CHANGES IN ISOMETRIC RATE OF FORCE DEVELOPMENT DURING SPECIFIC PHASES OF A BLOCK PERIODIZED TRAINING CYCLE IN WEIGHTLIFTERS

Dylan G. Suarez[1], Kristina P. Ushakova[1], Satoshi Mizuguchi[1], W. Guy Hornsby[2], Michael H. Stone[1]

[1]Center of Excellence of Sport Science and Coach Education, Department of Sport, Exercise, Recreation, and Kinesiology, East Tennessee State University, Johnson City, TN, USA; [2] College of Physical Activity and Sport Sciences, West Virginia University, Morgantown, WV, USA

INTRODUCTION: Competitive success in strength-power sports like weightlifting is highly reliant on an athlete's ability to generate high magnitudes of force during critical timepoints (Kipp et al., 2012; Stone et al., 1998). Weightlifters benefit from only competing a few times per year allowing distinct training phases (e.g., hypertrophy, maximum strength, speed, etc.) to be emphasized throughout the training process. Block periodization serves as a framework for sequentially eliciting these specific adaptations across training phases, culminating in a "peak," where the athlete has the greatest potential of demonstrating a successful performance on the day of competition (DeWeese, et al., 2015). Training in such a manner can benefit from a monitoring program that gives insight into whether the desired kinetic adaptations to a training phase are actually occurring, and to the extent at which they occur in different athletes.

The isometric mid-thigh pull (IMTP) is a relatively quick, safe, and less fatiguing alternative to using one-repetition maximum tests to monitor strength. Both the strength and explosiveness of the athlete can be monitored by measuring isometric peak force (PF) and rate of force development (RFD) (Beckham et al., 2013; Stone et al., 2005). Monitoring changes in these variables also provides the ability to examine individual performance alterations in response to a program without substantially disrupting the training. Additionally, associations have been observed between these variables and the ability to express strength and power in dynamic sporting performances (Beckham et al., 2013; Haff et al., 2005; Hornsby et al., 2017).

Hornsby et al. (2017) reported that RFD showed a superior sensitivity compared to PF for detecting fatigue and training strain associated with changes in volume load. The sensitivity of RFD is strongly influenced by neural factors that are highly dependent on changes made to the training emphasis (e.g., hypertrophy to strength, strength to power, etc.) (Maffiuletti et al., 2016). Previous research suggests that various training strategies may also potentially affect RFD time bands differently (Andersen et al., 2010; Blazevich et al., 2008). Low volume, high-intensity resistance training has been shown to elicit superior improvements in all RFD variables measured when compared to high volume, moderate intensity training (Mangine et al., 2016). However, changes in early RFD time bands (<100ms) have been more closely associated with improvements in neural function (Maffiuletti et al., 2016) and shifts in fiber type (Andersen et al., 2010) making them especially important to monitor during peaking phases. Therefore, the aim of this study is to examine the influence of three distinct training phases on IMTP measures in a population of well-trained weightlifters.

METHODS: Pre- and post-block IMTP monitoring data from eleven collegiate weightlifters (6 males and 5 females: 22±3 y; 75±16 kg; 165±8 cm) was used for analysis. Isometric peak force for males and females was 6587±1158 N and 4348±569 N, respectively. All athletes were familiar with the testing procedures and the data was collected as a part of an ongoing athlete monitoring program. The study was approved by the University's Institutional Review Board.

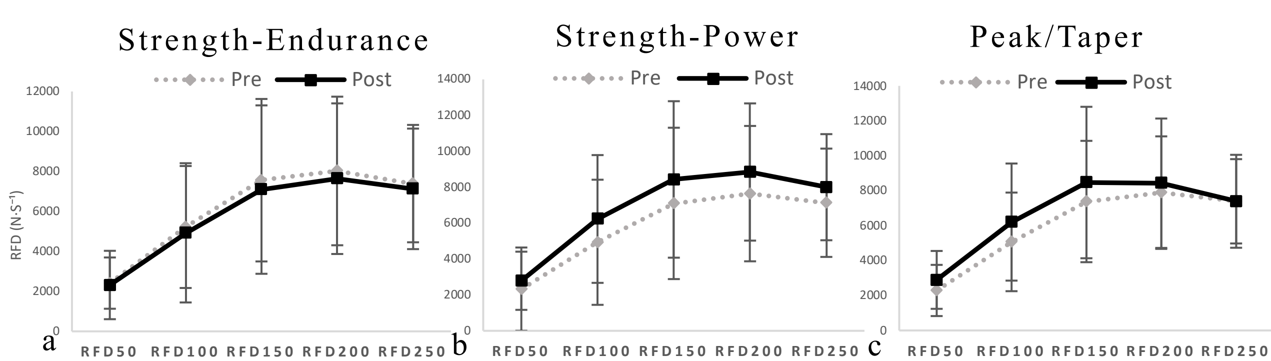
The athletes followed a training program using block periodization and were supervised by national level weightlifting coaches for all sessions. Due to differences in the timing and duration of the athlete's macrocycles pre- and post-block, monitoring results from just three distinct phases for each athlete were selected for comparison. The first training phase was the initial block of the cycle that consisted of high volumes of low to moderate relative intensities, termed a *strength-endurance* phase (SE). The second phase of training was the following block which consisted of more moderate volumes at higher intensities, termed a *strength-power* phase (SP). The final phase selected was the very last block of the macrocycle which began with a sharp increase in volume (planned overreach), followed by a three-week taper termed, a *peak/taper phase* (PT). In total five timepoints for each of the 11 athletes were used in order to compare the pre- to post-block changes of the three phases.

Isometric mid-thigh pull testing for the first and last time point (T1 and T5) took place 3-5 days after a major competition in an attempt to allow dissipation of fatigue from the competition as well as traveling back to the training site. The remaining testing timepoints (T2-T4) were conducted on the first day of each block >24 hours after the last training session and often after a planned reduced training week. Athletes were required to pass a hydration test (urine specific gravity <1.020) before beginning any testing sessions followed by a standardized warm-up routine. Isometric mid-thigh pull testing was conducted as previously described (Kraska et al., 2009). The mean of the best two attempts for measures of PF and RFD from 0-50ms (RFD50), 0-100ms (RFD100), 0-150ms (RFD150), 0-200ms (RFD200), and 0-250ms (RFD250) were taken from each testing.

Statistics: A 5x5 (testing x RFD time band) repeated measures analysis of variance (ANOVA) was performed ($p \leq 0.05$). Effect estimates such as percent changes, effect sizes (Cohen's d), and visual representations are reported to relay trends and small changes that are important to advanced athletes. Effect sizes were interpreted using the following scale 0.0-0.2 (trivial); 0.2-0.6 (small); 0.6-1.2 (moderate); 1.2-2.0 (large) (Hopkins et al., 2009). All statistical analyses were done using SPSS 25.0 (IBM Corp., Armonk, NY, USA) and Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA).

RESULTS: A repeated measures ANOVA revealed no statistically significant ($p \geq 0.05$) effects of testing on any of the variables measured. Although effects sizes were trivial (d = 0.06-0.11), all IMTP variables decreased from T1-T2. From T2-T3 there was a trivial increase in PF (d = 0.13) as well as small increases in all RFD time bands (d = 0.28-0.37). Between T3-T4 there was a trivial decrease in PF (0.05) and small decreases in RFD (d = 0.22-0.36). From T4-T5 there was small (d = 0.28-0.39) increases in the earlier (<150ms) RFD time bands, a trivial increase (d = 0.16) in RFD200, no effect (d = 0.00) on RFD250, and a trivial decrease (d = 0.11) in PF.

FIGURE 1. Phase specific changes in rate of force development. * All data are represented as mean ± SD.



When comparing the post block values from each phase to pre-training cycle values (Table 1), the largest increase in RFD200 (d = 0.22) and RFD250 (0.22) occurred post SP phase, while the peak in RFD50 (d = 0.32), RFD100 (d = 0.31), and RFD150 (d = 0.22) occurred after the PT phase. Additionally, when examining the changes in variables individually PF and RFD250 seemed to be the least sensitive measures while RFD100 displayed the most change throughout the training cycle.

TABLE 1. Comparison of each timepoint to pre-training cycle values

	T1-T2	T1-T3	T1-T4	T1-T5
PF %**Δ**	-3±14	-5±7	-1±9	-1±14
PF d	0.11	0.03	0.02	0.12
RFD50 %**Δ**	-9±31	22±24	-1±66	25±55
RFD50 d	0.06	0.25	0.09	0.32
RFD100 %**Δ**	-11±29	24±10	20±115	38±96
RFD100 d	0.09	0.30	0.05	0.31
RFD150 %**Δ**	-8±34	15±2	15±87	29±91
RFD150 d	0.11	0.21	0.05	0.22
RFD200 %**Δ**	-3±34	10±8	9±56	19±70
RFD200 d	0.10	0.22	0.04	0.11
RFD250 %**Δ**	-1±31	6±8	8±41	12±57
RFD250 d	0.09	0.20	0.00	0.00

*PF = peak force, RFD = rate of force development, %**Δ** = percentage change, d = effect size; T1 = pre, T2 = post strength- endurance, T3 = post strength-power, T4 = pre peak/taper, T5 = post peak/taper*

DISCUSSION: In applied sport science settings monitoring tools such as the IMTP are most often used to observe individual responses to training. Therefore, it is important to mention that not all athletes responded the same to each training phase. The trend for decreases in RFD post SE phase was seen in just seven out of the eleven athletes, while the other four displayed increases. After both the SP and PT phase, eight athlete's RFD values increased however three decreased. Although none of the group changes reached statistical significance, the overall trends in the SE (Figure 1a) and SP (Figure1b) phases responded as would be expected, but the PT phase (Figure 1c) resulted in increases only in the early RFD time bands. A possible explanation for not seeing corresponding increases in all variables after the PT phase may have been caused by lasting fatigue from competing and traveling just days before the final testing session, as well as possible changes in motivation and arousal. It is likely that the highest results for each variable could have been found on the day of the competition when the peak was specifically designed to occur. Still, increases in RFD50, RFD100, and RFD150 were observed after the PT phase leading to the possibility that a taper may have unique effects on earlier RFD time bands.

Based on the results of this study, it appears that changes in IMTP RFD may reflect the expected adaptations of block periodization making it an effective monitoring tool for examining whether the desired adaptations to a specific block of training are actually occurring in well-trained weightlifters. Additionally, it may be important to measure RFD across multiple time bands especially during a tapering period where changes in early and late RFD may not occur proportionally.

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