Open Access
KOSALB International Journal of Human Movements Science, Vol: 3, No: 1, 2024, p 10-18, DOI: 10.5281/zenodo.12538975 | ISSN: 2958-8332 | Published: 30.06.2024

KOSALB

Original Article

Effects of Jumping Techniques on Vertical Jump Performance: Professional Volleyball Players (U15)

Alberina Shabani[1ABE] Mevlana Jakupi[2BE] Anesa Korqa[3BE] Abedin Bahtiri[4ACDE*]

[1]*University for Business and Technology (UBT), Faculty of Sport and Movement Science, ORCID: 0009-0002-3108-7308, as63299@ubt-uni.net, Kosovo.*

[2]*University for Business and Technology (UBT), Faculty of Sport and Movement Science, ORCID: 0009-0009-4280-4860, mj61634@ubt-uni.net, Kosovo.*

[3]*University for Business and Technology (UBT), Faculty of Sport and Movement Science, ORCID: 0009-0006-7421-6105, ak63088@ubt-uni.net, Kosovo.*

[4]*University for Business and Technology (UBT), Faculty of Sport and Movement Science, ORCID: 0000-0002-9099-7961, abedin.bahtiri@ubt-uni.net, Kosovo.*

**Corresponding author: abedin.bahtiri@ubt-uni.net*

Authors' Contribution: A: Study design, B: Data collection, C: Data analysis, D: Manuscript preparation, E: Discussion and conclusion

ABSTRACT

Study aim(s): The study aims to determine the effect of arm swing technique and the elastic force stored in tendon during the eccentric phase of jumping on the vertical jump performance of Volleyball Players (U15).

Methods: Ten U15 women volleyball players from KV Theranda, averaging 157.0 cm in height and 48.8 kg in weight, participated. Participants performed Countermovement Jumps (CMJ) and Squat Jumps (SJ), recorded at 240 fps on an iPhone 13 Pro using My Jump 3 application. Jump heights were calculated from selected take-off and landing frames. Data analysis using SPSS 26 included normality tests and T-tests to compare CMJ and SJ performance, focusing on arm technique and elastic force.

Results: Based on the results, except for strength and power, which showed significant differences ($p < 0.05$), the analysis revealed a significant advantage for CMJ over SJ in all parameters ($p < 0.05$). This 70% difference is due to the elastic force in the tendons during the eccentric phase and arm momentum.

Conclusions: Countermovement jumps (CMJ) significantly outperform squat jumps (SJ) due to the elastic force stored in tendons and arm momentum during the eccentric phase, resulting in a 70% performance difference. Cheraghi et al. (2017) emphasized peak power's role in higher jumps. Future research should separately analyze CMJ with and without arm movement to understand their impacts.

Keywords: Countermovement Jump, Squat Jump, Arm Swing Technique, Elastic Force, Vertical Jumps

Open Access
KOSALB International Journal of Human Movements Science, Vol: 3, No: 1, 2024, p 10-18, DOI: 10.5281/zenodo.12538975 | ISSN: 2958-8332 | Published: 30.06.2024

KOSALB

Original Article

INTRODUCTION

Arm movement during the jumping phase in volleyball is considered an essential element of gameplay technique, as players often use their arms to ensure precise movement and to generate maximum force. Additionally, the phases of muscle contraction during the squat jump (SJ) and countermovement jump (CMJ) hold particular importance. The eccentric phase of contraction, where muscles lengthen before contracting, is crucial for powerful jump performance. This phase utilizes the elastic force stored in the muscle tendons during the concentric phase of the jump.

For common jumping movements, athletes use arm swings or countermovement to increase jump height. This study aimed to quantify and compare how arm movement and countermovement affect the torque and work of the lower extremities during vertical jumps and to understand the mechanisms enabling these actions to enhance jump height. Jump height, joint torque, and work were calculated by combining kinematic and kinetic data. It was found that participants jumped the highest when using an arm swing with countermovement. The increase in jump height with countermovement or arm swing is due to the increased work of the lower extremities [1].

To optimize jump performance during CMJ and CMRJ tests, training should focus on improving the strength around the knee and ankle joints. One approach to achieve this is through unloaded jump training, where the participant intentionally minimizes changes in hip angle by avoiding forward trunk inclination [2].

The My Jump app is the most well-known technology developed for measuring jump performance in sports science [3, 5]. It is widely agreed that My Jump offers many benefits, such as being user-friendly, accessible, portable, and affordable. Several studies report that this app is valid and provides reliable results, though there are concerns about potentially questionable outcomes [6, 7]. Therefore, a comprehensive assessment of the validity and reliability of the My Jump app across different populations is needed [2].

The concentric phase of muscle contraction occurs when muscles shorten to generate force and lift the body. Arms play a critical role in this phase by providing support and assistance in movement. However, despite extensive literature identifying the role of arms in enhancing jump performance in volleyball, there is still a lack of detailed information on concentric muscle contraction and the role of arms in jumps such as the squat jump (SJ) and countermovement jump (CMJ).

Jump testing is used across various sports to assess an athlete's neuromuscular performance. While both movements aim for maximum jump height, the squat jump (SJ) typically results in a lower height compared to the countermovement jump (CMJ). In CMJ, the athlete starts from a standing position, dips into a half-squat, and then jumps upward [8].

Vertical jump ability is crucial in many athletic events. Coaches and physical educators have implemented various training methods to improve this skill, including plyometric exercises and depth jumps. Depth jumps have become popular and have been shown to enhance vertical jump performance. This study aims to provide a comprehensive biomechanical analysis of depth jumps and describe the differences between depth jump performance and countermovement jump performance [9].

This study aimed to confirm the relationship between the concentric phase of muscle contraction and the impact of the upper extremities on jump performance in volleyball. By analyzing these elements in young volleyball players, the study seeks to determine how training the upper extremities and focusing on the concentric phase can improve performance in squat jumps, and countermovement

Open Access
KOSALB International Journal of Human Movements Science, Vol: 3, No: 1, 2024, p 10-18, DOI: 10.5281/zenodo.12538975 | ISSN: 2958-8332 | Published: 30.06.2024

KOSALB

Original Article

jumps. This research will contribute to enhancing the training and performance of volleyball players.

METHODS

Participants

The study comprised ten Women Volleyball players (U15), with an average height of $\bar{x}$ 157.0 ± .13 centimeters and an average weight of $\bar{x}$ 48.8 ± 12.10 kilograms. This selection criterion aimed to ensure uniformity in physical attributes and training backgrounds, thereby bolstering the study's validity and reliability. The participants are players of KV Theranda.

My Jump 3 app

The methodology of this study began with the collection of crucial performance parameters using the My Jump 3 application. This data encompassed height, weight, height at 90°, lever length, and leg length, all vital for analyzing jump performance outcomes. Each participant executed a series of jumps, including the Countermovement Jump (CMJ) and Squat Jump (SJ), while being recorded on an iPhone 13 Pro at 240 frames per second, capturing high-definition video resolution.

Within the My Jump 3 app, jump recordings were loaded, and specific frames for take-off and landing were manually selected. Clear criteria were established beforehand to ensure accuracy: for take-off, the first frame where both feet were off the ground was chosen, free from motion blur or shoe deformation; for landing, the frame where one foot touched down without a visible gap between the shoe and the ground, and no motion blur, was selected. Utilizing these defined events, the app calculated jump height based on flight time [10].

It's noteworthy to highlight that the validity of the My Jump 3 app has been confirmed by numerous studies [11, 13].

Data analysis

Following video analysis using the My Jump 3 app, the collected data underwent rigorous testing to ensure a comprehensive analysis of the results. Data collected from My Jump 3 were analyzed using the SPSS 26 package. Normality was assessed using Shapiro-Wilks tests to confirm that the data distribution met statistical assumptions. Descriptive statistics, including percentiles and percentages, were calculated to provide a clear overview of the data distribution and characteristics.

Moreover, Independent Samples T-tests were employed to scrutinize any significant differences between groups, facilitating a detailed comparison of jump performance across various parameters and conditions. The differences in jumps between the Countermovement Jump (CMJ) and Squat Jump (SJ) were examined using Independent Samples T-tests. Percentile statistics were used to assess percentage differences in arm technique and elastic force between CMJ and SJ.

Open Access
KOSALB International Journal of Human Movements Science, Vol: 3, No: 1, 2024, p 10-18, DOI: 10.5281/zenodo.12538975 | ISSN: 2958-8332 | Published: 30.06.2024

KOSALB

Original Article

FINDINGS

Table 1. Descriptive data of volleyball players

Body composition	Min	Max	X̄	SD	Skew	Kurt	Percentiles		
							25th	50th	75th
Weight (kg)	29.10	73.20	48.85	12.10	.40	.20	38.7	47.3	58.5
Body Mass Index (kg/m2)	15.97	23.37	19.51	2.42	.12	-1.18	17.1	19.8	21.1
Height (cm)	1.35	1.79	1.57	.13	.10	-.92	1.45	1.57	1.67

The descriptive data of the results, based on mean and standard deviation, indicate a normal distribution, which does not seem to be positive or negative (skew: <±2, as if no significant increase or suppression was observed (Kurt: <±2). Additionally, descriptive data such as weight, index, and body length are categorized into three groups based on percentages.

Table 2. Descriptive data of the metric characteristics of My Jump 3

Metric variables	Min	Max	X̄	SD
Leg Length (cm)	92.0	116.0	102.9	7.37
Height at 90 degrees (cm)	79.0	101.0	88.1	6.93
Lever (cm)	106.0	134.0	119.0	9.62

The table above presents the descriptive data utilized by the My Jump 3 program for the analysis of CMJ and SJ jumps. These data are input into the platform of My Jump 3, which calculates absolute and relative motor parameters from the dance videos, as outlined in the research methodology of this paper.

Table 3. Descriptive data for Countermovement jump (CMJ)

CMJ features	Min	Max	X̄	SD	Skew	Kurt	Percentiles		
							25th	50th	75th
Jump Height (cm)	13.20	25.30	17.88	3.26	.87	1.26	15.10	17.90	19.60
Force (N)	575.1	964.8	875.76	124.14	-2.59	7.01	880.72	918.15	924.60
Relative force (N/kg)	18.10	28.90	22.16	3.44	.69	-.30	19.20	21.55	24.52
Power (Watt)	462.50	877.50	783.05	137.30	-2.25	5.48	759.52	821.70	871.17
Relative Power (W/kg)	15.60	32.10	20.92	5.08	.96	.74	16.00	20.85	23.12
Mean velocity (m/s)	.80	1.11	.93	.08	.51	.49	.86	.93	.98
Flight time (m/s)	328.00	454.00	380.66	34.13	.60	.68	351.00	382.50	400.00

In the table above, the minimum, maximum, and average values of the factors of the CMJ motor test are presented, indicating a normal distribution with no significant deviation (skew: <±2) or suppression (Kurt: <±2) observed. The exceptions are Force (N) and Power (W), which exhibit negative deviation (skew: >±2) and a leptokurtic distribution (Kurt: >±2).

Open Access
KOSALB International Journal of Human Movements Science, Vol: 3, No: 1, 2024, p 10-18, DOI: 10.5281/zenodo.12538975 | ISSN: 2958-8332 | Published: 30.06.2024

KOSALB

Original Article

Table 4. Descriptive data for Squat Jump (SJ)

SJ features	Min	Max	X̄	SD	Skew	Kurt	Percentiles		
							25th	50th	75th
Jump Height (cm)	3.90	7.20	5.27	1.02	.517	-.33	4.70	5.00	6.00
Force (N)	371.90	661.50	559.02	101.27	-.98	.16	530.32	551.20	647.57
Relative force (N/kg)	12.50	14.70	13.50	.85	.20	-1.82	12.80	13.30	14.20
Power (Watt)	163.40	385.50	286.25	69.63	-.62	.13	261.80	298.50	326.77
Relative Power (W/kg)	5.60	8.40	6.85	1.03	.31	-1.65	6.10	6.50	8.00
Mean velocity (m/s)	.44	.59	.50	.04	.34	-.47	.48	.49	.54
Flight time (m/s)	179.00	242.00	206.58	19.56	.34	-.44	196.00	202.00	221.00

In the table above, the minimum, maximum, and average values of the factors of the SJ motor test are given, resulting in a normal distribution where no deviation (skew: <±2) or marked suppression (curt: <±2) was observed.

Table 5. Differences between the characteristics of the Countermovement Jump (CMJ) and Squat Jump (SJ) tests

Factors	Jumps	X̄	SD	Sig.	Cohen's d			
					Standardize	Point Estimate	95% Confidence Interval	
							Lower	Upper
Jump Height (cm)	CMJ	17.88	3.26	.001	2.419	5.21	3.47	6.92
	SJ	5.27	1.02					
Force (N)	CMJ	875.76	124.14	.001	110.733	2.86	1.55	4.12
	SJ	559.02	101.27					
Relative force (N/kg)	CMJ	22.16	3.44	.001	2.511	3.44	2.14	4.72
	SJ	13.50	.85					
Power (Watt)	CMJ	783.05	137.30	.001	101.463	4.89	3.05	6.70
	SJ	286.25	69.63					
Relative Power (W/kg)	CMJ	20.92	5.08	.001	3.667	3.83	2.44	5.20
	SJ	6.85	1.03					
Mean velocity (m/s)	CMJ	.93	.08	.001	.068	6.27	4.25	8.26
	SJ	.50	.04					
Take-off velocity (m/s)	CMJ	1.86	.16	.001	.136	6.27	4.25	8.27
	SJ	1.01	.09					
Impulse (kg*m/s)	CMJ	91.40	26.61	.001	20.005	2.45	1.36	3.51
	SJ	42.30	9.58					
Flight time (m/s)	CMJ	380.66	34.13	.001	27.818	6.25	4.24	8.24
	SJ	206.58	19.56					

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group

According to the differential analysis between CMJ and SJ, statistically significant differences favoring CMJ (p<0.05) are observed across all performance parameters. This highlights the significant impact of elastic force deposited in tendons during the eccentric phase and the momentum generated by arm movement in vertical dances.

Table 6. The effect of arm momentum and lower extremity elastic strength on high jump performance

Participants	CMJ (cm)	SJ (cm)	Diff. in cm	Diff. in %
X	15.1	4.9	10.2	68%
X	15.1	4.9	10.2	68%
X	16.9	6.7	10.2	60%
X	15	7.2	7.8	52%
X	18.1	5.3	12.8	71%
X	13.2	3.9	9.3	70%
X	18.3	4.7	13.6	74%
X	17.7	6	11.7	66%
X	25.3	5.1	20.2	80%
X	19.8	3.9	15.9	80%
X	19	4.7	14.3	75%
x	21.1	6	15.1	72%
Average	17.883	5.275	12.60	70%

The statistically significant difference between CMJ and SJ, as shown in the previous table, amounts to approximately 70%. This difference, as mentioned earlier, is attributed to the technique involving arm momentum and the storage deposition of elastic force in tendons during the eccentric phase of the dance.

DISCUSSION

According to the differential analysis between CMJ and SJ, all jump parameters show a statistically significant difference favoring CMJ (p<0.05). This underscores the significant impact of elastic force deposited in tendons during the eccentric phase of the dance. The results indicated no significant differences between the two types of jumps in take-off time (P > 0.05) or recovery time from the standing position (P > 0.05).

In terms of spatial parameters, there were no notable distinctions between CMJ and SQJ jumps in vertical height proportion (P > 0.05). Additionally, there were no significant variations between the two jumps in the speed of foot detachment from the ground at any given moment (P > 0.05). However, a significant difference was observed in the trunk angle between the two jumps at the lowest point of the center of mass (P < 0.05) [14].

Similarly, the elastic force deposited in tendons during the eccentric phase of jumps and the momentum of the arms are significant factors contributing to vertical dance performance. Cheraghi, M. et al. (2017) emphasize the importance of average and relative peak power during the concentric phase for achieving a higher jump. These variables, along with peak velocity during the concentric phase, strongly influence jump height. Coaches and athletes should also focus on variables such as peak force, peak

Open Access
KOSALB International Journal of Human Movements Science, Vol: 3, No: 1, 2024, p 10-18, DOI: 10.5281/zenodo.12538975 | ISSN: 2958-8332 | Published: 30.06.2024
KOSALB
Original Article

power, and average power during the eccentric phase, as these factors significantly impact these parameters [15].

The statistically valid differences between CMJ and SJ, as shown in the previous table, amount to approximately 70%. This difference is attributed to the technique involving arm momentum and the deposition of elastic force in tendons during the eccentric phase of the dance.

The increase in jump height with countermovement and/or arm swing is attributed to the greater work performed by the lower extremities. In the hip joint, the increase in torque during countermovement predominantly occurs at the beginning of the propulsion phase, possibly enhanced by a higher activation level compared to jumps without countermovement [16].

The 70% difference between 70% CMJ and SJ is influenced by both; the elastic force deposited in tendons during the eccentric phase of the jumps and the technique involving arm momentum.

A recent study has shown that the equations for calculating the eccentric utilization ratio (CMJ/SJ) and pre-stretch augmentation ([CMJ – SJ]/SJ * 100) provide identical information [17].

However, for a more detailed analysis and to discern the individual effects of these factors, separate analyses should be conducted for each, including CMJ with free arm, CMJ, and SJ. This approach will allow for a separate analysis of the 70% difference attributed to the arm technique and the elastic force deposited in tendons during the eccentric phase of the dance. The absence of separate analyses represents a limitation of this study, and we suggest that future research should consider conducting separate analyses of these factors.

The Impact of arm swing on jump height was significant, leading to a 27.08% increase in CMJ jump height. This emphasizes the critical role of arm movement in boosting jump performance [18].

CONCLUSIONS

In conclusion, the differential analysis between countermovement jumps (CMJ) and squat jumps (SJ) demonstrates a statistically significant advantage for CMJ across all jump parameters. This advantage can be attributed to the elastic force stored in tendons during the eccentric phase of the jump.

The study underscores the importance of the elastic force deposited in tendons and the momentum generated by arm movements during the eccentric phase, which significantly enhance jump performance. This finding is further supported by Cheraghi et al. (2017), who highlighted the critical role of average and relative peak power during the concentric phase in achieving higher jumps.

The observed 70% difference between CMJ and SJ underscores the combined impact of tendon elasticity and arm momentum on jump height. The increase in jump height with CMJ and/or arm swing is primarily attributed to the enhanced work of the lower extremities, particularly the increased torque in the hip joint at the beginning of the propulsion phase.

While the study demonstrates a substantial effect of these factors, a more detailed analysis is needed to separate the contributions of arm technique and tendon elasticity. Future research should focus on analyzing CMJ with free arms, CMJ, and SJ independently to better understand their individual impacts.

Open Access
KOSALB International Journal of Human Movements Science, Vol: 3, No: 1, 2024, p 10-18, DOI: 10.5281/zenodo.12538975 | ISSN: 2958-8332 | Published: 30.06.2024

CONFLICT OF INTERESTS

No potential conflict of interest was reported by the authors.

REFERENCES

1. Hara M, Shibayama A, Takeshita D, Hay DC, Fukashiro S. A comparison of the mechanical effect of arm swing and countermovement on the lower extremities in vertical jumping. *Hum Mov Sci.* 2008;27(4):636–48.
2. Xu J, Turner A, Comyns TM, Harry JR, Chavda S, Bishop C. Countermovement Rebound Jump: A Comparison of Joint Work and Joint Contribution to the Countermovement and Drop Jump Tests. *Appl Sci.*2023;13(19):10680.doi: 10.3390/app131910680.
3. Chiu LZ, Dæhlin TE. Comparing numerical methods to estimate vertical jump height using a force platform. *Meas Phys Educ Exerc Sci.* 2020;24:25–32.
4. Wade L, Lichtwark GA, Farris DJ. Comparisons of laboratory-based methods to calculate jump height and improvements to the field-based flight-time method. *Scand J Med Sci Sports*. 2020;30:31–7.
5. McBride JM, Nimphius S. Biological system energy algorithm reflected in sub-system joint work distribution movement strategies: Influence of strength and eccentric loading. *Sci Rep.* 2020;10:12052.
6. Bishop C, Turner A, Jordan M, Harry J, Loturco I, Lake J, et al. A Framework to Guide Practitioners for Selecting Metrics during the Countermovement and Drop Jump Tests. *Strength Cond J.* 2021;44:95–103.
7. Baca A. A comparison of methods for analyzing drop jump performance. *Med Sci Sports Exerc.* 1999;31:437–42.
8. Donahue PT, Wilson SJ, Williams CC, Hill CM, Garner JC. Comparison of countermovement and squat jumps performance in recreationally trained males. *Int J Exerc Sci.* 2021;14(1):462.
9. Bobbert MF, Mackay M, Schinkelshoek D, Huijing PA, van Ingen Schenau GJ. Biomechanical analysis of drop and countermovement jumps. *Eur J Appl Physiol Occup Physiol.* 1986;54:566–73.
10. Whiteley I, Sideris V, Kotsifaki R, King E, Whiteley R. The MyJump App is a Valid Method of Assessing and Classifying Limb Symmetry During Recovery from Anterior Cruciate Ligament Reconstruction. *Int J Sports Phys Ther.* 2023;18(5):1156–65. doi: 10.26603/001c.88005.
11. Turan M, Ulupınar S, Özbay S, Gençoğlu Ç, Savaş BÇ, İnce İ. *Validity and reliability of "My Jump app" to assess vertical jump performance: A meta-analytic review.* 2022.
12. Cruvinel-Cabral RM, Oliveira-Silva I, Medeiros AR, Claudino JG, Jiménez-Reyes P, Boullosa DA. The validity and reliability of the "My Jump App" for measuring jump height of the elderly. *PeerJ.* 2018;6 doi: 10.7717/peerj.5804.
13. Balsalobre-Fernández C, Glaister M, Lockey RA. The validity and reliability of an iPhone app for measuring vertical jump performance. *J Sports Sci.* 2015;33(15):1574-9. doi: 10.1080/02640414.2014.996184.
14. Zhao M, Zhang J. Analysis and Comparison of Motion Biomechanics Characteristics of Squat Jump and Half-Squat Jump. *Mob Inf Syst.* 2022.
15. Cheraghi M, Sarvestan J, Sebyani M, Shirzad E. Stretch-Shortening Cycle in Countermovement Jump: Exclusive Review of Force-Time Curve Variables in Eccentric and Concentric Phases. *Preprints* 2017, 2017080070. https://doi.org/10.20944/preprints201708.0070.v1.
16. Hara M, Shibayama A, Takeshita D, Hay DC, Fukashiro S. A comparison of the mechanical effect of arm swing and countermovement on the

lower extremities in vertical jumping. *Hum Mov Sci.* 2008 Aug;27(4):636-48. doi: 10.1016/j.humov.2008.04.001. Epub 2008 Jul 31. PMID: 18674837.

17. Van Hooren B, Zolotarjova J. The Difference Between Countermovement and Squat Jump Performances: A Review of Underlying Mechanisms with Practical Applications. *J Strength Cond Res.* 2017;31(7):2011-20. doi: 10.1519/JSC.0000000000001913.
18. Akl AR. A Comparison of Biomechanical Parameters between Two Methods of Countermovement Jump. *Int J Sports Sci Eng.* 2013;7(2):123-8.

FOR CITATION

Shabani et al. Effects of Jumping Techniques on Vertical Jump Performance: Professional Volleyball Players (U15). KOSALB International Journal of Human Movements Science, Vol: 3(1), 2024, p 10-18, DOI: 10.5281/zenodo.12538975.