Simple instructions on the crouch position improve performance in the countermovement jump

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The purpose of this study was to determine how simple instructions that modify the depth of countermovement lead to changes in the jump height and the biomechanical parameters related to centre of mass displacement and force application. Twenty-nine active males participated in this investigation and they performed three countermovement jumps using a self-selected crouch position, three countermovement jumps with a deeper crouch position and three countermovement jumps with a shallower crouch position in random order. The results of this study suggest that is possible to improve the jump performance in amateur competitive males with slight modification of the centre of mass displacement having the same physical condition level without any training intervention.

KEY WORDS: Biomechanics, performance, center of mass displacement, force.

INTRODUCTION: The vertical jump is one of the most common skills and numerous studies have examined the biomechanical parameters related to increases in jump height (González-Badillo & Marques, 2010; Kirby, McBride, Haines, & Dayne, 2011). The net vertical impulse relative to body mass has been shown to determine jump height (Kirby et al., 2011). The impulse represents the interaction between the vertical force applied and the time over which it is applied (McBride, McCaulley, & Cormie, 2008). Any change in vertical impulse is dependent on changes in either force or time. Therefore, athletes have two ways for improving the jump performance; increasing the force applied or the time over the athlete produces force.

In practice, the duration of force application can only be increased by increasing the centre of mass displacement during the countermovement because athletes seek to apply high forces as quickly as possible to achieve their maximum jump height (González-Badillo & Marques, 2010). Previous studies have analysed how changes in the depth of countermovement affect vertical jump performance and observed that increasing the displacement of the centre of mass over countermovement in unskilled jumpers increase jump height (Bobbert, Casius, Sijpkens, & Jaspers, 2008; Kirby et al., 2011; Le Pellec & Maton, 2002; Salles, Baltzopoulos, & Rittweger, 2011). However, non-significant differences in jump height were found between the preferred and the deeper jump depth (Kirby et al., 2011; Mandic, Jakovljevic, & Jaric, 2015; Salles et al., 2011). In these studies, participants were required to perform jumps from crouch positions which were very different from those commonly performed (Kirby et al., 2011; Salles et al., 2011) or with an elite population (Mandic et al., 2015). Therefore, it remains unclear whether simple instructions which slightly modify the depth of countermovement selected by the athlete can improve jump performance in amateur competitive males. In addition, greater understanding is required on how biomechanical variables can be modified by varying instructions on the countermovement technique. Therefore, the purpose of this study was to determine how simple instructions that modify the depth of countermovement might lead to changes in the jump height and the biomechanical parameters related to centre of mass displacement and force application.

METHODS: Twenty nine amateur competitive males participate in this investigation (age: 22.66 ± 1.37 years, height: 1.75 ± 0.05 m and body mass: 79.79 ± 12.30 kg) without any musculoskeletal injury or nervous system dysfunction within 6 months before participation in this study. The study had ethical approval from the local University Research Ethics Committee and all the participants provided informed consent before participation.

Participants were instructed to perform jumps with countermovement on a force plate (Dinascan 600M, IBV, Spain) sampling at 1000 Hz. A practise session was completed before the jumping experiment, during which it was verified that all participants could complete the jumping tasks to a satisfactory level. After the warm up that were performed, the participants were requested to perform 3 countermovement jumps using a self-selected crouch position, 3 countermovement jumps with a deeper crouch position and 3 countermovement jumps with a shallower crouch position in random order. The deep crouch position was identified by the displacement-time data. The displacement data was calculated 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, McMillan, Board, Rasmussen, & Heneghan, 2001) using the trapezoidal method (Kibele, 1998). The vertical centre of mass displacement was derived by integrating the vertical centre of mass velocity. To exclude the influence of weight and height on scores, all variables quantifying force were normalised to body weight (BW) and all variables quantifying displacement were normalized to leg height (LH) (standing height minus sitting height).

The instructions for each participant were standardised and the importance of jumping as high as possible was emphasised. The participants retained the arms akimbo position from the start until the landing phase in the jumps. In every jump, each participant stood upright and stationary for at least 2 seconds before initiating the jump. Three successful jumps were recorded for each jump type, with at least 2 minutes of rest allowed between jumps. The best trial of each type of jump was selected for analysis. The maximum jump height was used to determine the best jump.

The downward movement phase was defined from the instant of start of movement to the instance of the maximum downward displacement position of the centre of mass (i.e. maximum crouch position of the jump). The instant of start of movement was detected by searching forward from the first intersection of vertical ground reaction force within a predefined threshold of 1.75 times the peak residual force during the 2-s BW averaging period. A backwards search was then performed until ground reaction force passed through body weight (Street et al., 2001). The upward movement phase was defined from the instance of the maximum crouch position of centre 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 and this threshold was determined by adding the average flight time (i.e., 0.4 seconds) and the peak residual of the offset (Street et al., 2001).

The displacement variables: Maximal height, flight height, height at take-off and height at the beginning of upward phase (crouch position) was calculated by subtracting height values between the start of the upward phase and the take-off instant. The force variables calculated were: Minimum force, initial force, maximum force. Minimum force was measured as the minimum value of force reached during the downward movement phase. Force at the beginning of the upward movement phase was defined as the value of force at the instant of maximum crouch position. Peak force was measured as the maximum value of force reached during the upward phase.

Statistical analyses were conducted using PASW (SPSS, Inc., Chicago, IL). Normality of the 8 dependent variables was verified using the Shapiro-Wilk test. If the data were normally distributed, a general linear model a repeated measures ANOVA test was used, when a significant F-value was found, post hoc pair wise comparisons of means were made using the least significant difference post hoc test. Significance level was set at $P < 0.05$, the sequentially rejective Bonferroni (Bonferroni-Holm) post hoc test (Holm, 1979) was used for each group of variables (displacement and force) to adjust the P-level to account for multiple pairwise comparisons of strength measures. Since each participant performed three jumps from each crouch position (preferred, deep and shallow), the trial factor was included as a separate factor in the ANOVA. If the data were not normally distributed, then a Wilcoxon test was used. The magnitude of the differences between the jumps was expressed as a standardised 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, 2004).

RESULTS: The normalised mean ± SD values for the height and centre of mass displacement variables are presented in Table 1, together with the statistical significance of differences between the jumps. The results show that countermovement depth had a statistically significant effect on jump performance. Several displacement variables were modified when the countermovement depth was manipulated. The flight height and upward displacement were greater with the deeper crouch position compared with the self-selected position ($P<0.01$, effect size ≥ -0.67). Conversely, when the crouch position was shallower these parameters were lower in comparison with the self-selected countermovement jump ($P<0.01$, effect size ≥ 0.86). Nevertheless a unique statistically significant difference was found in force variables. The maximun force ($P\leq0.001$, effect size = 1.54) was higher in the shallower jump compared with self-selected countermovement jump.

Table 1
Results (mean ± SD) of height, displacement of center of mass and force variables

Displacement variables	CMJP	CMJS	CMJD	ES CMJP-CMJS	ES CMJP-CMJD
Jump height (LH)	0.48 ± 0.08	0.45 ± 0.06*	0.50 ± 0.08	0.55	-0.50
Flight height (LH)	0.36 ± 0.07	0.33 ± 0.06*	0.37 ± 0.06#	0.86	-0.67
Take-off height (LH)	0.12 ± 0.03	0.12 ± 0.02	0.13 ± 0.02	0.03	-0.09
Crouch position (LH)	0.32 ± 0.06	-0.23 ± 0.05*	-0.43 ± 0.06#	-2.02	2.47
D_{upward} CM (LH)	0.45 ± 0.06	0.35 ± 0.05*	0.55 ± 0.06#	1.90	-2.16
Force variables					
Minimun force (BW)	0.36 ± 0.22	0.40 ± 0.23	0.36 ± 0.18	-0.40	0.03
Initial force (BW)	2.35 ± 0.29	2.47 ± 0.35	2.36 ± 0.31	-0.46	-0.05
Maximun force (BW)	2.44 ± 0.23	2.81 ± 0.31*	2.38 ± 0.28	-1.54	0.32

*P<0.05 with Holm-Bonferroni sequential correction applied = Significant difference from CMJP and CMJS. #P<0.05 with Holm-Bonferroni sequential correction applied = Significant difference from CMJP and CMJD. Note: CMJP: preferred countermovement jump, CMJS: shallower countermovement jump, CMJD: deeper countermovement jump, ES: effect size. D_{upward} CM: vertical center of mass displacement of the upward movement phase.

DISCUSSION: The results of this investigation show that simple instructions modifying the countermovement depth have influences on jump performance in these participants. The flight height of vertical jump increased as the countermovement depth increased. Other studies (Kirby et al., 2011; Salles et al., 2011) have found that modifications in the countermovement depth led changes in height jumped although the jump performance was not higher than that achieved in a jump executed with self-selected depth (Kirby et al., 2011; Mandic et al., 2015; McBride et al., 2008). In our study, higher flight heights were achieved when the depth of countermovement was deeper than the self-selected condition. These contrasting findings could be attributed to the type of instructions given to the participants (Kirby et al., 2011; Salles et al., 2011) or the sample (Mandic et al., 2015). Previous studies required participants to adopt specific countermovement depths defined by either precise knee flexion angles or exact vertical displacement of the centre of mass (Kirby et al., 2011; McBride et al., 2008; Salles et al., 2011). It is possible that this could compromise the coordination of the jump in the participants by redirecting their focus on reaching the prescribed depth rather than jumping as high as possible and retaining a smooth movement pattern.

The present study found higher vertical forces were generated when the countermovement was shallow and not accompanied by an increase in height jump. This suggests that force increases without an optimal range of motion, do not produce improvements in the vertical jump (Kirby et al., 2011). Maximum forces during upward movement were higher in the shallower countermovement jump which achieved a lower height jumped. High levels of maximum force could be explained by the ability of ankle and knee joints to generate higher joint moments at the beginning of the upward movement phase. The results also found higher joint moments when countermovement jumps were performed at 70° compared with 90° knee flexion angle (Moran & Wallace, 2007). For this reason, researchers should be careful in interpreting the forces during the upward movement phase as a performance enhancement because they can be greatly influenced by the depth of the countermovement.

CONCLUSION: The results of this study support the hypothesis that it may be possible to improve the jump performance with slight modification of the centre of mass displacement in competitive amateur players having the same physical condition level without any training intervention. This hypothesis should be confirmed by further study with this population and other populations, as well as with prospective studies exploring the training effects of countermovement adjustments.

REFERENCES:

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*(5), 1428-1440.

González-Badillo, J. J., & Marques, M. C. (2010). Relationship between kinematic factors and countermovement jump height in trained track and field athletes. *The Journal of Strength & Conditioning Research, 24*(12), 3443-3447.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian journal of statistics*, 65-70.

Hopkins, W. G. (2004). How to interpret changes in an athletic performance test. *Sportscience, 8*(1), 1-7.

Kibele, A. (1998). Possibilities and limitations in the biomechanical analysis of countermovement jumps: A methodological study. *Journal of Applied Biomechanics, 14*, 105-117.

Kirby, T. J., McBride, J. M., Haines, T. L., & Dayne, A. M. (2011). Relative net vertical impulse determines jumping performance. *J Appl Biomech, 27*(3), 207-214.

Le Pellec, A., & Maton, B. (2002). Initiation of a vertical jump: the human body's upward propulsion depends on control of forward equilibrium. *Neuroscience letters, 323*(3), 183-186.

Linthorne, N. P. (2001). Analysis of standing vertical jumps using a force platform. *American Journal of Physics, 69*(11), 1198-1204.

Mandic, R., Jakovljevic, S., & Jaric, S. (2015). Effects of countermovement depth on kinematic and kinetic patterns of maximum vertical jumps. *Journal of Electromyography and Kinesiology, 25*(2), 265-272.

McBride, J. M., McCaulley, G. O., & Cormie, P. (2008). Influence of preactivity and eccentric muscle activity on concentric performance during vertical jumping. *The Journal of Strength & Conditioning Research, 22*(3), 750-757.

Moran, K. A., & Wallace, E. S. (2007). Eccentric loading and range of knee joint motion effects on performance enhancement in vertical jumping. *Human movement science, 26*(6), 824-840.

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*(3), 441-448.

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*(1), 43-54.