New methodology for determining lower limb asymmetries through force analysis during countermovement jumps

Nueva metodología para determinar asimetrías en miembros inferiores por análisis de fuerza durante el salto contra movimiento

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Abstract

Objective: This study employed an innovative method to determine lower limb asymmetries using countermovement jumps, force platforms, and a kinematic system with 30 reflective markers.
Methods: The sample included three doctoral students with an average age of 42.3 ± 15 years. The corresponding number of data points analyzed for each participant was: Subject 1 (n = 3669), Subject 2 (n = 3344), and Subject 3 (n = 3584). According to the impulse (IM) and landing (LA) phases, the data were distributed as follows: Subject 1 (IM: n = 2000; LA: n = 1669), Subject 2 (IM: n = 1891; LA: n = 1693), and Subject 3 (IM: n = 2102: LA: n = 1246). Force platforms recorded data during the impulse and landing phases, while the asymmetry index was calculated as the difference between the right and left leg, divided by the right leg value, and multiplied by one hundred.
Results: The analyses showed significant differences between the right and left legs ($p < 0.001$), with an asymmetry index ranging from 5.07% to 14.22%. The effect size was moderate to large (0.59 to 0.85). Significant differences were also found between the impulse and landing phases ($p < 0.001$), except in one case ($p = 0.069$), with effect sizes ranging from trivial to large (0.37 to 0.99).
Conclusions: The results indicate that this method provides valuable insights into lower limb asymmetries, potentially aiding in the detection of imbalances between the dominant and non-dominant sides before and after the flight phase, particularly in sports requiring explosive movements. Although the sample was limited, the findings highlight the importance of regularly monitoring asymmetries in both athletic and at-risk populations. This study also emphasizes the need for standardized protocols to assess asymmetries, contributing to improved injury prevention strategies.

Keywords

Injuries; strength; lower limbs; students.

Resumen

Objetivo: Este estudio empleó un método innovador para determinar asimetrías en los miembros inferiores mediante el salto con contramovimiento, utilizando plataformas de fuerza y un sistema cinemático con 30 marcadores reflectantes.
Métodos: La muestra incluyó tres estudiantes de doctorado con una edad promedio de 42,3 ± 15 años. Se analizaron los siguientes puntos de datos para cada participante: Sujeto 1 (n = 3669), Sujeto 2 (n = 3344) y Sujeto 3 (n = 3584). Según las fases de impulso (IM) y aterrizaje (AT), los datos se distribuyeron así: AN (IM: n = 2000; AT: n = 1669), AM (IM: n = 1891; AT: n = 1693) y MA (IM: n = 2102; AT: n = 1246). Las plataformas de fuerza registraron datos generados durante las fases de impulso y aterrizaje, mientras que el índice de asimetría se calculó como la diferencia entre la pierna derecha e izquierda, dividida por el valor de la pierna derecha y multiplicada por cien.
Resultados: Los análisis mostraron diferencias significativas entre las piernas derecha e izquierda ($p < 0,001$), con un índice de asimetría que osciló entre 5,07% y 14,22%. El tamaño del efecto fue de moderado a grande (0,59 a 0,85). También se encontraron diferencias significativas entre las fases de impulso y caída ($p < 0,001$), excepto en un caso ($p = 0,069$), con tamaños de efecto que variaron de trivial a grande (0,37 a 0,99).
Conclusiones: Los resultados indican que este método proporciona información valiosa sobre las asimetrías de los miembros inferiores, lo que podría facilitar la detección de desbalances entre el lado dominante y no dominante antes y después de la fase de vuelo, particularmente en deportes que requieren movimientos explosivos. Aunque la muestra fue limitada, los hallazgos resaltan la importancia de monitorear regularmente las asimetrías en poblaciones deportivas y en riesgo. Este estudio también destaca la necesidad de establecer protocolos estandarizados para la evaluación de asimetrías, contribuyendo así a la mejora de las estrategias de prevención de lesiones.

Palabras clave

Lesiones; fuerza; miembros inferiores; estudiantes.

Introduction

Research on lower limb asymmetries during the Counter Movement Jump (CMJ) has revealed complex relationships between force production, muscle mass, and physical performance. Recent studies have shown that CMJ protocols can affect asymmetry measurements (Heishman et al., 2019), showing that the interactions between strength asymmetries, overall strength, and muscle mass asymmetries are non-linear (Rossow et al., 2021). Research has demonstrated the effectiveness of both synchronous and asynchronous analysis procedures in assessing single-leg mechanical performance and asymmetries during bilateral CMJ (Janicijevic et al., 2022). While some research suggests that unilateral CMJs may provide a better indication of differences in functional strength (Benjanuvatra et al., 2013), other studies have found value in bilateral assessments (Menzel et al., 2013a). Asymmetries have been observed in various populations, including female sprinters (Prvulović et al., 2022) and athletes who have undergone anterior cruciate ligament reconstruction (Jordan et al., 2015). However, the relationship between asymmetry and speed performance remains uncertain (Prvulović et al., 2022), and lower limb symmetry cannot be assumed in dynamic sport-specific movements (Edwards et al., 2012).

Studies on symmetry using the Counter Movement Jump (CMJ) have gained relevance in research on sports performance and injury prevention. Although bilateral asymmetry alone may not significantly influence jumping performance (Yoshioka et al., 2010), it can affect sprint speed and ability to change direction in female footballers (Bishop et al., 2019). The magnitude and direction of the asymmetry vary depending on the jump test and the age group (Bishop et al., 2020; Cadens et al., 2023). Reliability in asymmetry measurements is critical, with vector-based metrics being more accurate than scalar measurements (Bailey et al., 2021). Furthermore, individual differences and previous injuries may influence asymmetrical profiles (Cohen et al., 2014; Graham-Smith et al., 2015). In young female sprinters, it has been observed that asymmetry in kinetic parameters during the CMJ does not correlate with sprint performance (Prvulović et al., 2022). These findings underscore the complexity of asymmetry and its potential implications for athletic performance and injury risk assessment.

In this context, it is hypothesized that the presence of lower limb asymmetries during the CMJ jump may be associated with a higher risk of injuries in various populations. Therefore, the objective of this study is to evaluate the use of a method to quantify lower limb asymmetries in order to determine their potential implications for injury prevention in a population of postgraduate students.

Method

Subject and Procedure

The present study included three doctoral students (two men and one woman) (Subject 1(S1), Subjec 2 (S2) and Subject 3 (S3) with backgrounds in gymnastics, basketball, and taekwondo, who are currently inactive in these sports: average age of 42.3 ± 15 years, body mass of 72 ± 15.6 kg, and height of 173.3 ± 1.5 cm. The corresponding number of data points analyzed in each jump for the participants' lower limbs were: S1 (3669); S2 (3344), and S3 (3584). According to the impulse (IM) and landing (LA) phases, the data were: S1 (IM: 2000), (LA: 1669); S2 (IM: 1891), (LA: 1693), and S3 (IM: 2102), (LA: 1482). Data collection was carried out at the Biomechanics Laboratory of the Universidad Manuela Beltrán, starting at 2:00 p.m. Participants were subjected to basic anthropometric assessments, such as measurement of height and body weight, while lower limb strength was assessed using the countermovement jump test (CMJ). All subjects were informed about the nature of the study and the potential risks associated with the experimental procedures prior to participating in the trials. The study protocol was approved in accordance with Resolution 8430 of the Colombian Ministry of Health and Social Protection, and the procedures were carried out in accordance with the Declaration of Helsinki. After reading the informed consent document, the participants signed their agreement to participate in the research.

Vertical jump and asymmetry index

The evaluation of the strength of the lower limbs using the Counter Movement Jump (CMJ) was carried out using 30 reflective markers, a Smart Capture BTS® kinematic system with 8 cameras at 250 Hz, and two P-6000 BTS® force platforms with a sampling rate of 1000 Hz. Prior to testing, the system was calibrated with markers placed on the subjects, who made three submaximal attempts to familiarize themselves with the technique. After these tests, the final evaluation was carried out. Before data collection, the force platforms were calibrated following the standard protocols established by the manufacturer, thereby ensuring the accuracy of the force measurements.

The CMJ was performed by placing each foot on one of the platforms to analyze symmetry during the impulse and landing phases. The athletes followed the protocol described by Bosco et al. (1983). Prior to the test, the participants completed a warm-up consisting of five minutes of stationary cycling and dynamic exercises such as partial squats, lunges, and leg swings. All jumps were executed with the hands on the hips to block the help of the arm impulse, avoiding the confusion of the evaluation of the strength of the lower limbs (Chaouachi et al., 2009). The asymmetry of the lower limbs was quantified using the equation proposed by Impellizzeri et al. (2007) where it specifies:

$$(1)\ \mathrm{AI}= \frac{(\mathrm{Right} - \mathrm{Left})}{Right} X100$$

To determine the resulting force, the values of the three axes (x, y, z) were calculated by applying the Pythagorean theorem, using the data provided by the software for both the right and left sides (data provided every 2 milliseconds). To evaluate the asymmetry index in the impulse and fall phases, the data corresponding to the pre- and post-zero values of the results generated by the force platform software were recorded, which can be visualized in Figure 1. Subsequently, equation (1) was applied to obtain the asymmetry index. Multiple repetitions of each jump were performed to assess the consistency of the measurements. Variability between repetitions remained within an acceptable range, suggesting high reliability of the instrument.

Statistical Analyses

All analyses were performed using the Jamovi® version 1.6 (https://www.jamovi.org). software. Data normality was verified using the Kolmogorov-Smirnov test. The difference in variables of study was assessed using the non-parametric Wilcoxon test. Effect size was calculated as proposed by Cohen (1988), and a significance level of $p \leq 0.05$ was determined.

Results

Table 1 displays the results of the force exerted by the left and right lower limbs, expressed in newtons, as well as their asymmetry index. Table 2 presents the values corresponding to the phases of the jump (impulse and landing), organized by participant and by the homolateral and contralateral sides. Finally, Table 3 shows the asymmetrical indices when comparing the dominant (right) side with the non-dominant side (left), with the values expressed as a percentage. All results were processed by the Wilcoxon test presenting median values.

Table 1. Comparison between lower limbs in study participants (Newtons values).

Participant	Median	Minimum	Maximum	AI	*p*	Effect Size
S1 R	328.99	39.41	1424.02	14.22	<.001	0.59
S1 L	283.02	0.00	1557.08			
S2 R	456.88	36.97	3262.18	12.13	<.001	0.73
S2 L	402.27	49.26	3692.89			
S3 R	302.04	35.30	1783.54	5.07	<.001	0.85
S3 L	289.01	53.41	2773.55			

R= right; L = Left; AI= Asymmetry Index; p= significance level (p≤0.05).

The findings reveal significant differences in all participants when comparing the left leg with the right leg ($p < .001$). The effect size ranged from moderate (ES = 0.59; ES = 0.73) to large (ES = 0.85), in accordance with the criteria established by Cohen (1988).

Table 2. Comparison of impulse phase vs. fall in right and left leg (values in Newtons).

Participant	Phase vs. Side	Median	*p*	Effect size
S1	R I LI	330.52 280.60	<.001	0.97
S1	RL LL	305.48 301.48	0.069	0.06
S2	R I LI	457.13 400.84	<.001	0.99
S2	RL LL	455.71 406.03	<.001	0.37
S3	R I LI	298.78 291.88	<.001	0.69
S3	RL LL	317.04 270.29	<.001	0.93

RI= Right Impulse; LI= Left Impulse; RL = Right landing; LL = Left landing; p= significance level (p≤0.05).

Significant differences were observed in almost all values when comparing the impulse phase with the fall phase, except in the participant S1 (p = 0.06). The effect size values were trivial (ES = 0.37), moderate (ES = 0.69) and large (ES = 0.97, 0.99, 0.93).

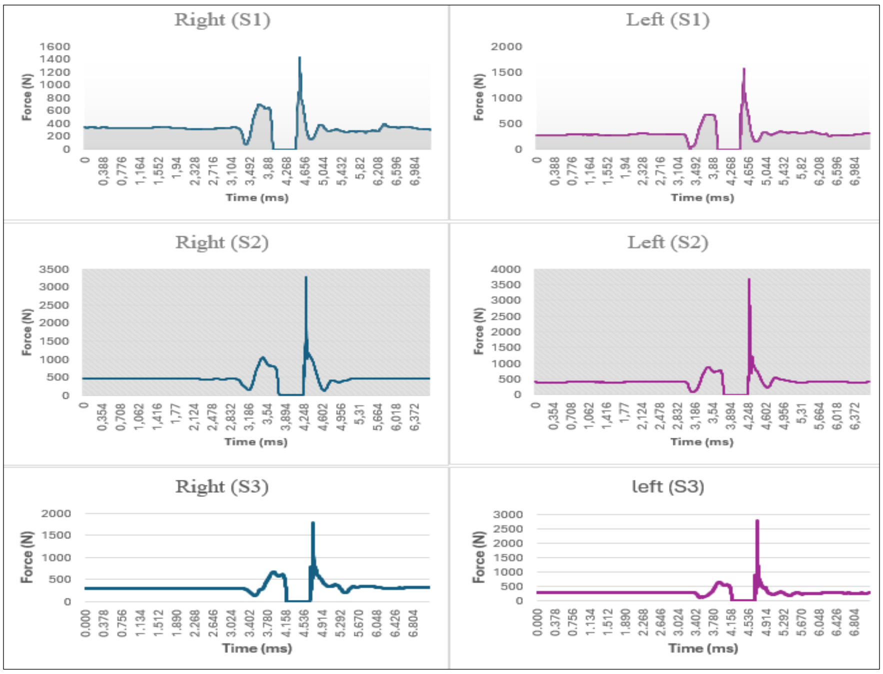
Table 3. Comparison of asymmetry index during impulse and fall (percentage).

Participant vs. Phase	Median	*p*	Effect size
S1 impulse S1 landing	14.99 -0.20	<.001	0.64
S2 impulse S2 landing	12.48 10.49	<.001	0.38
S3 impulse S3 landing	2.56 14.29	<.001	-0.93

p= significance level (p≤0.05).

The results show significant differences (p < .001) between the phases of the CMJ jump (impulse and fall), with effect sizes ranging from trivial (ES = 0.38), moderate (ES = 0.64) and large in the opposite direction (ES = -0.93).

Figure 1. Strength vs. time graph in lower limbs in study participants



The graph shows the curves generated from the resulting forces on the x, y, and z axes, represented for the right (blue) and left (purple) body segments of the study participants. The higher thresholds show the peak forces during the execution of the jump (Figure 1).

Discussion

In our opinion, this study is one of the few that analyzes and proposes a new method to determine the asymmetries of the lower limbs through the jump with countermovement (CMJ). Research on asymmetries in CMJ performance, using force platforms, has revealed key findings indicating that intermember asymmetries can be reliably measured during CMJ, with peak force and momentum being more consistent than peak power (Gordon et al., 2022; Menzel et al., 2013b). However, we have not found a specific protocol due to the wide variety of methods, protocols, and equipment used to measure asymmetries in the jump (Kozlenia et al., 2022), which leads to varying values in the magnitude and direction of the asymmetries, influenced by the type of jump and the metrics used (Bishop et al., 2020; Hewit et al., 2012).

The methodology employed in this study, which combines force platforms with a kinematic system using reflective markers, provides a robust approach for evaluating lower limb asymmetries during countermovement jumps (Bishop et al., 2020). The precision of these instruments enables detailed measurements of force production and movement, which are crucial for identifying significant differences between the right and left limbs. The use of force platforms allows real-time recording of forces generated during the propulsion and landing phases, facilitating a comprehensive analysis of asymmetries (Cadens et al., 2023). Furthermore, the calibration and validation of the instruments ensure that the data are reliable and consistent, which is essential for interpreting the results. The ability to calculate an asymmetry index based on the force differential between the legs provides a quantitative metric that can be used to assess injury risk in athletic populations. This approach not only aids in identifying strength imbalances but also allows for tracking changes over time, which is critical for injury prevention and optimizing athletic performance. In conclusion, the methodology used in this study not only enables precise evaluation of lower limb asymmetries but also establishes a framework for future research aimed at developing standardized protocols and improving injury prevention strategies across diverse athletic populations.

This study has several limitations and suggests the need for future research in the analysis of lower limb asymmetries using the CMJ. The lack of a standardized protocol for the measurement of asymmetries can lead to variations in the results, since the methods, protocols, and equipment used in the current literature are diverse. In addition, the generalizability of our findings is constrained by the small sample size, composed of only three subjects, which might not be representative of a larger population. Discrepancies in the asymmetry indices can also be influenced by differences in the equipment and equations used. Therefore, further research is needed to be conducted that considers factors like gender, competition level, and sport type. In this context, it would be beneficial to develop standardized protocols that facilitate the comparison of results and improve consistency in evaluation. It is also recommended to implement multi-method evaluations and carry out longitudinal studies to identify patterns of asymmetry in relation to performance and risk of injury. Finally, investigating asymmetries in various sports could provide a more comprehensive understanding of their impact on athletic performance and injury prevention.

Conclusions

The conclusions of this study highlight the novelty and relevance of the method used to assess lower limb asymmetries through the countermovement jump. The combination of force platforms and a kinematic system with reflective markers enables precise and detailed measurement of the forces generated during the propulsion and landing phases, representing a significant advancement in evaluating muscular functionality. The results, which reveal significant differences in the asymmetry index between the right and left limbs, underscore the importance of this approach in identifying strength imbalances that may predispose athletes to injuries. The ability to quantify these asymmetries, with a variation range of 5.07% to 14.22% and an effect size ranging from moderate to large, provides a robust foundation for implementing this method in clinical and sports settings. Moreover, the methodology extends beyond force evaluation, offering dynamic performance analysis crucial for designing personalized training programs and rehabilitation strategies. The capability to conduct longitudinal monitoring of asymmetries over time provides a valuable tool for tracking progression and the effectiveness of interventions. In summary, this innovative method not only enhances the precision of lower limb asymmetry evaluation but also establishes a new standard for research and practice in sports and rehabilitation. Its implementation could revolutionize the way strength assessments and injury risks are addressed, contributing to a more proactive, evidence-based approach to injury prevention and athletic performance optimization.

This study highlights the need to develop standardized protocols for the evaluation of asymmetries, which would allow a more accurate comparison between studies and populations. The diversity of methods and equipment currently used generates variability in the results, making it difficult to generalize the findings. Future studies should expand the sample and consider additional factors such as gender, sport type, and competitive level in order to gain a deeper understanding of how asymmetries affect performance and injury prevention.

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References

Bailey, C. A., Sato, K., & McInnis, T. C. (2021). A technical report on reliability measurement in asymmetry studies. Journal of Strength and Conditioning Research, 35(7), 1779–1783. https://doi.org/10.1519/JSC.0000000000004024

Benjanuvatra, N., Lay, B. S., Alderson, J. A., & Blanksby, B. A. (2013). Comparison of ground reaction force asymmetry in one- and two-legged countermovement jumps. Journal of Strength and Conditioning Research, 27(10), 2700–2707.

Bishop, C., Pereira, L. A., Reis, V. P., Read, P., Turner, A. N., & Loturco, I. (2020). Comparing the magnitude and direction of asymmetry during the squat, countermovement and drop jump tests in elite youth female soccer players. Journal of Sports Sciences, 38(11–12), 1296–1303. https://doi.org/10.1080/02640414.2019.1649525

Bishop, C., Turner, A., Maloney, S., Lake, J., Loturco, I., Bromley, T., & Read, P. (2019). Drop jump asymmetry is associated with reduced sprint and change-of-direction speed performance in adult female soccer players. Sports, 7(1), 1–10. https://doi.org/10.3390/sports7010029

Bosco, C., Luhtanen, P., & Komi, P. (1983). A simple method for measurement of mechanical power in jumping. European Journal of Applied Physiology and Occupational Physiology, 50, 273–282. https://doi.org/10.1525/abt.2010.72.7.10

Cadens, M., Planas-Anzano, A., Peirau-Terés, X., Bishop, C., Romero-Rodríguez, D., & Madruga-Parera, M. (2023). Relationship between Asymmetry Profiles and Jump Performance in Youth Female Handball Players. Journal of Human Kinetics, 88(July), 5–16. https://doi.org/10.5114/jhk/163432

Chaouachi, A., Brughelli, M., Charmari, K., & Levin, T. (2009). Lower limb maximal dynamic strength and agility determinants in elite basketball players. Journal of Strength and Conditioning Research, 23, 1570–1577.

Cohen, D., Clarke, N., Harland, S., & Lewin, C. (2014). Are Force Asymmetries Measured in Jump Tests Associated With Previous Injury in Professional Footballers? British Journal of Sports Medicine, 48(7), 579.2-580. https://doi.org/10.1136/bjsports-2014-093494.53

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (NJ (ed.)). Erlbaum.

Edwards, S., Steele, J. R., Cook, J. L., Purdam, C. R., & McGhee, D. E. (2012). Lower limb movement symmetry cannot be assumed when investigating the stop-jump landing. Medicine and Science in Sports and Exercise, 44(6), 1123–1130. https://doi.org/10.1249/MSS.0b013e31824299c3

Gordon, D., Hayward, S., van Lopik, K., Philpott, L., & West, A. (2022). Reliability of bilateral and shear components in a two-legged counter-movement jump. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 236(3), 159–171. https://doi.org/10.1177/1754337121995967

Graham-Smith, P., Al-Dukhail, A., & Jones, P. (2015). Agreement between attributes associated with bilateral jump asymmetry. ISBS-Conference Proceedings Archive, 926–929. https://ojs.ub.uni-konstanz.de/cpa/article/view/6555

Heishman, A., Daub, B., Miller, R., Brown, B., Freitas, E., & Bemben, M. (2019). Countermovement jump inter-limb asymmetries in collegiate basketball players. Sports, 7(5), 1–15. https://doi.org/10.3390/sports7050103

Hewit, J. K., Cronin, J. B., & Hume, P. A. (2012). Asymmetry in multi-directional jumping tasks. Physical Therapy in Sport, 13(4), 238–242. https://doi.org/10.1016/j.ptsp.2011.12.003

Impellizzeri, F. M., Rampinini, E., Maffiuletti, N., & Marcora, S. M. (2007). A vertical jump force test for assessing bilateral strength asymmetry in athletes. Medicine and Science in Sports and Exercise, 39(11), 2044–2050. https://doi.org/10.1249/mss.0b013e31814fb55c

Janicijevic, D., Sarabon, N., Pérez-Castilla, A., Smajla, D., Fernández-Revelles, A., & García-Ramos, A. (2022). Single-leg mechanical performance and inter-leg asymmetries during bilateral countermovement jumps: A comparison of different calculation methods. Gait and Posture, 96(April), 47–52. https://doi.org/10.1016/j.gaitpost.2022.05.012

Jordan, M. J., Aagaard, P., & Herzog, W. (2015). Lower limb asymmetry in mechanical muscle function: A comparison between ski racers with and without ACL reconstruction. Scandinavian Journal of Medicine and Science in Sports, 25(3), e301–e309. https://doi.org/10.1111/sms.12314

Kozlenia, D., Struzik, A., & Domaradzki, J. (2022). Force, Power, and Morphology Asymmetries as Injury Risk Factors in Physically Active Men and Women. Simmetry, 14(4), 787.

Menzel, H.-J., Chagas, M. H., Szmuchrowski, L. A., Araujo, S. R. S., de Andrade, A. G. P., & de Jesus-Moraleida, F. R. (2013a). Analysis of lower limb asymmetries by isokinetic and vertical jump tests in soccer players. Journal of Strength and Conditioning Research, 27(5), 1370–1377.

Menzel, H.-J., Chagas, M. H., Szmuchrowski, L. A., Araujo, S. R. S., de Andrade, A. G. P., & de Jesus-Moraleida, F. R. (2013b). Analysis of lower limb asymmetries by isokinetic and vertical jump tests in soccer players. Journal of Strength and Conditioning Research, 27(5), 1370–1377. https://doi.org/10.1519/JSC.0b013e318265a3c8

Prvulović, N., Čoh, M., Čular, D., Tomljanović, M., Sporiš, G., & Fišer, S. Ž. (2022). Countermovement Jump in Female Sprinters: Kinetic Parameters and Asymmetry. Symmetry, 14(6). https://doi.org/10.3390/sym14061130

Rossow, L. M., Fitts, J. M., Fahs, C. A., & Kizer, V. W. (2021). Lower-limb Force And Fat-free Mass Asymmetries And Their Relationships To Vertical Jump Performance. Medicine & Science in Sports & Exercise, 53(8S), 140.

Yoshioka, S., Nagano, A., Hay, D. C., & Fukashiro, S. (2010). The effect of bilateral asymmetry of muscle strength on jumping height of the countermovement jump: A computer simulation study. Journal of Sports Sciences, 28(2), 209–218. https://doi.org/10.1080/02640410903428566

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