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Relationship between vertical jump performance and playing time and efficiency in professional male basketball players

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With innovative force plate technology being available to many sports organizations worldwide that allow for time-efficient in-depth neuromuscular performance assessment, the purpose of the present study was to examine the relationship between some of the most commonly analyzed countermovement vertical jump (CVJ) force-time metrics and basketball playing time and efficiency. Twenty-four professional male basketball players volunteered to participate in the present study. The CVJ testing procedures were conducted within the first quarter of the competitive season span. Following a standardized warm-up protocol, each athlete stepped on a dual uni-axial force plate system sampling at 1,000 Hz and performed three maximum-effort CVJs with no arm swing. To minimize the possible influence of fatigue, each jump trial was separated by a 10–15 s rest interval and the average value across three jumps was used for performance analysis purposes. Basketball playing efficiency and average playing time were obtained at the end of the regular season competitive period from the coaching staff records and the official team records. Pearson product-moment correlation coefficients (r) were used to examine the strength of the relationships between force-time metrics and basketball playing time and efficiency, separately for each dependent variable ($p < 0.05$). A significant positive association was observed between playing efficiency and eccentric mean force and eccentric mean and peak power ($r = 0.406–0.552$). Similarly, an increase in eccentric mean power was positively correlated with the number of minutes played during the competitive season ($r = 0.464$). Moreover, the aforementioned relationship remained present even when eccentric mean power was expressed relative to the player's body mass ($r = 0.406$). Thus, the findings of the present study indicate that, at the professional level of men's basketball competition, CVJ eccentric strength and power have a positive impact on both playing time and efficiency.

KEYWORDS

force, strength, power, monitoring, eccentric, concentric, rebounding, shooting

1 Introduction

Basketball is a world-renowned sport characterized by repetitive high-intensity jumping, sprinting, and change-of-direction movements (1–3). Based on the on-court competitive demands, basketball players are required to possess adequate levels of lower-body strength and power, regardless of the playing position (4–9). Alongside tactical-technical comprehension and proficiency, these physical performance parameters are known to be of critical importance for successful participation in the game of basketball (10–13).

The countermovement vertical jump (CVJ) is a foundational movement for performing various basketball-specific skills such as shooting, rebounding, and dunking. Thus, it has been widely used by sports scientists and strength and conditioning practitioners as a non-invasive and time-efficient testing modality for the assessment of lower-body neuromuscular performance characteristics (14–19). When performed on portable force plate systems that allow rapid data analysis, a plethora of force-time metrics can be obtained with high levels of validity and reliability (16, 20). This includes metrics within both the eccentric and concentric phases of the jumping movement, which offers a comprehensive movement analysis and avoids quantifying an athlete's performance based on a single variable (e.g., jump height) (12, 18, 19). For example, a series of recently published research reports examined changes in CVJ force-time metrics pre-post practice, differences between playing positions (e.g., guards, forwards, centers), and differences between starters and non-starters at the professional level of men's basketball competition (6, 12, 21). However, it should be noted that representing force-time metrics in both relative and absolute terms may be beneficial, as heavier athletes often demonstrate superior absolute force production simply due to greater body mass (i.e., force = mass \times acceleration) (6). Moreover, the same CVJ analysis approach has been used to track season-long neuromuscular performance changes in high-level collegiate basketball players (22). Overall, this type of information can help sports practitioners obtain a deeper insight into individual player's capabilities that can ultimately be used to optimize their on-court performance.

Despite being widely used in an applied sports setting, to date only a few research studies have focused on examining the relationship between CVJ performance and playing time and efficiency (8, 23, 24). When studying a cohort of National Collegiate Athletic Association (NCAA) Division-I basketball players, Hoffman et al. (8) found that greater vertical jump height was strongly correlated with playing time ($r = 0.68$). On the other hand, Lockie et al. (24) reported a weak non-statistically significant relationship ($r = 0.22$) between the same two variables of interest, suggesting that basketball-specific skills may have a larger impact on securing more playing time than CVJ performance at the NCAA Division-II competitive level. Similar findings were reported by McGill et al. (23) who found that vertical jump height had no significant relationship with the number of games played and minutes, points, and rebounds per

game ($r = 0.15$ – 0.36), as game-related parameters used to derive player's efficiency ratings. However, the aforementioned research reports were primarily focused on studying outcome metrics such as jump height. This may be misleading in certain instances as it may fail to account for neuromuscular strategies used to attain a certain level of performance (e.g., how the specific outcome was achieved) (25, 26). Therefore, the analysis of force-time metrics within both eccentric and concentric phases of the CVJ may be advantageous in detecting differences in neuromuscular performance.

With innovative force plate technology being available to many sports organizations worldwide that allow for time-efficient in-depth neuromuscular performance assessment, the purpose of the present study was to examine the correlation between some of the most commonly analyzed CVJ force-time metrics and playing time and efficiency on the professional level of basketball competition. It is hypothesized that superior CVJ performance would be positively related to athletes' on-court playing performance (8).

2 Materials and methods

2.1 Participants

Twenty-four professional male basketball players (age = 22.7 ± 3.9 years; height = $198.1 \text{ cm} \pm 6.6 \text{ cm}$; body mass = $92.8 \pm 8.9 \text{ kg}$; playing experience = 9.2 ± 2.1 years) volunteered to participate in the present study. All athletes competed on a similar level of basketball competition (e.g., Adriatic Basketball League) and were free of musculoskeletal injuries that could impact CVJ performance. 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 Research design

The CVJ testing procedures were conducted within the first quarter of the competitive season (i.e., September–May/6–8 games after the start of the season), 48 h following the last game played during the testing week (17:00–20:00 h). Following a standardized warm-up protocol (i.e., dynamic stretching exercises and low-intensity 5–10 min of basketball partner shooting), each athlete stepped on a dual uni-axial force plate system (ForceDecks max, VALD, Brisbane, Australia) and performed three maximum-effort CVJs with no arm swing (i.e., hands on the hips during the entire movement) (11, 18). The sampling frequency of the force plate system was 1,000 Hz and the average value across three jumps was used for performance analysis purposes. To minimize the possible influence of fatigue, each trial was separated by a 10–15 s rest interval. Throughout the testing procedures, strong verbal encouragement was provided while the athletes were instructed to focus on pushing the ground as forcefully as possible (27).

2.3 Variables

The CVJ force-time metrics examined in the present investigation were eccentric and concentric mean and peak power [i.e., expressed in absolute and relative terms, adjusted by athletes' body mass (BM)], jump height (i.e., impulse-momentum calculation) and reactive strength index-modified (i.e., jump height divided by contraction time). The selection of the aforementioned variables was based on previously published research reports that demonstrated strong levels of validity and reliability for neuromuscular performance assessment (11, 19, 28–31). In addition, the basketball playing efficiency (Equation 1) (32) and average playing time were obtained at the end of the season (i.e., regular season competitive period) from the coaching staff records and the official team records.

Equation 1. Basketball playing efficiency formula (EFF – efficiency; PTS – points; RBD – rebounds; AS – assists; ST – steals; BL – blocks; MFG – missed field goals; MFT – missed free-throws; TO – turnovers; GP – games played).

$$EFF = \frac{(PTS + RBD + AS + ST + BL - MFG - MFT - TO)}{GP} \tag{1}$$

2.4 Statistical analysis

Descriptive statistics, means and standard deviations ($\bar{x} \pm SD$) were calculated for each dependent variable. Shapiro–Wilk test and Q-Q plots were used to assess the assumption of normality. Pearson product-moment correlation coefficients (r) were used to examine the strength of the relationships between force-time metrics and basketball playing time and efficiency, separately for each dependent variable. The magnitude correlation thresholds were interpreted as follows: 0.0–0.1–trivial; 0.1–0.3–small; 0.3–0.5–moderate; 0.5–0.7–large; 0.7–0.9–very large; 0.9–1.0–near-perfect to perfect (33, 34). 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 for each dependent variable are presented in Table 1. The average basketball playing efficiency score and playing time were 7.3 ± 4.8 and 16.3 ± 8.9 min, respectively. Statistically significant moderate relationships were found between basketball playing efficiency and eccentric mean power, eccentric peak power, and eccentric mean force. Also, a significant moderate association was observed between playing time and eccentric mean power as well as eccentric mean power/BM. No other relationships reached the level of statistical significance ($p > 0.05$) and were negligible to small in magnitude (Table 2). The graphical representation of the association

TABLE 1 Descriptive statistics means and standard deviations ($\bar{x} \pm SD$) for each vertical jump performance parameter.

| Variable [unit] | Value |
|---------------------------------|-----------------|
| Eccentric mean power [W] | 581.9 ± 103.9 |
| Eccentric peak power [W] | 1,716.7 ± 482.4 |
| Eccentric mean power/BM [W/kg] | 6.1 ± 0.9 |
| Eccentric peak power/BM [W/kg] | 18.3 ± 5.1 |
| Eccentric mean force [N] | 936.9 ± 84.9 |
| Eccentric peak force [N] | 2,279.1 ± 300.7 |
| Eccentric mean force/BM [N/kg] | 9.8 ± 0.1 |
| Eccentric peak force/BM [N/kg] | 24.0 ± 2.9 |
| Concentric mean power [W] | 2,930.9 ± 331.0 |
| Concentric peak power [W] | 5,146.6 ± 554.1 |
| Concentric mean power/BM [W/kg] | 30.9 ± 3.5 |
| Concentric peak power/BM [W/kg] | 54.2 ± 6.4 |
| Concentric mean force [N] | 1,969.9 ± 200.1 |
| Concentric peak force [N] | 2,416.9 ± 305.1 |
| Concentric mean force/BM [N/kg] | 20.7 ± 1.9 |
| Concentric peak force/BM [N/kg] | 25.4 ± 3.1 |
| Jump height [cm] | 37.9 ± 5.1 |
| RSI-modified [ratio] | 0.51 ± 0.1 |

BM, body mass; RSI, reactive strength index.

TABLE 2 Pearson product-moment correlation coefficients (r) and their statistical significance (p -value) between force-time metrics and basketball playing time and efficiency.

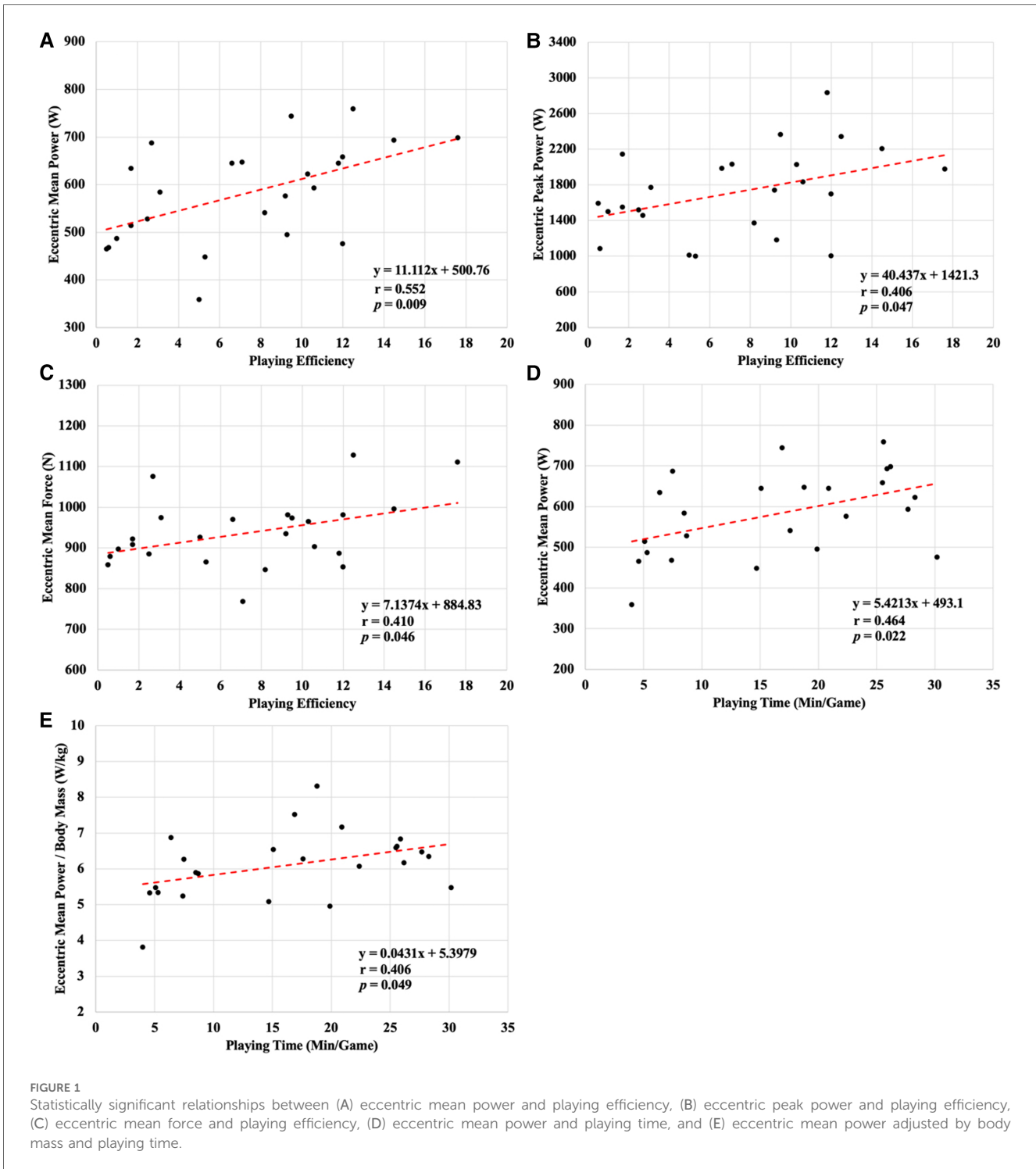
| Variable [unit] | Playing efficiency | | Playing time | |
|---------------------------------|--------------------|--------------|--------------|--------------|
| | r | p -value | r | p -value |
| Eccentric mean power [W] | 0.522 | 0.009 | 0.464 | 0.022 |
| Eccentric peak power [W] | 0.406 | 0.047 | 0.325 | 0.121 |
| Eccentric mean power/BM [W/kg] | 0.364 | 0.180 | 0.406 | 0.049 |
| Eccentric peak power/BM [W/kg] | 0.273 | 0.197 | 0.243 | 0.252 |
| Eccentric mean force [N] | 0.410 | 0.046 | 0.235 | 0.270 |
| Eccentric peak force [N] | 0.148 | 0.490 | 0.007 | 0.972 |
| Eccentric mean force/BM [N/kg] | 0.260 | 0.221 | 0.266 | 0.223 |
| Eccentric peak force/BM [N/kg] | 0.146 | 0.496 | 0.190 | 0.374 |
| Concentric mean power [W] | 0.018 | 0.933 | 0.013 | 0.953 |
| Concentric peak power [W] | 0.025 | 0.906 | 0.053 | 0.806 |
| Concentric mean power/BM [W/kg] | 0.280 | 0.185 | 0.177 | 0.407 |
| Concentric peak power/BM [W/kg] | 0.265 | 0.211 | 0.260 | 0.220 |
| Concentric mean force [N] | 0.121 | 0.574 | 0.030 | 0.889 |
| Concentric peak force [N] | 0.105 | 0.625 | 0.067 | 0.758 |
| Concentric mean force/BM [N/kg] | 0.260 | 0.221 | 0.226 | 0.220 |
| Concentric peak force/BM [N/kg] | 0.179 | 0.401 | 0.234 | 0.271 |
| Jump height [cm] | 0.130 | 0.546 | 0.072 | 0.737 |
| RSI-modified [ratio] | 0.108 | 0.616 | 0.057 | 0.792 |

Bolded values represent statistically significant relationships ($p < 0.05$).

between statistically significant vertical jump performance metrics and basketball playing efficiency and time is presented in Figure 1.

4 Discussion

To the best of our knowledge, this is the first study that focused on examining the relationship between CVJ force-time metrics and playing time and efficiency on the professional level of men's



basketball competition. Overall, the findings reveal a meaningful impact of the CVJ eccentric phase on basketball on-court playing performance. A significant positive association was observed between playing efficiency and eccentric mean force and eccentric mean and peak power ($r = 0.406$ – 0.552). In a similar manner, an increase in eccentric mean power was positively correlated with the number of minutes played during the competitive season ($r = 0.464$). Moreover, it should be noted that the aforementioned relationship remained present even when

eccentric mean power was expressed relative to the player’s body mass ($r = 0.406$).

Our findings are similar to the results obtained in the previously published research reports (8, 9). Specifically, Hoffman et al. (8) found statistically significant moderate correlations between vertical jump performance and playing time ($r = 0.58$ – 0.68) within a cohort of NCAA Division-I male basketball players. The results of the aforementioned investigation indicated that players who had higher vertical jump values had greater playing time.

Moreover, Spiteri et al. (9) emphasized the significant contribution (i.e., 25.3%) of the eccentric phase of CVJ when assessing overall player's strength profile, showing a strong association ($r = -0.79-0.89$) between eccentric strength and change-of-direction performance (i.e., *T*-test and 505 test), as commonly used testing modalities with basketball players (35, 36). This implies that the eccentric phase of the CVJ is particularly important for performing various basketball-specific movements, especially given the fact that this phase corresponds to the active stretching of leg extensor muscles which enable the body to effectively decelerate and change the movement direction (37). Furthermore, considering the well-known force-velocity relationship, increments in the velocity of eccentric muscle actions can contribute to greater force generation and higher jump heights (38, 39). As basketball players typically execute 40–50 vertical jumps per game (40, 41) and perform multidirectional movement changes approximately every 1–2 s during gameplay (10), the role of eccentric muscle actions becomes crucial for successful on-court performance, especially when considering the execution of tasks such as rebounding and blocking. Thus, it can be inferred that players who possess superior eccentric muscle qualities are likely to exhibit more efficient gameplay and ultimately secure more playing time.

While eccentric force-time metrics emerge as the predominant factors associated with basketball players' performance, it is equally important not to disregard the significance of concentric strength and power when conducting the overall assessment of basketball players. Despite no statistically significant correlations being observed in the present investigation, the development of these physical performance attributes is foundational for attaining peak levels of competition (9). For example, a recent study revealed that top-tier basketball players (e.g., NBA) possess notably higher levels of lower-body strength and power compared to college-level players (e.g., NCAA Division-I) (4). Moreover, it is well-known that maximal strength serves as a foundational piece for all other strength components, including eccentric strength (42). In a basketball-specific context, this notion is reinforced by the previously mentioned study conducted by Hoffman et al. (8), which revealed a positive correlation between maximal players' strength (i.e., barbell back squat one-repetition maximum) and playing time within a cohort collegiate basketball players. However, it should be noted that the same study also indicated that exceeding the normative levels of maximal strength did not yield additional improvements in on-court basketball performance. Thus, it is reasonable to assume that the participants in our study already had adequate levels of strength and power, particularly considering the fact that they are all already competing at the professional level of play (e.g., Adriatic Basketball League). Moreover, the observed magnitudes for both the eccentric and concentric CVJ force-time metrics fall well within the range observed in previously published research reports involving top-tier basketball players (6, 22, 39).

While the present investigation focused on examining some specific physical performance characteristics (e.g., mean and peak force and power), it is important to acknowledge that a player's

excellence is a multifaceted concept. As highlighted by Hoffman et al. (8), besides vertical jump performance being one of the key predictors for securing more playing time, the best predictor was found to be the coach's evaluation of the player's competitive abilities. This notion emphasizes the fact that assessing a player's physical performance characteristics is just one piece of a large puzzle that contributes to a successful on-court basketball performance. Therefore, objective and comprehensive evaluation of players' capabilities should be always prioritized.

Despite providing additional insight into neuromuscular performance characteristics of professional male basketball players and how they relate to playing time and efficiency, this study is not without limitations. The CVJ testing procedures took place at a single time point during the in-season competitive period, suggesting that potential variations in results may be present if the testing procedures were carried out throughout different stages of the training macrocycle. Moreover, more comprehensive insight into athletes' performance might be obtained through frequent testing, perhaps on a weekly or bi-weekly basis, as this would allow sports practitioners to observe changes in various force-time metrics throughout an entire season. Last but not least, future research should also explore whether these findings are position-specific and sex-specific as well as if they remain applicable to other competitive levels (e.g., amateur, collegiate).

In conclusion, the findings of the present study indicate that, at the professional level of men's basketball competition, eccentric strength and power during a CVJ have a positive impact on both playing time and efficiency. These insights are particularly beneficial for coaches, strength and conditioning practitioners, and sports scientists, as they highlight the importance of phase-specific CVJ evaluation in order to detect differences in neuromuscular performance characteristics. Moreover, these findings provide normative ranges for this specific group of basketball players that could help sports practitioners with developing training regimens targeted toward eccentric strength and power, which may ultimately yield better overall performance of players, particularly in terms of better playing efficiency and increased playing time.

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, Data curation, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing. DVC: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. JA: Methodology, Writing – original draft, Writing – review & editing. AS: Writing – original draft, Writing – review & editing. AF: Conceptualization, Supervision, 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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