

ORIGINAL ARTICLE

Performance and force production asymmetries in female basketball and soccer players: a comparative study

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ABSTRACT

BACKGROUND: Basketball and soccer require distinct neuromuscular abilities, yet research on performance asymmetries and force production in female athletes remains limited. Understanding these sport-specific traits is crucial for optimizing training and reducing injury risks.

METHODS: This study compared explosive strength, force production, and asymmetry between 18 elite female basketball players and 23 national-level WU19 soccer players. Countermovement jump (CMJ) and isometric mid-thigh pull (IMTP) tests were performed using VALD dual force plates to assess strength, power, and asymmetry. Group differences were analyzed using independent *t*-tests and Mann-Whitney U Tests ($P < 0.05$).

RESULTS: Basketball players showed greater absolute strength and power in CMJ Concentric Peak Force ($P < 0.05$; $g = 1.32$) and IMTP Peak Vertical Force ($P < 0.05$; $g = 0.71$), as well as a higher Dynamic Strength Index (DSI) ($P < 0.05$; $g = 0.68$). However, when adjusted for body mass (BM), soccer players had greater relative strength, particularly in IMTP Peak Force/BM ($P < 0.05$; $g = -0.76$), Force at 150 ms/BM ($P < 0.05$; $g = -0.63$), and Force at 200 ms/BM ($P < 0.05$; $r = 0.52$). Basketball players also showed greater Peak Vertical Force Asymmetry in IMTP ($P < 0.05$; $r = 0.4$), while CMJ force asymmetries did not differ between groups.

CONCLUSIONS: Basketball players showed greater absolute strength and power, whereas soccer players exhibited greater relative strength efficiency. Sport-specific adaptations appear to influence force asymmetry, underscoring the need to monitor bilateral imbalances to optimize performance and reduce injury risk.

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KEY WORDS: Athletic performance; Basketball; Soccer; Athletes; Extremities.

Introduction

Female basketball and soccer players face unique challenges that extend beyond performance, including a higher risk of injuries and a lack of research-based guidelines tailored to their physiological and biomechanical charac-

teristics.^{1, 2} Despite the increasing involvement of women in these sports, scholarly investigations concerning female athletes remain significantly underrepresented, particularly in domains such as explosive strength, force production asymmetry, and the risk factors associated with injuries. It is necessary to address these deficien-

cies to formulate sport-specific training methodologies that not only enhance performance but also moderate the risk of injuries.

Female athletes, especially those participating in high-intensity sports with multidirectional movements, such as soccer and basketball, frequently experience injuries to the anterior cruciate ligament (ACL) and bone stress. These are considered some of the most prevalent injuries among women in sports.^{3, 4} Female athletes exhibit an increased predisposition to ACL injuries, with risk factors as much as eight times higher than those of their male counterparts, attributable to anatomical and biomechanical characteristics, including reduced ACL size, elevated knee valgus angles, and suboptimal landing mechanisms.^{5, 6} Although bilateral CMJ kinetics have not been directly linked to ACL injury risk in female football players,⁷ research suggests that inter-limb asymmetries, reduced vertical jump capacity, and lower intermittent aerobic fitness increase susceptibility to injury.⁸ Given that the CMJ is widely used to assess explosive strength and asymmetry, these findings highlight the importance of evaluating inter-limb differences in force production. Basketball and soccer demand both aerobic and anaerobic fitness, explosive movements, and coordination; however, their distinct physical requirements shape vertical force production and asymmetry.

Basketball is a high-intensity intermittent sport that requires both offensive and defensive maneuvers, rapid transitions, and frequent bursts of explosive actions such as sprinting, deceleration, direction change, acceleration, and jumping.^{9, 10} Optimal performance relies on lower-body explosive strength, agility, speed, upper-body strength, anaerobic endurance, and technical skills such as shooting precision and ball control.^{11, 12} These attributes influence both offensive and defensive strategies, affecting player movements with and without ball possessions.¹³

Similarly, soccer performance depends on physical, technical, and tactical skills, with speed, agility, and passing playing crucial roles.¹⁴ Research suggests that structured training programs enhance these attributes, leading to significant performance improvement.¹⁵

Physiologically, soccer players must maintain high aerobic and anaerobic capacities, sustaining heart rates around 85% of their maximum during matches while covering 10-12 km at varying intensities.¹⁶ In addition to physical conditioning, psychological and tactical factors also contribute to matching outcomes.

Although both sports rely on explosive power, agility, and neuromuscular coordination, basketball places greater emphasis on repeated vertical force production and short bursts of maximal effort, whereas soccer requires sustained endurance and multidirectional movements. These sport-specific differences likely influence force production and asymmetry, which may in turn affect both the performance and injury risk in female athletes. Consequently, the objective of this study was to conduct a comparative analysis of the explosive capabilities of elite female basketball players and national-level WU19 female soccer players, with particular attention directed towards investigating disparities in power, strength, and asymmetry between the two cohorts. Identifying the key physical parameters that contribute to sport-specific performance will provide insights into optimizing training strategies in basketball and soccer.

Materials and methods

Subjects

This study included 18 elite female basketball (age = 20.90 ± 2.96 years, body height = 177.37 ± 8.25 cm, body mass (BM) = 69.33 ± 10.31 kg) and 23 elite female soccer players (age = 18.16 ± 0.88 years, body height = 167.48 ± 5.65 cm, BM = 59.75 ± 7.30 kg). Basketball players competed in the highest national league, whereas soccer players were members of the national team. All participants were active members of professional clubs, met the criteria of full medical fitness, and engaged in a minimum of five training sessions per week, including strength and conditioning training. Athletes with recent musculoskeletal injuries or medical conditions affecting performance were excluded to ensure valid and reliable results. Participants were recruited from professional clubs in collaboration

with team coaches. No randomization or blinding was applied due to the nature of the study.

The sample size was based on the available population of eligible athletes during the data collection period and was not determined by formal power analysis. The chosen group sizes reflect a pragmatic approach consistent with similar studies in elite athlete populations.

Experimental design

This study employed a cross-sectional comparative design aimed at evaluating inter-sport differences in explosive strength, force production, and inter-limb asymmetry. Two independent groups of female athletes – elite basketball players and national-level U19 soccer players – were assessed at a single time point. The design allowed for a between-group comparison of neuromuscular performance variables measured through countermovement jump (CMJ) and isometric mid-thigh pull (IMTP) tests using force plate technology. By focusing on both absolute and relative performance parameters, as well as asymmetry metrics, the study sought to identify sport-specific neuromuscular profiles and potential bilateral imbalances relevant to injury risk and performance optimization.

This manuscript was prepared in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.¹⁷

Testing procedures

The testing took place indoors and was carried out under controlled conditions, with participants advised to avoid any intense physical activity 24 h before testing to minimize the impact of fatigue.

Testing was performed using force plates from the VALD performance with high reliability and validity in each test.¹⁸ The IMTP test assesses isometric strength by measuring the maximum force exerted in a fixed position. Athletes pull bar at mid-thigh height with pre-tension and following maximal effort for 2-3 s. The key metrics analyzed included the Peak Vertical Force normalized to BM (N/BM) and force at 50, 100, 150, and 200 ms (N/BM) to evaluate the explosive strength at different time frames (F-v

profile).¹⁹ The CMJ test measures lower-body power and neuromuscular performance through vertical jumps involving an eccentric phase followed by an explosive concentric phase for maximum jump height. The key metrics analyzed included Concentric Peak Force (N/BM), Eccentric Peak Force (N/BM), Peak Power (N/BM), and Peak Landing Force (N/BM), all of which were normalized to BM.²⁰ The Dynamic Strength Index (DSI) was derived from these tests by calculating the ratio of maximal dynamic force in the CMJ to maximal isometric force in the IMTP. This measure reflects the athlete's ability to translate strength into explosive power. DSI can also help to identify neuromuscular imbalances that may increase the risk of ACL injuries. Based on these metrics, we can evaluate force production, landing, and change in direction, which are crucial for soccer and basketball players.^{21, 22} To minimize potential measurement bias, all tests were conducted under the supervision of an experienced coach, who ensured consistent instructions (cues) for all participants to achieve consistency and performance maximization.

AI tools (DeepL and ChatGPT) were used solely for translation and language refinement. No AI tools were used for data analysis, interpretation, or content generation.

Statistical analysis

Statistical analysis in JASP (0.19.2.0) (JASP, Amsterdam, the Netherlands) with a significance level of P value ($P < 0.05$) was used to compare female basketball and soccer players. Descriptive statistics, including means and standard deviations, were calculated to summarize the data distribution. The normality of the data was verified using the Shapiro-Wilk Test. The homogeneity of variances was assessed using Levene's Test for datasets exhibiting normal distribution and the Brown-Forsythe Test for those not conforming to normality. An independent *t*-test was used for datasets that satisfied the criteria for a normal distribution. When the normality premise was compromised, the Mann-Whitney U Test was used as an alternative.

The concept of effect size was expressed using Hedge's *g* for the *t*-test, with intervals de-

financed as small ($d \leq 0.2$), medium ($0.2 < d \leq 0.5$), and large ($d > 0.8$). For the Mann-Whitney U Test, rank biserial correlation as effect size was used, with thresholds set at small ($r \leq 0.1$), medium ($0.1 < r \leq 0.3$), and large ($r > 0.5$). The threshold for statistical significance was established at $P < 0.05$, with effect size metrics serving to provide additional information regarding the practical significance of the discerned differences.

No subgroup or interaction analyses were conducted, as they were not part of the study design. Additionally, no sensitivity analyses were performed. The dataset was complete, with all participants successfully completing the full battery of tests.

Ethical statement

The study was approved by the Ethics Committee of Matej Bel University in Banská Bystrica (Chairperson: doc. PhDr. Miriam Martinkovičová, PhD) under protocol N. 216/2025 on 10 March 2025. All participants provided written informed consent prior to participation. The research protocols were conducted in accordance with the ethical standards set forth in the Declaration of Helsinki.

Results

Differences in performance parameters

The Shapiro-Wilk Test confirmed the normal distribution of BM data in both basketball and soccer players ($P > 0.05$), and Levene's Test indicated homogeneity of variances ($P > 0.05$). However, an independent t -test revealed a significant difference in BM between groups ($P < 0.05$; $g = 1.27$), suggesting that differences in absolute performance parameters may be influenced by BM. Therefore, relative values adjusted for BM have also been reported in addition to absolute performance measures.

Independent sample t -test revealed significant differences ($P < 0.05$) with large and medium effect sizes in favor of basketball players in the absolute parameters CMJ Concentric Peak Force ($g = 1.32$) and IMTP Peak Vertical Force ($g = 0.71$), as well as in their ratio, the DSI ($g = 0.68$). Figure 1 illustrates the distribution and comparison of the CMJ Concentric Peak Force,

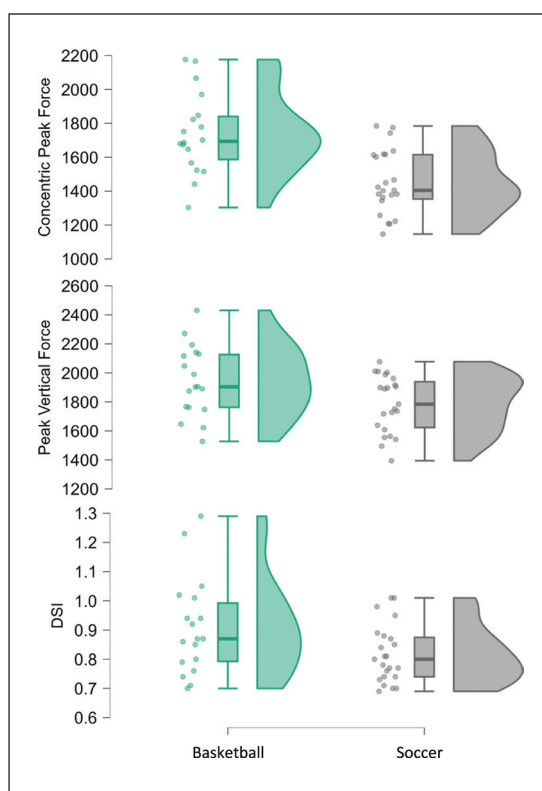


Figure 1.—Distribution of absolute performance parameters between basketball and soccer players.

IMTP Peak Vertical Force, and the DSI between basketball and soccer players using raincloud plots and boxplots.

No significant differences ($P > 0.05$) were found in any of the CMJ-derived parameters that account for BM, including Relative Concentric Peak Force, Relative Eccentric Peak Force, Relative Peak Landing Force, and Relative Peak Power. Among these, only the Relative Peak Power exhibited a medium effect size ($g = -0.51$). In contrast, the IMTP strength test revealed significant differences ($P < 0.05$) in relative parameters, specifically Relative Peak Force, Relative Force at 150 ms, and Relative Force at 200 ms, all of which favored soccer players. The effect sizes for these parameters were as follows: Relative Peak Force demonstrated a medium effect ($g = -0.76$); relative force at 150 ms also showed a medium effect ($g = -0.63$); and force at 200 ms, where normality was violated, had a large effect size ($r = 0.52$) (Table I).

TABLE I.—Summary of performance parameters in female basketball and soccer players, including statistical tests used, descriptive statistics, test statistics, and effect sizes.

Performance test	Performance parameter	Statistical test	(Mean ± SD)		Test statistic (t/U)	Effect size (g/r)
			Basketball (N.=18)	Soccer (N.=23)		
CMJ/IMTP	DSI	Student	0.91±0.17	0.82±0.10	2.202*	0.68
CMJ	Concentric peak force	Student	1740±240	1453±188	4.288*	1.32
	Concentric peak force/BM	Mann-Whitney	24.79±1.86	24.50±2.34	230	0.11
	Eccentric peak force/BM	Mann-Whitney	24.86±1.83	24.20±2.57	241	0.16
	Peak power/BM	Student	43.64±4.94	46.54±6.01	-1.658	-0.51
	Peak landing force/BM	Student	44.22±9.64	49.57±13.03	-1.454	-0.45
IMTP	Peak vertical force	Student	1943±243	1786±195	2.298*	0.71
	Peak vertical force/BM	Student	27.91±4.17	30.73±3.20	-2.453*	-0.76
	Force at 50 ms/BM	Student	12.66±2.58	12.71±1.67	-0.077	-0.02
	Force at 100 ms/BM	Mann-Whitney	15.23±2.82	16.20±2.46	168.5	-0.19
	Force at 150 ms/BM	Student	17.50±3.19	19.52±3.14	-2.029*	-0.63
	Force at 200 ms/BM	Mann-Whitney	19.88±3.60	22.62±2.96	99.5*	-0.52

Mean ± SD.

BM: body mass; CMJ: countermovement jump; DSI: Dynamic Strength Index; g: Hedges's; IMTP: isometric mid-thigh pull; Mann-Whitney: Mann-Whitney U Test; r: rank-biserial correlation; SD: standard deviation; Student: independent t-test; t: independent t-test statistic; U: Mann-Whitney U Test statistic.

*Statistical significance $\alpha=0.05$ ($P<0.05$).

Asymmetries in performance parameters

Since normality was violated in at least one group for all asymmetry parameters, the Mann-Whitney U Test was used. In the CMJ Test, asymmetries in Concentric Peak Force (Basketball: 7.87 ± 4.81 , Soccer: 6.04 ± 5.44) and Eccentric Peak Force (Basketball: 8.83 ± 5.11 , Soccer: 8.87 ± 7.46) were analyzed. No significant differences were found between groups ($P>0.05$), and the effect size was small (Table II). However, a significant difference was identified in Peak Vertical Force Asymmetry from the IMTP Test (Basketball: 14.84 ± 9.32 , Soccer: 8.99 ± 7.69), with a

medium effect size ($r=0.4$), highlighting greater asymmetry in basketball players. Additionally, no significant differences were observed in force generation at 50, 100, or 150 ms during the IMTP Test. However, at 200 ms, the P value was close to significance ($P=0.053$) with a medium effect size ($r=0.36$).

Discussion

This study aimed to compare the explosive abilities of elite female basketball players and national-level WU19 female soccer players. To the best of our knowledge, no prior research has

TABLE II.—Bilateral force production asymmetries in basketball and soccer players: descriptive statistics and Mann-Whitney U Test results.

Parameter	Mean ± SD		Variance		Mann-Whitney	
	Basketball	Soccer	Basketball	Soccer	U	ES (r)
CMJ concentric peak force asym [% L, R]	7.87±4.81	6.04±5.44	23.14	29.61	265.50	0.28
CMJ eccentric peak force asym [% L, R]	8.83±5.11	8.87±7.46	26.15	55.62	222.50	0.08
IMTP peak vertical force asym [% L, R]	14.84±9.32	8.99±7.69	0.63	0.86	289.00*	0.40
IMTP force at 50 ms asym [% L, R]	10.89±8.72	8.82±9.16	0.80	1.40	253.50	0.23
IMTP force at 100 ms asym [% L, R]	10.85±7.85	10.44±8.30	0.72	0.79	218.00	0.05
IMTP force at 150 ms asym [% L, R]	12.28±8.52	9.69±8.60	0.69	0.89	254.00	0.23
IMTP force at 200 ms asym [% L, R]	14.93±8.72	9.73±8.43	0.58	0.87	281.00	0.36

asym: asymmetry; BM: body mass; CMJ: countermovement jump; IMTP: isometric mid-thigh pull; L: left lower limb; Mann-Whitney: Mann-Whitney U Test; r: rank-biserial correlation; R: right lower limb; SD: standard deviation; U: Mann-Whitney U Test statistic.

*Statistical significance $\alpha=0.05$ ($P<0.05$).

explicitly contrasted these two sports disciplines among female athletes regarding performance metrics and asymmetry parameters, although analogous assessments have been performed in male athletes.²³ Our results highlight the dominance of basketball players in terms of absolute strength and explosive power parameters with significant differences in BM. However, when relative values accounting for BM were analyzed, soccer players demonstrated significantly greater strength in the Peak Vertical Force parameter measured by the IMTP, and a medium effect size was observed for Relative Peak Power measured by the CMJ. This finding suggests that soccer players may possess superior relative strength and power efficiency when considering their BM.

In our study, asymmetries were observed in several performance parameters, with a more pronounced difference found in peak force asymmetry during the IMTP Test, in which basketball players exhibited a statistically significant difference. However, no statistically significant differences were found between the groups in other parameters. Slightly higher asymmetry values were observed in basketball players in certain phases of force production during the IMTP Test, particularly in the later phase at 200 ms. This trend suggests that both soccer and basketball, unilateral loading sports, may influence differences in bilateral force production.

Bailey *et al.*²⁴ observed similar patterns, noting that five of seven individuals with a Weight-Distribution Testing Score Symmetry Index above eight were members of a women's soccer team. They also found that force production asymmetry was more pronounced in female athletes, particularly in SJ and CMJ tests.²⁴ These results corroborate the hypothesis that force production asymmetry may be affected not only by sports specialization but also by gender disparities and neuromuscular coordination.

Another factor that influences asymmetry levels is the overall strength of athletes. It has been proposed that athletes with lower strength levels exhibit higher degrees of asymmetry compared to their stronger counterparts, with increased strength potentially resulting in a reduction of disparities between the dominant and non-

dominant limbs.²⁴ This may explain why soccer players in our study, who demonstrated higher relative strength values, exhibited lower asymmetry in certain parameters than did basketball players. These results highlight the importance of relative strength and its influence on bilateral force balance, which could have significant implications in designing training programs aimed at optimizing performance and preventing asymmetric movement patterns.

Limitations of the study

This study has several limitations that should be considered. Basketball players were older and heavier than soccer players, which may have influenced the absolute strength and power comparisons, despite adjustments for BM. The small sample size may have limited the generalization of our findings. Additionally, variations in training background and load across sports were not fully controlled, potentially influencing the performance differences. This study assessed bilateral force production using the CMJ and IMTP tests; however, the absence of unilateral strength assessments (*e.g.*, single-leg jumps or isometric tests) may have limited insights into neuromuscular control and inter-limb asymmetries.

Conclusions

This study offers valuable information on how elite female basketball players and national-level WU19 female soccer players differ in their explosive capabilities, ability to generate force, and asymmetry. These results provide insights into the distinct physical characteristics of the two athlete groups. The results suggest that soccer players exhibit greater relative strength efficiency, while basketball players demonstrate superior absolute strength and power, particularly in the later phases of force production.

Furthermore, the presence of force production asymmetries highlights the importance of monitoring bilateral strength imbalances in both sports. Although some degree of asymmetry may result from sport-specific loading patterns, excessive imbalances can contribute to performance limitations and an increased injury risk. Previous studies have indicated that when

strength imbalances exceed 15%, the risk of lower-limb injuries may increase.²⁵ These findings emphasize the need for targeted strength training and corrective interventions to mitigate potential asymmetry-related disadvantages and optimize athletic performance.

Future research should focus on long-term adaptations to training, and how sport-specific mechanics influence force asymmetries over time. Additionally, exploring the effect of strength training interventions on reducing asymmetries and optimizing performance could provide practical applications for injury prevention and athletic development.

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Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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This research was conducted independently with internal resources provided by Matej Bel University. The institution had no role in the study design, data collection, analysis, interpretation, or manuscript preparation.

Ethical approval

All procedures performed in this study involving human participants received ethical approval from the competent authorities, as described in the appropriate section of the manuscript, and have been conducted in accordance with the 1964 Helsinki Declaration and its later amendments. The authors confirm that this article does not report any studies involving embryos, gametes and human embryonic stem cells conducted by the authors. The authors confirm that this article does not report any studies involving animals conducted by the authors.

Informed consent

Written informed consent was obtained from all participants prior to inclusion in the study and for publication of their data, as described in the appropriate section of the manuscript.

Authors' contributions

Marián Škorik and Lukáš Karabin have given substantial contributions to the study conception and design; Roman Švantner and Martin Pupiš contributed to the manuscript draft and revised it critically. All authors read and approved the final version of the manuscript.

History

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