International Journal of Strength and Conditioning

Comparison of Countermovement Jump Strategy With and Without an Arm Swing

Ayden Klaire McInnis[1] and Paul T Donahue[1]*
[1]School of School of Kinesiology and Nutrition, University of Southern Mississippi, Hattiesburg, Mississippi, USA
*Corresponding author: Paul.Donahue@usm.edu

ABSTRACT

The countermovement jump (CMJ) is commonly used to assess both acute neuromuscular performance as well as adaptions to periods of training. Two methodologies are typically employed when performing the CMJ assessment. The first allows for the use of an arm swing (AS) to add a level of sport-specificity to the testing. The second restricts the movement of the arms (NAS) to allow for an assessment of the musculature of only the lower body. Thus, the purpose of this investigation was to examine differences in jump strategy between the two methodologies. Twenty-five female Division I collegiate athletes (volleyball = 13, beach volleyball = 12) participated in this investigation. Participants performed two CMJ in both the AS and NAS conditions. A paired samples t-test was used to evaluate differences in jump performance and jump strategy variables. During the braking phase of the CMJ statistical higher force values ($p < 0.01$) were seen in the NAS condition while longer phase durations were present in the AS condition ($p < 0.001$). No difference was seen in braking net impulse. During the propulsive phase statistically greater duration was seen in the AS condition ($p < 0.001$) leading to a greater propulsive net impulse ($p < 0.001$). The AS condition also displayed greater jump heights, countermovement depth and time to take off durations ($p < 0.001$) with no differences in reactive strength index modified. When performing CMJ assessments practitioners should consider which methodology they use carefully as the NAS assessment used a more force driven strategy while the AS used a time driven strategy.

Keywords: Countermovement jump, jump strategy, athlete testing

INTRODUCTION

The countermovement jump (CMJ) is commonly used as a tool in the assessment of both acute and long-term changes in athletic populations (1,10,11). This is largely due to the ease of implementation and the lack of additional fatigue that is imparted on the athlete during testing (3,11,29). During CMJ testing, two protocols are routinely used. The primary difference between these protocols centers on allowing the athlete to use an arm swing (AS) during the assessment. Additionally, when athletes use an arm swing, greater jump heights are achieved (9,12,14,15,20,27,30). Thus, it has been suggested that when performing the CMJ, an AS should be used to understand the maximal jumping abilities of an individual. Having this maximal output would then guide practitioners in the design of training programs to improve total athletic performance (14). In a recent review of current methods used in the assessment of neuromuscular fatigue, the NAS protocol was suggested based on lower variability (1). Thus, both methods can be effective methods to assess athletes.

When performing the CMJ using an AS, jump heights increase between 15 – 32% based on population and the method used to assess jump height (9,12–15,20,27,30). This increase in jump height when using AS is attributed to a combination of several factors resulting in a greater center of mass velocities (20). This increase in the velocity is a result of an increase in the propulsive net impulse. Several studies have reported increases in force production when using an AS. If the duration of the propulsive phase is held constant then this would result in a greater net impulse. Feltner et al (9) showed that no statistically significant differences were seen in the vertical force during the propulsive phase, with a statistically significant increase in duration creating an increase in propulsive impulse. Vaverka et al. (30) reported both phase-specific force and time being statistically different between AS and NAS conditions in the propulsive phase. The increase in both propulsive duration and mean force allowed an increase in propulsive impulse. As jump height is determined through the propulsive impulse, and with different strategies being employed to increase impulse it is important to examine each variable used in the calculation.

The reactive strength index modified (RSIm) is a commonly used variable in the assessment of CMJ performance (8). RSIm is calculated as the ratio of jump height and time to take-off (TTT). The utility of this variable is that a higher RSIm would typically signal a positive adaption through either a greater jump height being achieved or a reduction in TTT. While RSIm was not calculated, Lees et al (20) reported increases in jump height while also having an increase in TTT when using an AS. However, contrasting findings have been reported by Vaverka, et al (30), where jump height increased when using an AS but no change was seen in the time to take off. Again, RSIm was not calculated but the increase in jump height with no change in TTT would support an increase in RSIm. Though no difference was seen in the TTT, phase-specific times differed between methodologies used, with a decrease in braking duration and an increase in the propulsive phase duration when using the AS. More recently Heishman et al (14) provided supporting evidence for a change in RSIm when including an AS in collegiate basketball athletes, however, they did not report jump height or TTT.

These previous findings demonstrate that the impact of using an arm swing on RSIm needs to be investigated further. In addition to the conflict in the reported findings, the previous investigations all used male participants. Recently, it has been displayed that males and females may use different strategies to achieve maximal CMJ performance (19,21,28). When investigating the difference in high and low performers based on RSIm, males were separated based on propulsive phase variables whereas, in females, differences were present in the loading phases (7,18). Additionally, McMahon et al (21) reported differences between males and females regarding countermovement depth with similar TTT creating a higher movement velocity. Thus, the purpose of this investigation was to examine the effect of performing the CMJ task with and without an AS on RSIm in a sample of female athletes.

METHODS

Experimental Approach to the Problem

This investigation used a cross-sectional within-subject design, and differences in CMJ strategy were examined based on the use of an arm swing in a sample of female collegiate athletes across two teams. All testing took place during the regular athlete-testing program that all athletes participated in as a part of their sport participation. Data used in this analysis was collected during the preseason for each sport.

Subjects

Twenty-five NCAA Division I female athletes (volleyball n = 13, beach volleyball n = 12) participated in this study. Athletes were selected from these particular sports as the vertical jump task is a critical part of the sport they participated in. All testing took place prior to team resistance training sessions during the preseason. All participants were cleared for to take part in team related activities by the sports medicine staff. Before testing all participants provided written informed consent as approved by the university's institutional review board.

Procedures

Participants performed two countermovement (CMJ) trials after performing a warm-up directed by the individual team's strength and conditioning staff. Warm-ups took approximately 10 minutes to complete and consisted of dynamic lower body movements as well as submaximal vertical jumps. All trials were completed using a self-selected countermovement depth and foot position. Verbal instructions were given prior to initiation of each trial to "jump as high as possible". During the no arm swing (NAS) trials, a dowel (polyvinyl chloride, <1.0 kg) was placed across the upper back in a manner similar to the position of a barbell during the back squat exercise. Participants were instructed to maintain contact between the dowel and the upper back during the duration of the trial. During the arm swing (AS) trials, participants were instructed to begin each trial with both arms raised above their head. They were then allowed to swing their arms in any manner they desired to obtain the greatest jump height. All trials were collected using a portable force platform (AMTI, Accupower, Watertown, MA, USA) sampling at 1000 Hz. Each trial began with participants having one second of quiet standing before being given a "3, 2, 1, Go" countdown. During the quiet standing phase, body mass was calculated from the vertical ground reaction force.

Data Analysis

Raw vertical ground reaction force data was exported and analyzed using a customized Excel spreadsheet (Microsoft, Redmond WA, USA). The customized spreadsheet was modelled using the methods described by Chavda et al (4) and McMahon et al (22). Phases of the CMJ were defined following the methods and terminology of McMahon et al (22). Phases specific to this investigation were the braking and propulsive phases. The braking phases was defined as the point in which vertical ground reaction force data surpassed the calculated body mass during the one second of quiet standing to the instant of the center of mass velocity reached zero. Propulsive duration was defined as the end of the braking phase to the instant of take-off. Center of mass velocity was calculated by subtracting the calculated mass from the vertical force data to obtain center of mass acceleration. Integration of acceleration data with respect to time began 30ms before the initiation of movement as recommended by Owen et al (24) to obtain the center of mass velocity. Movement initiation was determined using the recommendation of subtracting 5SD of the vertical force data during the quiet standing from the calculated mass. Take-off was defined as the instant in which vertical ground reaction force fell below 10 N.

Time to take-off was calculated as the duration from movement initiation to the point of take-off. Jump height was calculated from the vertical velocity of the center of mass at take-off. Reactive strength index modified (RSIm) was calculated as jump height divided by time to take off. Finally, all force variables are presented as net force (measured force – body mass).

Statistical Analysis

Mean data for the two trials in each condition were used in the statistical analysis. Reliability analysis for each variable using both intraclass correlation coefficient (ICC) and coefficient of variation (CV). Reliability was deemed acceptable with ICC values greater than 0.80 and CV values of less than 10%. To compare conditions, a paired samples t-test was conducted for each variable. Significance for all tests was a priori set at $p < 0.05$. Effect sizes were calculated as Cohen's d and interpreted using the criteria of trivial (< 0.2), small (0.2 – 0.49), moderate (0.5 – 0.79) and large (> 0.8) (16). All statistical analyses were performed using SPSS (v28.0, SPSS Inc., Chicago, IL, USA).

RESULTS

All data is reported as means ± SD and displayed in Table 3. All variables demonstrated acceptable levels of reliability. Jump height was statistically greater in the AS condition ($p \leq 0.001$, $d = 1.96$). The AS condition also showed a statistically significant increase all phase durations and time to take-off ($p \leq 0.001$, $d = 0.76 – 1.44$). This coincided

Table 1. No Arm Swing Intraclass Correlation Coefficient (ICC) and Coefficient of Variations (CV)

	ICC (95% CI)	CV (95% CI)
Braking Mean Force	0.91 (0.77 – 0.96)	3.71 (5.00 – 9.04)
Braking Duration	0.94 (0.86 – 0.97)	5.22 (2.94 – 6.27)
Braking Impulse	0.84 (0.61 – 0.93)	5.77 (3.88 – 6.38)
Propulsive Mean Force	0.91 (0.80 – 0.96)	1.81 (2.09 – 4.78)
Propulsive Duration	0.88 (0.64 – 0.95)	2.12 (2.30 – 4.27)
Propulsive Net Impulse	0.93 (0.85 – 0.97)	1.84 (1.22 – 3.16)
Countermovement Depth	0.88 (0.61 – 0.96)	3.26 (2.59 – 5.29)
Time To Take-off	0.94 (0.87 – 0.98)	1.08 (1.66 – 2.99)
Jump Height	0.97 (0.93 – 0.99)	1.97 (1.34 – 3.03)
RSIm	0.95 (0.90 – 0.98)	2.39 (2.97 – 5.17)

Table 2. Arm Swing Intraclass Correlation Coefficient (ICC) and Coefficient of Variations (CV)

	ICC (95% CI)	CV (95% CI)
Braking Mean Force	0.91 (0.77 – 0.96)	5.63 (3.29 – 7.96)
Braking Duration	0.94 (0.86 – 0.97)	5.43 (3.24 – 7.62)
Braking Impulse	0.84 (0.61 – 0.93)	3.27 (1.94 – 4.61)
Propulsive Mean Force	0.91 (0.80 – 0.96)	2.79 (2.05 – 3.53)
Propulsive Duration	0.88 (0.64 – 0.95)	2.54 (1.77 – 3.31)
Propulsive Net Impulse	0.93 (0.85 – 0.97)	1.35 (0.78 – 1.91)
Countermovement Depth	0.88 (0.61 – 0.96)	2.48 (1.44 – 3.53)
Time To Take-off	0.94 (0.87 – 0.98)	2.24 (1.73 – 2.75)
Jump Height	0.97 (0.93 – 0.99)	1.98 (1.40 – 2.57)
RSIm	0.95 (0.90 – 0.98)	3.17 (2.29 – 4.04)

with a statistically greater countermovement depth during the AS condition ($p \leq 0.001$, $d = 1.07$). No difference was found in RSIm between the two jumping conditions ($p = 0.8$, $d = 0.05$).

The NAS condition exhibited greater mean braking force values being statistical greater than the AS condition ($p = 0.005$, $d = 0.61$). However, no statistically significant difference was found between conditions regarding propulsive mean force ($p = 0.36$, $d = 0.19$). Braking net impulse was not statistically different between the conditions ($p = 0.85$, $d = 0.04$) while propulsive net impulse was statistically greater in the AS condition ($p \leq 0.001$, $d = 1.45$).

DISCUSSION

The purpose of this study was to examine CMJ performance when using an AS compared to a NAS condition. Results of this study indicate differences between conditions concerning the kinetic variables during the loading phases as well as variables associated with the movement strategy.

As CMJ testing has continued to gain popularity as an effective method to assess athletic populations because of the ease of implementation and not inducing additional fatigue, a framework for variable selection has been proposed to guide practitioners in understanding CMJ performance (3). This framework suggests using RSIm as the starting point (3). This is largely due to increases in RSIm being a result of an increase in jump height or a reduction in time to take-off, either of which would be a positive adaptation as a result of training. However, it is important to recognize that this is a ratio variable derived from jump height and time to take-off and that those variables should be included in the examination of CMJ performance to gain a more robust understanding of task performance. RSIm was not found to be significantly different in the present investigation when comparing CMJ performance. Thus, demonstrating that further analysis of not only the variables used to calculate RSIm but also variables that can be used to explain any changes in jump height and time to take-off would be warranted.

The results of this study showed that jump height

Table 3. Comparison of Arm Swing and No Arm Swing Conditions (mean ± SD)

	Arm Swing	No Arm Swing	*p*	*d*
Braking Mean Force (N)	412.13 ± 147.50	496.52 ± 138.28	0.005	0.61
Braking Duration (ms)	234.70 ± 70.52	188.10 ± 45.62	<0.001	0.76
Braking Net Impulse (N*s)	88.67 ± 22.03	87.97 ± 13.02	0.85	0.04
Propulsive Mean Force (N)	578.51 ± 118.38	608.26 ± 96.72†	0.36	0.19
Propulsive Duration (ms)	337.92 ± 43.81	312.02 ± 37.77	<0.001	0.93
Propulsive Net Impulse (N*s)	199.28 ± 24.76	188.33 ± 22.04	<0.001	1.45
Countermovement Depth (cm)	39.43 ± 6.75	34.98 ± 5.23	<0.001	1.07
Time to Take-off (ms)	979.9 ± 84.59	850.96 ± 111.16	<0.001	1.44
Jump Height (cm)	35.37 ± 5.43	30.59 ± 5.25	<0.001	1.98
RSIm	0.36 ± 0.07	0.37 ± 0.08	0.80	0.05

RSIm = Reactive Strength Index modified was statistically greater (14.33%) during the arm swing condition. This is similar to previous investigations that have demonstrated that jump heights are increased when using an arm swing (9,12,13,15,23,30). It is important to note that within the current investigation, we used a sample of female athletes that participate in sports that are heavily reliant on the vertical jump task. The jump heights were lower in the present study than those reported previously in males but were close in terms of a relative difference between conditions (~16 – 21%) (9,12,13,15,23,30). While well established that jump height is increased when using an arm swing during the CMJ, few investigations have examined the specific changes that occur lead to these differences as well as phase-specific variables.

During the AS condition time to take off increased by approximately 129 ms. This increase coincided with the increase in jump height to maintain a similar ratio seen in the RSIm. The results of the present study are in contrast to those reported by Heishman et al. (14). Direct comparison between studies is difficult as neither jump height nor the time to take-off is reported in the previous investigation. In comparing the reliability of CMJ variables when using an AS, Heishman et al (15) reported an increase in jump height while maintaining time to take-off in a sample of male collegiate basketball athletes. The difference in movement onset threshold used between investigations may explain the increased time to take-off seen in the present that was not seen previously. Heishman et al. (15) used an absolute movement threshold of 20N whereas the current investigation used a 5SD threshold. The use of different movement onset thresholds has been shown to impact time to take-off in different jump tasks (2,5,25). Finally, it is of note that this is a novel investigation into changes in RSIm while using an AS in female athletes. As such, differences in CMJ performance between males and females was previously shown, and the lack of change in RSIm in the current investigation that was previously reported in males may be a result of these differences (19,21,28). However, several other variables showed statistically significant differences between conditions suggesting that the differences between studies may be a result of methodologies used rather than sex differences.

One such difference was an increase in the countermovement depth during the AS condition. Previous investigations have reported that increasing countermovement depth allowed for greater jump heights due to an increase in the propulsive net impulse (26). The increase in countermovement depth allows for greater time to be spent in the propulsive phase thus increasing the net impulse. The present study displayed greater countermovement depth which coincided with increases in all phase durations. The current investigation provides evidence of a shift in the strategy used during the AS condition. With differences seen in both mean braking force and braking duration with no difference in braking net impulse, it appears individuals went from a force driven to time-driven strategy to create a similar impulse. This carried over to the propulsive phase again with a change in the duration; however, no differences were seen in force production. Thus, creating a greater propulsive impulse and greater jump height. These shifts to a time-driven strategy are supported by an increase in the countermovement depth.

This strategy shift is of interest as it would be important when selecting which CMJ method to use during the assessment of athletic populations. When examining neuromuscular fatigue, it is common to see that individuals may achieve a given jump height under fatigued conditions, yet they use more of a time strategy rather than force driven strategy (17). If one were to use the arm swing method during this assessment, individuals may mask fatigue due to the inherent time-driven strategy seen in the current investigation. Thus, the use of a NAS protocol may allow for a better evaluation of neuromuscular fatigue from a monitor perspective. Additionally, when selecting which CMJ protocol to use the inherent nature of the certain sports jump should also be considered. Recently, Donahue et al (6) examined jump strategy differences between female athletes from three sports that rely on vertical jump ability. Jump heights between basketball and beach volleyball athletes were similar while using opposing time and force strategies (6). Future investigations should examine how the use of an arm swing impacts different sports as athletes from each sport may have inherently different jump strategies.

This study is not without limitations. Firstly, data from this investigation was pooled from two sports. As mentioned previously, individual sports appear to have their jump strategy based on participation. Using a within-subject study design, the between-sport differences were not a focus and thus not of concern. Secondly, while all participants take part in routine athlete monitoring protocols throughout the year, the NAS condition could still be a relatively novel task in comparison to the AS condition, especially with the reliance on the vertical jump task within both indoor and beach volleyball. However, RSIm was not different between conditions within the present study, and a consistent shift (24 of 2 participants) to a longer time to take off in the AS condition was seen. This supports the theory of a shift in jump strategy as a result of using the AS.

PRACTICAL APPLICATIONS

Findings from the current study can be implemented by practitioners in determining which methodology to use when assessing athletes. Regardless of the assessment method, RSIm was not significantly different suggesting that it will be consistent between the methods. However, depending on the goal of the testing practitioners and researchers alike should not use methodologies interchangeably and should be aware of the potential shift in jump strategy being used to achieve maximal performance. When performing CMJ testing as a part of an athlete monitoring protocol the use of a NAS methodology may allow for an understanding of potential neuromuscular fatigue.

CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

FUNDING

This study received no specific funding in order to be completed.

ETHICAL APPROVAL

Ethics for this study were approved in line with University of Southern Mississippis ethics procedure.

DATES OF REFERENCE

Submission - 04/03/2024
Acceptance - 08/07/2024
Publication - 11/10/2024

CORRESPONDING AUTHOR

Paul Donahue - paul.donahue@usm.edu

REFERENCES

1. Alba-Jiménez, C, Moreno-Doutres, D, and Peña, J. Trends Assessing Neuromuscular Fatigue in Team Sports: A Narrative Review. Sports 10: 33, 2022.
2. Barefoot, M, Lamont, H, and Smith, JC. Comparison of the Reliability of Four Different Movement Thresholds When Evaluating Vertical Jump Performance. Sports 10: 193, 2022.
3. 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 44: 95–103, 2021.
4. Chavda, S, Bromley, T, Jarvis, P, Williams, S, Bishop, C, Turner, AN, et al. Force-time Characteristics of the Countermovement Jump: Analyzing the Curve in Excel. Strength Cond J 20: 67–77, 2018.
5. Donahue, PT, Hill, CM, Wilson, SJ, Williams, CC, and Garner, JC. Squat Jump Movement Onset Thresholds Influence on Kinetics and Kinematics. Int J Kinesiol Sports Sci 9: 1–7, 2021.
6. Donahue, PT, Peel, SA, Rush, M, McInnis, A, Littlefield, T, Calci, C, et al. Examining Countermovement Jump Strategies Between Women's NCAA Division I Sports. J Strength Cond Res PAP, 2023.
7. Donahue, PT, Rush, M, McInnis, AK, and Littlefield, T. Phase Specific Comparisons of High and Low Vertical Jump Performance in Collegiate Female Athletes. J Sci Sport Exerc PAP, 2022.
8. Ebben, WP and Petushek, EJ. Using the reactive strength index modified to evaluate plyometric performance. J Strength Cond Res 24: 1983–1987, 2010.
9. Feltner, ME, Bishop, EJ, and Perez, CM. Segmental and kinetic contributions in vertical jumps performed with and without an arm swing. Res Q Exerc Sport 75: 216–230, 2004.
10. Gathercole, R, Sporer, B, Stellingwerff, T, and Sleivert, G. Alternative countermovement-jump analysis to quantify acute neuromuscular fatigue. Int J Sports Physiol Perform 10: 84–92, 2015.
11. Gathercole, RJ, Sporer, BC, Stellingwerff, T, and Sleivert, GG. Comparison of the capacity of different jump and sprint field tests to detect neuromuscular fatigue. J Strength Cond Res 29: 2522–2531, 2015.
12. Hara, M, Shibayama, A, Takeshita, D, Hay, DC, and Fukashiro, S. A comparison of the mechanical effect of arm swing and countermovement on the lower extremities in vertical jumping. Hum Mov Sci 27: 636–648, 2008.
13. Harman, EA, Rosenstein, MT, Frykman, PN, and Rosenstein, RM. The effects of arms and countermovement on vertical jumping. Med Sci Sports Exerc 22: 825, 1990.

14. Heishman, A, Brown, B, Daub, B, Miller, R, Freitas, E, and Bemben, M. The Influence of Countermovement Jump Protocol on Reactive Strength Index Modified and Flight Time: Contraction Time in Collegiate Basketball Players. Sports 7: 37, 2019.
15. Heishman, AD, Daub, BD, Miller, RM, Freitas, EDS, Frantz, BA, and Bemben, MG. Countermovement Jump Reliability Performed With and Without an Arm Swing in NCAA Division 1 Intercollegiate Basketball Players. J Strength Cond Res 34: 546, 2020.
16. Hopkins, WG. A scale of magnitudes for effect statistics. Sportscience. , 2002.Available from: http://www.sportsci.org/resource/stats/effectmag.html
17. Kennedy, RA and Drake, D. The effect of acute fatigue on countermovement jump performance in rugby union players during preseason. J Sports Med Phys Fitness 57: 1261–1266, 2017.
18. Krzyszkowski, J, Chowning, LD, and Harry, JR. Phase-Specific Predictors of Countermovement Jump Performance That Distinguish Good From Poor Jumpers. J Strength Cond Res Publish Ah: 1–7, 2020.
19. Laffaye, G, Wagner, PP, and Tombleson, TIL. Countermovement jump height: Gender and sport-specific differences in the force-time variables. J Strength Cond Res 28, 2014.
20. Lees, A, Vanrenterghem, J, and Clercq, DD. Understanding how an arm swing enhances performance in the vertical jump. J Biomech 37: 1929–1940, 2004.
21. McMahon, J, Rej, S, and Comfort, P. Sex Differences in Countermovement Jump Phase Characteristics. Sports 5: 8, 2017.
22. McMahon, JJ, Suchomel, TJ, Lake, JP, and Comfort, P. Understanding the Key Phases of the Countermovement Jump Force-Time Curve. Strength Cond J 40: 96–106, 2018.
23. Mosier, EM, Fry, AC, and Lane, MT. Kinetic Contributions of The Upper Limbs During Counter-Movement Verical Jumps With and Without Arm Swing. J Strength Cond Res 33: 2066, 2019.
24. Owen, NJ, Watkins, J, Kilduff, LP, Bevan, HR, and Bennett, MA. Development of a Criterion Method to Determine Peak Mechanical Power Output in a Countermovement. J Strength Cond Res 28: 1552–1558, 2014.
25. Pérez-Castilla, A, Fernandes, JFT, Rojas, FJ, and García-Ramos, A. Reliability and Magnitude of Countermovement Jump Performance Variables: Influence of the Take-off Threshold. Meas Phys Educ Exerc Sci 25: 227–235, 2021.
26. Sánchez-Sixto, A, Harrison, AJ, and Floría, P. Larger Countermovement Increases the Jump Height of Countermovement Jump. Sports 6: 131, 2018.
27. Slinde, F, Suber, C, Suber, L, Edwén, CE, and Svantesson, U. Test-Retest Reliability of Three Different Countermovement Jumping Tests. J Strength Cond Res 22: 640, 2008.
28. Sole, CJ, Mizuguchi, S, Sato, K, Moir, GL, and Stone, MH. Phase Characteristics Of The Countermovement Jump Force-Time Curve: A Comparison Of Athletes By Jumping Ability. J Strength Cond Res 32: 1155–1165, 2018.
29. Taylor, K-L, Chapman, DW, Cronin, JB, Newton, MJ, and Gill, N. Fatigue Monitoring in High Performance Sport: a Survey of Current Trends. J Aust Strength Cond 20: 12–23, 2012.
30. Vaverka, F, Jandačka, D, Zahradník, D, Uchytil, J, Farana, R, Supej, M, et al. Effect of an Arm Swing on Countermovement Vertical Jump Performance in Elite Volleyball Players. J Hum Kinet 53: 41–50, 2016.