable	M ± SD
Age (yr.)	19.42 ± 1.16
Height (cm)	1.68. ± 0.07

Body mass (kg)	73.52 ± 13.27
Body Mass Index ($Kg \cdot m^{-2}$)	26.21 ± 4.53

Table 2. Normative IMTP neuromuscular performance data and 1RM hexagonal bar deadlift performance (n = 12) data.

Variable	M ± SD
Time to peak force (s)	2.25 ± 1.19
IMTP Peak Force (N)	902.83 ± 288.21
IMTP Relative Peak Force ($N \cdot kg^{-1}$)	12.40 ± 3.53
RFD 0-50 ms ($N \cdot s^{-1}$)	2013.33 ± 1477.32
RFD 0-100 ms ($N \cdot s^{-1}$)	2180.83 ± 1357.72
RFD 0-150 ms ($N \cdot s^{-1}$)	1846.58 ± 933.90
RFD 0-250 ms ($N \cdot s^{-1}$)	2088.67 ± 835.40
Force at 50 (N)	128.58 ± 72.38
Force at 100 (N)	241.50 ± 130.82
Force at 150 (N)	300.42 ± 134.95
Force at 200 (N)	406.17 ± 169.07
Force at 250 (N)	545.58 ± 199.07
Deadlift 1 RM (Lb)	249.58 ± 38.52

IMTP = Isometric Mid-Thigh Pull, RFD = Rate of force development.

Table 3. Pearson Product-Moment Correlations ® between IMTP neuromuscular performance and 1RM hexagonal bar deadlift performance (n = 12) data.

Variable	1 RM hexagonal bar deadlift performance	Association
IMTP Peak Force	0.75*	Large
IMTP Relative Peak Force	0.56	Large
RFD 0-50 ms	0.61	Large
RFD 0-100 ms	0.58	Large
RFD 0-150 ms	0.33	Medium
RFD 0-250 ms	0.56	Large
Force at 50	0.55	Large
Force at 100	0.54	Large
Force at 150	0.30	Small
Force at 200	0.23	Small
Force at 250	0.56	Large

IMTP = Isometric Mid-Thigh Pull, RFD = Rate of force development, *$p \leq 0.05$.

Discussion

After conducting our research, we found one main finding, which was a large positive correlation between IMTP peak force and 1RM deadlift performance ($r = 0.75$, $p < 0.05$) specifically among NCAA Division III female basketball players. Therefore, these findings indicate that athletes with higher maximal isometric force production tend to exhibit greater dynamic strength during the deadlift pattern. This result is consistent with studies we discussed earlier that examined the relationship between dynamic and isometric strength measurements, with the difference that our research is applicable to female athletes in the NCAA Division III. De Witt et al. (2018), for example, found a strong correlation ($r = 0.88$) between deadlift 1RM performance and IMTP peak force. This finding indicated, once again, that maximal force production in an isometric movement translates directly to dynamic lifting exercises. Furthermore, Miller et al. (2021) conducted a study demonstrating the importance of isometric testing for predicting dynamic strength power output, finding high correlations between maximal isometric pulls and hex bar deadlift performance. These results have been shown to be consistent across different populations and testing methods, confirming that IMTP peak force is a valid measure of maximal strength. Likewise, additional research findings support the correlation between isometric and dynamic strength outputs. These strong connections between IMTP peak force and 1RM strength were found across various lifts and populations and reported by McGuigan and Winchester (2008) and McGuigan et al. (2010). Moreover, these studies show that a key factor influencing total strength performance is the capacity to produce large peak force, regardless of the type of contraction.

Nonetheless, other IMTP-derived variables showed moderate-to-high relationships with deadlift performance, whereas only IMTP peak force was statistically significant. For example, although a statistical significance was not found, relative peak force (r = 0.56), RFD at 0–50 ms (r = 0.61), RFD at 0–100 ms (r = 0.58), and force at 250 ms (r = 0.56) all showed strong associations with 1RM deadlift performance. Therefore, these results are important because they show that dynamic strength performance can be influenced by factors beyond peak force. It is important to note that, when conducting our study, we had a small number of participants (n = 12), which provides limited statistical power. This means that substantial associations might exist in these mentioned variables, but were not detected due to the limited statistical power. In addition to that, there are multiple studies, such as the ones conducted by Wang et al. (2016) and Scanlan et al. (2020), that have demonstrated how early force production characteristics and rate of force development (RFD) are frequently linked to athletic performance outcomes, such as strength, sprinting, or jumping ability. Therefore, these moderate-to-large associations should not be overlooked, as they can still represent important findings for practical application.

In practical terms, these findings show that the IMTP tool can be a quick, safer alternative to conventional 1RM testing. Therefore, strength and conditioning coaches can assess maximal strength without exposing athletes to the fatigue and injury risk associated with maximal lifts, given the strong correlation between IMTP peak force and deadlift performance. In team sports, specifically basketball, controlling fatigue and reducing injury risk are crucial throughout the season, and tools like these can make it much easier to maintain high-level performance while minimizing risk. On top of this, it is important to understand that these moderate-to-large associations in

certain non-significant variables imply that a deeper analysis of the IMTP force-time characteristics can provide further insight into an athlete's performance development. It can be useful to apply measurements to monitor not only peak force but also early force production variables, as these may relate to explosive movements such as sprinting and jumping, which are essential in basketball performance.

Conclusion

In conclusion, during this study, there was a strong correlation between 1RM trap-bar deadlift performance and IMTP peak force in NCAA Division III female basketball players. Our findings support the validity of the IMTP as a strength assessment instrument and highlight maximal isometric force production as an indicator of dynamic strength performance. Even though multiple IMTP-derived variables demonstrated moderate-to-large relationships with deadlift performance, these results indicate that force-time characteristics may also play a role in overall strength expression. That said, future studies should look forward to including bigger populations in order to further investigate the impact of early force production factors and their relationship to performance outcomes, as the limitation of this study was the small sample size. Ultimately, this study helps demonstrate the IMTP test efficacy as a tool for evaluating strength and further explores the force-time characteristics that can be developed in athletes to boost their performance on the court.

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