

A COMPARISON OF LOWER BODY POWER CHARACTERISTICS BETWEEN  
NAIA AND NCAA DIVISION I COLLEGIATE ATHLETES

by

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A comparison of lower-body power characteristics between NAIA and NCAA division I collegiate athletes.

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### **ABSTRACT**

The countermovement jump (CMJ) is a practical, reliable and valid test used to measure lower-body power. The CMJ is frequently utilized by strength and conditioning professionals working with athletes, given its relationship to a multitude of performance variables associated with success in sports. **PURPOSE:** To examine characteristics of CMJ performance between differing levels of competition. A secondary aim was to report descriptive data on jump performance for NAIA and NCAA Division I male and female athletes. **METHODS:** Archival data for 275 student athletes from two NCAA division 1 universities (NCAA DI; males = 84, females = 74) and one NAIA university (NAIA; males = 66, females = 51) were utilized for this analysis. The CMJ was performed utilizing a dual single axis (Pasco PS 2141 plates, sampling rate 1000hz unfiltered) force platform system. A 2 x 2 multivariate analysis of variance (MANOVA) was used to determine whether significant differences in the three dependent variables of VJ height (cm) calculated by flight time, concentric RPD-100ms, and peak power existed between athletes at different playing levels. A discriminant function analysis (DFA) was the used to investigate how the three dependent variables or outcome variables may discriminate the participants based on a combined variable (sex and competition level). **RESULTS:** The MANOVA showed significant differences based on sex and competition level in the dependent variables (Wilk's Lambda = 0.908,  $F(3,259) = 8.732, p < .001$ ,

partial $\eta^2 = .092$ ). Discriminant analysis revealed one significant function (Wilk's Lambda = .3,  $\chi^2(9) = 316.9$ ,  $p < .001$ , canonical  $R^2 = .69$ ). The significant function was primarily represented differences based on peak power (W) and jump height.

DISCUSSION: The findings of this study revealed that females at the DI level performed significantly better in the CMJ based on jump height, peak power and concentric RPD-100ms compared to females at the NAIA. Division I males displayed significantly higher peak power than their NAIA counterparts.

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## CHAPTER I

### INTRODUCTION

The National Collegiate Athletic Association (NCAA) or the National Association of Intercollegiate Athletics (NAIA) are the two major governing bodies for collegiate athletics in the United States. Approximately 550,000 collegiate-athletes compete in the NCAA and NAIA (NAIA, 2018; NCAA, 2018). Unlike the NAIA, which is mainly comprised of one level of competition, the NCAA is made up of three distinctive divisions: division 1 (DI), division 2 (DII), and division 3 (DIII). Anecdotally, one would anticipate that NCAA DI athletes are physically superior to their DII & DIII and NAIA counterparts. This supposition is in part due to DI institutions having the ability to provide better facilities and scholarship opportunities to their athletes, based in part to greater national notoriety and larger athletic budgets when compared to schools at other levels of competition (Burrell, 2019; NCAA, 2018; O'Rourke, n.d.). However, this assumption is largely anecdotal as relatively few studies have compared the physical differences between athletes at these different levels of competition (Barnes, Schilling, Falvo, Weiss, Creasy, & Fry, 2007; Brummitt & Engillis, 2016; Fry & Kraemer, 1991; Harmon & Dick, 1998; Smith et al., 2007; Spaniol, 2009). Understanding how athletes of different playing levels differ may aid identify talent and predicting success at each level of play. Coaches could theoretically use that information to target recruits who display similar performance measures to athletes either at or above their competition level. Thus, understanding what differences may exist and/or if it is sport dependent can all aid in

coaches who are trying to improve their teams' chances of success via recruiting and talent identification.

An institution's athletic success (championships won or success in the Athletics Directors' Cup) has been believed to increase revenue, media attention, donor contributions, sponsorships, and fan affinity (Lawrence, Li, Regas & Kander, 2012). Given that performance in many individual and team sports has been linked to an athlete's ability to produce force quickly, estimating measures of power through various field tests may be advantageous for coaches, athletes and institutions to predict athletic potential (i.e. talent identification; Stockbrugger & Haennel, 2001). Lower-body power measurements have previously been reported to possibly allow coaches to predict the defensive run value of a player over the course of a professional baseball season (Mangine, Hoffman, Vazquez, Pichardo, Fragaia, & Stout, 2013). Lower-body power has also been shown to differentiate athletes based on position as well as competition levels (Argus, Gill and Keogh, 2012; Bullock, Arnold, Plisky, Butler, 2016; Fry and Kraemer, 1991; Hoffman, Vazque, Pichardo, & Tenenbaum, 2009; Latin, Berg, Baechle, & 1994; Metaxas, Koutlianos, Sendelides, & Mandroukas, 2009; Schaal, Ransdell, Simonson, & Gao, 2013; Spaniol, 2009; Sporis, Jukic, Ostojic, & Milanovic, 2009). Comparing competition levels has most commonly been measured by examining performance differences in elite vs. non elite athletes, youth vs. adult, high school vs college vs pros. In general, athletes at higher levels of competition have performed better in strength and power measures than their lower level peers (Argus, Gill and Keogh, 2012; Barnes et al. 2007; Bullock, Arnold, Plisky, Butler, 2016; Fry and Kraemer, 1991; Hoffman, Vazque, Pichardo, & Tenenbaum, 2009; Latin, Berg, Baechle, & 1994;

Metaxas, Koutlianos, Sendelides, & Mandroukas, 2009; Schaal, Ransdell, Simonson, & Gao, 2013; Smith et al. 2007; Spaniol, 2009; Sporis, Jukic, Ostojic, & Milanovic, 2009). However, antidotally it would seem likely than professional athletes would outperform college athletes and college athletes would outperform youth. Yet, even at the professional and collegiate levels respectively, lower-body power measures have been shown to discriminate athletes of different levels.

In professional baseball, it was reported that MLB players showed significantly greater vertical jump power measures than AA, A, and rookie league players (Hoffman, Vazque, Pichardo, & Tenenbaum, 2009). In college athletics, vertical jump performance has been shown to differentiate NCAA athletes in multiple sports. Division I football and female volleyball athletes demonstrated significantly higher vertical jump performance than their peers at DII and DIII (Fry & Kraemer, 1991; Barnes et al., 2007). Smith et al. (2007) reported DI female soccer players jumped a mean of 4.5 cm higher than DIII players. The observed difference represented a relative 12% higher level of whole body power performance DI players compared to DIII. However, little data has been published comparing performance on field based tests between NAIA and NCAA athletes.

Few studies have compared performance on field based tests between NAIA and NCAA athletes. Brummit and Engillis (2016) reported significant differences in performance during the standing long jump and single-leg hop tests. These differences were noted between the two groups of athletes as well as between athletes in the same group based on: by player position, and by starter status. Spaniol (2009) reported that DI baseball players obtained higher vertical jump heights than high school and NAIA players. However, in his review, Spaniol (2009) took normative data from previously

published abstracts to make these comparisons (Spaniol, 2007; Spaniol, Melrose, Bohling, & Bonnette, 2005). Neither the comparison review (Spaniol, 2009) nor the previously published abstracts stated what type of vertical jump test (i.e. countermovement jump, squat jump, jump and reach) was used for measurement (Spaniol, 2007; Spaniol, Melrose, Bohling, & Bonnette, 2005). Based on the limited amount of data available, further research is required to better understand the physical performance differences between collegiate athletes competing at different levels. The knowledge gained from examining using performance scores for athletes with regard to commonly examined variables but not limited to: gender, playing level, sport participation, training age, and/or starter vs. non-starter status for athletes at different levels of play could aid coaches and researchers with the development of a “athletic performance profile” for success.

The countermovement jump (CMJ) is a practical and trustworthy performance test frequently used to measure an athlete’s lower-body power (Castagna & Castellini, 2013; Markovic, Dizdar, Jukic, & Cardinale, 2004; Mori, 2008; Nordin, Kivi, Zerpa, & Newhouse, 2014). In fact, it is one of the most commonly used performance tests by coaches and researchers to indirectly measure lower body power (Dias, Pupo, Reis, Borges, Santos, Moro, & Borges, 2011). CMJ performance is typically assessed and reported as either jump height (an estimate of the height change in the athlete’s center of mass) or estimated peak power output (which can be calculated by inputting jump height into a validated equation such as Sayers’; Laffaye, Wagner, & Tombleson, 2014; Moir, 2008; Sayers, Harackiewicz, Harman, Frykman, & Rosenstein, 1999; Walker, 2016). The CMJ has previously been measured using a number of different devices such as contact

mats, force platforms, infrared platforms, accelerometers or linear position transducers and even video analysis, though force platforms are often regarded as the ‘gold-standard’ for test accuracy (Dias, Pupo, Reis, Borges, Santos, Moro, & Borges, 2011; Glatthorn, Gouge, Nussbaumer, Stauffacher, Impellizzeri, & Maffiuletti, 2011; Nuzzo, Anning, & Scharfenberg, 2011; Walker, 2016).

A common method for calculating jump height is to use flight time which is the total duration the athlete spends in the air with no ground contact. The flight time method of calculation is typically utilized when measuring CMJ on contacts mats or force plates. Flight time does not start until the athlete loses contact with the jumping surface and stops the moment their foot contacts the landing surface (Balsalobre-Fernandez, Tejero-Gonzalez, Del Campo-Vecino, & Bavaresco, 2014; Dias, Pupo, Reis, Borges, Santos, Moro, & Borges, 2011). Force platforms are able to directly ground reaction forces (GRFs) which are used to extrapolate or calculate additional variables such as: velocity at different points during the movement, thereby providing a more robust measure of lower-body power compared to other devices (Nuzzo, Anning, & Scharfenberg, 2011). The velocity and GRF values, in addition to jump height, can provide possible insight into an athlete’s physiological capabilities (force producing capabilities, neuromuscular coordination, and/or stretch shortening cycle (SSC) capabilities) which other instruments cannot provide. In order to fully understand and utilize the information obtained from lower body power measures requires not only knowing how high an athlete can jump but also how they summate or produce force and how quickly that is accomplished (Laffaye, Wagner, & Tomblason, 2014).

To the best of the investigators knowledge, a comparison of CMJ characteristics: jump height, peak power, and concentric rate of power development-100ms (RPD-100ms) between athletes from the NCAA and NAIA has only been reported once (Spaniol, 2009). Furthermore, few research studies have provided concurrent normative data from NCAA Divisions and NAIA athletes in the same study.

### **Statement of Purpose**

The purpose of this study is two-fold. The first aim of this study is to describe the relationship between CMJ characteristics and level of competition. The second aim of this study is to report descriptive data on jump performance for NAIA and NCAA Division I male and female athletes.

### **Hypothesis**

The null hypotheses for this study are:

1. There will be no difference in the countermovement jump characteristics between the two levels of competition.
2. There will be no difference in the anthropometric data between the two groups.

### **Assumptions of the Study**

1. The subjects performed the countermovement jump as instructed.
2. The subjects abided by the outlined testing protocols and did not withhold information about injury or other potential variables that may have affected the results.
3. The data collected was accurate.
4. The athletes gave a maximal effort on each jump.

**Definition of Terms** (McGinnis, 2013)

Peak – the peak value of any measurement is the point with the greatest magnitude in a data set.

Mean – the mean value of any measurement is an average of a data set and is calculated by taking the sum of all the values and dividing this number by the number of values.

Absolute – absolute most commonly means that the value being reported is not being expressed relative to bodyweight.

Relative – relative most commonly means expressing another biomechanical value in relation to bodyweight. It can be calculated by dividing a value by the bodyweight of the subjects.

Force – force equals mass times acceleration ( $F = ma$ ) and where mass (kg) and acceleration (m/s/s) are expressed in standard international (SI) units, force is automatically expressed in Newtons (N).

Ground reaction force (GRF) – When you jump, sprint, or perform an Olympic lift, you exert force into the ground. Force-plates measure these forces. During vertical jumping, most of the force produced is vertical. However, in sprinting, you have vertical forces as well as horizontal forces.

Rate of force development (RFD) – RFD is the rate of change of force over time, expressed as N/s.

Impulse – impulse is force multiplied by time over which the force acts, expressed as Ns.

Work – work is force multiplied by the distance moved as a result of the force acting, expressed in Joules (J).

Power – power is the rate at which work is done, and can be calculated either by dividing the work done by the time in which the work was done or by multiplying the force applied by the velocity at which it was applied, expressed in Watts (W).

Momentum – momentum is mass multiplied by velocity, expressed in kg m/s.

Iso-inertial resistance – iso-inertial external resistance is any external resistance that remains constant throughout the movement. Most typical free weight exercises are iso-inertial, as the mass or load do not change during the exercise.

Displacement – displacement is a change in position of an object. Jumping height is an example of a displacement that is often measured in biomechanics.

Ground contact time – ground contact times are the durations of time in which feet are in contact with the ground during athletic movements, such as drop jumps or sprint running. Sprint running displays some of the shortest ground contact times, which are around 0.1 seconds, which does not allow much time for the athletes to exert force to propel themselves forwards.

Flight time – flight times are the durations of time in which an athlete is not in contact with the ground during athletic movements, such as during vertical jumps or sprint running. During vertical jumps, flight time can be used to estimate jump height by using Newton's laws of motion.

Velocity – velocity is the rate of change of position of an athlete (in m/s), which is the displacement divided by time. It is a vector quantity (meaning that it has a direction associated with it) and speed is its scalar equivalent.

Acceleration – acceleration is the rate of change of velocity of an athlete (in m/s/s), which is the change in velocity divided by time. It is also vector quantity (meaning that it has a direction associated with it) and is proportional to both the external force exerted upon it and its mass.

### **Delimitations**

The delimitations of this study are:

1. Only subjects who were athletes at the universities to be used were included.
2. A maximal countermovement jump test was used to measure power.

### **Limitations**

The limitations of this study are:

1. The results may not be generalizable to untrained or sedentary individuals.
2. The results may not be generalizable to athletes in sports not included in this study at the NAIA or NCAA Division I levels.
3. Only tests of lower-body power will be investigated and may not be generalize to other performance tests (e.g. strength or cardiovascular endurance or agility or flexibility).

## CHAPTER II

### REVIEW OF LITERATURE

Thousands of athletes compete in various sports in the collegiate ranks or divisions. Anecdotally, it would be of fair judgement that the top performing athletes compete at the NCAA Division I level. However, whether or not those athletes are in actuality the best athlete's in respect to athletic performance (measured by field and laboratory tests) is still relatively unclear. This review will provide an overview of previous literature which has reported on lower-body power performance measured by vertical jump testing. Three specific areas were identified: 1) vertical jump measures and the relationship to different sports (soccer, basketball, and baseball), 2) vertical jump and the relationship playing time/status (starters vs. non-starters), 3) vertical jump and the relationship playing level. In addition to the identified areas above, a brief review of two of the major organizations that govern collegiate athletes: National Collegiate Athletic Association or the National Association of Intercollegiate Athletics will be presented initially. Similarities and differences between the two organizations will be presented to aid in the understanding of the landscape of collegiate athletics. This chapter examines previous research comparing different levels of the NCAA (I, II, III), involving NCAA level athletes and NAIA athletes, and also studies that reported descriptive information regarding athletes at the NAIA level.

#### **Comparing different competition levels and divisions collegiate athletic.**

Roughly 550,000 student-athletes compete in collegiate sports that fall into either the National Association of Intercollegiate Athletics or the National Collegiate Athletic

Association (NAIA, 2018; NCAA, 2018). A common assumption may be that the physical capabilities and skill level of these athletes would differ between the different organizations and divisions within them. One reason for this assumption would be that the opportunities and/or amenities athletes are afforded such as scholarships differ greatly between the different organizations (Burrell, 2019; O'Rourke, n.d.; White, 2017).

The NCAA is comprised of three divisions: Division I (DI), Division II (DII), and Division III (DIII). Division I is comprised of 353 institutions and could be considered the "premier league" of college athletics due to the fact that these institutions typically have larger budgets, more advanced facilities, more athletic scholarships than DII or DIII, and typically featured on more often on national television (Burrell, 2019; NCAA, 2018; O'Rourke, n.d.). The resources available for DI institutions can provide a serious advantage when recruiting athletes. Division II is the middle division of the NCAA, made up of nearly 320 institutions and is commonly believed to be slightly less competitive than Division I (Burrell, 2019; White, 2017). Division III is the lowest division of NCAA athletics but is the largest in terms of membership with roughly 450 member institutions (NCAA, 2018). However, DIII can be considered by many to be the most relaxed competitive experience of all three divisions (Burrell, 2019; White, 2017). Division III athletics do not offer athletic scholarships which may pose a dilemma for Division III programs because there is less monetary incentive for high level athletes to choose a program at this level compared to a Division I/II program (Burrell, 2019).

The NAIA offers another route for athletes to compete in college athletics. The NAIA is composed of two divisions (I & II) and is commonly compared to NCAA Division II and III with regard to competition level (Martin, 2015; NCSA, n.d.; White,

2017). The NAIA offers nearly \$500 million dollars in athletic scholarships each year (Winters, 2017). In comparison, NCAA DI and DII institutions offered approximately 2.8 billion in athletics funding for the 2015 fiscal year (White, 2017). The NAIA offers a similar athletic scholarships as DII institutions, with the majority of the scholarships offered by both organizations being partial scholarships (only a portion of cost of attendance covered; NAIA, 2018; NCAA, 2018; O'Rourke, n.d.). NAIA programs benefit from greater flexibility with organizational guidelines regarding budgeting and rules at each school and conference. In contrast, NCAA has extensive rules for each sport and division with regard to areas such as athlete recruitment and athletic budgeting (Burrell, 2019; Martin, 2015; White, 2017). The NAIA also benefits from less stringent recruiting regulations and rules which can allow recruiters to provide a more personalized process (Martin, 2015).

Anecdotally, one would anticipate that athletes competing at the DI level would most likely be better performers in their chosen sport than athletes at lower levels. The amount of research investigating athletic performance differences between college athletes of differing divisions or levels is relatively small. The relationships between field tests or assessments and athletic performance are of importance to team coaches, researchers, and strength and conditioning professionals. The results of such tests are particularly important for the purpose of training and monitoring (Markovic, Dizdar, Jukic, & Cardinale, 2004). Levels of lower-body power have been shown to effectively discriminate between different levels of competition (youth, college, professional) in a range of sports including American Football, rugby league, volleyball, and ice hockey (Argus, Gill, & Keogh, 2012). Although these relationships may not provide the source

for cause and effect, they do provide coaches and researchers with a better understanding of the use of appropriate tests when assessing the effectiveness of experimental treatments and programs on strength, power, and other performance measures.

Understanding how athletes of different playing levels differ may be of vital interest for institutions. An institution's athletic success has been believed to lead to increased revenue, media attention, donor contributions, sponsorships, and fan affinity following team success during the playing season (Lawrence, Li, Regas & Kander, 2012). Given that performance in many individual and team sports has been linked or related to an athlete's ability to produce force quickly, estimating measures of power through various field tests can aid in the process of obtaining success (Markovic, Dizdar, Jukic, & Cardinale, 2004; Newton & Kraemer, 1994).

### **Relationship between vertical jump measures and various sports**

Success in sports performance is not only a result of proficient skill in the given sport but is a product of underlying mechanisms related to sport performance that are associated with characteristics of strength such as peak force, rate of force development, velocity and power-generating capacity (Kraska, Ramsey, Haff, Fethke, Sands, Stone, & Stone, 2009). According to several authors, success in sport relies upon the development of strength and power, both of which contribute to vertical jump performance (Kraska et al. 2009; Peterson, Alvar, Rhea, 2006; Reiser, Rocheford, & Armstrong, 2006; Stone, O'Bryant, McCoy, Coglianesi, Lehmkuhl, & Schilling, 2003; Wisloff et al. 2004). Previous researchers has reported differences in countermovement jump peak force, countermovement jump reactive-strength index modified, and isometric mid-thigh pull peak force between collegiate athletes from different sports (Kobal, Nakamura, Kitamura,

Abad, Pereira, & Loturco, 2017; Sato et al., 2012; Suchomel, Sole, Bailey, Grazer, & Beckham, 2015; Thomas, Dos'Santos, & Jones, 2017). Similarly, previous research has found correlations between vertical jump performance and other performance qualities such as muscular strength, agility and change of direction, which are important attributes in different sports like soccer, basketball and baseball (McGuigan, Wright, & Fleck, 2012).

### Soccer

The vertical jump test has previously been shown to have a significant positive relationship with soccer performance (Castagna, & Castellini, 2013; Datson, Hulton, Andersson, Lewis, Weston, Drust, & Gregson, 2014; Haugen, Tonnessen, & Seiler, 2012; Manson, et al. 2014; Reilly, Bangsbo, & Franks, 2000). Previous research has reported significant correlations between lower-body strength and athletic performance measures such as sprinting performance, change of direction/agility performance and vertical jump performance in soccer players (Andersen, Lockie, & Dawes, 2018; Manson et al., 2004; McFarland et al., 2016; Shalfawi, Haugen, Jakobsen, Enoksen, & Tonnessen, 2013; Wisloff et al., 2004). The CMJ is an essential tool for strength and conditioning professionals working with soccer athletes, given its relationship to a multitude of performance variables (such as sprinting, jumping, agility) which have been associated with success in the sport (Castagna & Castellini, 2013; Haugen, Tonnessen, & Seiler, 2012; Haugen, Tonnessen, & Seiler, 2013; Jajtner et al., 2013; Koklu, Alemdaroglu, Ozkan, Koz, & Ersoz, 2015; Lockie, Dawes, & Jones, 2018). Rodriquez-Rosell, Mora-Custodio, Franco-Marquez, Yanez-Garcia, and Gonzalez-Badillo (2016) compared the reliability and validity of traditional vs. sport-specific vertical jump tests with relationship

to leg strength and sprint performance in adult and youth soccer and basketball players. The authors suggested that CMJ and AJ are the most reliable tests for estimation of explosive force in soccer and basketball players in different age groups.

### Basketball

Vertical jump testing is the most prevalent used test to assess anaerobic power in female and male basketball players (Ziv, & Lidor, 2009). Vertical jumping is an activity which defensive and offensive players must frequently perform throughout a game. Rodriguez-Rosell et al. (2016) suggested that the CMJ is one of the most reliable tests for estimation of explosive force in basketball players. The authors also reported that CMJ was a significant predictor of 10m and 20m sprint performance. The authors identified that CMJ was a significant predictor of 1RM in youth players, estimated from an iso-inertial front squat test performed on a smith machine. The later sections discuss the additional literature on vertical jump performance and basketball, as it pertains to playing time, status and differentiation between levels of play.

### Baseball

Power production is an important attribute for success in baseball as hitting, running, and throwing all require a summation of forceful movements generated from the ground up (Spaniol, 2009). Leg power has been shown to have a positive relationship with throwing velocity, bat speed, and batted-ball velocity in youth and collegiate players (Spaniol, 2009). Conversely, other studies have found little to no correlation between throwing velocity and vertical jump performance (Lehman, Drinkwater, & Behm, 2013). One study did report significantly greater vertical jump power measures in MLB players

than AA, A, and rookie league professional players (Hoffman, Vazque, Pichardo, & Tenenbaum, 2009). However, this has not been examined at the collegiate or youth level.

Although the literature has shown that vertical jumping ability and characteristics such as mean power are correlated to different physical capabilities that are essential to sport, there is little to no research on this topic in NAIA level athletes. It is important for strength and conditioning professionals to be able to draw upon findings from research to assist in programming for athletes. Knowing whether or not a certain physical performance measure like the vertical jump is related to a certain sport or population of athletes can allow strength and conditioning professionals to better focus their time and resources when performing testing and assessments.

### **Relationship between vertical jump and playing status, time, &/or position**

The key determining physical characteristics of an athlete that are essential for success in sport are often difficult to quantify due to the vast variation in a given characteristic or attribute between players (Dawes, Marshall, & Spiteri, 2016). Numerous studies have reported findings of physical performance measures being associated with differentiating collegiate athletes based on starters and nonstarters, playing position, and playing time (Brumitt, Engilis, Mattocks, Ellis, & Reyes, 2018; Dawes, Marshall, & Spiteri, 2016; Fry, & Kraemer, 1991; Jajtner et al., 2013; Hoffman, Ratamess, Neese, Ross, Kang, Magrelli, & Faigenbaum, 2009; Latin, Berg, & Baechle, 1994; Magrini et al, 2017; Metaxas, Koutlianos, Sendelides, & Mandroukas, 2009; Sawyer, Ostarello, Suess, & Dempsey, 2002; Schaal, Ransdell, Simonson, & Gao, 2013; Sell et al., 2018; Silvestre, West, Maresh, & Kraemer, 2006; Ziv, & Lidor, 2009).

Studies involving collegiate athletes have examined the relationship between vertical jump performance measures and playing status, commonly described as starters vs. non-starters, across a number of sports (Brumitt, Engilis, Mattocks, Ellis, & Reyes, 2018; Fry, & Kraemer, 1991; Jajtner et al., 2013; Hoffman, Ratamess, Neese, Ross, Kang, Magrelli, & Faigenbaum, 2009; Latin, Berg, & Baechle, 1994; Magrini et al, 2017; Metaxas, Koutlianos, Sendelides, & Mandroukas, 2009; Sawyer, Ostarello, Suess, & Dempsey, 2002; Schaal, Ransdell, Simonson, & Gao, 2013; Sell et al., 2018; Silvestre, West, Maresh, & Kraemer, 2006; Ziv, & Lidor, 2009). Regardless of sport or competition level, typically starters have been reported to attain greater jump heights and estimates of peak power measured during countermovement jump (CMJ) and squat jump (SJ) testing. Additionally, starters have outperformed non-starters based on positions in collegiate sports such as American football, basketball, lacrosse, soccer and volleyball (Brumitt, Engilis, Mattocks, Ellis, & Reyes, 2018; Fry, & Kraemer, 1991; Fry, Kraemer, Weseman, 1991; Jajtner et al., 2013; Hoffman, Ratamess, Neese, Ross, Kang, Magrelli, & Faigenbaum, 2009; Latin, Berg, & Baechle, 1994; Magrini et al, 2017; Metaxas, Koutlianos, Sendelides, & Mandroukas, 2009; Sawyer, Ostarello, Suess, & Dempsey, 2002; Schaal, Ransdell, Simonson, & Gao, 2013; Sell et al., 2018; Ziv, & Lidor, 2009). Along with comparing performance measures between positions, studies have examined the relationship between vertical jump performance and playing time.

Hoffman, Tenenbaum, Maresh, and Kraemer (1996) studied the relationship of athletic performance tests, player evaluations from coaches and playing experience relative to playing time in 29 Division I basketball players over 4 years. The results showed that when controlling for player evaluation and experience by excluding them

from a regression analysis, the athletic performance tests explained 64-81% of variance found in playing time. The authors reported that in one of the four seasons, vertical jump performance (jump height) alone added 19% to the explained variance to player evaluation to predict playing time. In a separate study, Dawes et al. (2016) found that vertical jump displayed a moderate non-significant correlation to playing time in NCAA Division II male basketball players.

As with any research topic, there may be contradicting results from studies examining similar variables. Further research is needed in order to continue to advance current knowledge on the relationship between performance measures and sport success. Furthermore, the need to explore the relationship between performance variables at other levels of competition is of importance to coaches and researchers alike. Attempting to understand what physiological capabilities separate athletes from different levels of college competition is vital for not only sport coaches who are attempting to recruit the best players but also to strength and conditioning professionals who is trying to assist athletes in bettering themselves physically for their sport.

### **Relationship between vertical jump and collegiate competition level**

Athletes are not subjugated to a certain level of college athletic for the entirety of their career. There are opportunities for athletes that compete in the NCAA Division II, III, and NAIA to obtain a position on a NCAA Division I team either by obtaining a scholarship or transferring and attempting to make the team as a walk-on. Quantifying what sporting skills and what level of proficiency is needed in those skills to determine sport success is difficult to pinpoint as those are highly individual characteristics (Dawes et al. 2016). Researchers and coaches have often attempted to compare skill level and

physical performance measures in an effort to discover what, if any, physical attributes are related to playing level. Only a number of studies have reported data on physical performance values between different levels of athletics. The most common sports studied have been American football, soccer, volleyball, and basketball (Barnes, Schilling, Falvo, Weiss, Creasy, & Fry, 2007; Brumitt, Engilis, Mattocks, Ellis, & Reyes, 2018; Bullock, Arnold, Plisky, & Butler, 2018; Fry, & Kraemer, 1991; Garstecki, Latin, & Cuppett, 2004; Jones, & Thompson, 2011; Lockie, Dawes, & Jones, 2018; Metaxas, , Koutlianos, Sendelides, & Mandroukas, 2009; Smith, Ford, Myer, Holleran, Treadway, & Hewett, 2007; Spaniol, Melrose, Bohling, & Bonnette, 2005; Spaniol, 2007; Spaniol, 2009; Thompson, & Jones, 2011).

The majority of published research comparing collegiate athletes has used populations from different divisions of the NCAA. A common finding in the literature has been that DI athletes have significantly outperformed their DII and DIII counterparts during various jumping tests. (Bullock, Arnold, Plisky, & Butler, 2018; Fry, & Kraemer, 1991; Garstecki, Latin, & Cuppett, 2004; Lockie, Dawes, & Jones, 2018; Metaxas, Koutlianos, Sendelides, & Mandroukas, 2009; Thompson, & Jones, 2011). In addition, DII athletes have generally performed (not necessarily significant) better than DIII athletes. Currently, the number of studies that have reported values of physical performance between NCAA and NAIA athletes is extremely limited. Brummit and Engillis (2016) reported NAIA male basketball players jumped further in the single leg hop (left leg;  $p < .05$ ) than NCAA DIII male basketball players. Another study reported that DI baseball players obtained higher vertical jump heights than high school and NAIA players (Spaniol, 2009). However, it is important to note that in his review, Spaniol

(2009) took normative data from previously published abstracts to make the comparisons (Spaniol, 2007; Spaniol, Melrose, Bohling, & Bonnette, 2005). Neither the comparison review (Spaniol, 2009) nor the previously published abstracts stated what type of vertical jump test (i.e. countermovement jump, squat jump, jump and reach) was used for measurement (Spaniol, 2007; Spaniol, Melrose, Bohling, & Bonnette, 2005). Previous research has shown differences in athletic performance and injury rates between male and female athletes within the same sport (Smith, Ford, Myer, Holleran, Treadway, & Hewett, 2007). Examining comparisons between athletic performance and competition level in females is essential for development and structuring of resistance-training programs for injury prevention and athletic performance.

Female collegiate athletes have been compared between divisions and levels, in a similar number of studies as their male counterparts. Lockie et al. (2018) reported that DI male and female soccer players outperformed DII players in the following performance tests/measures: 5-0-5, 5-0-5 change of direction deficit, vertical jump height, peak anaerobic power measured in watts, and power-to-body mass ratio. The authors also reported that DII players were faster in the modified t-test than DI players. Similarly, Smith et al. (2007) reported that DI female soccer players demonstrated significantly higher vertical jump heights compared to Division III players. A small number of studies have reported comparisons of female athletes between more than one sport, or between multiple levels (Barnes et al. 2007; Jones & Thompson, 2011). Barnes et al. (2007) examined the performance of 29 female collegiate volleyball players (DI n = 9, DII n = 11, DIII n = 9) in a novel agility test, countermovement jump and drop jump. The results showed that DI athletes had a significantly higher mean countermovement jump height

than DIII athletes. Jones and Thompson (2011) compared agility, body composition, strength and power in NCAA Division I and III female athletes. Results showed that DI field hockey athletes had significantly faster pro-agility scores ( $5.0 \pm 0.2s$  vs.  $5.3 \pm 0.3s$ ) than DIII athletes. DI softball athletes had higher bench press, back squat, vertical jump, and pro-agility values than DIII ( $p < .05$ ). DI volleyball had higher bench press, back squat, vertical jump, 3-step vertical jumps, agility t-tests scores than D-III ( $p < .05$ ). As with their male counterparts, relatively little is known about NAIA female athletes and their performances in various physical performance measures like the countermovement jump.

Although there is research currently that has included athletes of the NAIA level and NCAA levels, they have provided little with respect to normative or comparative data. Universities at the NAIA level are typically smaller and have less financial resources than some of their counterparts in the NCAA side. Therefore, it is imperative that strength and conditioning coaches at the NAIA level have some baseline data or normative data with which they can assess their athletes and training programs in order to best serve their athletes. These studies not only provide coaches and researchers with vital knowledge about divisional differences in sports but also could aid athletes who aspire to play higher levels of their sport.

## CHAPTER III

### METHODOLOGY

This chapter describes the methodology of the study with detail on data collection and analysis procedures utilized in this study to examine the differences in lower-body power characteristics between NAIA and NCAA Division I collegiate athletes from countermovement jump measures. The methods section is subdivided as follows: (a) subjects (b) procedure (c) measurements (d) data analysis.

#### **Participants**

Archival data for 275 student athletes from three universities at different competition levels (NCAA DI (2): (male = 84, female 74; NAIA (1) (male = 66, female 51) were utilized for this analysis. This data was collected by the athletic performance training staff for each university, as part of routine athletic testing. All of the athletes in this sample reported being injury free within the 6 months prior to testing. Permission to conduct this study was provided by the Institutional Review Board from the University of Colorado Colorado Springs and University of Missouri. Based on the archival nature for this data, this study qualified for expedited review.

#### **Procedure**

The countermovement jump (CMJ) was performed utilizing a dual single-axis force platform system (Pasco PS 2141, Roseville, CA, USA) with a sampling frequency of 1000hz unfiltered. Previous research has recommended a sampling frequency of at least 1000hz for CMJ force-time measurements (McMahon, Suchomel, Lake, & Comfort, 2018; Owen, Watkins, Kilduff, Bevan, & Bennett, 2014; Street, Mcmillan, Board,

Rasmussen, & Heneghan, 2001; Vanrenterghem, Clercq, & Cleven, 2001). Additionally, exporting and analyzing the unfiltered or raw vertical force data has been recommended over the filtered force time data due to the possibility of underestimation of CMJ height (Street, Mcmillan, Board, Rasmussen, & Heneghan, 2001; Vanrenterghem, Clercq, & Cleven, 2001). The athlete was instructed to stand with one foot on each platform with their hands on their hips. To prevent injury, the platforms were surrounded by a foam platform of the same height as the force platform. The athlete was asked to stand still for a period of 3 seconds to allow the system to ascertain body weight and the onset of movement threshold (McMahon, Suchomel, Lake, & Comfort, 2018; Owen, Watkins, Kilduff, Bevan, & Bennett, 2014). Once the system had recorded body weight, the athlete was instructed to jump as high as they could while keeping their hands on their hips. For each jump the athlete was required to return to the “quiet standing” position with the hands remaining on the hips for 3 seconds in order for the system to again ascertain body weight and the onset of movement threshold before performing a second trial. If the athlete failed to keep their hands on the hips during the jump, or the athlete did not land on the force platform, the jump did not count and was not considered successful. Two attempts were given for each athlete. If for any reason a jump was unsuccessful, the athlete was required to perform additional jumps until they had achieved two successful jumps that were recorded and saved by the system.

### **Measurements**

Athlete height (cm) was recorded by a member of the athletic performance staff. Force-Decks software (Vald Performance, Newstead QLD, Australia) was utilized to collect and process/extrapolate the force-time data into commonly used discrete

variables. Discrete values from the trial attempt in which the athlete jumped the highest (using flight time method) were utilized for analysis. Concentric-RPD100ms was measured as the change in power over the first 100ms of the concentric phase (L.O'B, personal communication, April 5, 2019). The flight time method of jump height calculation was calculated as  $\text{jump height (cm)} = (g * t^2) / 8$ . Where  $g$  is the acceleration due to gravity and  $t$  is the flight time (L.O'B, personal communication, April 5, 2019).

### **Statistical analysis**

Univariate outliers were identified by transforming the univariate scores into z-scores. Multivariate outliers were identified and removed by finding Mahalanobis distances. Ten participants were identified as univariate and/or multivariate outliers and were not used for primary analyses. A description of the statistical tests conducted and the follow-up analyses are presented in Table 3.1. All statistics were conducted with IBM SPSS v.25. Alpha was set at  $p < .05$  for all tests (IBM, New York, NY, USA).

**Table 3. 1:** Description analyses conducted.

Type of Analysis Used (# of tests)	IVs (levels)	DVs	Additional follow-Up Analysis (# of tests)	Rationale for follow-up testing
2x2 Multivariate analysis of variance (MANOVA)	1) Sex (male & female)  2) Competition level (NCAA DI & NAIA)	1) CMJ height (cm) 2) Peak power (W) 3) Concentric RPD-100ms (W/s)	#1) Separate (2) Factorial analysis of variance (ANOVA)  #2) Discriminant Function Analysis (DFA)	- The multivariate interaction was significant, therefore it is recommended to evaluate the univariate interactions.  - Field (2018) suggests that when homogeneity of covariance matrices cannot be demonstrated, rather than conducting separate univariate ANOVAs for each outcome variable that a discriminant function analysis be used. - The belief is that the core underlying principles of these tests are the same: theory of MANOVA is that it works by identifying linear variates that best differentiate the groups, those linear variates are the functions in DFA.
Discriminant Function Analysis* (DFA)	1) CMJ height (cm) 2) Peak power (W) 3) Concentric RPD-100ms (W/s)	1) Combined variable for Sex & Competition Level	#1) One Univariate ANOVA	- The saved scores from the significant function (discriminant function #1 (DF1)) were analyzed with the combined variables for Sex & Competition Level in order to objectively determine which group centroids were different.
(3) Univariate ANOVAs	1) Combined variable for Sex & Competition Level	1) Athlete height (cm) 2) Athlete weight (kg) 3) Athlete age (yrs.)		- Analysis on the athlete descriptive variables

Note: \*The dependent variables are used as the predictor or independent variables in a discriminant function analysis. The variables are used to predict group membership for the combined variable for sex & competition level.

## CHAPTER IV

### MANUSCRIPT

#### Introduction

The National Collegiate Athletic Association (NCAA) and the National Association of Intercollegiate Athletics (NAIA) are the two major governing bodies for collegiate athletics in the United States. Approximately 550,000 collegiate-athletes compete in the NCAA and NAIA (NAIA, 2018; NCAA, 2018). Unlike the NAIA, which is mainly comprised of one level of competition, the NCAA is made up of three distinctive divisions: DI, DII, and DIII. Anecdotally, one would anticipate that NCAA DI athletes are superior to their DII & DIII as well as their NAIA counterparts due to those institutions having the ability to provide more benefits to athlete's thanks in part to national notoriety and larger athletic budgets (i.e., more money for facilities and scholarships; Burrell, 2019; NCAA, 2018; O'Rourke, n.d.). However, this supposition is largely anecdotal as relatively few studies have compared performance on predictors of athletic success between athletes in these organizations (Barnes, Schilling, Falvo, Weiss, Creasy, & Fry, 2007; Spaniol, 2009; Brummitt & Engillis, 2016; Fry & Kraemer, 1991).

Levels of lower-body power have been shown to effectively discriminate between different levels of competition in a range of sports including American Football, rugby league, volleyball, and ice hockey (Argus, Gill, & Keogh, 2012). In a study by Fry and Kraemer (1991) it was discovered that vertical jump performance was significantly greater among Division I football players compared to Division II and III players. Similarly, Barnes et al. (2007) found that Division I female volleyball players had

significantly greater countermovement jump heights than their peers at the Division II and III levels. However, little data has been published comparing performance on field based tests between NCAA and NAIA athletes.

Brummit and Engillis (2016) reported NAIA male basketball players jumped further in the single leg hop (left leg;  $p < .05$ ) than NCAA DIII male basketball players. Spaniol (2009) reported that DI baseball players obtained higher vertical jump heights than high school and NAIA players. However, it is important to note that in his review, Spaniol (2009) took normative data from previously published abstracts to make these comparisons (Spaniol, 2007; Spaniol, Melrose, Bohling, & Bonnette, 2005). Neither the comparison review (Spaniol, 2009) nor the previously published abstracts stated what type of vertical jump test (i.e. countermovement jump, squat jump, jump and reach) was used for measurement. Based on the limited amount of data available, further research is required to better understand the physical performance differences between collegiate athletes competing at different levels. By developing a profile for athletes at different levels of play, coaches may be able to assess an athlete's potential for success at a specific level of play, which may assist in team recruitment and retention decisions.

The countermovement jump (CMJ) is a practical and trustworthy performance test frequently used to measure an athlete's lower-body power (Castagna & Castellini, 2013; Markovic, Dizdar, Jukic, & Cardinale, 2004; Mori, 2008; Nordin, Kivi, Zerpa, & Newhouse, 2014). In fact, it is one of the most commonly used performance tests by coaches and researchers to indirectly measure power of the lower-body (Dias, Pupo, Reis, Borges, Santos, Moro, & Borges, 2011). CMJ performance is typically assessed and reported as either jump height (an estimate of the height change in the athlete's center of

mass) or estimated peak power output (which can be calculated by inputting jump height into a validated equation such as Sayers'; Laffaye, Wagner, & Tombleson, 2014; Moir, 2008; Sayers, Harackiewicz, Harman, Frykman, & Rosenstein, 1999; Walker, 2016). The CMJ has previously been measured using a number of different devices such as contact mats, force platforms, infrared platforms, accelerometers or linear position transducers and even video analysis, though force platforms are often regarded as the 'gold-standard' for test accuracy (Dias, Pupo, Reis, Borges, Santos, Moro, & Borges, 2011; Glatthorn, Gouge, Nussbaumer, Stauffacher, Impellizzeri, & Maffiuletti, 2011; Nuzzo, Anning, & Scharfenberg, 2011; Walker, 2016).

A common method for calculating jump height is to use flight time which is the total duration the athlete spends in the air with no ground contact. The flight time method of calculation is typically utilized when measuring CMJ on contact mats or force plates. Flight time does not start until the athlete loses contact with the jumping surface and stops the moment their foot contacts the landing surface (Balsalobre-Fernandez, Tejero-Gonzalez, Del Campo-Vecino, & Bavaresco, 2014; Dias, Pupo, Reis, Borges, Santos, Moro, & Borges, 2011). Force platforms are able to directly measure ground reaction forces (GRFs) which are used to extrapolate or calculate additional variables such as velocity at different points during the movement, thereby providing a more robust measure of lower-body power compared to other devices (Nuzzo, Anning, & Scharfenberg, 2011). The velocity and GRF values, in addition to jump height, can provide possible insight into an athlete's physiological capabilities (force producing capabilities, neuromuscular coordination, and/or stretch shortening cycle (SSC) capabilities) which other instruments cannot provide. In order to fully understand and

utilize the information obtained from lower body power measures requires not only knowing how high an athlete can jump but also how they summate or produce force and how quickly that is accomplished (Laffaye, Wagner, & Tombleson, 2014).

To the best of the investigator's knowledge, a comparison of CMJ characteristics (jump height, peak power, and concentric rate of power development-100ms (RPD-100ms) between athletes from the NCAA and NAIA has only been reported once (Spaniol, 2009). Furthermore, few research studies have provided concurrent normative data from NCAA Divisions and NAIA athletes in the same study. Therefore, the aim of the present study is to (a) describe the relationship between CMJ characteristics and level of competition and (b) report descriptive data on jump performance for male and female athletes at the NAIA and NCAA DI levels.

## **Methods**

### Participants

Archival data for 275 student athletes from two NCAA division 1 universities (NCAA DI; males = 84, females = 74) and one NAIA university (NAIA; males = 66, females = 51) were utilized for this analysis. This data was collected by the athletic performance training staff for each university, as part of routine athletic testing. All of the athletes in this sample reported being injury free within the 6 months prior to testing. Permission to conduct this study was provided by the Institutional Review Board from the University of Colorado Colorado Springs and University of Missouri. Based on the archival nature for this data, this study qualified for expedited review.

## Procedure

The countermovement jump (CMJ) was performed utilizing a dual single-axis force platform system (Pasco PS 2141, Roseville, CA, USA) with a sampling frequency of 1000hz unfiltered. Previous research has recommended a sampling frequency of at least 1000hz for CMJ force-time measurements (McMahon, Suchomel, Lake, & Comfort, 2018; Owen, Watkins, Kilduff, Bevan, & Bennett, 2014; Street, Mcmillan, Board, Rasmussen, & Heneghan, 2001; Vanrenterghem, Clercq, & Cleven, 2001). Additionally, exporting and analyzing the unfiltered or raw vertical force data has been recommended over the filtered force time data due to the possibility of underestimation of CMJ height (Street, Mcmillan, Board, Rasmussen, & Heneghan, 2001; Vanrenterghem, Clercq, & Cleven, 2001). The athlete was instructed to stand with one foot on each platform with their hands on their hips. To prevent injury, the platforms were surrounded by a foam platform of the same height as the force platform. The athlete was asked to stand still for a period of 3 seconds to allow the system to ascertain body weight and the onset of movement threshold (McMahon, Suchomel, Lake, & Comfort, 2018; Owen, Watkins, Kilduff, Bevan, & Bennett, 2014). Once the system had recorded body weight, the athlete was instructed to jump as high as they could while keeping their hands on their hips. For each jump the athlete was required to return to the “quiet standing” position with the hands remaining on the hips for 3 seconds in order for the system to again ascertain body weight and the onset of movement threshold before performing a second trial. If the athlete failed to keep their hands on the hips during the jump, or the athlete did not land on the force platform, the jump did not count and was not considered successful. Two attempts were given for each athlete. If for any reason a jump was unsuccessful, the

athlete was required to perform additional jumps until they had achieved two successful jumps that were recorded and saved by the system.

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### Statistical analysis

Univariate outliers were identified by transforming the univariate scores into z-scores. Multivariate outliers were identified and removed by finding Mahalanobis distances. Ten participants were identified as univariate and/or multivariate outliers and were not used for primary analyses. A description of the statistical tests conducted and the follow-up analyses are presented in Table 4.1. All statistics were conducted with IBM SPSS v.25. Alpha was set at  $p < .05$  for all tests (IBM, New York, NY, USA).

**Table 4. 1:** Description analyses conducted.

Type of Analysis Used (# of tests)	IVs (levels)	DVs	Additional follow-Up Analysis (# of tests)	Rationale for follow-up testing
2x2 Multivariate analysis of variance (MANOVA)	1) Sex (male & female)  2) Competition level (NCAA DI & NAIA)	1) CMJ height (cm) 2) Peak power (W) 3) Concentric RPD-100ms (W/s)	#1) Separate (2) Factorial analysis of variance (ANOVA) #2) Discriminant Function Analysis (DFA)	- The multivariate interaction was significant, therefore it is recommended to evaluate the univariate interactions.  - Field (2018) suggests that when homogeneity of covariance matrices cannot be demonstrated, rather than conducting separate univariate ANOVAs for each outcome variable that a discriminant function analysis be used. - The belief is that the core underlying principles of these tests are the same: theory of MANOVA is that it works by identifying linear variates that best differentiate the groups, those linear variates are the functions in DFA.
Discriminant Function Analysis* (DFA)	1) CMJ height (cm) 2) Peak power (W) 3) Concentric RPD-100ms (W/s)	1) Combined variable for Sex & Competition Level	#1) One Univariate ANOVA	- The saved scores from the significant function (discriminant function #1 (DF1)) were analyzed with the combined variables for Sex & Competition Level in order to objectively determine which group centroids were different.
(3) Univariate ANOVAs	1) Combined variable for Sex & Competition Level	1) Athlete height (cm) 2) Athlete weight (kg) 3) Athlete age (yrs.)		- Analysis on the athlete descriptive variables

Note: \*The dependent variables are used as the predictor or independent variables in a discriminant function analysis. The variables are used to predict group membership for the combined variable for sex & competition level.

## Results

Results of the MANOVA showed significant differences (Table 4.2) based on sex and competition level in the dependent variables (Wilk's Lambda = 0.908,  $F(3,259) = 8.732$ ,  $p < .001$ , partial  $\eta^2 = .092$ ). Examining the univariate interaction revealed significant differences between participants based on sex (males vs. females) at the NCAA Division I (Wilk's  $\lambda = 0.48$ ,  $F(3,259) = 93.345$ ,  $p < .001$ , partial  $\eta^2 = .520$ ) and NAIA (Wilk's  $\lambda = 0.49$ ,  $F(3,259) = 89.824$ ,  $p < .001$ , partial  $\eta^2 = 0.520$ ). It also revealed significant differences between females based on competition level for all variables (Wilk's  $\lambda = 0.911$ ,  $F(3,259) = 8.418$ ,  $p < .001$ , partial  $\eta^2 = 0.089$ ) and a significant difference between males in peak power (Wilk's  $\lambda = 0.955$ ,  $F(3,259) = 4.096$ ,  $p < .01$ , partial  $\eta^2 = .045$ ).

**Table 4. 2:** Performance results for each dependent variable based on sex and competition level (mean  $\pm$  SD).

	Females		Males		All Participants Combined			
	DI (n=73)	NAIA (n=62)	DI (n=79)	NAIA (n=51)	DI (n=152)	NAIA (n=113)	Females (n=135)	Males (n=130)
Jump Ht.(cm)	32.2 $\pm 4.99$	27.4 $\pm 5.17$	42.6 $\pm 4.75$	41.2 $\pm 6.47$	37.1 $\pm 7.51$	33.6 $\pm 9.01$	29.4 $\pm 5.40$	42.0 $\pm 5.50$
Peak Power [W]	3264.26 $\pm 628.088$	2835.68 $\pm 464.482$	4888.63 $\pm 683.407$	4538.59 $\pm 892.157$	4108.51 $\pm 1045.15$	3604.25 $\pm 1094.237$	3067.43 $\pm 596.771$	4751.31 $\pm 787.619$
Concentric RPD - 100ms [W/s]	15548.734 $\pm 7002.5733$	11718.742 $\pm 4338.9070$	22964.633 $\pm 7366.6182$	23160.090 $\pm 7326.6601$	19403.050 $\pm 8076.6199$	16882.536 $\pm 8184.3159$	13789.775 $\pm 6211.9131$	23041.312 $\pm 7326.6601$

**Table 4. 3:** Anthropometrics (mean  $\pm$  SD) for age, height (ht.), and weight (wt.).

Group	<i>n</i> (Age)	Age (yrs.)	<i>n</i> (Ht.)	Height (cm)	<i>n</i> (Wt.)	Weight (kg)
DI Female	68	19.5 $\pm$ 0.1	68	174.25 $\pm$ 8.95	71	68.85 $\pm$ 11.19
NAIA Female	49	19.5 $\pm$ 0.1	49	169.66 $\pm$ 9.13	62	66.81 $\pm$ 10.6
DI Male	82	19.4 $\pm$ 0.2	82	186.91 $\pm$ 8.47	79	89.59 $\pm$ 9.52
NAIA Male	50	19.5 $\pm$ 0.2	45	185.76 $\pm$ 7.97	51	82.4 $\pm$ 14.37

\*Note: Due to use of archival data, *n* was not the same for each variable.

Univariate ANOVAs indicated significant differences in height and weight but not age based on the combined competition level and sex variable (Table 4.3; height:  $p < .001$ , partial  $\eta^2 = 0.417$ ; weight:  $p < .001$ , partial  $\eta^2 = 0.464$ ; age:  $p > .05$ , partial  $\eta^2 = 0.005$ ). Both groups of females (DI & NAIA) differed significantly in height and weight from both groups of males (DI & NAIA;  $p < .001$ ). Division I females differed significantly from NAIA females in both height ( $p < .05$ ) and weight ( $p < .001$ ). Conversely, DI males did not differ significantly from NAIA males in height, or weight ( $p > .05$ ).

Discriminant analysis revealed one significant function primarily represented differences based on peak power (W) and jump height (flight time; Table 4.4) (Wilk's Lambda = .3,  $\chi^2(9) = 316.9$ ,  $p < .001$ , canonical  $R^2 = .69$ ). Group centroids for the DFA are shown in Figure 1. Overall the DFA correctly classified 56.6% of the participants into their groups (Table 4.5). The follow-up ANOVA using the scores from the significant discriminant function (discriminant function #1 or DF1) revealed a significant difference based on the combined variable for competition level and sex ( $F(3,261) = 196.885$ ,  $p < .001$ , partial  $\eta^2 = 0.694$ ). Both groups of females differed significantly from both groups of males based on DF1 scores ( $p < .001$ ). Division I and NAIA females differed significantly based on DF1 scores ( $p < .001$ ). Males did not differ based on DF1 scores ( $p > .05$ ).

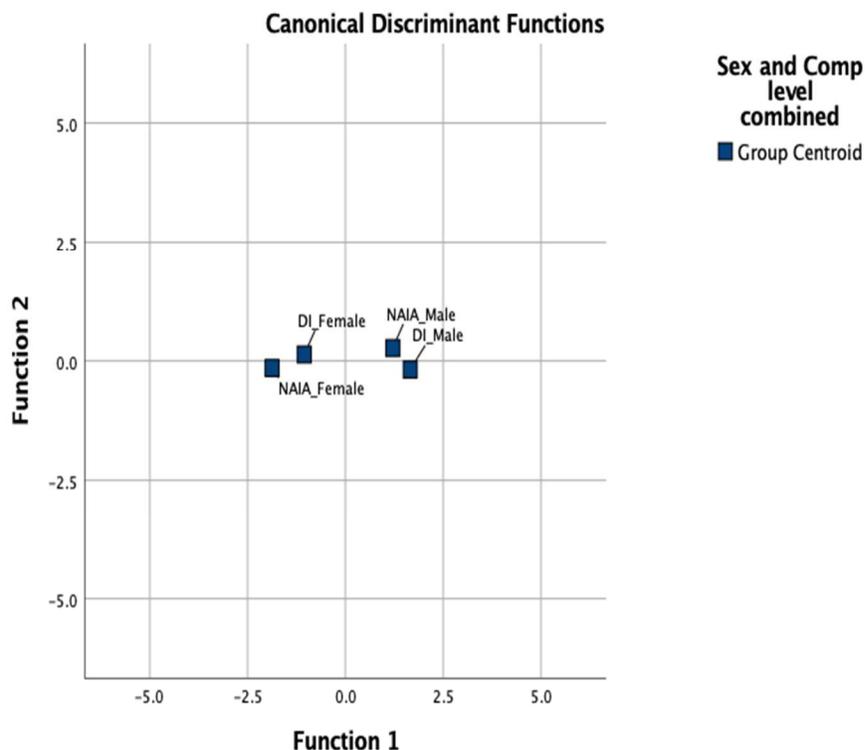


Figure 4. 1. *Group centroid plot from DFA.*

**Table 4. 4:** Summary of Structure matrix for DFA.

Structure Matrix	Function		
	1	2	3
Jump Height (Flight Time) [cm]	.861*	-.290	.419
Peak Power [W]	.821*	.206	-.532
Concentric RPD - 100ms [W/s]	.479	.570	.667*

Note. \*Largest absolute correlation between each variable and any discriminant function

**Table 4. 5:** Classification results for all discriminant functions.

Group	n	Predicted Group Membership, n (%)			
		DI Female	NAIA Female	DI Male	NAIA Male
DI Female	73	33 (45.2)	29 (39.7)	2 (2.7)	9 (12.3)
NAIA Female	62	15 (24.2)	46 (74.2)	0 (0.0)	1 (1.6)
DI Male	79	2 (2.5)	0 (0.0)	46 (58.2)	31 (39.2)
NAIA Male	51	5 (9.8)	2 (3.9)	19 (37.3)	25 (49.0)

*Percent of correctly classified cases: 56.6%*

## Discussion

The discriminant function analysis revealed one significant function (discriminant function #1 or DF1) which indicated that jump height and peak power discriminate between female athletes at NCAA DI institutions and NAIA institutions. These two variables can be viewed as an athlete's ability to propel or accelerate their body vertically off the ground and produce power in multiple directions (i.e. jumping, sprinting, change of direction ability). The DFA follow-up ANOVA showed a significant difference between all males and females regardless of competition level based on the scores from the discriminant analysis function 1. The scores of females were also significantly different between the two competition levels. However, male scores were not significantly different based on the DF1 scores. Overall DF1 had a large effect on discriminating between the four groups (canonical  $R^2 = .69$ . This metric is used to convey the effect size). The results displayed in the group centroid plots (figure 1) and the DFA follow-up ANOVA indicates that the significant function could be indicative of strength differences between the participants.

The findings of this study are believed to be the first to attempt to examine differences in athletes from NCAA DI and NAIA institutions based on performance variables recorded in the CMJ. The findings of this study based on the results of the MANOVA and follow-up univariate ANOVAs are that females at the DI level performed significantly better in the CMJ based on jump height, peak power and concentric RPD-100ms compared to females at the NAIA. The results displayed in Table 1 show that DI females jumped roughly 5cm higher with higher power outputs and did so faster (RPD-100ms) than their NAIA counterparts. Previous research using female participants at

different levels of NCAA competition has shown that DI athletes across different sports (soccer, volleyball, softball) had greater vertical jump heights than their DII or DIII counterparts (Lockie, Dawes, Jones, 2018; Barnes et al. 2007; Jones and Thompson, 2011; Smith, Ford, Myer, Holleran, Treadway, & Hewett, 2007). The findings in this study showed that female DI athletes differed significantly from their NAIA counterparts in all performance variables measured. The previous literature on female participants at different collegiate competition levels did not report on peak power or concentric RPD-100ms. However, because jump height and power are correlated variables it would be likely that similar results would be seen in those populations.

The findings of this study showed DI male participants obtained a higher vertical jump than NAIA males, however the difference was roughly 1cm (Table 4.2). This study is believed to be the first study to report peak power and concentric RPD-100ms for male athletes at the NCAA DI and NAIA levels. Only peak power was found to be significantly different between the two groups of males. However, it was noted that the NCAA DI group differed significantly in body mass for the NAIA group (Table 4.3). This difference is possible reason for the observed difference in peak power and although there was a difference both groups obtained nearly the same jump height. This suggests that the two groups may not be as different in respect to physical performance as previously thought. Previous research has shown that male athletes from DI have jumped higher than their counterparts at DII or DIII (Fry & Kraemer, 1991; Garstecki, Latin & Cuppett, 2004). Brummitt & Engillis (2016) found that DIII and NAIA did not differ significantly in the single leg hop or standing long jump. Only one study was identified which reported vertical jump performance comparisons between NCAA DI and NAIA

male athletes (Spaniol, 2009). The DI baseball players obtained higher vertical jump heights than their NAIA counterparts.

The results of the current study show that females differed from males in all variables measured regardless of competition level. Given that females and males differ in body mass, this variable was not included as a covariate. Future research comparing athletes from different competition levels should include body mass in the analysis. In the current study, sport was not used as a covariate because the group sizes based on sport were small. Further research should seek to obtain a sufficient number of participants to include sport as a covariate. One major limitation of the analysis is that Box's M was violated ( $p < .001$ ) which decreases the MANOVA's trustworthiness. It is important to note that Field (2018) warns of the disadvantage of using Box's M particularly that it is very sensitive. Furthermore, the results of the univariate and multivariate analyses, in addition to the large squared canonical correlation show findings that are generally consistent. Thus, the researchers are confident that the outcomes of this study are trustworthy.

Despite the collegiate athlete status of all the examined athletes, significant differences in the selected CMJ variables were observed between males and females at and across the two competition levels. Males did not differ significantly between the two competition levels with the exception of peak power. However, the larger group size and body mass values for the NCAA DI males group is possibly the underlying cause of this difference. The descriptive results presented in this study for NAIA athletes can serve as normative values for comparison or as target values for research and coaches.

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