Jumping Performance of Elite NCAA Division 1 Student-athletes: The Effect of Basketball Shoe Design – Part I

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ABSTRACT

Background: Assessment of basketball shoes as personal protection equipment (PPE) at the collegiate level is unique. **Objective:** The purpose of Part I in this pilot study was to examine the effect of shoe design on jump height in elite male and female National Collegiate Athletic Association (NCAA) Division 1 basketball student-athletes. **Method:** Each team selected two pairs of Adidas™ branded shoes. The male student-athletes selected the Adidas™ Harden Vol. 3 and the Adidas™ SM Pro basketball shoes. The female student-athletes selected the Adidas™ Harden Vol. 3 and the Adidas™ Captain Marvel basketball shoes. A total of sixteen basketball student-athletes (six males, ten females) performed an acute series of four styled basketball jumps on two ForceDecks™ Force Platforms while trying to maximize jump height by tapping Vertec™ Jump Vanes. Two trials were performed in each shoe and for each type of jump which included a countermovement jump, drop jump from 30cm, step and jump, and a series of plyometric jumps. **Results:** The results of this pilot study indicated a non-significant effect of basketball shoe design on jump height while performing an acute series of basketball style jumps for either the male or female basketball student-athletes. However, there were significant differences in jump height and peak power between the male and female basketball student-athletes (p = 0.001). **Conclusion:** In addition to the results, the use of quantitative performance testing on the effectiveness of basketball shoe designs as PPE may assist in the mitigation of non-contact ankle and lower limb injuries.

Key words: Shoes, Basketball, Ankle, Traction, Ankle Joint, Athletic Performance, Basketball

INTRODUCTION

How basketball shoe design impacts jumping performance

Applying HFE assessment tools to athletic PPE footwear can begin to quantify and define the impact of sport-specific shoe design on positive and negative performance parameters. Discussed in the first study Basketball Shoe Taxonomy (BST, paper under review), the evaluation of basketball shoe design should focus on personal preferences, mechanical shoe structures, and dynamic cause-and-effect characteristics of design and performance. The importance of evaluating dynamic foot-ground interactions in determining shoe selection can be traced back to shoe's ability to mitigate injuries and affect performance. This was recently witnessed in collegiate athletics when in February 2019, Zion Williamson, former basketball player for Duke University and the number one pick in the 2019 NBA draft, made a move during competition and, quite literally, blew out his shoe in front of the one of the largest watched games in NCAA history.

Unfortunately, Zion suffered a knee injury which continues to negatively impact his 2019/2020 NBA playing season and resulted in Nike losing over $1 billion of stock value the day following the event (Curtis, Laudner, McLoda, & McCaw, 2008). To assess a shoe's effect on basketball jumping performance, understanding the design factors that influence kinematic and kinetic output during basketball specific jumps are discussed below.

How Basketball Shoe Design Impacts Jumping Performance

Basketball shoe design can be broken down into four main components: (a) upper, (b) insole, (c) midsole, and (d) outer-sole (Figure. 1). A basketball shoe must support the repetitive GRF movements including forward and backwards sprinting, quick changes in direction, and jumping. Basketball shoes have been traditionally designed based on how much the malleolus of the ankle is covered by the upper, "Low to Mid cut" for guards and small forwards and "Mid

to High cut" designed for forwards and centers (Figure. 2) (Brauner, Zwinzscher, & Sterzing, 2012). Specific basketball shoe design parameters can include weight, traction, collar height, mid and upper design, sole design, cushioning systems, and many more, but choosing the proper design based on athlete playing style has shown to be preferred (Brauner et al., 2012).

Based on a basketball shoe's design and its impact on the range of motion in the ankle joint, athletes may unintentionally alter their kinematics in the knee and hip joints creating compensatory movement which have shown to increase the risk of musculoskeletal injuries (Irzmańska, 2014). The foot to ground interaction is managed by the foot-ankle complex. The foot-ankle complex allows the foot to move through a wide range of motions, including inversion, eversion, dorsiflexion, plantarflexion, pronation, and supination (Lamberth, Martin, & Sanguinetti, 2016). The foot-ankle complex is comprised of the tibia, fibula of the lower leg, the talus within the ankle joint, and the calcaneus of the foot. Movement is comprised of three articulations: the talocrural joint, the subtalar joint, and the distal tibiofibular syndesmosis (Hertel, 2002). Due to the shape of the talocrural joint, the axis of rotation goes through the medial and lateral malleolus at a 42-degree angle and transversely at a 23-degree angle creating a tri-planar motion of pronation and supination (Hertel, 2002). Further stressors on the lateral ligaments can also occur when the lower leg is externally rotated during plantar flexion and ground reaction forces (GRFs) are high (Brizuela, Garcia, Ferrandis, Lozano, & Llana, 1996). This places the foot-ankle complex as an important shock absorber during initial contact with the ground and maintaining directional forces during a movement.
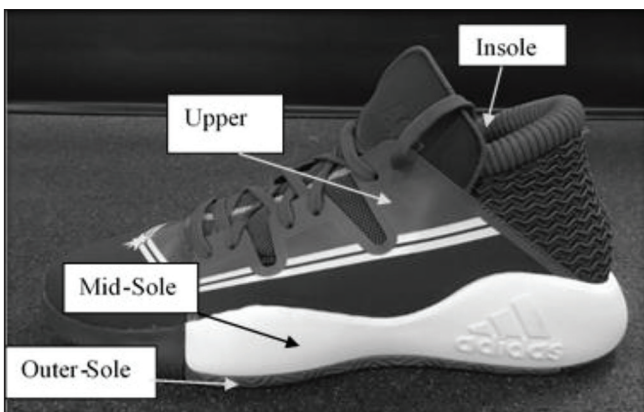

Figure 1. Parts of the Adidas™ Captain Marvel basketball shoe

Low-Mid Cut Shoe – 78mm

Mid-High Cut Shoe 110mm

Figure 2. Collar height differences of Adidas™ Harden Vol 3. Low-Cut and Adidas™ Captain Marvel basketball shoe

Kinetic Assessment

Testing for specific type of shoe functionality can be performed on a force plate with basketball specific movement patterns. Force plates measure external forces applied by the athlete during movement in three planes: vertical, medial-lateral, and anterior-posterior (Beckham, Suchomel, & Mizuguchi, 2014). Examining an athlete's lower body biomechanics can shed light on leg strength asymmetry, kinematics, and the effectiveness of training programs which can be identifiers for improved strength or potential injury factors (Addie et al., 2019; Allen, Fu, & Garner, 2016; Beckham et al., 2014; Harry et al., 2015; Kovács et al., 1999). Force plate jumping variables can include the athlete's rate of force development, peak force, take-off, flight time, and landing (Beckham et al., 2014). Figure 3 illustrates a countermovement jump's kinetic output from the ForceDecks software. The start of the movement is a reduction of GRF due to the downward squatting motion which eccentrically loads the lower limb musculature through the muscle's stretch-shorten cycle which will be followed with a rapid concentric contraction and extension of the foot-ankle, knee, and hip joints (Baker, 1996; Komi & Bosco, 1978). With an arm swing (Harman, Rosenstein, Frykman, & Rosenstein, 1990) the individual can apply greater GRF producing the ability to overcome gravity. The greater the rate of force developed (RFD), steepness of the slope, and shorter impulse the higher the jump will be (McClay et al., 1994). When the force plate measures zero, the athlete is in the air; this is known as flight time. Greater GRFs are produced due to the acceleration of the athlete's mass being applied to plate when landing from their peak jump height. Peak landing GRFs concerns from basketball jumps have shown intensities up six-times body weight, which when repeated may produce stress-related injuries (McClay et al., 1994). Based on the athlete's mass and acceleration rates, an athlete's force production may offer an improved application to establish type of play profiles and shoe selection (Mohr, Trudeau, Nigg, & Nigg, 2016). A combination of ensuring the athlete can perform proper landing techniques and basketball shoe designs may allow proper range of motion and should be the goal to optimize performance and safety. This poses the question of whether different shoes impact men's and women's basketball athlete's jumping performance at the NCAA DI level? To evaluate shoe effect, two different Adidas™ brand basketball shoes were worn to assess their influence on performing four basketball-specific jumps: (a) countermovement jump, (b) drop jump, (c) step jump, and (d) plyometric jump.

METHODS

Participants and Design

This study was conducted under the approval of the Mississippi State University's (MSU) Institutional Review Board (IRB protocol #19-351) at Mississippi State University. A total of 16 MSU basketball student-athletes, six from the men's team (198.48cm ± 8.97, 94.48kg ± 15.96, 13.5US Men's ± 2.35) and 10 from the women's team (184.15cm ± 9.29, 78kg ± 10.84, 10US Men's ± 2.35) ages 18 – 22 years
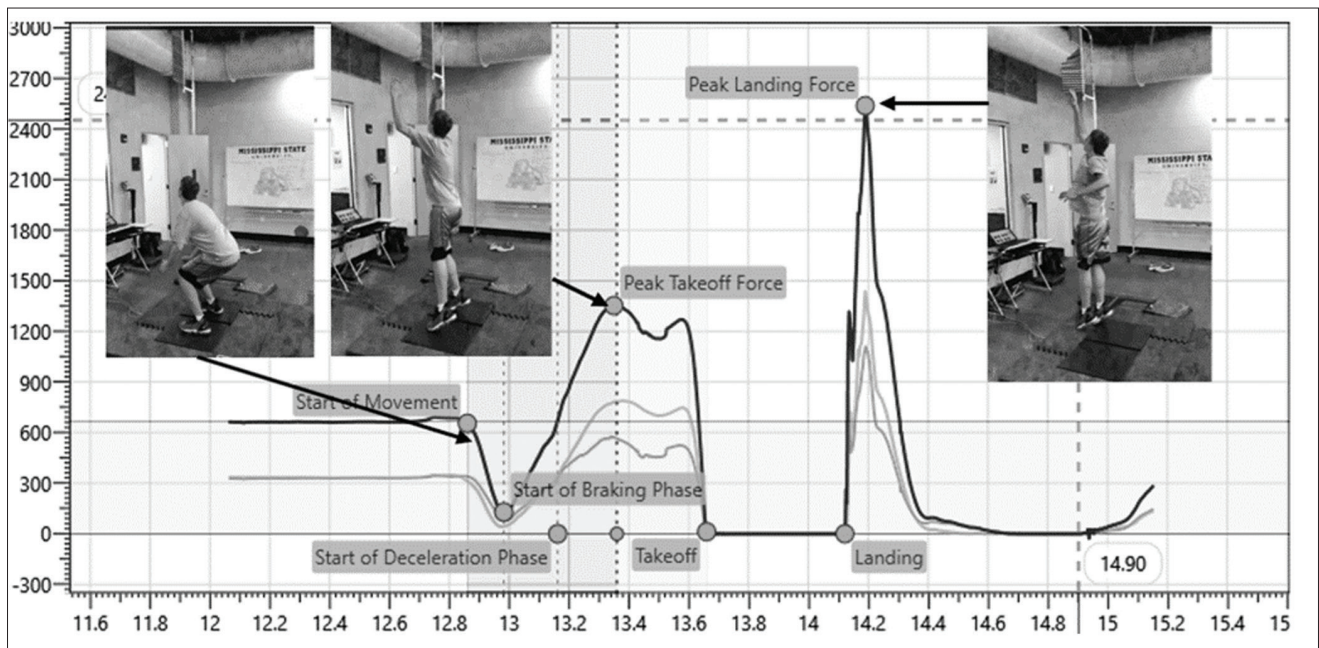
Figure 3. Jump measurements taken from a screenshot of ForceDecks software; this image and data were not taken from participant data collection. https://www.forcedecks.com/

of age volunteered and participated in the study. Before performing the test, student-athletes were informed of the testing protocol and provided a written informed consent form and PAR-Q form to "determine the safety or possible risk of exercising for an individual based on their health history, and current symptoms and risk factors"(Thomas, Reading, & Shephard, 1992). Any questions from the participants were addressed at that time. Student-athletes who were not allowed to practice determined by the strength and conditioning coaches (SCCs) were not recruited for the study.

Study Design

All student-athletes were instructed to visit the Mize Center basketball weight room. The cross-sectional study design followed a single day testing protocol with an initial familiarization session conducted before testing. During the familiarization session, student-athletes watched a demonstration by the researcher in how to perform each of the four jump types. The testing station included two force plates controlled by a Microsoft Windows-based laptop, surrounded by a firm foam pad to expand the platform area for safety purposes. Adjacent to the platform was a Vertec jump measurement apparatus set to the student-athletes' dominant side. The Vertec was preset at specific marks on the vertical support for the men's team at 2.896m and 3.048m height and 2.4384m and 2.5908m for the women (Figure. 1.). Pre-setting the Vertec allowed for consistent time management of measuring vanes reached, record kinetic data, and differences in height and jumping ability. The experimental procedures included measurements of GRFs in two different types of basketball shoes for each team, Adidas™ shoe A and B for the men's team and Adidas™ shoe C and D for the women's team (Figure. 4). Shoe order was counter balanced to minimize order effect and reduce the impact of fatigue. Each

Figure 4. Men's Team Shoe –Harden (a) and SM Pro (b), Women's Team Shoe –Harden (c) and Captain Marvel (d). All shoes are Adidas™ brand

student-athlete warmed up based on their chosen method. Student-athletes then performed jumps onto two ForceDecks Dual Force Plate System (Vald Performance, Brisbane, Australia) measuring at 1000 Hz, surrounded by rubber matting with a Vertec positioned on their dominant side (upper extremity) for hitting the Vertec vanes with their dominant hand during the jumping tasks (Figure. 5). Each participant performed two trials of each jump (Table 1). Upon completion, the student-athlete completed a comfort and fit survey and changed shoes. The jump protocol and comfort and fit assessment survey was repeated with the second pair of shoes.

Instrumentation and Participant Preparation

Adidas™ (Herzogenaurach, Germany) shoe selection was determined by the men's and women's strength and conditioning coaches based on the current available supply and stu-

dent-athlete preference. The men's team chose the Adidas™ basketball shoe Harden Vol. 3 – shoe A and the Adidas™ basketball shoe SM Pro Bounce Madness Team – shoe B to assess jumping parameters (Fig. 4). While the women's team choose Adidas™ basketball shoe Harden Vol. 3 – shoe C and the Adidas™ Pro Vision Marvel's Captain Marvel – shoe D (Fig. 4).

Shoe dimensions are presented in Table 2. Weight of the shoes were measured with an electronic scale (Mainstays™ Slimline Digital Scale). A sliding caliper was used to measure a straight-line difference between reference points on each shoe (Lafayette Instruments, Anthropometer, Model 01291). Previous research has reported that athletes prefer lighter weight shoes (Mohr et al., 2016), wider outsoles provide increased lateral stability (Worobets & Wannop, 2015), and "heavy + high" shoes have shown to decrease vertical jump height (Blache, Beguin, & Monteil, 2011). The weight of these shoes is considered medium for the men's team and light for the women's team (Blache et al., 2011). Shoe A, B, and C are considered low-cut shoes, while shoe D is a high-cut shoe. Higher collared shoes have shown decreased ankle range of motion and reduced lateral motion in the heel which may lead to increased strain on ankle ligaments (G Brizuela et al., 1996).

Experimental Procedures

Each student-athlete was first instructed to read through a participation consent form. Upon agreement to the expectations and signature for approval as per IRB protocol, the student-athlete was instructed on which pair of shoes should be worn first. Additional demographic information was gathered including shoe size, height, and weight. The order of the shoes was counter balanced to reduce bias of shoe type and fatigue in the study. Demonstrations by the test administrator were given to the student-athletes for each of the jumps as follows: (a) jump as high as possible by bending your knees and hit the vanes with your dominant hand (CMJ), (b) step and drop onto the force platform from the 30cm box and immediately on landing, jump as high as possible reaching for the Vertec vanes (DJ), (c) standing off the force plate, take a step forward with one foot, then the other into a counter movement pattern, jump as high as possible reaching for the Vertec vanes (STJ), and (d) jump as high as possible bending your knees, and on landing, perform a series of 4 consecutive CMJ jumps (PJ). Athletes used their individualized arm swings during all jumps attempting to create maximum jump height and touch Vertec vanes (Figure. 6). Student-athletes were paired together for motivation in performing maximal effort jumps. Student-athletes completed two trials of each jump and rested while the other participant completed their two trials. Between jumps, the Vertec vanes were reset, this provided the student-athletes rest between jumps. The jump and rest routine were followed until all jumps were completed. Student-athletes then rested to put on the second pair of test shoes and fill out a comfort and fit survey. The exact same protocol was repeated with the second pair of shoes. This marked the completion of the kinetic assessment study.
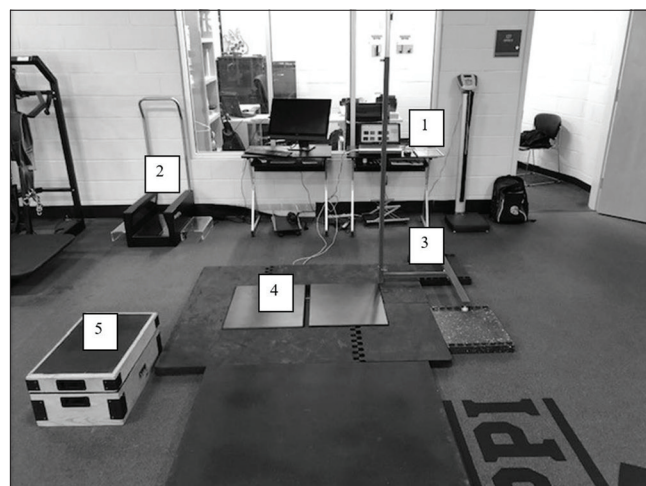

Figure 5. Experimental jump set-up: (1) Laptop running ForceDecks Software, (2) Adidas™ Foot Scanner, (3) Vertec Jump System, (4) Dual Force Plates, and (5) Drop Jump Box was positioned on platform adjacent to force plates during testing

Figure 6. Example of a Vertec Jump Measurement Test. Data from the photo was not used for this study

Table 1. List of jump types performed

Jump Tests (1 testing session – 2 trials each):
1. Countermovement vertical jump (CMJ)
2. Depth jump (30cm box) (DJ)
3. Step and jump (STJ)
4. Plyometric jump (PJ)

Data Processing

Jump force data was collected and processed using Force-Decks software. The Force Decks system auto-detected the CMJ, DJ, and PJ. The STJ was manually saved into the software. Prior to each jump, the athlete stepped onto the force plate to determine weight. Analysis of the jump was accomplished through the auto-analysis feature for the CMJ, DJ, and PJ. The STJ data was post selected into a counter jump movement for analysis. Recognizing the first jump within the PJ is a CMJ, that jump performance is ignored. The highest jump from the remaining three PJ was manually

selected as indicated from the ForceDecks analysis. Peak jumps from each athlete was then transferred to a Microsoft Excel (Redmond, WA, USA, ver. 365) program for further analysis.

Statistical Analysis

A Paired Samples t-Test was conducted using the Statistical Package for Social Sciences (SPSS ver.26, IBM Corporation, New York, NY, USA) to compare the interaction effect of shoe model on calculated jump height (cm) and normalized body weight peak power (W/kg) production (PPr). Jump height and PPr were determined using the ForceDecks software. Independent t-Test was conducted to compare differences in jump types between the men's and women's team. Two repeated measures analysis of variance (ANOVA) pairwise comparisons were conducted to compare jump types. Results are summarized in the following paragraphs. Statistical significance was set a priori at $p \leq 0.05$.

RESULTS

This pilot study selected the highest jump from the two trials performed within each jump and of each shoe tested and the highest of the three PJ performed after performing the initial CMJ to minimize any effect of loss of balance and fatigue that can occur in continuous jump protocols (McNeal, Sands, & Stone, 2010). Calculated jump height and PPr was obtained from the ForceDecks software (Table 3 and 4).

Shoe Effect on Jump Height

A Paired Samples t-Test was conducted to compare the effects of shoe types on jump height and PPr for both the men's and women's teams. Jump height was calculated in centimeters, peak power is normalized to body weight (W/kg). Results from the statistical analysis are presented. There was no significant difference in CMJ jump height for shoe A mean 46.85 (SD = 3.91) and shoe B mean 46.32 (SD = 4.52), $t(5) = 0.809$, $p = 0.455$. There was no significant difference in CMJ jump height for shoe C mean

Table 2. Sample shoe dimensions for both the men's and women's team

Men's team	Weight	Collar height at ankle (mm)	Collar height at heel (mm)	Top eyelet (mm)	Insole thickness (mm)	Heel sole height (mm)	Forefoot width (mm)	Heel width (mm)	Size
Shoe A	535	88	140	114	4	30	124	98	14
Shoe B	488	95	134	110	3	40	128	97	14
Women's team									
Shoe A	373	78	121	102	4	30	110	89	7
Shoe B	338	110	129	118	4	40	114	95	7

Table 3. Men's selected jump results

SHOE A	CMJ		DROP JUMP		STEP JUMP		PLYO JUMP	
	Peak Power/ BW (W/kg)	Max Height (cm)	Peak Power/ BW (W/kg)	Max Height	Peak Power/ BW (W/kg)	Max Height	Peak Power/ BW (W/kg)	Max Height
1	65.7	43	109.1	41.1	97	47	90.7	42.8
2	70.9	44.7	127.3	45	88.4	49.6	76.2	43
3	90.3	45.6	152.2	45.8	104.3	54.9	125.2	47.3
4	92.3	49.3	141.7	56.7	78.9	59	115.1	52.8
5	94.2	53.6	126.6	51.5	113	63.4	104.1	51.8
6	61.6	44.9	96.2	44.9	86.7	48.3	67.9	46.5
Ave.	79.17	46.85	125.52	47.50	94.72	53.70	96.53	47.37
SHOE B	Peak Power/ BW (W/kg)	Max Height (cm)	Peak Power/ BW (W/kg)	Max Height	Peak Power/ BW (W/kg)	Max Height	Peak Power/ BW (W/kg)	Max Height
1	60.6	42.82	107.1	49.6	92.4	48.8	64	40.5
2	69.7	46.1	120.3	44.6	89	47.1	64.4	41.5
3	81.8	44.1	154.2	48	99.2	57.9	108.8	45.3
4	98.1	49.6	147.4	61.4	110.4	60.2	111.1	56.5
5	72.4	53.6	119.7	51.6	114.8	63.9	114.1	51.3
6	58.4	41.7	96.9	43.5	91.7	49.4	88.5	47.7
Ave.	73.50	46.32	124.27	49.78	99.58	54.55	91.82	47.13

Table 4. Women's selected jump results

SHOE A	CMJ		DROP JUMP		STEP JUMP		PLYO JUMP	
	Peak Power/ BW (W/kg)	Max Height (cm)	Peak Power/ BW (W/kg)	Max Height	Peak Power/ BW (W/kg)	Max Height	Peak Power/ BW (W/kg)	Max Height
1	48.9	22.7	115.4	25.9	44.9	29	146.4	26.5
2	45.3	29.3	100.1	27.4	49.4	33.1	153.1	26.3
3	38.1	22.9	72	23.4	59.3	31.3	46.2	25.2
4	69.2	35.9	85.5	35.9	82.8	41.8	60.8	37.2
5	49.9	29.8	90.8	28.8	75	31.8	65.8	28.7
6	57	34.7	101.8	35.3	80.2	38.9	90.6	37.8
7	53.5	30.3	110	31.9	85.4	34.7	84.4	32.3
8	51.7	31.4	96.4	29.3	66.5	31.5	75.5	29.8
9	40.8	23.1	91	25.6	64.3	27.9	64.7	24.6
10	44.3	27.8	92.3	24.4	70.5	34.6	68.7	26.5
SHOE B	Peak Power/ BW (W/kg)	Max Height (cm)	Peak Power/ BW (W/kg)	Max Height	Peak Power/ BW (W/kg)	Max Height	Peak Power/ BW (W/kg)	Max Height
1	52.7	25.4	120.4	26.6	42.9	28.7	141.8	27
2	45.6	28.7	112	29.1	72.1	31.6	145.7	25.9
3	38.6	25.7	72.2	22.6	28.3	29	62.7	23.8
4	64.8	35.3	70.6	40	85.9	40.1	76.9	36.7
5	47.8	27.5	85.5	27.7	75.9	31.5	68.8	28.5
6	51.9	32.4	89.3	36.5	80.2	39.1	87.1	37.6
7	78.1	35	109.6	33.3	89.3	39.4	93.2	33.9
8	24.9	30.8	100.2	29.6	66.4	32.6	68.4	29.8
9	40.1	23.6	88.4	26.5	66.6	28.8	69.4	26.8
10	37.5	29.9	79.2	23.9	64.5	24.3	60.7	24.4
Ave.	48.20	29.43	92.74	29.58	67.21	32.51	87.47	29.44

28.79 (SD = 4.73) and shoe D mean 29.43 (SD = 4.01), t(9) = -0.863, p = 0.410. There was no significant difference in DJ jump height for shoe A mean 47.50 (SD = 5.61) and shoe B mean 49.78 (SD = 6.45), t(5) = 1.494, p = 0.195. There was no significant difference in DJ jump height for shoe C mean 28.79 (SD = 4.37) and shoe D mean 29.58 (SD = 5.51), t(9) = -1.661, p = 0.131. There was no significant difference in STJ jump height for shoe A mean 53.70 (SD = 6.55) and shoe B mean 54.55 (SD = 7.01), t(5) = 0.809, p = 0.455. There was no significant difference in STJ jump height for shoe C mean 33.46 (SD = 4.27) and shoe D mean 32.51 (SD = 5.36), t(9) = .0785, p = 0.453. There was no significant difference in PJ jump height for shoe A mean 47.37 (SD = 4.24) and shoe B mean 47.13 (SD = 6.08), t(5) = 0.249, p = 0.814. There was no significant difference in PJ jump height for shoe C mean 29.49 (SD = 4.80) and shoe D mean 29.44 (SD = 4.97), t(9) = 0.125, p = 0.904.

Shoe Effect on Peak Power

Normalized PPr (w/kg) was computed, which has shown to reduce the effects of a covariate on the dependent variable in assessing GRFs (Mullineaux, Milner, Davis, & Ha-

mill, 2006). Results from the statistical analysis are presented. Pearson correlation coefficients was conducted to compare shoe effect on PPr. There was no significant difference in CMJ PPr for shoe A mean 79.17 (SD = 14.70) and shoe B mean 73.50 (SD = 14.73), t(5) = 1.504, p = 0.193. There was no significant difference in CMJ PPr for shoe C mean 49.87 (SD = 8.91) and shoe D mean 48.20 (SD = 15.00), t(9) = 0.422, p = 0.683. There was no significant difference in DJ PPr for shoe A mean 125.52 (SD = 20.53) and shoe B mean 124.27 (SD = 22.41), t(5) = 0.605, p = 0.572. There was no significant difference in DJ PPr for shoe C mean 95.53(SD = 12.35) and shoe D mean 92.74 (SD = 17.17), t(9) = 1.009, p = 0.339. There was no significant difference in STJ PPr for shoe A mean 94.72 (SD = 12.54) and shoe B mean 99.58 (SD = 10.72), t(5) = -0.876, p = 0.421. There was no significant difference in STJ PPr for shoe C mean 67.83 (SD = 13.73) and shoe D mean 67.21 (SD = 18.91), t(9) = .150, p = 0.884. There was no significant difference in PJ PPr for shoe A mean 96.53 (SD = 22.32) and shoe B mean 91.82 (SD = 23.21), t(5) = 0.661, p = 0.538. There was no significant difference in PJ PPr for shoe C mean 85.62 (SD = 35.99) and shoe D mean 87.47 (SD = 31.37), t(9) = -0.617, p = 0.552.

Comparison of Men's Team vs. Women's Team Jump Height

An Independent Samples Test was conducted to compare average jump height (cm) and PPr (W/kg) of the male and female student-athletes (Table 5). There was a significant difference in men's (M = 46.59, SD = 4.04) and women's CMJ height (M= 29.11, SD= 4.28) t(30) = 11.414, p = 0.001). There was a significant difference in men's (M = 48.64, SD = 5.88) and women's DJ height (M= 29.19, SD= 4.86) t(30) = 10.136, p = 0.001). There was a significant difference in men's (M = 54.13, SD = 6.48) and women's STJ height (M= 32.99, SD= 4.74) t(30) = 10.633, p = 0.001). There was a significant difference in men's (M = 47.25, SD = 5.00) and women's PJ height (M= 29.47, SD= 4.76) t(30) = 10.048, p = 0.001).

Comparison of Men's Team vs. Women's Team Peak Power

There was a significant difference in men's (M = 76.33, SD = 14.34) and women's CMJ PPr (M= 49.04, SD= 12.04) t(30) = 5.782, p = 0.001). There was a significant difference in men's (M = 124.89, SD = 20.50) and women's DJ PPr (M= 94.14, SD= 14.63) t(30) = 4.949, p = 0.001). There was a significant difference in men's (M = 97.15, SD = 11.41) and women's STJ PPr (M= 67.52, SD= 16.09) t(30) = 5.578,

p = 0.001). There was a nonsignificant difference in men's (M = 94.18, SD = 21.85) and women's PJ PPr (M= 86.55, SD= 32.88) t(30) = 0.713, p = 0.482).

Comparison of Jump Types

Descriptive statistics of jump types within the men's team resulted in CMJ max height mean of 46.59 (SD = 6.48), DJ max height of 48.64 (SD = 5.88), STJ max height mean of 54.13 (SD – 6.48), and PJ max height mean of 47.25 (SD = 5.00). Pairwise comparisons resulted in significant differences of men's STJ max height compared to CMJ max height (p = 0.001), to DJ max height (p = 0.009), and PJ max height (p = 0.001).

Descriptive statistics of jump types within the women's team resulted in CMJ max height mean of 29.11 (SD = 0.96), DJ max height of 29.19 (SD = 1.09), STJ max height mean of 32.99 (SD – 1.06), and PJ max height mean of 29.47 (SD = 1.06). Pairwise comparisons resulted in significant differences in only the women's STJ max height compared to CMJ max height (p = 0.001), to DJ max height (p = 0.001), and PJ max height (p = 0.001).

DISCUSSION

This pilot study examined the jump height differences of an acute jump assessment performing four different bas-

Table 5. ANOVA comparing Men's and Women's jump performance

Variables		Sum of squares	df	Mean square	F	Sig.
CMJ_Peak Power/BW (W/kg)	Between groups	5588.993	1	5588.993	33.431	.000
	Within groups	5015.352	30	167.178		
	Total	10604.345	31			
CMJ_Max Height (cm)	Between Groups	2290.317	1	2290.317	130.284	.000
	Within groups	527.384	30	17.579		
	Total	2817.701	31			
DJ_Peak Power/BW (W/kg)	Between groups	7094.794	1	7094.794	24.495	.000
	Within groups	8689.375	30	289.646		
	Total	15784.169	31			
DJ_Max Height (cm)	Between groups	2839.214	1	2839.214	102.729	.000
	Within groups	829.135	30	27.638		
	Total	3668.349	31			
STJ_Peak Power/BW (W/kg)	Between groups	6584.527	1	6584.527	31.114	.000
	Within groups	6348.682	30	211.623		
	Total	12933.209	31			
STJ_Max Height (cm)	Between groups	3351.747	1	3351.747	113.061	.000
	Within groups	889.368	30	29.646		
	Total	4241.115	31			
PJ_Peak Power/BW (W/kg)	Between groups	436.627	1	436.627	.508	.482
	Within groups	25787.532	30	859.584		
	Total	26224.159	31			
PJ_Max Height (cm)	Between groups	2372.297	1	2372.297	100.964	.000
	Within groups	704.896	30	23.497		
	Total	3077.192	31			

ketball specific jumps while wearing two different pairs of basketball shoes. There were no significant differences in shoe effect in any of the four jumps for either the men's or the women's teams (p > 0.05). Commentary from the student-athletes about various aspects of the shoes seem to indicate a preference for one shoe over the other. Shoe D – Adidas™ Marvel Captain Marvel shoe, the visual appearance did impact the likelihood of whether the student-athletes would wear the shoe during practice and games. Understanding personal psychological shoe preferences have shown to influence athlete playing performance and should be considered in designing basketball shoes (Mohr et al., 2016).

The results of this study reported that the STJ produced the highest average jump height in all four jumps for both the men's women's teams. This is due, in part, to the additional momentum and eccentric loading from the student-athletes mass during the stepping phase and greater velocity of arm swing creating the potential for quicker rate of force development (Harman et al., 1990). Significant differences existed in jump height between genders resulting in significantly higher average jump height in all four jumps for the men's team compared to the women's team. There were significant differences in CMJ PPr, DJ PPr, and DJ PPr between genders. Interestingly, there was no significant difference in PJ PPr between the men's and women's teams even though PJ height was significantly different. Differences in jump height between genders may be a result of differences in body dimensions and utilization of potential elastic energy in the musculoskeletal system (Komi & Bosco, 1978).

The importance of applying basketball specific movement patterns in evaluating basketball shoes should be considered a necessity when comparing different designs (Lam, Sterzing, & Cheung, 2011). Laboratory ground reaction force testing is often conducted first when evaluating sports performance and equipment (Beckham et al., 2014). Limitations exist in the lab, for instance, when evaluating medial arch supports while performing a leg press movement resulted in no changes in lower leg muscle activation compared to no shoes (Sheikhi, Piroozi, Khoshalani, Motiallah, & Zolanvar, 2017). However, after a one month study on the impact of a medial arch support insole, the medial arch support produced significant changes in load placement within the foot (Farzadi, Safaeepour, Mousavi, & Saeedi, 2015). Thus, the importance of evaluating the effectiveness of a medial arch or other PPE requires evaluation used within a normal framework of daily experiences which cannot always be duplicated within a lab setting.

Another factor derived from this study is the establishment of a baseline of jump height performance in evaluating basketball shoe PPE with specific basketball jumps performed on force plates. The influence of basketball shoes on jumping height, has been examined by Blache et al. (2011), with eight pairs of basketball shoes based on the following parameters: height of the upper on the backside of the shoe (high/low), the mass (heavy/light), the flexibility of the upper (flexible/stiff), as compared to jumping barefoot which produced the highest jump (Fu, Fang, Liu, & Hou, 2014). Three parameters (heavier, taller, and stiffer) reduced jumping performance and altered landing mechanics limiting

maximum plantar flexion and affected the coordination of the knee and hip joints (Fu et al., 2014). Wearing shoes that maximize GRFs allowed the basketball athlete to move quicker but also placed a greater strain on the body (Nigg, 2001). To reduce the chance of injury, a reduction of force placed upon the body during a basketball game requires understanding the impact of shoe design on landing mechanics and vector GRF movement alignments (Nigg, Nurse, & Stefanyshyn, 1999; Zhang, Clowers, Kohstall, & Yu, 2005). Next step evaluations can examine how basketball shoe PPE influence self-focus (Hammond, Davis IV, & Ziachowsky, 2015), comfort and fit (Lam et al., 2011), and during practice and games (Brauner et al., 2012).

Limitations of this pilot study include the limited number of volunteer student-athletes, the volume of jumps attempted per shoe, and the similarities of the men's shoes tested. Both the men's shoes were low cut and had similar features, but are the shoes worn by the players for their upcoming season. The type of basketball shoes provided by ™ is limited by decisions of the coaching staff, athlete choice, and the corporate-school contract. Time to complete the pilot study was a concern of the coaching staff as not to interfere normal practice time. Expansion of the testing methodology was not possible at this time of the basketball season.

Several recommendations for future research are the inclusion of using optical motion capture, mechanical testing of the shoes, and video analysis of playing performance in a game or practice. The use of optical motion capture may provide biomechanical assessments that may occur due to different shoes. Mechanical testing of each shoe may provide design parameters that affect biomechanical adjustments. Identifying biomechanical adaptations throughout an entire game or practice because of shoe design may lead to injury mitigation and improved performance.

CONCLUSION

The impact of shoe design on acute basketball jumping performance did not significantly affect student-athlete jump height and power production during a countermovement jump, drop jump, step jump, and plyometric jump. It is recommended that higher game-intensities should be used to evaluate basketball shoes on individual athlete performance and physiological factors. Comments from the student-athletes suggested the idea of assessing basketball shoes based on performance was a novel idea and expressed interest in additional information and future testing. Understanding the psychological factors that influence perception about basketball shoe performance should be taken into consideration when designing shoes. Not all colors and styles have the same effect on athletes.

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