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Physical determinants of Division 1 Collegiate basketball, Women's National Basketball League and Women's National Basketball Association athletes: with reference to lower body sidedness

Running head: Physical determinants of female basketball athletes

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ABSTRACT

In female basketball the assumed components of success include power, agility, and the proficiency at executing movements using each limb. However, the importance of these attributes in discriminating between playing levels in female basketball have yet to be determined. The purpose of this study was to compare lower body power, change of direction (COD) speed, agility, and lower-body sidedness between basketball athletes participating in Division 1 Collegiate basketball (United States), Women's National Basketball League (WNBL) (Australia), and Women's National Basketball Association (WNBA) (United States). Fifteen female athletes from each league (N = 45) completed a double and single leg counter-movement jump, static jump, drop jump, 5-0-5 COD

Test, and an offensive and defensive Agility Test. One-way analysis of variance with post-hoc comparisons, were conducted to compare differences in physical characteristics (height, body mass, age) and performance outcomes (jump, COD, agility assessments) between playing levels. Separate dependent t-tests were performed to compare lower body sidedness (left vs. right lower-limbs) during the single-leg CMJ jumps (vertical jump height) and 5-0-5 COD test for each limb within each playing level. WNBA athletes displayed significantly greater lower body power (P = 0.01–0.03) compared to WNBL athletes, significantly faster COD speed (P = 0.02–0.03), and offensive and defensive agility performance (P = 0.02 – 0.03) compared to WNBL and Collegiate athletes. WNBL athletes also produced faster defensive agility performance compared to Collegiate athletes (P = 0.02). Further, WNBA and WNBL athletes exhibited reduced lower body sidedness compared to Collegiate athletes. These findings indicate the importance of lower body power, agility, and reduced lower body imbalances to execute more proficient on court movements, required to compete at higher playing levels.

Key Words: Change of Direction, Agility, Speed, Power, Muscular Imbalances, Decision-making, WNBA

INTRODUCTION

Basketball remains a popular sport worldwide, with high participation rates in many countries. For instance, basketball participation across various ages and genders rank first and second among team sports in the United States (37) and Australia (2) in 2013-2014, respectively. Accordingly, basketball competitions are administered at various playing levels, with developmental pathways available to players for career progression in the sport. In women's basketball, Division I Collegiate competition serves as a developmental pathway into the elite Women's National Basketball Association (WNBA) in the United States. A similar hierarchy is also evident in Australia, with the elite Women's National Basketball League (WNBL) serving as an incoming pathway for collegiate athletes and an outgoing pathway for athletes into the WNBA. Despite this integrated nature of women's basketball in the United States and Australia, the physical attributes discriminating between playing levels and possibly contributing to success at the elite level have yet to be determined.

In elite-level basketball, the physical components of success are embodied by the ability of the athlete to generate power, decelerate and accelerate quickly, changing direction in response to a stimulus, and possess adequate levels of cardiorespiratory and musculoskeletal endurance (1). Due to the importance of power and agility for on-court basketball success, training programs frequently focus on increasing these properties in athletes across various playing levels (21). Numerous studies have attempted to provide normative data for sport-specific physical attributes using various testing protocols in basketball players, with the majority of available data representative of male athletes

(1,3,8,14,20,24,27,38). Some studies have used a combination of sprint and change of direction speed tests to assess acceleration, maximal speed, and agility performance (1,14,27), whereas other studies have adopted tests to assess lower body strength and power in basketball players (1,3,8,20).

Explosive power and force production of the lower limbs determined from counter-movement jump performance (CMJ) has been shown to be a strong predictor of playing time in men's basketball (10), with elite male athletes producing significantly greater peak power outputs during CMJ compared to novice counterparts (3). While limited research exists for female basketball athletes, it appears a superior jump performance is a deterministic factor for higher team selection in other elite female sports such as volleyball (29). Moreover, the ability to decelerate and accelerate to execute directional changes has also been considered a physiological pre-requisite for basketball performance (5,34). Despite differences in change of direction (COD) speed being identified between playing levels (3) and positions (3,27) in men's basketball; research has only reported moderate correlations to total playing time. While the high-intensity intermittent nature of basketball requires athletes to perform multiple directional changes, they are often executed in response to an external stimulus (26,33,35), which may explain the lack of correlation between a pre-planned COD movement and playing time. This integration between movement execution and decision-making ability, assessed via agility tests (REF), has been shown to replicate the temporal and spatial demands of team sports (30), and has been shown to discriminate between starters and non-starters (28), as well as playing levels (14) in male basketball athletes. However, despite these findings, there is a distinct lack of research assessing agility performance in female basketball. During a typical basketball game, female athletes execute 35-45 jumps and change speed and/or direction every 1.4-2.8 s (16,25). To execute these movements, proficiency in to the left and right is required for effective positioning and function on court. Time-motion analyses reveal athletes are required to perform multiple unilateral movements throughout a game including directional changes, lay-ups and single leg vertical jumps (4), inherently suggesting some level of imbalance may be observed in basketball athletes due to the imposed movement demands. Previous research has demonstrated that muscular imbalances negatively impact performance outcomes, and increase the risk of injury incidence (1,6,15,23). Therefore, it is of practical relevance to examine and compare the level of movement deficiency between limbs, as athletes with a reduced imbalance may be more proficient at executing functional movements on court, potentially separating themselves from lower-level players.

Therefore, the purpose of this study is to present data on lower body power, change of direction speed, agility, and lower-body sidedness of female basketball athletes participating in Division 1 Collegiate basketball (United States), WNBL (Australia), and WNBA (United States) basketball leagues. This data will be compared between playing levels to determine the importance of these physical attributes relative to each playing league, and in the process identify qualities required to progress to higher player levels in women’s basketball. As athletes competing in the WNBA are considered elite level players participating at the highest playing level in women's basketball, it is hypothesised that WNBA athletes will possess greater lower body power, reduced lower body sidedness and produce a faster COD and agility performance in comparison to WNBL and Collegiate athletes.

METHODS

Experimental Approach to the Problem

A cross-sectional design was utilized to identify differences in physical attributes (lower body power, change of direction speed, agility, and sidedness) between Division I Collegiate, WNBL, and WNBA basketball athletes. Subjects were required to attend one testing session, which consisted of a series of jump assessments, including a CMJ (double, and single-leg left and right), static jump and drop jump; a 5-0-5 COD Test; and an offensive and defensive agility test. These assessments of lower body power, COD speed, agility, and sidedness were chosen as female basketball athletes are required to perform multiple jumps, and undergo frequent changes in movement direction and speed during game-play, highlighting the relevance of such athletic movements to performance (16,25). All testing occurred on an indoor basketball court, prior to any scheduled training sessions for that week. Prior to testing, a standardized 10-minute dynamic warm up was performed. Subjects were instructed to refrain from performing any strenuous activity or lower-body resistance training within 48 hours of their assigned testing session.

Subjects

Forty-five (N = 45) female basketball athletes, consisting of 15 Division I Collegiate athletes, 15 WNBL athletes, and 15 WNBA athletes, were recruited for this study (Table 1). Athletes were required to have played basketball for a minimum of five years and partake in a minimum of one competitive game and two structured skill based training sessions each week, in which jumping and change of direction movements formed part of the regular on court training regime. Data collection occurred after pre-season training for all athletes to ensure adequate fitness and minimal fatigue as a result of in-season competitive games. All athletes were required to be injury free at the time of testing, and report no previous history of major lower limb injuries such as anterior cruciate ligament injuries. Ethics approval was obtained from an institutional Human Research Ethics Committee prior to testing and all testing procedures were explained to athletes prior to obtaining informed consent to participate.

INSERT TABLE 1 ABOUT HERE

Countermovement Jump Assessments

The double leg CMJ assessment was conducted with athletes positioning their hands on a carbon fiber pole held on the superior surface of the upper trapezius muscle, and placing their feet shoulder width apart (36). This starting position was chosen to reduce the involvement of arm-swing during the jump, which has been shown to influence vertical jump performance (17). Athletes lowered to a self-selected depth while being instructed to "jump as high as possible", similar to previous research (7).

Single leg left and right CMJ required a similar starting position to the CMJ; however, the non-support leg was flexed to 90°, while athletes stood standing on the support leg to complete the required jump (18). Athletes lowered to a self-selected depth and were instructed to "jump as high as possible", landing on the same leg used to perform the jump. Athletes then completed a static jump; starting in an isometric squat position, with a 90° knee angle as monitored by a goniometer and an elastic band placed around the back of the squat rack (11). Athletes then performed a concentric only action, jumping vertically for maximal height (11). For the drop jump protocol, athletes began standing on a 30-cm box with their hands positioned on a carbon fiber pole held on the superior surface of the upper trapezius muscle. Athletes were then instructed to step off the box, land, and jump vertically for maximum height while minimizing ground contact time (15).

Each jump assessment was separated by a 2-min passive, rest period, with athletes completing three trials of each jump assessment, 30 s apart. All jumps were performed on a portable force plate sampling at 600 Hz (400 Series Performance Plate; Fitness Technology, Adelaide, Australia), with the force trace for each jump collected using the Ballistic Measurement System Software (Version 3.4, Fitness Technologies, Adelaide, SA, Australia). Variables of interest for all jump trials included, average jump height (cm), average relative peak force (N/kg), and average relative peak power (W/kg).

5-0-5 Change of Direction Test

The 5-0-5 COD Test required athletes to start behind a set of timing lights (Fusion Sport, Queensland, Australia), sprint 10 m in a straight line through a second set of timing lights, continue sprinting in a straight line a further 5 m before planting their foot on a marked line, turning 180°, and sprinting 5 m back through timing lights to complete the test (36). Athletes completed six trials, with three trials involving planting and changing direction with the right leg and three trials with the left leg.

Trials were completed in a randomized ordered, with athletes instructed verbally prior to completing each trial as to which direction (left or right) to run and change direction. Each COD trial was separated by a 30-s rest period. Approach speed (s) across the first 10 m, and change of direction time (s), calculated as the time taken to run 5 m after triggering the second set of timing lights, turn 180° and sprint 5 m back through the timing lights, were taken as outcome measures and averaged across the three trials for each leg.

Offensive and Defensive Agility Tests

The offensive and defensive agility test required athletes to start behind a set of timing lights (Fusion Sport, Queensland, Australia) and sprint 10 m in a straight line through a second set of timing lights (Figure 1). Triggering the second set of timing lights resulted in a light stimulus to illuminate on an additional set of timing lights positioned 5 m away at 45° angles to the left and right of the second set of timing gates (33; 35). Athletes were required to respond to the light stimulus by performing a 45 ± 5° cut, sprinting a final 5 m to complete the test. The delay for the light stimulus to appear after passing through the second set of timing gates was set at 0 s in the Smartbase software (Fusion Sport, Queensland, Australia). The order (left or right) for the light to appear was set at random so that the athletes could not anticipate the direction of travel. Athletes were required perform two trials changing direction towards the light stimulus (termed defensive agility) and two trials changing direction in the opposition direction to the light stimulus (termed offensive agility), similar to previous research (33,35). Each agility trial was separated by a 30-s rest period.

Approach speed (s) across the first 10 m, and agility time (s) calculated as the time take to run 5 m after triggering the second set of timing lights and pass through the final set of timing lights was averaged across the two trials for each agility condition. The offensive and defensive agility test has been shown to be reliable assessments of agility performance in basketball athletes (ICC = 0.8, CV = 4.77%) (33; 35).

INSERT FIGURE 1 ABOUT HERE

Statistical Analysis

All statistical comparisons were performed using a statistical analysis program (IBM SPSS Statistics, Version 19.0; Chicago, Illinois) with significance set at $P \leq$ 0.05. The Shapiro-Wilks statistic and Levene's test for equality in variances were conducted for all data and confirmed normality and homogeneity of variances. As a result, differences in physical characteristics (height, body mass, and age) and performance outcomes (jump, COD, and agility assessments) between each playing level (Collegiate, WNBL, and WNBA) were compared using separate one-way ANOVAs. When applicable, a Tukey post-hoc test was used to determine the source of any significant differences. Separate dependent t-tests with follow up Bonferonni corrections were performed to compare lower body sidedness (left vs. right lower-limbs) during the single-leg CMJ jumps (vertical jump height) and the 5-0-5 COD Test (change of direction time for each limb) within each playing level. Effect sizes (*d*) were calculated for group comparisons by dividing the difference between groups by the pooled standard deviation (6). The magnitude of effect size calculations were interpreted following Hopkins' guidelines (12), with the following descriptors: *trivial* = 0-0.1; *small* = 0.11 – 0.3 ; *moderate* = 0.31 – 0.5; *large* = 0.51 – 0.7; *very large* = 0.71 – 0.9.

RESULTS

Performance outcome measures for each playing level are presented in Tables 2 and 3. WNBA athletes demonstrated significantly greater jump height during the right single (P = 0.03), left single (P = 0.02), and double (P = 0.03) leg CMJ, as well as relative peak power during the right single (P = 0.01), left single (P = 0.01), and double (P = 0.02) leg CMJ compared to WNBL athletes (Table 2). In contrast, jump measures for Collegiate athletes did not significantly differ from WNBL or WNBA athletes. While no significant difference was observed in static jump performance, or drop jump height between leagues (Table 2), WNBA athletes produced significantly greater relative peak force (P = 0.03) compared to WNBL athletes. Interpreting COD performance (Table 3), WNBA athletes demonstrated a significantly faster approach time (vs. WNBL, right: P = 0.03; left: P = 0.03; vs. Collegiate, right: P = 0.02) and COD time (vs. WNBL, right: P = 0.02; left: P = 0.02; vs. Collegiate, right: P = 0.03; left: P = 0.03) than the other playing groups. Further, WNBL players possessed a significantly faster right approach time (P = 0.02) than Collegiate athletes during the COD assessment. In the offensive and defensive agility test, defensive approach time (P = 0.02), defensive COD time (P = 0.01), and offensive COD time (P = 0,02) were significantly faster in WNBA athletes compared to Collegiate athletes. Furthermore, WNBA athletes produced a significantly faster defensive COD time than WNBL athletes (P = 0.03), and WNBL athletes had a significantly quicker defensive COD time compared to Collegiate athletes (*P* = 0.02).

INSERT TABLES 2 AND 3 ABOUT HERE

Differences (%) between lower-limbs during single-leg CMJ performance and left and right COD time are presented in Figure 2. Across all playing levels, greater CMJ height and faster COD time were observed when athletes were utilizing their left leg. Although non-significant differences were observed, Collegiate athletes demonstrated a greater imbalance (%) during the single leg CMJ and COD test, followed by WNBL athletes, and WNBA athletes.

INSERT FIGURE 2 ABOUT HERE

DISCUSSION

This study is the first to compare physical attributes between three different leagues (Division I Collegiate, WNBL, and WNBA) in female basketball. The provided data will assist to determine the physical attributes that separate these athletes, with a view to understanding factors that are important for competing at higher playing levels in female basketball. The results are in support of the hypothesis, demonstrating that WNBA athletes display greater lower body power, faster COD speed, and superior agility performance compared to WNBL and Collegiate athletes. Further WNBA and WNBL athletes exhibit reduced lower body sidedness as compared to Collegiate athletes. These findings emphasize: (i) the importance of well-developed physical qualities, specifically lower body power, to enable a greater jump height; and (ii) that superior COD ability, and reduced lower body imbalance may enable female basketball athletes to compete at higher playing levels.

Increased muscular power is a pre-requisite for many team sports that require athletes to produce a great amount of force within short time periods (31,40). The execution of explosive and dynamic movements in basketball, including vertical jumps, is well documented (4,19), highlighting the importance of increased lower body power for basketball athletes. Findings of the current study indicate WNBA athletes possess greater lower body power and vertical jump height during double and single leg CMJ compared to WNBL athletes. Interestingly, all CMJ outcome measures did not differ between Collegiate athletes and WNBA or WNBL athletes, respectively (Table 1). These findings are in agreement with previous research examining male basketball athletes, where greater lower body power and vertical jump height were observed in elite level athletes (22,23). As no differences were observed in SJ performance between the three different leagues, we can assume that optimization of lower body stretch-shortening cycle capability, is an important factor to compete at higher playing levels. Further, despite no differences observed in force application during CMJ, WNBA athletes produced significantly greater peak force during the drop jump compared to WNBL athletes. These findings indicate that WNBA athletes are able to rapidly load and tolerate a greater eccentric load, increasing the muscles capability to store and utilize elastic energy (10) to achieve a greater jump height. This finding is particularly relevant in basketball, enabling athletes to execute explosive on court movements including layups, rebounding, and blocking opposition shots at the basket to achieve both and offensive and defensive advantage during the game.

The ability to rapidly load and tolerate a greater eccentric load may also have direct implications for COD performance. Change of direction ability is an important physical attribute in basketball, with elite male athletes executing 50-60 changes in movement direction and speed (4) throughout the duration of a game. Findings from the current study support previous research observing a faster 5-0-5 COD performance in elite basketball athletes (9), with WNBA athletes producing a superior 5-0-5 COD time and approaching the 180° directional change significantly faster compared to WNBL and Collegiate athletes (Table 2). Faster approach speeds observed during COD tests have been associated with increased braking forces (32) during the deceleration phase, promoting the storage and utilization of elastic energy to increase propulsive ability and acceleration in the new movement direction (32). In particular, the high velocity 180° directional change requires athletes to absorb an increased eccentric load as the muscle lengthens to aid deceleration, requiring athletes to possess sufficient eccentric strength to enable a faster directional change (32,34). Additionally, research has observed a strong and significant correlation between drop jump performance and COD tests, suggesting shorter contact times and the ability to tolerate a greater eccentric load, results in the development of sufficient muscle power through stretch-shortening cycle actions (14,12). These findings may explain why WNBA athletes produced a faster 5-0-5 COD performance compared to WNBL and Collegiate athletes. While the 5-0-5 COD replicates specific on court movements such as a backdoor cut, it fails to replicate the reactive nature in which directional changes are performed in game scenarios.

During a basketball game athletes are confronted with multiple offensive and defensive scenarios, requiring sufficient physical and technical attributes to execute required movement, in addition to a fast and accurate decision-making ability to successively manoeuvre about the court (33). As a result, athletes often engage in offensive and defensive agility movements during games to evade or pursue opponents and gain positional advantage. Findings of the current study indicate WNBA athletes produced a faster offensive and defensive agility performance compared to WNBL and Collegiate athletes, emphasizing the importance of agility performance to succeed at the elite level in female basketball (33,24,26). It is well establish that a combination of physical, technical and perceptual-cognitive qualities are required to execute a fast and accurate agility performance (14). While decision-making was not directly measured during this study, this finding supports previous agility research (28) demonstrating the importance of perceptual-cognitive ability to seperate between higher and lower level athletes, and a key attribute required to succeed at higher playing levels (33). Interestingly, defensive agility was found to the best discriminate between leagues, with WNBL athletes producing a faster defensive agility time compared to Collegiate athletes. While athletes physical attributes may contribute to the observed difference in agility performance, this finding supports the notion that an athletes ability to read and respond to opposing players movements on court may be a critical factor to compete at higher playing levels, compared to offensive ability which in some instances can be more pre-meditated through specific plays and positioning on court. Producing a delayed response to a stimulus in both offensive and defensive scenarios has been shown to affect movement output (4,7,27,32), decreasing the amount of muscle pre-activation (35) and force application negatively impacting agility performance in basketball athletes. Therefore, it appears the ability to successfully read the play and determine the correct movement direction sooner is an important characteristic for female basketball athletes to compete at higher playing levels. While it is advantageous for athletes to be proficient at executing movements equally to the left and right, athletes may become predisposed to favor a certain limb when executing unilateral on court movements including directional changes, vertical jumps, and layups, leading to the development of a lower body muscular imbalance. In the current study, WNBA and WNBL athletes exhibited reduced lower body sidedness during single leg CMJ and 5-0-5 COD assessments compared to Collegiate athletes. This finding aligns with previous research observing a reduced imbalance improves performance outcomes (13) in female athletes. While the precise factors contributing to the degree of sidedness observed in the current population is unknown, it appears reduced lower body sidedness results in proficient execution of on court movements required to compete at higher levels of play. Interestingly, across all leagues lower body sidedness is favored towards the left limb. Again, while the precise mechanisms for this observed differences is unknown, we can assume that if the majority of athletes in the current study were right-hand dominant, they would be trained to leap from their left leg when creating various scoring opportunities. For example, if athletes drive to the basket using their right hand performing a layup, the final step in the two-step sequence, would be the left leg, requiring athletes to leap off this leg creating vertical displacement to increase scoring success. Therefore, strength-training programs may need to emphasize the development of strength and power qualities in both the dominant and non-dominant leg, particularly in younger athletes at the Collegiate level athletes to compensate for potential imbalances developed during game play.

This is the first study to compare female basketball athletes across three different leagues (Division I Collegiate, WNBL, and WNBA) to determine the physical attributes that separate these athletes to better understand factors that are important to compete at higher playing levels. Despite the novel findings of this study, there are limitations that require acknowledgment. Firstly, while subjects were required to perform a side-stepping only directional change, the limb used to change direction during the offensive and defensive agility tests was not monitored. Therefore, we cannot conclude if a sidedness and/or cognitive deficit are the reason for the observed differences in agility performance. Further while we can infer in part that differences between athletes performance during the agility tests were due to differences in perceptual-cognitive ability, a true measure of reaction time was not performed. Additionally, training load and history was not recorded in the current study, which may have provided further insight into the findings presented. While previous research has stated that early athletic development is desirable for success at the elite level (39), future research should aim to investigate the impact of training history on performance and playing level in female basketball athletes. The findings of this study are also limited to three individual basketball teams, making further comparisons between positional groups challenging due to small sample sizes. Future research should seek to compare position-specific data between leagues to determine if physical qualities further differ based on functional roles and the reliance of difference physical attributes across playing positions (3).

PRACTICAL APPLICATIONS

The current study provides evidence for the importance of lower body power, COD and agility in female basketball athletes to compete at higher playing levels. Specifically, developing lower body power and importantly the stretch-shortening cycle ability of the muscle through Olympic lifting and plyometric exercises to increase vertical jump height during competition, appears crucial to compete at a higher playing level. It appears the development of eccentric strength, similar to previous research (41), would assist to improve athletes COD ability. Prescribing squats, power cleans or plyometric exercises, emphasizing the eccentric phase of the movement will develop an athletes ability to tolerate a greater eccentric load assisting athletes to decelerate sooner improving on court COD movements. During a basketball game a majority of movements are executed using a single limb (4), which may predispose athletes to develop a lower body muscular imbalance as observed in the current study. As a result, strength-training programs should aim to develop strength and power qualities in dominant and non-dominant limbs to reduce the level of sidedness; a characteristic apparent in the present study across various levels of female basketball athletes. While an athlete’s physical development is important, training perceptual-cognitive ability should be equally addressed. Incorporating drills which couple perception and action, for example executing various directional changes in response different verbal or visual cues, to develop an athletes agility performance, would be beneficial for female basketball athletes to compete at higher playing levels.

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Figure Legend

Figure 1. Layout of the Offensive and Defensive Agility Test

Figure 2. Percent difference between right and left limbs assessed during the single-leg countermovement jumps and 5-0-5 Change of Direction (COD) tests in Division 1 Collegiate (N = 15), Women's National Basketball League (WNBL) (N = 15), and Women's National Basketball Association (WNBA) (N = 15) athletes. *Note*: Positive difference indicates imbalance towards the left limb.

Table Legend

Table 1. Subject demographics (mean ± SD) in Division 1 Collegiate, Women's National Basketball League (WNBL), and Women's National Basketball Association (WNBA) basketball athletes.

Table 2. Vertical jump tests (mean ± SD) in Division 1 Collegiate, Women's National Basketball League (WNBL) and Women's National Basketball Association (WNBA) athletes.

Table 3. Change of direction and agility tests (mean ± SD) in Division 1 Collegiate, Women's National Basketball League (WNBL) and Women's National Basketball Association (WNBA) athletes.

Table 1. Subject demographics (mean ± SD) in Division 1 Collegiate, Women's National Basketball League (WNBL), and Women's National Basketball Association (WNBA) basketball athletes.

	1. Collegiate (N = 15)	2. WNBL (N = 15)	3. WNBA (N = 15)	Effect Size (Cohen's *d*)		
				1 vs. 2	**1 vs. 3**	**2 vs. 3**
Age (years)	20.3 ± 2.7	24.2 ± 2.5	26.2 ± 4.0	**1.49**	**1.72**	0.59
Body Mass (kg)	71.09 ± 23.8	75.5 ± 14.5	79.9 ± 14.8	0.22	0.44	0.30
Height (kg)	177.0 ± 12.9	177.7 ± 7.25	179.8 ± 11.4	0.06	0.23	0.21

Note: Bolded effect size = *very large* difference.

Table 2. Vertical jump tests (mean ± SD) in Division 1 Collegiate, Women's National Basketball League (WNBL) and Women's National Basketball Association (WNBA) athletes.

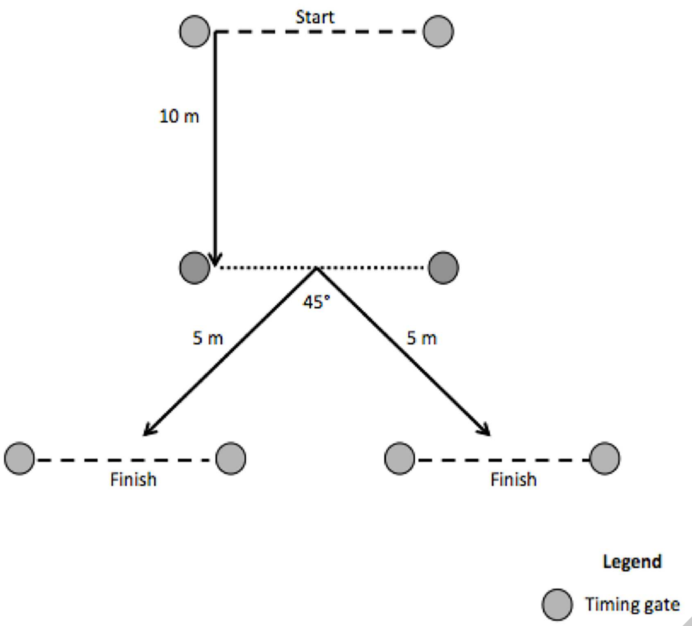
	1. Collegiate (N = 15)	2. WNBL (N = 15)	3. WNBA (N = 15)	Effect Size (Cohen's *d*)		
				1 vs. 2	**1 vs. 3**	**2 vs. 3**
Countermovement Jump (CMJ)						
Height (cm)	32.03 ± 5.14	30.58 ± 3.91	34.78 ± 3.31 *	0.32	**0.63**	**1.15**
Relative Peak Force (N.kg)	24.82 ± 2.80	24.29 ± 3.86	25.79 ± 2.94	0.16	0.33	0.44
Relative Peak Power (W.kg)	48.39 ± 5.58	42.50 ± 5.94	55.87 ± 9.04 *	**1.02**	**0.99**	**1.74**
Single-Leg Right CMJ						
Height (cm)	15.47 ± 2.55	13.29 ± 1.51	17.58 ± 4.60 *	**1.04**	0.57	**1.25**
Relative Peak Force (N.kg)	18.67 ± 3.08	17.32 ± 2.51	20.64 ± 2.49	0.48	**0.71**	**1.33**
Relative Peak Power (W.kg)	28.93 ± 4.73	23.33 ± 3.41	32.91 ± 5.68 *	**1.35**	**0.76**	**2.04**
Single-Leg Left CMJ						
Height (cm)	16.11 ± 3.58	13.66 ± 2.47	18.09 ± 2.50 *	**0.79**	0.56	**1.46**
Relative Peak Force (N.kg)	22.21 ± 3.07	20.02 ± 2.69	20.78 ± 1.64	**0.75**	0.58	0.34
Relative Peak Power (W.kg)	29.74 ± 4.59	23.91 ± 3.17	35.20 ± 6.02 *	**1.47**	**1.01**	**2.34**
Static Jump						
Height (cm)	24.15 ± 4.16	23.93 ± 3.42	26.22 ± 6.13	0.07	0.39	0.46
Relative Peak Force (N.kg)	23.04 ± 5.17	24.28 ± 3.41	26.01 ± 2.35	0.28	**0.74**	0.59
Relative Peak Power (W.kg)	46.70 ± 6.44	43.10 ± 5.72	50.31 ± 8.57	0.59	0.47	**0.98**
Drop Jump						
Height (cm)	28.27 ± 5.67	26.51 ± 4.32	30.58 ± 7.42	0.34	0.35	**0.67**
Relative Peak Force (N.kg)	27.78 ± 8.37	24.94 ± 6.72	33.08 ± 5.66 *	0.37	**0.74**	**1.31**

Note: Significantly different ($p \leq 0.05$) from Collegiate^ and WNBL*; Bolded effect size = *large* to *nearly perfect* difference.

Table 3. Change of direction and agility tests (mean ± SD) in Division 1 Collegiate, Women's National Basketball League (WNBL) and Women's National Basketball Association (WNBA) athletes

	1. Collegiate (N = 15)	2. WNBL (N = 15)	3. WNBA (N = 15)	Effect Size (Cohen's *d*)		
				1 vs. 2	1 vs. 3	2 vs. 3
5-0-5 Change of Direction Test						
Right Approach Time (s)	2.49 ± 0.18	2.15 ± 0.12 ^	2.29 ± 0.15 ^*	**2.22**	**1.21**	**1.03**
Right COD Time (s)	4.43 ± 0.12	4.58 ± 0.17	4.27 ± 0.16 ^*	**0.95**	**1.20**	**1.87**
Left Approach Time (s)	2.48 ± 0.29	2.11 ± 0.16	2.38 ± 0.21 *	**1.57**	0.39	**1.44**
Left COD Time (s)	4.44 ± 0.12	4.59 ± 0.14	4.27 ± 0.25 ^*	**1.22**	**0.81**	**1.57**
Offensive and Defensive Agility Test						
Defensive Approach Time (s)	1.54 ± 0.25	1.49 ± 0.19	1.18 ± 0.12 ^	0.22	**1.83**	**1.95**
Defensive COD Time (s)	4.21 ± 0.31	3.58 ± 0.27 ^	3.22 ± 0.22 ^*	**2.16**	**3.72**	**1.50**
Offensive Approach Time (s)	1.54 ± 0.21	1.50 ± 0.20	1.25 ± 0.12	0.19	**1.69**	**1.51**
Offensive COD Time (s)	3.58 ± 0.27	3.60 ± 0.28	3.35 ± 0.26 ^	0.07	**0.86**	**0.92**

Note: Significantly different ($p \leq 0.05$) from Collegiate^ and WNBL*; Bolded effect size = *large* to *nearly perfect* difference.


Start
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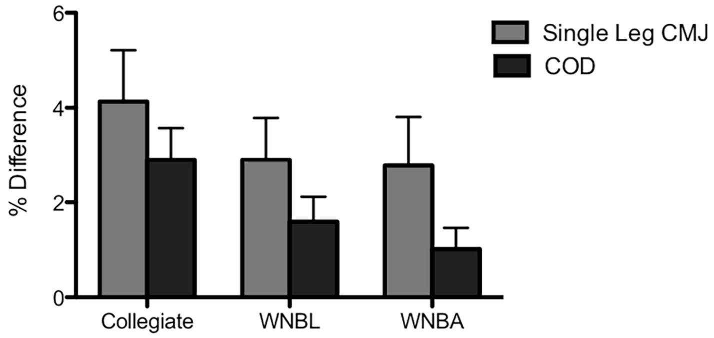
Single Leg CMJ
COD
% Difference
6
4
2
0
Collegiate
WNBL
WNBA