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Longitudinal Monitoring of Countermovement Jump Mechanical Variables: A Preliminary Investigation

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Description

The purpose of this study was to examine the influence of accumulated volume load on countermovement jump (CMJ) mechanical variables. Eight athletes underwent weekly CMJ testing using a force plate. Statistical changes were observed in certain CMJ variables over the observation period. Jump height (0.42±0.05 m) and allometrically scaled peak power (88.86±7.49 W·kg-0.67) exhibited multiple statistical changes. These changes appeared to exhibit a delayed effect in response to accumulated volume load. Specifically, following several weeks of large accumulated volume loads these variables declined. In addition subsequently decreasing accumulated volume loads resulted in an increase in both variables. The findings of this study indicate measuring jump height and peak power may be an effective method for monitoring a resistance training process.

Keywords

countermovement jump, mechanical variables

Disciplines

Sports Sciences

Copyright Statement

LONGITUDINAL MONITORING OF COUNTERMOVEMENT JUMP MECHANICAL VARIABLES: A PRILIMINARY INVESTIGATION

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The purpose of this study was to examine the influence of accumulated volume load on countermovement jump (CMJ) mechanical variables. Eight athletes underwent weekly CMJ testing using a force plate. Statistical changes were observed in certain CMJ variables over the observation period. Jump height (0.42±0.05 m) and allometrically scaled peak power (88.86±7.49 $W \cdot kg^{-0.67}$) exhibited multiple statistical changes. These changes appeared to exhibit a delayed effect in response to accumulated volume load. Specifically, following several weeks of large accumulated volume loads these variables declined. In addition subsequently decreasing accumulated volume loads resulted in an increase in both variables. The findings of this study indicate measuring jump height and peak power may be an effective method for monitoring a resistance training process.

KEYWORDS: vertical jump, peak power, jump height, volume load, athlete monitoring

INTRODUCTION: The countermovement vertical jump (CMJ) is a simple, reliable, and non-invasive method of assessing lower-body explosiveness in athletes (Mizuguchi, 2012; Moir, Button, Glaister, & Stone, 2004; Moir, Sanders, Button, & Glaister, 2005). Measurement of CMJs performed on a force plate allows for examination of the force-time record and calculation of mechanical variables (Linthorne, 2001). Mechanical variables associated with the CMJ, as well as the characteristics of the force-time record have been shown to reflect neuromuscular adaptations (Cormie, McGuigan, & Newton, 2010), and even provide insight into the timing and nature of these adaptations (Cormie, McBride, & McCaulley, 2009). Additionally, previous research indicates that CMJ and static jump performance may reflect neuromuscular fatigue. (Byrne & Eston, 2002; Hortobagyi, Lambert, & Kroll, 1991; Robineau, Jouaux, Lacroix, & Babault, 2012)

Considering the practical nature of this measurement and its ability to reflect both adaptation and fatigue, the CMJ has been suggested as a method of monitoring training (Mizuguchi, 2012). Regularly testing the CMJ may give practitioners the ability to monitor fatigue and establish relationships between performance preparation activity dose and response. However, there has yet to be a study exploring serial CMJ monitoring of athletes *"in situ"*. Therefore, the purpose of this study was to examine the influence of accumulated volume load on CMJ mechanical variables, in an effort to address performance preparation activity dose response.

METHODS: Eight NCAA Division I female volleyball athletes (age 19.9 ± 0.6 y, body mass 69.5 ± 8.6 kg, height 175.6 ± 11.3 cm) participated in this study. This investigation was approved by the East Tennessee State University Institutional Review Board. Athletes performed CMJs weekly for a period of eleven weeks. Each testing session was held on the fourth day of the microcycle (week) at the same time of day prior to team resistance training. After completing a standardized warm-up, participants performed a specific warm-up consisting of three CMJs (50%, 75%, and 100% of their perceived maximum effort). Maximal effort CMJs were then performed. Participants were instructed to jump with maximum effort utilizing a modified arm-action as used in the volleyball "block jump". During this jump the arms were held in front of the body with palms facing forward, and elbows flexed at approximately 90 degrees. During the jump the arms were extend overhead into the block position. Flight time was used to estimate jump height during each maximal effort jump, and jumps were performed until two consistent trials were recorded (criterion ≤ 2 cm difference in jump height between trials). A thirty-second recovery was allowed between jumps. All jumps were performed on a force plate (1.00 m x 0.76 m, AMTI AccuPower, Watertown, MA, USA) sampling at 400 Hz. Force-time curves were created from the data obtained from the force plate and the mechanical variables, jump height (JH), allometrically scaled peak force (PFa), peak velocity (PV), allometrically scaled peak power (PPa), take-off velocity (TV), allometrically scaled force at peak power (FaPP), and velocity at peak power (VPP) were calculated using a custom program (LabVIEW, ver. 2010, National Instruments, Austin, TX, USA). Allometric scaling was used to obviate changes in body mass over the eleven-week testing period.

To estimate the total amount of work performed during resistance training, volume load (VL) was calculated from the total number of repetitions performed, multiplied by the mass of the barbell in kilograms. Because testing took place once every microcycle, the total of VL seven days preceding each testing session (VL7) was calculated to account for the effect of resistance training over each microcycle. VL7 was calculated for a total of twenty microcycles (Figures 1 and 2). To evaluate rate of change, each mechanical variable was converted to a z-score and the first week's measurement was subtracted from the final week's and divided by 10.14 (total number of weeks during the CMJ testing period).

Intra-session reliability was assessed using intraclass correlation coefficient (ICC) and coefficient of variation (CV) (JH (ICC=0.90-0.99, CV=0.83-3.7%), TV (ICC=0.96-0.99, CV=0.7-2.4 %), PFa (ICC=0.91-0.99, CV=1.5-4.9%), PV (ICC=0.84–0.98, CV=0.66-2.4%), PPa (ICC=0.95-0.99, CV=1.4-4.1%), FaPP (ICC =0.94-0.99, CV=1.5-3.8%), VPP (ICC=0.88-0.96, CV=1.3-2.6%).

Eight one-way repeated measures analyses of variance were used to determine statistical differences in CMJ variables and VL7 over time with Bonferroni correction as *post-hoc* tests. In addition, effect size (Partial η^2) and statistical power were calculated. A single one-way repeated measures analyses of variance were used to determine differences in rate of change between variables. All data analyses were completed using SPSS 21 (IBM, New York, NY, USA). The critical alpha level for all analyses was set at $p \leq 0.05$. Due to the exploratory nature of the study, no adjustment was made on the critical alpha level.

RESULTS: Statistical differences were observed in five of seven mechanical variables examined (Table 1). Results of *post-hoc* analyses for JH and PPa are displayed in Figures 1 and 2. Analysis of VL7 (10985.76±2046.28 kg) revealed statistical differences over 20 weeks (F (1.44, 10.01) =220.05, $p < 0.001$). Analysis of rate of change revealed no statistical (F (6, 49) =1.23, $p = 0.306$) differences between variables.

Table 1
Comparison of Mean for CMJ Variables Over 11 Testing Sessions

	Mean ± SD	Unit	*df*	*F*	*p*	Partial η^2	Power
JH*	0.42 ± 0.05	m	(4.54, 31.77)	7.80	<0.001	0.527	0.99
TV*	2.84 ± 0.17	$m \cdot s^{-1}$	(3.36, 23.55)	5.46	0.004	0.438	0.91
PFa	37.42 ± 2.36	$N \cdot kg^{-0.67}$	(4.21, 29.44)	2.32	0.077	0.249	0.61
PV*	2.95 ± 0.17	$m \cdot s^{-1}$	(3.77, 26.37)	8.33	<0.001	0.543	0.99
PPa*	88.86 ± 7.49	$W \cdot kg^{-0.67}$	(2.63, 18.37)	15.16	<0.001	0.684	0.99
FaPP	35.10 ± 0.38	$N \cdot kg^{-0.67}$	(3.18, 22.28)	2.23	0.110	0.241	0.50
VPP*	2.63 ± 0.16	$m \cdot s^{-1}$	(4.20, 29.38)	6.02	0.001	0.462	0.97

*Note: * Indicates statistically significant main effect p < 0.05 level.*

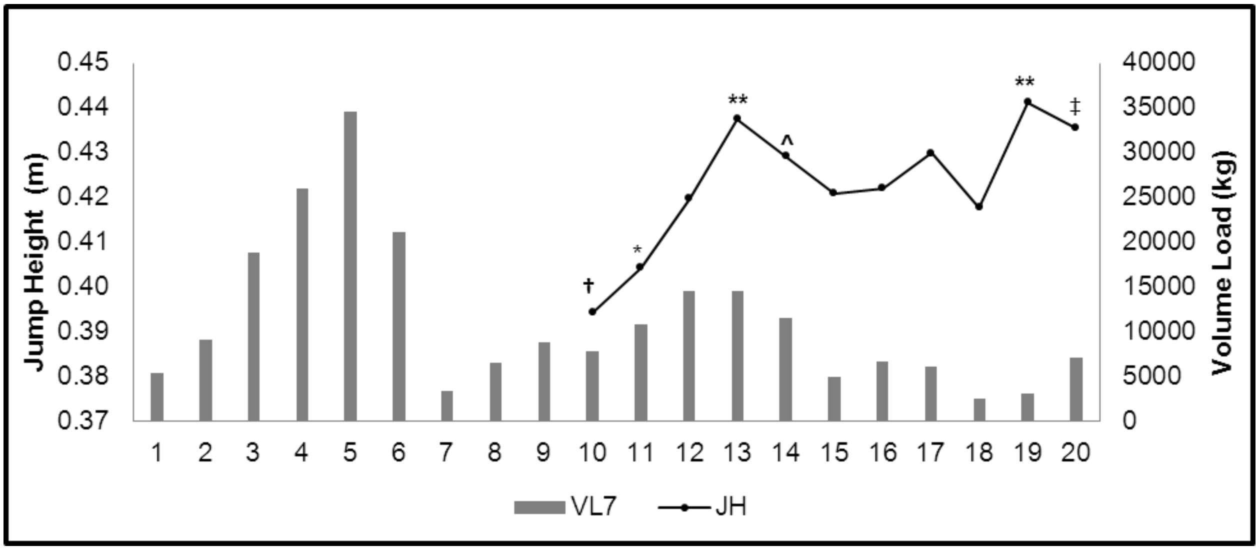

Figure 1. Seven-day accumulation of volume load (VL7) and jump height (JH) over 20 weeks. Values are displayed as means

Note: For jump height: †=statistically different than wks. 13, 19, and 20; *=statistically different than wk.13, 14, and 19; **=statistically different than wks. 10 and 11; ^=statistically different than wk. 11; ‡=statistically different than wk. 10; (p < 0.05).

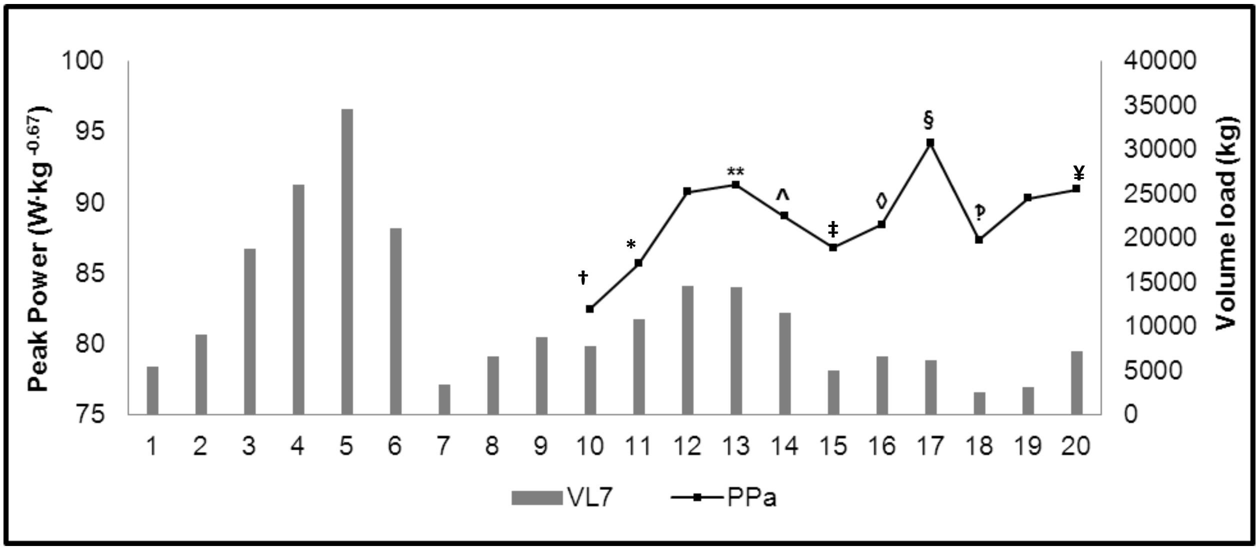

Figure 2. Seven-day accumulation of volume load (VL7) and allometrically scaled peak power (PPa) over 20 weeks. Values are displayed as means.

Note: For peak power; †=statistically different than wks. 13, 14,16,17,18, and 20; *=statistically different than wks. 13 and 17; **=statistically different than wks.10, 11, 14, 15, 17, and 18; ^=statistically different than wks. 10, 13, 15, and 17; ‡=statistically different than wks. 13, 14, and 17; ◊=statistically different than wks.10 and 17; §=statistically different than wks. 10, 11, 13,14,15,16, and 18; ƥ=statistically different than wks. 10, 13, and 17; ¥=statistically different than wk. 10; (p < 0.05).

DISCUSSION: The purpose of the study was to examine the influence of accumulated volume load on CMJ mechanical variables. PPa and JH exhibited perhaps the most interesting behavior (Figures 1 and 2). Both JH and PPa were lowest at weeks 10, 11, and 15. JH peaked at week 13 and again at week 19, whereas PPa exhibited peaks at weeks 13 and 17. Interestingly, PFa and

FaPP remained relatively consistent, exhibiting no statistical changes over eleven weeks of testing.

When VL7 was considered, it appears a delayed response may exist between VL7, JH and PPa. Several weeks of increased VL7 as in weeks 12-14, where VL7 was statistically ($p<0.05$) greater than weeks 7-10, subsequently decreased both JH and PPa. When VL7 was statistically ($p<0.05$) reduced (weeks 15-19), as compared to weeks 12-14, both variables subsequently increased (i.e. supercompensation effect). Although jump data are lacking, a similar effect may have occurred following the statistically significant increases in VL7 in weeks 4-6, and subsequent decreases in weeks 7-13. Additionally, it appears the timing of the peak of supercompensation effect may depend on total accumulated VL and/or length of accumulation.

Given the behavior of these variables, it seems considering accumulated volume load plays an important role in predicting physical performance and monitoring a resistance training process. Future studies should take into consideration not only accumulation of volume load but all other physical activity of athletes. Moreover, additional methods of quantifying volume load should be explored, considering all methods have been shown not to yield the same results (McBride et al., 2009)

CONCLUSION: Longitudinal measurement of CMJ variables may be a viable method of monitoring a resistance training process. Of the mechanical variables examined, it appears that JH and PPa are perhaps most sensitive to changes in resistance training volume. Therefore, practitioners may consider these variables when monitoring to ensure athletes are responding as expected to resistance training.

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