RELATIONSHIP BETWEEN ACCUMULATED VOLUME-LOAD AND RATE OF FORCE DEVELOPMENT IN THE COUNTERMOVEMENT VERTICAL JUMP

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INTRODUCTION: Sport scientists commonly use measures of muscular performance to assess an athlete's state and/or progress during a training process. One such measure popular among practitioners is the countermovement vertical jump (CMJ) (Taylor, Chapman, Cronin, Newton, & Gill, 2012). The criterion performance variable for the CMJ is jump height; however there exist numerous variables used to characterize CMJ performance. Currently there is no agreement among practitioners as to the most important CMJ variable to monitor (Taylor et al., 2012). Therefore, further research is warranted to identify a variable that is both meaningful and sensitive enough to be used in athlete performance monitoring.

Rate of force development (RFD), or the slope of the force-time curve, is a variable found to be directly related to the neural activation of muscle (Komi & Viitasalo, 1976). The ability to exhibit high RFD is referred to as "explosive strength". RFD has been shown to be influenced by both resistance training (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002; Andersen, Andersen, Zebis, & Aagaard, 2010) and neuromuscular fatigue (Molina & Denadai, 2012; Thorlund, Aagaard, & Madsen, 2009). Considering the potential of RFD to reflect both adaptation and fatigue, this variable may prove useful when analyzing CMJs for athlete performance monitoring. Frequently assessing RFD may provide insight into an athlete's response to training variables such as resistance training volume-load (RTVL), a training variable linked to both adaptation and fatigue/recovery (Behm, Reardon, Fitzgerald, & Drinkwater, 2002). Therefore, the purpose of the study was to examine the influence of accumulated RTVL and RFD measured during the CMJ in an attempt to further understand the training dose-response relationship.

METHODS: The participants of this study were nine NCAA Division I women's volleyball players (age: 19.4 ± 0.7 y, height: 176.6 ± 9.2 cm, body mass: 71.2 ± 6.5 kg). All data were collected as part on an ongoing athlete monitoring program. This was study was reviewed and approved by the East Tennessee State University Institutional Review Board.

Countermovement jump testing was held a total of ten occasions over the course of fifteen-weeks. Each testing session was held on the first day of the training microcycle (week), prior to a team resistance training session. Following a standardized warm-up, athletes performed a CMJ specific warm-up consisting of two submaximal CMJs (50 and 75% of perceived maximum effort). To eliminate the use of the arms and only measure lower-body performance, athletes performed all jumps while holding a near-weightless (0.3 kg) plastic bar across the shoulders. Following the specific warm-up, athletes performed two maximal single CMJs. All jumps were performed on a custom-built uniaxial portable force plate (Major, Sands, McNeal, Paine, & Kipp, 1998) sampling at 1,000 Hz. From laboratory calibrations, the voltage data obtained from the force plate were then converted to vertical ground reaction force and force-time curves were constructed. From the force-time curves the following variables were calculated: RFD, jump height (JH), and allometrically-scaled peak force (PFa). RFD was calculated from the slope of the positive impulse. JH was estimated from flight time. Finally, PFa was calculated by dividing the peak ground reaction force by two-thirds body mass. All data collection and analysis were performed using a custom program (LabVIEW, ver. 2010, National Instruments, Austin, TX).

(RTVL) was calculated as the total sets and repetitions multiplied by the mass of the barbell in kilograms. RTVL was calculated for a total of twenty-two weeks including seven weeks of out-of-season training that preceded the fifteen-week examination period. Considering this investigation was held in the midst of an entire training process this period of off-season RTVL (mainly composed of general preparation work) was added to provide perspective. Because the purpose of the study was to determine the influence of accumulated RTVL, the total of RTVL for two weeks preceding each jump testing session was calculated (RTVLacc).

To assess the relationship between VLacc, RFD, PFa, and JH a series of Pearson product-moment zero order correlation coefficients were used. The relationship between RTVLacc and CMJ variables were assessed for each individual athlete (Table 1). Intra-class correlation coefficient and coefficient of variation were used to assess the intra-session reliability of the CMJ variables. During this investigation RFD (ICC= 0.92-0.97, CV=6.8-11.9%), JH (ICC= 0.97-0.99, CV=1.6-2.5%), and PFa (ICC= 0.95-0.99, CV 1.8-3.2%) were found to have acceptable reliability. Statistical analyses were performed using SPSS 22 (IBM, New York, NY) and statistical significance for all analyses was set at $p \leq 0.05$.

RESULTS: Mean values for RFD, JH, PFa, and RTVL were 5,461.94 ± 1,572.21 N·s, 0.37 ± 0.06 m 35.05 ± 3.92 N·kg $^{-0.67}$, 7,847.81 ± 3,245.13 kg respectively. Table 1 displays correlation values for each performance variable by individual athlete.

Table 1: Correlation values for CMJ performance variables by individual athlete

Athlete	RFD	PFa	JH
1	-0.232	-0.192	-0.565
2	0.623	0.678*	-0.508
3	-0.352	-0.512	-0.332
4	-0.364	-0.633*	-0.487
5	0.063	-0.069	-0.586
6	-0.451	-0.432	-0.404
7	-0.364	-0.519	-0.645*
8	0.087	-0.097	-0.697*
9	-0.510	-0.716*	-0.653

*Note. *indicates statistically significant (p≤ 0.05)*

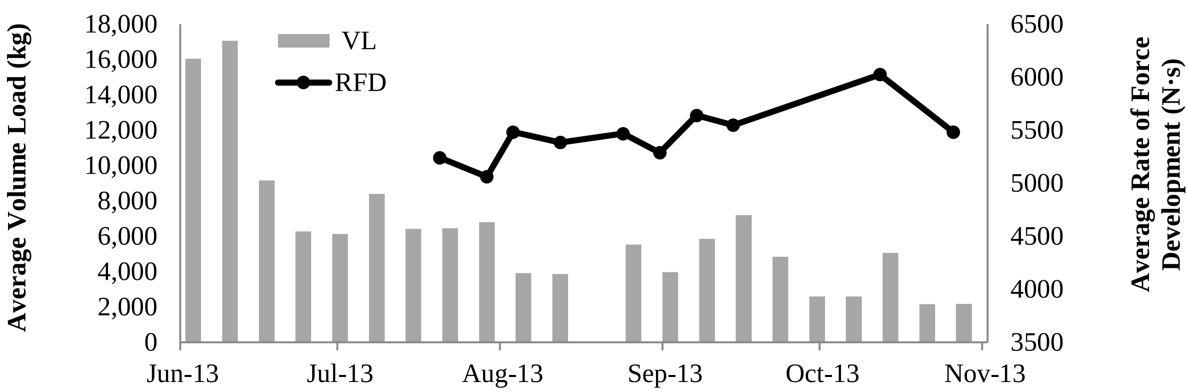

Figure 1. Time-series plot displaying average weekly RTVL and average RFD.
Note: correlations represent RFD data point and the sum of the two preceding RTVL data points.

DISCUSSION: This purpose of this study was to examine the influence of RTVLacc on RFD during the CMJ. In addition to RFD, JH and PFa were included as they are common CMJ performance variables. In general, a negative relationship existed between VLacc and the three variables, meaning that when VLacc was increased, RFD, JH, and PFa decreased. Conversely, an increase in these variables was associated with a lower RTVLacc. When comparing all variables, RFD and PFa displayed the greatest variability in correlation values. Jump height however was least variable (Table 1) including two athletes displaying statistically significant ($p \leq 0.05$) negative correlations. These results would suggest that JH may more strongly reflect RTVLacc as compared to RFD, as measured in the CMJ. In conclusion, CMJ RFD may be a relatively weak diagnostic tool for monitoring athlete's responses to RTVLacc. However, considering the variability of the results between individuals, it is possible that the effectiveness of this variable may be dependent on the individual. Additionally, it must be noted that although RTVL is a crucial variable when assessing training dosage, in many cases such as this study, RTVL represents a small fraction of the overall training-load experienced by athletes. Future studies should seek to establish relationships between CMJ variables and more substantial portions of athlete training-loads such as those experiences during practice and competition.

REFERENCES:

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *J App Phyiol, 93*(4), 1318-1326.

Andersen, L. L., Andersen, J. L., Zebis, M. K., & Aagaard, P. (2010). Early and late rate of force development: differential adaptive responses to resistance training? *Scand J Med Sci Spor, 20*(1), e162-e169.

Behm, D. G., Reardon, G., Fitzgerald, J., & Drinkwater, E. (2002). The effect of 5, 10, and 20 repetition maximums on the recovery of voluntary and evoked contractile properties. *J Strength Cond Res, 16*(2), 209-218.

Komi, P., & Viitasalo, J. (1976). Signal characteristics of EMG at different levels of muscle tension. *Acta Physiol Scandinavica, 96*(2), 267-276.

Major, J. A., Sands, W. A., McNeal, J. R., Paine, D. D., & Kipp, R. (1998). Design, construction, and validation of a portable one-dimensional force platform. *J Strength Cond Res, 12*(1), 37-41.

Molina, R., & Denadai, B. S. (2012). Dissociated time course recovery between rate of force development and peak torque after eccentric exercise. *Clin Physiol Funct I, 32*(3), 179-184.

Taylor, K. L., Chapman, D. W., Cronin, J. B., Newton, M. J., & Gill, N. D. (2012). Monitoring in high performance sport: A survey of current trends. *J Australian Strength Cond, 20*(1), 12-23.

Thorlund, J. B., Aagaard, P., & Madsen, K. (2009). Rapid muscle force capacity changes after soccer match play. *Int J Sport Med, 30*(04), 273-278.