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# Differences in countermovement vertical jump force-time metrics between starting and non-starting professional male basketball players

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With force plates being widely implemented for neuromuscular performance assessment in sport-specific settings and various force-time metrics being able to differentiate athletes based on their performance capabilities, the purpose of the present study was to examine the differences in countermovement vertical jump (CVJ) characteristics between starting and non-starting professional male basketball players (e.g., ABA League). Twenty-three athletes (height =  $199.2 \pm 7.7$  kg, body mass =  $94.2 \pm 8.2$  kg, age =  $23.8 \pm 4.9$  years) volunteered to participate in the present investigation. Upon completion of a standardized warm-up protocol, each athlete performed three maximal-effort CVJs without an arm swing while standing on a uni-axial force plate system sampling at 1,000 Hz. Independent *t*-tests were used to examine statistically significant differences ( $p < 0.05$ ) in each force-time metric between starters ( $n = 10$ ) and non-starters ( $n = 13$ ). No significant differences in any of the CVJ force-time metrics of interest were observed between the two groups, during both the eccentric and concentric phases of the movement (i.e., impulse, duration, peak velocity, and mean and peak force and power). Moreover, starters and non-starters demonstrated similar performance on CVJ outcome (e.g., jump height) and strategy metrics (e.g., countermovement depth). Overall, these findings suggest that at the professional level of play, the ability to secure a spot in the starting lineup is not primarily determined by the players' CVJ performance characteristics.

## KEYWORDS

force, power, impulse, eccentric, concentric, sport, performance, monitoring

## 1. Introduction

Basketball stands out as a fast-paced team sport characterized by its high-intensity intermittent nature which requires a combination of technical skills, strategic brilliance, and exceptional physical conditioning (1, 2). These requirements are particularly evident during live gameplay where basketball players typically engage in rapid changes in speed and direction and frequent jumping maneuvers, making neuromuscular performance an important cornerstone for success in this sport (3). Previous research has documented that neuromuscular performance characteristics of basketball players can differ based on

age (4), sex (5, 6), and level of play (7–10). For example, top-tier basketball teams tend to have a better physiological capacity to sustain repetitive explosive actions over an extended period of time compared to lower-ranked teams (11). Similarly, national-level male basketball players demonstrated greater isometric midhigh-pull and countermovement vertical jump (CVJ) peak force when compared to their state-level age-matched counterparts (10). Moreover, these differences can also be position-specific (9, 12, 13). A considerably higher absolute leg muscle strength was found in centers than in guards (12), and lower reactive strength index, repeated reactive strength ability, and running vertical jump performance when compared to forwards and guards (13).

All of the aforementioned distinctions emphasize the complexity of the game of basketball and the need for in-depth player assessment to gain a better understanding of factors that contribute to success in this sport (14). With that in mind, one of the commonly implemented approaches used to evaluate the desired sport-specific physiological profile is by comparing athletes selected to play (i.e., starters) with those on the bench (i.e., non-starters) (15). So far, only a few studies have examined differences in various neuromuscular performance parameters between starters and non-starters in team sports such as soccer (16), volleyball (17), and rugby (15). Interestingly, the number of similar research reports pertaining to the game of basketball is even lower (18, 19). Overall, these studies tend to display superior neuromuscular performance characteristics in starters than non-starters, implying a potential influence of these findings on the selection process of the team's starting lineup.

As one of the commonly used testing modalities, the CVJ performed on force plates allows for non-invasive and time-efficient neuromuscular performance assessment in a sport-specific setting, mainly due to the simplicity of the testing protocol and a variety of force-time metrics that can be obtained with strong reliability (20–22). Depending on the purpose of the assessment, these force-time metrics are often used in return-to-play evaluation (23), monitoring fatigue-induced changes during practice and/or competition (24, 25), and assessing the athlete's overall neuromuscular performance capacities (26). Specifically, in the game of basketball, the CVJ has been used to monitor season-long neuromuscular performance changes (27) and distinguish players based on their jump strategy (28) and playing position (21). However, there is a lack of scientific literature that uses in-depth CVJ assessment to differentiate between starters and non-starters in the game of basketball, especially at the professional level of competition.

Thus, with force plates being widely implemented for neuromuscular performance assessment in the basketball-specific setting and various force-time metrics being able to differentiate athletes based on their performance capabilities, the purpose of the present study was to examine the differences in CVJ characteristics between starters and non-starters within a cohort of professional male basketball players.

## 2. Materials and methods

### 2.1. Participants

Twenty-three professional male basketball players ( $\bar{x} \pm SD$ ; height =  $199.2 \pm 7.7$  kg, body mass =  $94.2 \pm 8.2$  kg, age =  $23.8 \pm 4.9$  years) volunteered to participate in the present investigation. The players included in the starting lineup in more than 75% of the total games played during a full-season span were classified as starters ( $n = 10$ ) and the rest of the players as non-starters ( $n = 13$ ). The cohort of athletes encompassed two basketball teams competing at a similar level of play (e.g., ABA League) during a single competitive season. All athletes were free of musculoskeletal injuries and were granted permission to participate in team activities by their respective sports medicine staff. The testing procedures performed in this investigation were previously approved by the University's Institutional Review Board and all participants signed an informed consent document.

### 2.2. Procedures

The CVJ testing procedures were conducted during the middle of the regular season competitive period within the same time frame (i.e., 15:00–19:00 h) three days following the completion of the official game (e.g., the game was played on Sunday and CVJ testing was conducted on Wednesday) (21, 29). During this timeframe (Sunday–Wednesday) the athletes were not exposed to high-intensity fatiguing training sessions. Upon arrival to the gym for their regular team practice, all players completed a standardized 10-min warm-up procedure consisting of dynamic stretching exercises (e.g., walking lunges, squat-to-heel raise, A-skips, high knees, butt-kicks) administered by their respective strength and conditioning coaching staff. Then, each athlete stepped on a dual uni-axial force plate (ForceDecks Max, VALD Performance, Brisbane, Australia) and performed three maximal-effort CVJs without an arm swing (i.e., hands on the hips during the entire movement) with 10–15 s rest between each jump trial. If an athlete did not jump or land correctly, the CVJ trial was repeated. A strong verbal encouragement was provided throughout the testing procedures by research assistants, while instructing to focus on pushing the ground as hard and forcefully as possible (30). The force plate system sampling at 1,000 Hz was re-calibrated between each athlete and the mean value across three jumps was used for performance analysis purposes. Following the testing procedures, the players' age and height were obtained from the official team roster.

### 2.3. Variables

The dependent variables examined in the present investigation were based on the previously published research reports that

demonstrated strong levels of validity and reliability for neuromuscular performance assessment (24, 31–33). The force-time metrics analyzed during the eccentric phase of the CVJ were: braking phase duration and impulse, eccentric duration, peak velocity, and mean and peak force and power. The force-time metrics analyzed during the concentric phase of the CVJ were: concentric duration, impulse, and peak and mean force and power. Alongside the detailed examination of the ground reaction force curve, the following CVJ metrics were derived: contraction time, jump height (i.e., impulse-momentum calculation), reactive strength index-modified (i.e., jump height divided by contraction time), and countermovement depth. The start of the contraction time was determined when the system mass was reduced by 20 N and ended at take-off (i.e., drop in vertical force below the 20 N threshold). The eccentric phase was defined as the phase with a negative center of mass velocity. As a subphase of the eccentric phase, the braking phase started at minimum force until the end of the eccentric phase. Impulse within both concentric and eccentric phases of CVJ were calculated as the area under the ground reaction force curve (21, 26, 27, 34). Additional information pertaining to data analysis software can be found at <https://valdperformance.com/forcedecks/>.

TABLE 1 Anthropometric characteristics ( $\bar{x} \pm SD$ ) and comparison statistics between starters and non-starters.

Variable [unit]	Starters	Non-starters	p-value	Effect size
Height [cm]	198.8 ± 7.7	199.6 ± 8.1	0.807	0.100
Body mass [kg]	97.1 ± 8.0	93.0 ± 7.9	0.134	0.516
Age [years]	25.6 ± 5.6	22.5 ± 3.9	0.170	0.658

## 2.4. Statistical analysis

Shapiro–Wilk test and Q–Q plots corroborated that the assumption of normality was not violated. Independent *t*-tests were used to examine statistically significant differences in each CVJ force-time metric between starters (*n* = 10) and non-starters (*n* = 13). Due to the within-group sample size (*n* < 20), Hedge’s *g* was used to calculate the magnitude of between-group differences (*g* = 0.2—small effect, *g* = 0.5—moderate effect, *g* = 0.8—large effect) (21, 35). Statistical significance was set *a priori* to *p* < 0.05. All statistical analyses were completed with SPSS (Version 26.0; IBM Corp., Armonk, NY, USA).

## 3. Results

Descriptive statistics, means and standard deviations ( $\bar{x} \pm SD$ ), for each dependent variable are presented in Table 1 (anthropometric and comparison statistics) and Table 2 (CVJ force-time metrics and comparison statistics). No statistically significant differences were found between starters and non-starters in any force-time metrics examined in the present study (*p* > 0.05). In addition, the majority of the effect sizes were small to moderate in magnitude (*g* = 0.064–0.658).

## 4. Discussion

To the best of our knowledge, this is the first study focused on examining differences in neuromuscular performance

TABLE 2 Countermovement vertical jump force-time metrics ( $\bar{x} \pm SD$ ) and comparison statistics between starters and non-starters.

Variable [unit]	Starters	Non-starters	p-value	Effect size
<b>Eccentric phase</b>				
Braking phase duration [s]	0.293 ± 0.057	0.297 ± 0.066	0.884	0.064
Eccentric braking impulse [N·s]	66.1 ± 13.9	57.9 ± 16.5	0.111	0.531
Eccentric duration [s]	0.508 ± 0.095	0.495 ± 0.071	0.696	0.158
Eccentric peak velocity [m·s <sup>-1</sup> ]	1.25 ± 0.20	1.17 ± 0.28	0.357	0.321
Eccentric peak force [N]	2,154.1 ± 352.9	2,128.9 ± 374.1	0.871	0.069
Eccentric mean force [N]	956.0 ± 79.1	914.2 ± 77.2	0.132	0.535
Eccentric peak power [W]	1,783.8 ± 580.3	1,514.7 ± 552.8	0.270	0.476
Eccentric mean power [W]	577.9 ± 113.9	517.5 ± 117.5	0.228	0.520
<b>Concentric phase</b>				
Concentric duration [s]	0.247 ± 0.044	0.265 ± 0.025	0.700	0.522
Concentric impulse [N·s]	265.8 ± 25.5	257.1 ± 23.5	0.411	0.357
Concentric peak velocity [m·s <sup>-1</sup> ]	2.86 ± 0.26	2.91 ± 0.14	0.646	0.249
Concentric peak force [N]	2,573.6 ± 188.9	2,493.8 ± 423.5	0.586	0.232
Concentric mean force [N]	2,004.9 ± 141.5	1,972.6 ± 262.8	0.730	0.147
Concentric peak power [W]	5,669.0 ± 1,011.3	5,401.5 ± 702.1	0.462	0.315
Concentric mean power [W]	2,954.8 ± 297.5	2,979.2 ± 447.3	0.883	0.063
<b>Other</b>				
Contraction time [s]	0.751 ± 0.102	0.742 ± 0.103	0.649	0.088
Jump height [cm]	38.8 ± 7.4	40.0 ± 4.2	0.615	0.207
RSI-modified [ratio]	0.525 ± 0.080	0.559 ± 0.088	0.347	0.402
Countermovement depth [cm]	29.9 ± 4.1	28.8 ± 6.9	0.637	0.187

RSI, reactive strength index.

characteristics between starters and non-starters within a cohort of professional male basketball players. No significant differences were observed in any CVJ force-time metrics of interest between the two groups, during both the eccentric and concentric phases of the movement (e.g., impulse, duration, peak force, mean power). In addition, starters and non-starters demonstrated similar performance on CVJ outcome metrics (e.g., jump height) as well as strategy metrics (e.g., countermovement depth).

Previous literature has been primarily focused on examining anthropometric and physical performance characteristics of starters and non-starters in team sports such as volleyball, rugby, and soccer (15–17, 36, 37). The observed differences based on the players' ability to secure a spot in the starting lineup were not highly prominent, with the majority of performance parameters being comparable in magnitude (15, 17, 37), which is similar to the results obtained in the present investigation. For example, when studying a cohort of National Collegiate Athletic Association (NCAA) Division-I female volleyball players, Fry et al. (17) found no differences in the vertical jump height, isokinetic strength (i.e., quadriceps and hamstring peak torques), sprint (i.e., 9.1 m) and agility (i.e., *T*-test) performance, and isometric peak and mean force between the players included in the starting lineup and their substitutions. Similar observations were made by Gabbett et al. (15) when examining junior elite and sub-elite male rugby players. No significant differences were detected in vertical jump performance, sprint time and velocity (i.e., 10, 20, and 40 m), and change-of-direction ability (i.e., 505 test) between starters and non-starters at both levels of play (15). Also, it should be noted that the aforementioned research reports found no statistically significant differences in age, height, and body mass between the starters and non-starters (15, 17), which is identical to the results obtained in the present investigation. In addition, in a cross-sectional study conducted on state-level basketball players, Scanlan et al. (38) found no significant difference in change-of-direction speed between starters and non-starters. Combined, these findings suggest that the ability to secure the spot in the starting lineup on the same level of competition (e.g., junior, collegiate, professional) is not primarily determined by the players' anthropometric and physical performance characteristics. Although further research is warranted on this topic, it is likely that sport-specific skills (e.g., rebounding, shooting efficiency) and a player's ability to successfully execute offensive and defensive actions may have a greater impact in differentiating starters from non-starters in professional men's basketball (2).

Despite not being able to capture differences between starters and non-starters based on neuromuscular performance characteristics, the importance of strength and power development in team sport athletes should not be diminished. A recently published study revealed that greater values of lower-body strength and power were observed in basketball players competing at higher levels of play (i.e., collegiate vs. professional) (39). Further, when monitoring NCAA Division-I basketball players over a four-year competitive season span, Hoffman et al. (40) found a positive relationship between playing time and player's strength (i.e., one-repetition maximum), speed (i.e., 27 m

sprint), and agility (i.e., *T*-test) performance. However, it is interesting to note that additional strength gains above the average values observed for a specific level of play do not seem to directly yield improvements in on-court performance (40). Thus, we can assume that both starters and non-starters examined in the present investigation already possessed adequate levels of strength and power. The values for CVJ force-time metrics observed during both eccentric and concentric phases of CVJ were similar in magnitude to the recently published research report focused on examining position-specific differences on a similar level of professional basketball play (21).

Although not reaching the level of statistical significance, moderate effect sizes observed within the eccentric phase of the CVJ should be noted ( $g = 0.520\text{--}0.535$ ). When compared to non-starters, the players selected to be a part of the starting lineup tended to display slightly greater mean values in eccentric braking impulse, mean force, and mean power. In a similar investigation focused on examining a cohort of elite female professional basketball players, Spiteri et al. (41) found that eccentric strength was the strongest predictor on change-of-direction performance tests (i.e., 505 and *T*-test). Thus, considering the nature of the game of basketball and on-court competitive demands, we can assume that eccentric qualities are of critical importance for this specific group of athletes. In addition, another interesting observation pertaining to the results obtained in the present study is the moderate effect size difference in the age between the two groups ( $g = 0.685$ ). Although further research is warranted on this topic, the starters being slightly older may imply that they had more basketball playing experience than non-starters (i.e., better technical-tactical understanding of the game through greater exposure to the sport) alongside displaying similar neuromuscular performance characteristics, which potentially allowed them to secure the spot in the starting lineup.

While providing practitioners with additional insight into neuromuscular performance characteristics of professional male basketball players, this study is not without limitations. The testing procedures were conducted at a single testing timepoint (i.e., in-season competitive period) for two teams competing on a similar level of play (e.g., ABA League). Alongside monitoring external load during practice and competition, implementing CVJ testing on a weekly or bi-weekly basis might provide additional insight into possible differences in force-time metrics between starting and non-starting players across a full season span. Also, further research needs to examine if the same findings apply to other competitive levels (e.g., amateur, collegiate) as well as if they are sex-specific.

In conclusion, the findings of the present study suggest that at the professional level of play, the ability to secure the spot in the starting lineup is not determined by the players' CVJ performance characteristics, but rather by other factors such as playing experience or their ability to proficiently execute sport-specific skills and offensive and defensive actions. These findings may help coaches, strength and conditioning practitioners, and sports scientists to obtain an additional insight into CVJ performance parameters of professional male basketball players

as well as give direction and guidance when selecting assessments and training strategies targeted toward optimizing on-court basketball performance.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by University of Kansas—Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

DC: conceptualization, formal analysis, methodology, writing – original draft, writing – review & editing. DVC: conceptualization, data curation, methodology, writing – original draft, writing – review & editing. JA: writing – original draft. NP: writing –

review & editing. AS: writing – review & editing. QJ: writing – review & editing. AF: writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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