Sánchez-Sixto, A.; Harrison, A.J. y Floría, P. (2019) La importancia de la profundidad del contramovimiento en el ciclo estiramiento-acortamiento / Importance of Countermovement Depth in Stretching and Shortening Cycle Analysis. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 19 (73) pp. 33-44 Http://cdeporte.rediris.es/revista/revista73/artimportancia1003.htm
DOI: http://doi.org/10.15366/rimcafd2019.73.003

ORIGINAL

LA IMPORTANCIA DE LA PROFUNDIDAD DEL CONTRAMOVIMIENTO EN EL CICLO ESTIRAMIENTO-ACORTAMIENTO

IMPORTANCE OF COUNTERMOVEMENT DEPTH IN STRETCHING AND SHORTENING CYCLE ANALYSIS

Sánchez-Sixto, A.[1]; Harrison, AJ.[2]; Floría, P.[3]

[1] Doctorando en Ciencias de la Actividad Física y el Deporte. Departamento de Deporte. Centro de Estudios Universitarios Cardenal Spínola CEU. Bormujos (España) asanchezsixto@ceuandalucia.es
[2] Doctor en Ciencias de la Actividad Física y el Deporte. Physical Education & Sport Sciences. University of Limerick. Limerick (Irlanda) Drew.Harrison@ul.ie
[3] Doctor en Ciencias de la Actividad Física y el Deporte. Departamento de Deporte e Informática. Universidad Pablo de Olavide. Sevilla (España) pfloriam@upo.es

Spanish-English translator: Andrew J Harrison, drew.harrison@ul.ie

Código UNESCO / UNESCO CODE: 2406.04 Biomecánica / Biomechanics
Clasificación del Consejo de Europa / Council of Europe Classification: 3. Biomecánica del deporte / Biomechanics of sport

Recibido 7 de abril de 2017 **Received** April 7, 2017
Aceptado 11 de septiembre de 2017 **Accepted** September 11, 2017

ABSTRACT

The aim of this investigation was to determine the influences of force application related variables and center of mass displacement on jump height differences between squat jump (SJ) and countermovement jump (CMJ). Twenty six males performed three squat jumps and three countermovement jumps with a 90° knee flexion. The center of mass displacement during the upward movement phase and the average force were significantly greater in CMJ than in SJ. Both variables explained 75% of the differences in the flight height, having 30% more influence on the center of mass displacement. There were no differences in peak force. The results of this research suggest the need to examine the center of mass displacement during SJ and CMJ when a 90°of knee flexion criteria is established.

KEY WORDS: Biomechanics, Jump, Kinetics, Kinematics.

RESUMEN

El objetivo de la presente investigación fue determinar la influencia de las variables relacionadas con la aplicación de fuerza y el desplazamiento del centro de masas en las diferencias en la altura saltada entre el salto sin contramovimiento (SJ) y el salto con contramovimiento (CMJ). Participaron veintiséis hombres, realizando tres SJ y tres CMJ con 90° de flexión de rodilla. El desplazamiento del centro de masas y la fuerza media durante la fase de propulsión fueron significativamente superiores en el CMJ en comparación con el SJ, explicando el 75% de la diferencia entre los dos saltos y teniendo un 30% más de influencia el desplazamiento del centro de masas. No hubo diferencias en la fuerza máxima. Los resultados sugieren la necesidad de examinar el desplazamiento del centro de masas para interpretar adecuadamente las diferencias entre el SJ y el CMJ cuando el criterio establecido es 90° de flexión de rodilla.

PALABRAS CLAVE: Biomecánica, Salto, Cinética, Cinemática.

INTRODUCCIÓN

The jump height difference between a squat jump (SJ) and a countermovement jump (CMJ) is the principal variable frequently used by researchers and coaches to evaluate stretch-shortening cycle (SSC) function (Castagna & Castellini, 2013; Yang, Chou, Chen, Shiang, & Liu, 2014). Generally, jump height is greater in the CMJ than the SJ and this performance difference has been attributed to the muscle´s ability to produce greater work and power after a counter-movement action (Bobbert, Gerritsen, Litjens, & Van Soest, 1996). As mechanical work is the product of force and displacement of the center of mass, researchers have analyzed the influence of both parameters on the jump height contribution (Kirby, McBride, Haines, & Dayne, 2011).

Force analysis has been used extensively to examine differences in performance between jumps (Cormie, McBride, & McCaulley, 2009; Feltner, Bishop, & Perez, 2004; González-Badillo & Marques, 2010; Kirby et al., 2011; Nuzzo, McBride, Cormie, & McCaulley, 2008). Some research has shown that the peak force during the jump influences jump height (Cormie et al., 2009; González-Badillo & Marques, 2010) but, other studies have shown an inconsistent relationship between these variables (Kirby et al., 2011; Salles, Baltzopoulos, & Rittweger, 2011). While the average force has not been widely used by coaches and researchers to assess the vertical jump height, it has been used to examine the differences in performance between jumps (Feltner et al., 2004). In addition, a high initial force at the onset of the upward movement phase which results in increased work done during that phase, can be related to higher vertical jump performance (Bobbert et al., 1996).

The role of center of mass displacement during jumping has been extensively investigated (Kirby et al., 2011; Salles et al., 2011). Increasing the range of motion of the center of mass during force application may increase the net impulse during the concentric phase and thereby improve take-off velocity (Alexander, 1995; Bobbert, Casius, Sijpkens, & Jaspers, 2008; Samozino, Morin, Hintzy, & Belli, 2010). It is well established that highly trained athletes achieve larger center of mass displacements in the upward movement phase and attain higher jump heights in comparison with untrained individuals (Ugrinowitsch, Tricoli, Rodacki, Batista, & Ricard, 2007). Due to this influence of center of mass displacement on jump performance, coaches and researchers often control the angle of knee flexion during the SJ and CMJ tests (Hébert-Losier, Jensen, & Holmberg, 2014; Lloyd, Oliver, Hughes, & Williams, 2011). Despite this, differences in center of mass displacement may appear because of the influence of other segment movements (Kopper, Ureczky, & Tihanyi, 2012). Therefore, it is important to determine whether potential differences in the displacement of the center of mass during the execution of SJ and CMJ may explain the performance differences between the two jumps.

When coaches and strength and conditioning professionals estimate the SSC function through the jump height difference between the SJ and CMJ, various parameters related to either force applied or displacement of the center of mass may influence the result (Bobbert et al., 2008). However, is not clear which of these parameters has greater influence on the difference in jumping performance between the types of jump. This knowledge can help researchers and coaches to understand the role of each parameter on vertical jump performance. Consequently, the aim of this investigation was to determine the influences of force application related variables and center of mass displacement on jump height differences between SJ and CMJ.

MATERIAL AND METHODS

PARTICIPANTS

Twenty six active males participated in this investigation (age: 20.62 ± 3.46 years, height: 1.79 ± 0.06 m and body mass: 74.60 ± 6.14 kg). No participants had any musculoskeletal injury or nervous system dysfunction within 6 months before participation. The study had ethical approval from the local University Research Ethics Committee and all the participants provided informed consent before participation. The data of the present investigation were anonymized and saved according to the protection data laws.

PROCEDURES

Participants were instructed to perform vertical jumps with a countermovement (CMJ) and without a countermovement (SJ) on a force plate (Quattro Jump, Kistler Instrument AG, Winterthur, Switzerland) sampling vertical force at 500 Hz. Before the test, all participants performed 10 minutes of general warm up activity including, 2 minutes of low-intensity aerobic exercise, dynamic stretching exercises and one set of 6, sub-maximal jumps (Vetter, 2007). These 6 jumps were used as a familiarization session. Since all participants were physically active and regularly performed activities including jumping, a short familiarization session was sufficient to ensure the participants could complete the jumping tasks. After the warm up, the participants were requested to perform 3 maximum-effort SJ and 3 maximum-effort CMJ in a randomized order. The instructions for each participant were standardized and the importance of jumping as high as possible was emphasized. The participants retained the arms akimbo position until the landing phase during both jumps. They also were instructed to keep their feet on the floor during the countermovement phase. For the SJ test, the participants flexed their knees slowly to 90º. They were instructed to hold this position for 2 s before jumping for maximum height without prior countermovement. For the CMJ, participants started from an upright standing position the dynamically reached a knee angle of 90º and executed an immediate vertical (Hébert-Losier et al., 2014; Lloyd et al., 2011). The researchers controlled every attempt and when an incorrect execution occurred, the participants repeated the attempt. Three successful jumps were recorded for each jump type and at least 2 minutes rest was allowed between jumps.

ANALYSIS

The best of three trials, in terms of jump height, was selected for analysis. Force-plate computer software (QuattroJump, Type 2822A1-1, Version 1.0.9.2) was utilized to record the force values and calculate the maximum jump using the impulse method (Linthorne, 2001). Net impulse was obtained by integrating the net vertical force with respect to time, from 2 s prior to the first movement of the participant (Street et al., 2001), using the trapezoidal method (Street, McMillan, Board, Rasmussen, & Heneghan, 2001), using the trapezoidal method (Kibele, 1998). Subsequently, the center of mass vertical velocity was calculated by dividing the net impulse by the participant´s body mass. The vertical center of mass displacement was derived by integrating the vertical center of mass velocity. Finally, work done during the jump was calculated by multiplying the force by the center of mass displacement. While work done is precisely determined as force multiplied by the distance moved by the point of application of force, the product of ground reaction force and displacement of the center of mass provides a good estimate of work done on the center of mass during the jump (Street et al., 2001). In order to exclude the influence of weight on scores, all variables quantifying force were normalized to body weight (BW).

Several performance parameters were determined during the upward movement phase, which was defined from the instant of zero velocity of center of mass to take-off. The instant of take-off was defined as the first intersection of vertical ground reaction force within an offset threshold. The threshold was determined by adding the average flight time and the peak residual of the offset (Street et al., 2001).

Maximal height, flight height, height at take-off and height at the beginning of upward movement phase (crouch position) were identified by visual inspection of the displacement data (Figure 1). Center of mass displacement during upward movement phase was calculated by subtracting height values between the start of the upward movement phase and take-off instant. Peak force was measured as the maximum force value reached during the upward movement phase. Average force was calculated during the upward movement phase. Force at the beginning of the upward movement phase was the force at the beginning of the upward movement phase.

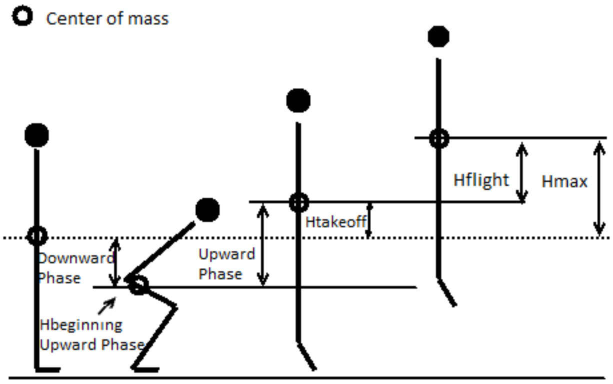

Figure 1. Center of mass displacement variables

STATISTICAL ANALYSIS

Statistical analyses were conducted using SPSS 18.0 software. Means and standard deviations for each participant were computed for all the measured variables. Normality of the data-sets was verified using the Shapiro-Wilk test. If the data were normally distributed, a repeated-measures t-test was used to evaluate the differences in measures between SJ and CMJ conditions. If the data were not normally distributed, then a Wilcoxon test was used. Significance level was set at $P < 0.05$. The magnitude of the differences between the jumps was expressed as a standardized mean effect size (i.e. Cohen's dz). The criteria to interpret the magnitude of the effect size were: trivial = 0.00 – 0.19, small = 0.20 – 0.59, moderate = 0.60 – 1.20 and high > 1.20 (Hopkins, Marshall, Batterham, & Hanin, 2009).

Stepwise (backward) multiple regression analyses were used to determine which parameters significantly predict height difference between the SJ and CMJ. The independent variables were: center of mass displacement difference between the SJ and CMJ, force at the beginning of the upward movement difference between the SJ and CMJ, peak force difference between the SJ and CMJ and average force differences between both jumps. The dependent variable was the difference in maximum vertical flight height between the SJ and CMJ. Finally, the standard beta-coefficients were used to estimate the influence of each of the independent variables on the dependent variable.

RESULTS

Mean scores and standard deviation (mean ± SD) for each variable during SJ and CMJ, are presented in Table 1. (Insert Table 1 here) The results show that jumping performance increased by 15% when using a CMJ and this change was a moderate effect size. There was no difference in height at take-off between the SJ and the CMJ, but there were significant differences in flight height between jump conditions, with a large effect size. During the upward movement phase, the work produced was higher in the CMJ than in the SJ, resulting in a high effect size. There were significant differences between jump types in the variables related to center of mass position. These differences were observed during the upward movement phase and in vertical height of the center of mass in the crouch position. The results show that the upward movement phase in the CMJ began from a deeper crouch position in comparison to the SJ, thereby increasing the vertical displacement of center of mass in the upward movement phase of the CMJ compared to the SJ. In force application related parameters, there were significant differences in the average force and initial force variables; obtaining higher values in the CMJ. However no differences in peak force values were observed.

Table 1. Results (mean ± SD) of upward phase variables.

Variables	SJ	CMJ	Effect size
h_{max} (m)	0,41 ± 0,07	0,47 ± 0,06*	0,85
H_{flight} (m)	0,28 ± 0,05	0,33 ± 0,05*	1,29
$H_{takeoff}$ (m)	0,13 ± 0,04	0,14 ± 0,03	0,12
W ($J{\cdot}kg^{-1}$)	2,93 ± 0,50	3,41 ± 0,55*	1,27
$F_{average}$ (BW)	1,95 ± 0,21	2,05 ± 0,15*	0,53
$F_{inicial}$ (BW)	1,00 ± 0,00	2,44 ± 0,22*	6,64
F_{max} (BW)	2,52 ± 0,24	2,52 ± 0,20	-0,01
D_{upward} (m)	0,35 ± 0,05	0,42 ± 0,03*	1,55
Crouch (m)	-0,22 ± 0,07	-0,28 ± 0,04*	0,82

Note: H_{max} = maximal height, H_{flight} = flight height, $H_{takeoff}$ = take-off height, W = work, $F_{average}$ = average force, $F_{inicial}$ = force at the beginning of upward movement phase, F_{max} = peak force, D_{upward} = displacement of the upward movement phase, Crouch = crouch position.
*P < 0,05.

The results of the multiple regression analysis showed a strong relationship between the flight height difference between SJ and CMJ and the differences in center of mass displacement and average forces between both jumps (Table 2). The flight height differences between SJ and CMJ were associated with greater propulsion distance (P < 0.001) and higher average force (P < 0.001) in the CMJ and both variables explained a large percentage (75%) of variance (Figure 2). Of these parameters, the difference in displacement during the upward movement phase between CMJ and SJ had the greatest influence on the height differences, with average force having 30% less influence.

Table 2. Multiple regression to predict the influence of variables related to displacement and force application on flight height changes between SJ and CMJ.

Independent variables	Non-standardised coefficients B	Standard error	Beta standardised coefficients	t-value
R^2 = 0,745, *F* = 33,96*				
(Constant)	-0,019	0,009		-2,083
ΔD_{upward}	0,795	0,103	0,901	7,750*
ΔF_{av}	0,146	0,024	0,702	5,943*

ΔD_{upward}: displacement differences during concentric phase between SJ and CMJ. ΔF_{av}: average force differences between SJ and CMJ. *indicates *P*<0,01

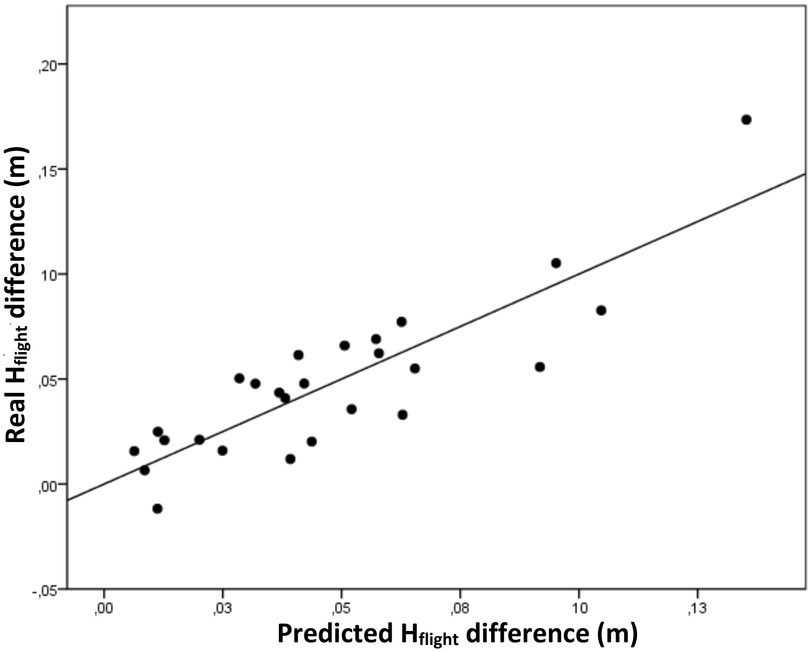

Figure 2. Dispersion diagram of the relationship between the real difference of flight height (H_{flight}) and expected between SJ and CMJ.

DISCUSSION

The purpose of this investigation was to determine the influences of force application related parameters and center of mass displacement on changes in jump height between SJ and CMJ. The increment on flight height between SJ and CMJ was explained 75% of the differences on center of mass displacement and average force between the two types of jump. The vertical displacement of center of mass had the greatest influence in determining the difference in flight height between SJ and CMJ. The take-off positions were similar in both jumps; therefore the results showed that when examining the differences between SJ and CMJ, an upward movement from a deeper crouch position had 28% more influence than the differences in the forces applied. These results concur with previous studies which found that vertical jump performance can be enhanced by a large increase in the displacement of the center of mass during the upward phase (Kirby et al., 2011; Salles et al., 2011). In the current study, the differences in center of mass displacement between the jumps were small but the variance of the difference in jump height between SJ and CMJ explained by this displacement was large. For this reason, a large increase in the displacement of the center of mass is not required to improve vertical jump performance because small increments may further explain the differences in performance between both jumps (Sánchez-Sixto, Harrison, & Floría, 2016). In addition, previous investigations found a statistically significant relationship between the jump height and the center of mass displacement (Barker, Harry, & Mercer, 2017). This suggests a need to pay close attention to the way the SJ and CMJ are executed when they are used to evaluate the SSC effectiveness. Coaches and strength and conditioning professionals often use a criterion of 90° knee flexion to standardize the SJ and CMJ (Hébert-Losier et al., 2014; Lloyd et al., 2011). The results of this study suggest that this approach may not be sufficient to ensure similar displacements of the center of mass in both jumps. It is likely that other body segments with a larger mass, such as the trunk, can influence the position of the center of mass (Kopper et al., 2012). This may cause small differences in the path of the center of mass which ultimately affect the performance differences between both jump types. Consequently, there is a need to look for further methods to provide a consistent and reproducible protocol to evaluate the effectiveness SSC and decrease the influence of the technique used by the athlete.

The average force during the upward movement showed significant differences between SJ and CMJ and this was the only force application related parameter which determined the jump height difference between SJ and CMJ. However, no relationships were found between the average force and the jump height in a previous investigations (Barker et al., 2017), other studies showed the average force as a determinant of performance in the vertical jump (Feltner et al., 2004). As average force is derived from a large number of data points, the information obtained by the average force could be more representative of the complete movement than other instantaneous variables. Any instantaneous force variable extracted from the continuous force-time signal discards a large amount of potentially important data which may be useful to evaluate the performance. However, peak force is one of the most analyzed instantaneous variables (Cormie et al., 2009; Kirby et al., 2011; Nuzzo et al., 2008; Salles et al., 2011), but in the present study, peak force did not differ between the SJ and the CMJ although CMJ performance was higher. Our findings are consistent with other studies which found no relationship between peak force and vertical jump performance (Kirby et al., 2011; Nuzzo et al., 2008). It is possible that the deeper crouch position achieved in the CMJ resulted in a lower peak force which is consistent with previous studies that showed lower peak force when larger center of mass displacements were performed (Kirby et al., 2011; Markovic, Mirkov, Knezevic, & Jaric, 2013; Salles et al., 2011). Therefore, the peak force does not appear to adequately discriminate the performance differences between SJ and CMJ. As it was expected, the force at the beginning of the upward movement phase showed significant differences between the jumps. At SJ the force at the beginning of the upward phase must be identical as BW, while at CMJ this force should be higher due to the braking action during the downward phase. The force at the beginning of upward movement phase has been described as an important factor in determining differences between SJ and CMJ (Bobbert et al., 1996). It is suggested that this should increase the net impulse generated during the upward movement and consequently enhance the take-off velocity of the center of mass (Kirby et al., 2011). However, at the present investigation, participants with higher initial force values were not the participant that achieved a higher jump height. In addition, a recent study did not found a relationship between the force at the beginning of the upward movement phase and the jump height (Barker et al., 2017). Future studies should examine the role of force at the beginning of the upward movement phase controlling the center of mass displacement, due to the possible relevance in the vertical jump performance.

CONCLUSION

This study demonstrated the important role of center of mass displacement in the analysis of SSC through the SJ and CMJ. The 90º knee angle flexion criteria appear insufficient in order to guarantee a similar displacement of the center of mass between both jumps. The influence of the center of mass displacement was the most important variable explaining the differences between the SJ and CMJ. For that reason, in order to evaluate the SSC through the SJ and CMJ, the control of the countermovement depth is necessary. Finally, peak force and force at the beginning of the upward movement phase did not predict the jump height performance, whereas the average force at this phase was the force applied variables which explain a higher percent of the differences between the CMJ and the SJ.

REFERENCES

Alexander, R. M. (1995). Leg design and jumping technique for humans, other vertebrates and insects. Philosophical Transactions of the Royal Society of London B: Biological Sciences, 347, 235-248. doi: https://doi.org/10.1098/rstb.1995.0024.

Barker, L. A., Harry, J. R., & Mercer, J. A. (in press). Relationships Between Countermovement Jump Ground Reaction Forces and Jump Height, Reactive Strength Index, and Jump Time. Journal of Strength & Conditioning Research.

Bobbert, M. F., Casius, L. R., Sijpkens, I. W., & Jaspers, R. T. (2008). Humans adjust control to initial squat depth in vertical squat jumping. Journal of Applied Physiology, 105, 1428-1440. doi: https://doi.org/10.1152/japplphysiol.90571.2008.

Bobbert, M. F., Gerritsen, K. G., Litjens, M. C., & Van Soest, A. J. (1996). Why is countermovement jump height greater than squat jump height? Medicine and Science in Sports and Exercise, 28, 1402-1412. doi: https://doi.org/10.1097/00005768-199611000-00009.

Castagna, C., & Castellini, E. (2013). Vertical jump performance in Italian male and female national team soccer players. Journal of Strength & Conditioning Research, 27, 1156-1161. doi: https://doi.org/10.1519/JSC.0b013e3182610999.

Cormie, P., McBride, J. M., & McCaulley, G. O. (2009). Power-time, force-time, and velocity-time curve analysis of the countermovement jump: impact of training. Journal of Strength & Conditioning Research, 23, 177-186. doi: https://doi.org/10.1519/JSC.0b013e3181889324.

Feltner, M. E., Bishop, E. J., & Perez, C. M. (2004). Segmental and kinetic contributions in vertical jumps performed with and without an arm swing. Research Quarterly for Exercise and Sport, 75, 216-230. doi: https://doi.org/10.1080/02701367.2004.10609155.

González-Badillo, J. J., & Marques, M. C. (2010). Relationship between kinematic factors and countermovement jump height in trained track and field athletes. Journal of strength and conditioning research, 24, 3443-3447. doi: https://doi.org/10.1519/JSC.0b013e3181bac37d.

Hébert-Losier, K., Jensen, K., & Holmberg, H. C. (2014). Jumping and hopping in elite and amateur orienteering athletes and correlations to sprinting and running. International Journal of Sports Physiology and Performance, 9, 993-999. doi: https://doi.org/10.1123/ijspp.2013-0486.

Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. Medicine and Science in Sports and Exercise, 41, 3. doi: https://doi.org/10.1249/MSS.0b013e31818cb278.

Kibele, A. (1998). Possibilities and limitations in the biomechanical analysis of countermovement jumps: A methodological study. Journal of Applied Biomechanics, 14, 105-117. doi: https://doi.org/10.1123/jab.14.1.105.

Kirby, T. J., McBride, J. M., Haines, T. L., & Dayne, A. M. (2011). Relative net vertical impulse determines jumping performance. Journal of Applied Biomechanics, 27, 207-214. doi: https://doi.org/10.1123/jab.27.3.207.

Kopper, B., Ureczky, D., & Tihanyi, J. (2012). Trunk position influences joint activation pattern and physical performance during vertical jumping. Acta Physiologica Hungarica, 99, 194-205. doi: https://doi.org/10.1556/APhysiol.99.2012.2.13.

Linthorne, N. P. (2001). Analysis of standing vertical jumps using a force platform. American Journal of Physics, 69, 1198-1204. doi: https://doi.org/10.1119/1.1397460.

Lloyd, R. S., Oliver, J. L., Hughes, M. G., & Williams, C. A. (2011). The influence of chronological age on periods of accelerated adaptation of stretch-shortening cycle performance in pre and postpubescent boys. Journal of Strength and Conditioning Research, 25, 1889-1897. doi: https://doi.org/10.1519/JSC.0b013e3181e7faa8.

Markovic, S., Mirkov, D. M., Knezevic, O. M., & Jaric, S. (2013). Jump training with different loads: effects on jumping performance and power output. European Journal of Applied Physiology, 113, 2511-2521. doi: https://doi.org/10.1007/s00421-013-2688-6.

Nuzzo, J. L., McBride, J. M., Cormie, P., & McCaulley, G. O. (2008). Relationship between countermovement jump performance and multijoint isometric and dynamic tests of strength. Journal of Strength and Conditioning Research, 22, 699-707. doi: https://doi.org/10.1519/JSC.0b013e31816d5eda.

Salles, A. S., Baltzopoulos, V., & Rittweger, J. (2011). Differential effects of countermovement magnitude and volitional effort on vertical jumping. European Journal of Applied Physiology, 111, 441-448. doi: https://doi.org/10.1007/s00421-010-1665-6.

Samozino, P., Morin, J.-B., Hintzy, F., & Belli, A. (2010). Jumping ability: a theoretical integrative approach. Journal of Theoretical Biology, 264, 11-18. doi: https://doi.org/10.1016/j.jtbi.2010.01.021.

Sánchez-Sixto, A., Harrison, A., & Floría, P. (2016). Simple instructions on the crouch position improve performance in the countermovement jump. 34 International Conference on Biomechanics in Sports, 949-952.

Street, G., McMillan, S., Board, W., Rasmussen, M., & Heneghan, J. M. (2001). Sources of error in determining countermovement jump height with the impulse method. Journal of Applied Biomechanics, 17, 43-54. doi: https://doi.org/10.1123/jab.17.1.43.

Ugrinowitsch, C., Tricoli, V., Rodacki, A. L., Batista, M., & Ricard, M. D. (2007). Influence of training background on jumping height. Journal of Strength and Conditioning Research, 21, 848-852.

Vetter, R. E. (2007). Effects of six warm-up protocols on sprint and jump performance. Journal of Strength and Conditioning Research, 21, 819-823.

Yang, W. W., Chou, L. W., Chen, W. H., Shiang, T. Y., & Liu, C. (in press). Dual-frequency whole body vibration enhances vertical jumping and change-of-direction ability in rugby players. Journal of Sport and Health Science.

Número de citas totales / Total references: 24 (100%)
Número de citas propias de la revista / Journal´s own references: 0 (0%)