International Journal of
EXERCISE SCIENCE

Original Research

A Comparison of Lower Body Power Characteristics Between Collegiate Athletes from Different Competition Levels.

CODY A. STAHL†1, KESTON G. LINDSAY‡2, J. BRYAN MANN‡3, MARGARET HUNT‡2, and J. JAY DAWES‡1

[1]School of Kinesiology, Applied Health and Recreation, Oklahoma State University, Stillwater, Oklahoma, USA; [2]Helen and Arthur E. Johnson Beth-El College of Nursing and Health Sciences, University of Colorado Colorado Springs, Colorado Springs, Colorado, USA; [3]School of Education and Human Development, University of Miami, Miami, Florida, USA.

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 13(6): 470-479, 2020. The counter-movement jump (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 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), concentric RPD-100ms, and peak power existed between athletes at different playing levels. RESULTS: A MANOVA revealed significant differences based on sex and competition level in the dependent variables measured (Wilk's Lambda = 0.908, $F(3,259) = 8.732$, $p < .001$, partial $\eta^2 = .092$). DISCUSSION: The findings of this study revealed that females at the Division I level achieved significantly greater jump heights, peak power and concentric RPD-100ms compared to females at the NAIA level. Division I males displayed significantly higher peak power than their NAIA counterparts.

KEY WORDS: Counter-movement jump (CMJ), NCAA, NAIA

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 (16, 17). Unlike the NAIA, which is mainly comprised of one level of competition, the NCAA is made up of three distinctive divisions: Division I (DI), Division II (DII), and Division III (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 athletes, thanks in part to national notoriety and larger athletic budgets (i.e., more money for facilities and scholarships; 16, 17). However, this supposition is largely speculative as relatively few studies have compared performance on predictors of athletic success between athletes in these organizations (3, 4, 9, 23).

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 (1). In a study by Fry and Kraemer (9) 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. (3) 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 (4) reported NAIA male basketball players jumped further in the single leg hop (left leg; $p < .05$) than NCAA DIII male basketball players. Spaniol (23) reported that DI baseball players obtained higher vertical jump heights than NAIA players. However, it is important to note that in his review, Spaniol (23) used normative data from previously published abstracts to make these comparisons (24, 25). Neither the comparison review (23) 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 reliable performance test frequently used to measure an athlete's lower-body power (5, 13, 15). In fact, it is one of the most commonly used performance tests by coaches and researchers to indirectly measure power of the lower-body (6). 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 the Sayers' equation; 12, 15, 21). 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 (6, 11, 19).

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 (2, 6). 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 (19). 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, one should not only know how high an athlete can jump but also how they summate or produce force and how quickly that is accomplished (12).

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 (23). Furthermore, few research studies have provided concurrent normative data from NCAA Divisions and NAIA athletes in the same study. Therefore, the purpose 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 CMJ 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. Descriptive variables such as age, height, and weight are presented in table 1. A post hoc power analysis conducted with G*POWER 3.1 (7) showed that with an alpha set at $p < .05$ the achieved power and effect size in the present study were 0.983 and 0.0494 respectively. These data were 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 and completed an informed consent. 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. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (18).

Table 1. Anthropometrics (mean ± SD) for age, height (Ht.), and weight (Wt.).

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

Note. Due to use of archival data the ages, heights, and weights were not provided by the performance staff for all 275 athletes. This is the reason for the changing *n* for those variables. The *n* column is meant to show what was available for analysis.

Protocol

The CMJ was performed utilizing a dual single-axis force platform system (Pasco PS 2141 plates, Pasco Scientific Inc., 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 (14, 20, 26, 27). 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 (26, 27). 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 (14, 20). 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.

Athlete height (cm) was recorded by a member of the athletic performance staff. Force- Decks software (Vald Performance, Newstead, QLD, AUS) 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. The flight time method of jump height calculation was calculated as jump height (cm) = $(g*t^2)/8$. Where g is the acceleration due to gravity and t is the flight time.

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. Primary analyses were conducted on the CMJ data from the remaining 265 participants. 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), concentric RPD-100ms, and peak power existed between athletes at different playing levels. A discriminant function analysis (DFA) was used to investigate how the three dependent variables (jump height, peak power, and concentric rate of power development [concentric-RPD100ms]) or outcome variables may discriminate the participants based on a combined variables (sex and competition level). A description of the primary statistical tests conducted and the follow-up analyses are presented in Table 2. All statistics were conducted with IBM SPSS v.25. Alpha was set at $p < .05$ for all tests (IBM, New York, NY, USA).

Table 2. Description analyses conducted.

Type of Analysis Used (# of tests)	IVs (levels)	DVs	Additional follow-up Analysis (# of tests)	Rationale for follow-up testing
2 x 2 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)[a] #2) Discriminant Function Analysis (DFA)[b]	-The multivariate interaction was significant; therefore, it is recommended to evaluate the univariate interactions.[a] -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.[b]
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[c]	-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.[b]
(3) Univariate ANOVAs	1) Combined variable for Sex & Competition Level	1) Athlete height (cm) 2) Athlete weight (kg) 3) Athlete age (yrs.)		-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.[c]

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. Superscript [a,b,c] are meant to show which test the rationale column is referring to.

RESULTS

Results of the MANOVA showed significant differences (Table 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 3. Performance results based on sex and competition level (mean ± SD).

	Jump Ht. (cm)	Peak Power (W)	Concentric RPD-100ms (W/s)
DI Females (*n* = 73)	32.2 ± 4.99	3264.3 ± 628.1	15548.7 ± 702.6
NAIA Females (*n* = 62)	27.4 ± 5.17	2835.7 ± 464.5	11718.7 ± 4338.9
DI Males (*n* = 79)	42.6 ± 4.75	4888.6 ± 683.4	22964.6 ± 7366.6
NAIA Males (*n* = 51)	41.2 ± 6.47	4538.6 ± 892.2	23160.1 ± 7326.7
DI (ALL; *n* = 152)	37.1 ± 7.51	4108.5 ± 1045.2	19403.1 ± 8076.6
NAIA (ALL; *n* = 113)	33.6 ± 9.01	3604.3 ± 1094.2	16882.5 ± 8184.3
Females (ALL; *n* = 135)	29.4 ± 5.40	3067.4 ± 596.8	13789.8 ± 6211.9
Males (All, *n* = 130)	42.0 ± 5.50	4751.3 ± 787.6	23041.3 ± 7326.7

Univariate ANOVAs indicated significant differences in height and weight but not age based on the combined competition level and sex variable (Table 1; 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) (Wilk's Lambda = .3, η^2 (9) = 316.9, $p < .001$, canonical R2 = .69). Group centroids for the DFA are shown in Figure 1. 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 ($p > .05$).

Table 4. Summary of Structure matrix for DFA.

Structure Matrix	Function 1	Function 2	Function 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.

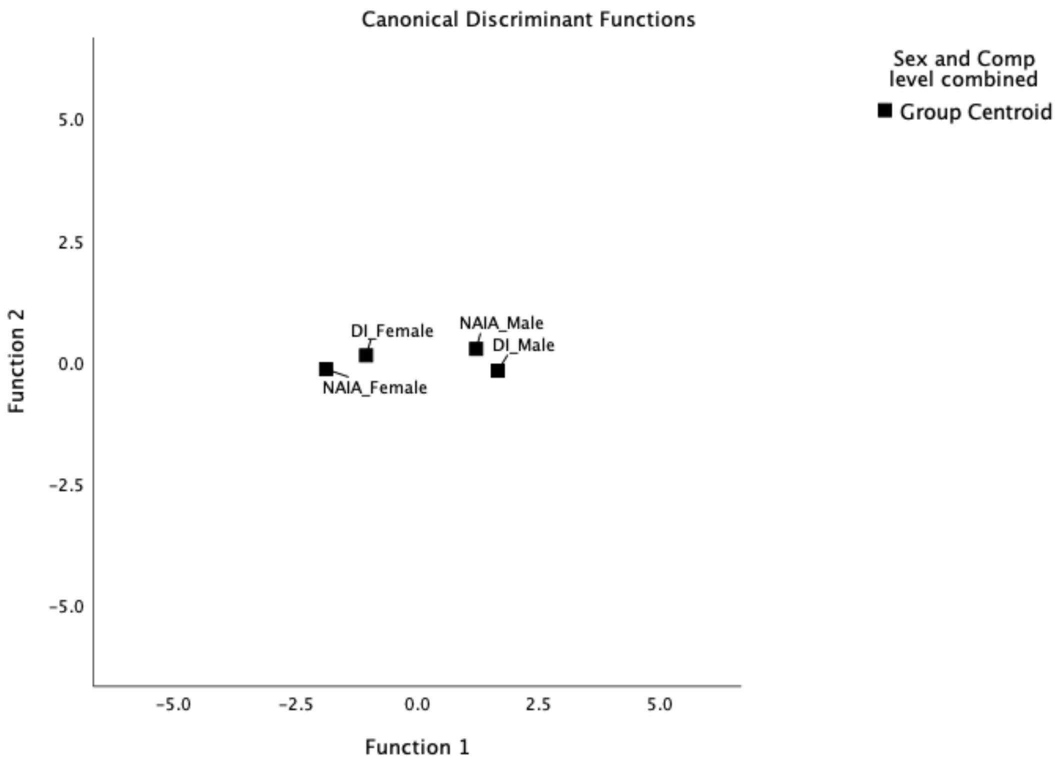

Figure 1. Group centroid plot from DFA.

DISCUSSION

The discriminant function analysis revealed one significant function (discriminant function #1/DF1; Table 4) 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, and 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 DF1. 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 3 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 (3, 22). 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 3). 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 1). This body mass difference is most likely the reason for the observed difference in peak power, and although there was a difference in body mass, 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 (9, 10). Brummitt & Engillis (4) 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 (23). 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 (n) 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 (8) 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.

The key message in this study is that significant differences in lower-body power measures from the CMJ were observed between males and females within their respective competition levels as well as between the two levels. Previously it has been suggested that NCAA DI athletes are the best athletes in collegiate athletics because DI is the top level of competition. Female DI athletes have previously outperformed their NCAA peers in measures of physical performance (3). The results found for female athletes in the present study further add to the previous research findings and may suggest that DI female athletes should be considered the best collegiate athletes. However, for male athletes more research should be conducted to confidently state DI NCAA males are better performers than NAIA males in physical fitness measures. The descriptive results presented in this study for NAIA athletes are believed to be the first such values reported for this population. Future research is needed to continue to collect and compile data to help establish normative values for this population. Researchers and coaches can use the results presented in this study to compare with until that time. Strength coaches at NAIA universities can track countermovement jump performance and subsequent calculations of lower body power to aid in programming for athletes whose aims may be to compete in the NCAA or as professionals.

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