THE TIME COURSE OF RECOVERY FROM A MESOCYCLE OF PERIODIZED PLYOMETRIC TRAINING

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This study evaluated the effectiveness of a mesocycle of periodized plyometric training and the influence of the duration of the post training recovery period. All subjects' countermovement jump height, peak power, and body mass were assessed with a force platform prior to and 2, 4, 6, 8, and 10 days after training. Jump height was 25.0% greater ($p \leq 0.05$) after training with no difference ($p > 0.05$) between the recovery periods of 2, 4, 6, 8, or 10 days. Peak power was 11.6 to 14.3 % greater ($p \leq 0.001$) after training for the training group with no difference ($p > 0.05$) between recovery periods of 2, 4, 6, 8, or 10 days. Periodized plyometric programs with decreasing volume and increasing intensity improve jump performance without a need for a post training recovery period.

KEYWORDS: jump training, stretch shortening cycle, taper, rest, fatigue

INTRODUCTION: The positive effect of plyometric training on jumping performance has been well established in the literature (Markovic, 2007). However, the specifics of plyometric program design remain unclear. The systematic use of periodization, as well as the related concepts of the training taper (Bosquet et al., 2007) and post training recovery period (Weis et al., 2003), is well established for some training modalities such as strength training and may also be applied to plyometric program design.

Key features of periodized programs such as a systematic decrease in volume or increase in exercise intensity are not used in many plyometric training studies (Markovic, 2007). Nonetheless, some studies demonstrate small to moderate improvement in countermovement jump height (Chimera, et al., 2004; Fatouros et al., 2000; Gehri, et al., 1998) and power (Fatouros et al., 2000). In some cases, countermovement jump height and power did not improve, or even decreased, when testing was performed immediately after training, and only improved after a period of recovery (Luebbers et al., 2003). Thus, recovery from the plyometric training stimuli seems important.

Popular literature includes recommendations for the increase in plyometric intensity and decrease volume (Potach and Chu, 2008), though the specifics for doing so remain unclear. Previous plyometric research has begun to quantify the intensity of plyometric exercises (Ebben et al., 2008; Jensen and Ebben, 2007) and recommendations have been made for the development of periodized plyometric programs (Jensen and Ebben, 2007).

The training taper prior to competition is related to periodization in that each share the goal of reducing training volume in order to maximize performance. Performance of a variety of exercise modes may be optimized with a 41-60 percent reduction in training volume (Bosquet et al., 2007). Two studies specifically compared a no training recovery period to a period of reduced volume taper demonstrating superior performance in torque, strength, and power with tapering than with a non training recovery period of 10 days (Gibala, et al., 1994) or 4 weeks (Izquierdo et al., 2007).

To date, the application of periodization to plyometric training programs and the value of periodization and/or post training recovery has not been investigated. The purpose of this study is to evaluate the effect of a mesocycle of periodized plyometric program and the duration of the post training recovery period that optimizes jump height and peak power during the countermovement jump.

METHODS: Fourteen women served as training subjects (mean ± SD, age 19.29 ± 0.91 yr; body mass 62.56 ± 7.24 kg; height 167.19 ± 6.51 cm). Controls included 10 women (mean ± SD, age 19.5 ± 1.18 yr; body mass 60.41 ± 7.93 kg; height 163.45 ± 6.50 cm). Body mass was assessed for all test sessions and a repeated measures ANOVA showed no change for the training or control groups across any of the test sessions as described in Table 1. The subjects were informed of the risks associated with the study and provided informed written consent. The study was approved by the institution's internal review board.

Prior to all testing and training sessions, subjects warmed up and performed dynamic stretching exercises and 5 countermovement jumps of increasing intensity. All training and control group subjects were instructed to refrain from physical activity during the 6 week training period which was confirmed via analysis of subject activity logs.

Subjects participated in a pre-training testing session and five post training testing sessions. The post training testing sessions were performed 2, 4, 6, 8, and 10 days after the 6 week training program for training subjects, and 6 weeks after the pre test for the control subjects. The pre training and post training testing sessions consisted of 3 repetitions of the countermovement jump.

Subjects were randomly assigned to either a non-training control or plyometric training group. The plyometric group trained twice per week with 48 to 96 hours recovery between training sessions. The program was periodized consistent with previous recommendation for decreasing volume and increasing plyometric intensity (Potach and Chu, 2008). The volume was reduced by 40 percent from a high of 100 foot contacts early in the program to 60 foot contacts near the end of the program. This degree of volume reduction is consistent with the results of a meta-analysis showing performance is optimized with this degree of training volume reduction (Bosquet et al., 2007). The total volume of the plyometric program was 475 foot contacts. The intensity of the plyometric exercises was determined based on previous research examining ground reaction forces, knee joint reaction forces, and muscle activation (Ebben et al., 2008; Jensen and Ebben, 2007). Subjects rested approximately 30 seconds between sets and 15 seconds between single jumps. The recovery duration between reps and sets was chosen based on previously recommended work to rest ratios of at least 1:5 (Potach and Chu, 2008), research showing that there is no advantage in jump performance with more than 15 seconds rest between repetitions (Read and Cisar, 2001).

The countermovement jump tests were assessed with a 60 x 120 cm force platform (BP6001200, Advanced Mechanical Technologies Inc., Watertown, MA). The force platform was calibrated with known loads to the voltage recorded prior to the testing session. Kinetic data were collected at 1000 Hz, real time displayed, and saved with the use of computer software (BioAnalysis 3.1, Advanced Mechanical Technologies, Inc., Watertown, MA) for later analysis. Jump height and peak power were analyzed since these variables are frequently used to assess countermovement jump performance (Canavan and Vescovi, 2004, Moir, 2008). Jump height was calculated from the force-time records consistent with methods previously used (Moir, 2008). Peak power was calculated using the equation proffered by Canavan and Vescovi (2004).

Data were analyzed with SPSS 17.0 using a repeated measures ANOVA with Bonferroni adjusted pairwise comparison in order to identify the specific differences in jump height, peak power, and body mass between the pre-training baseline testing and testing sessions performed at 2, 4, 6, 8, and 10 days after training. The reliability of the trials was assessed using intraclass correlation coefficient (ICC), for each of the dependent variables for the pre-training and last post-training testing session. Assumptions for linearity of statistics were tested and met. Statistical power (d) and effect size (η_p^2) are reported and all data are expressed as means ± SD. The *a priori* alpha level was set at $p \leq 0.05$.

RESULTS: Results revealed significant main effects for countermovement jump height ($p \leq 0.001$, $d = 0.98$, $\eta_p^2 = 0.41$) and peak power ($p \leq 0.001$, $d = 1.00$, $\eta_p^2 = 0.56$), but not for body mass ($p > 0.05$), between test sessions, for the subjects in the plyometric training group. Post hoc analysis demonstrated that jump height and peak power were different between the pre-training testing session and all post training testing sessions, with no difference between any of the post training testing sessions. Results of post hoc analysis are shown in Table 1. No significant main effects were found, demonstrating no differences in countermovement jump height ($p > 0.05$), peak power ($p > 0.05$), or body mass ($p > 0.05$) between testing sessions, for subjects in the control group. Interclass correlation coefficients were calculated for the training subjects and controls for the countermovement jump height and power with all values ranging between 0.84 and 0.99.

Table 1. Training (N=14) and control (N=10) group jump height (cm) and power (W), each expressed as mean ± SD prior to training and 2, 4, 6, 8, 10 days post training

	Training Group		Control Group	
	Jump height	Power**	Jump Height	Power
Pre training	0.21 ± 0.08	1810.98 ± 323.76	0.25 ± 0.06	1861.23 ± 428.68
2 days post training	0.28 ± 0.03*	2053.13 ± 305.18**	0.25 ± 0.05	1874.41 ± 452.45
4 days post training	0.28 ± 0.03*	2048.80 ± 331.21**	0.25 ± 0.05	1929.07 ± 455.42
6 days post training	0.28 ± 0.03*	2073.83 ± 283.51**	0.25 ± 0.05	1910.06 ± 470.26
8 days post training	0.28 ± 0.04*	2088.16 ± 314.65**	0.25 ± 0.05	1938.12 ± 428.33
10 days post training	0.28 ± 0.04*	2076.36 ± 320.60**	0.25 ± 0.05	1931.24 ± 410.17

*Significantly different from the pre training value ($p \leq 0.05$)

**Significantly different from the pre training value ($p \leq 0.01$)

DISCUSSION: This study demonstrates that a mesocycle of periodized plyometric training produces substantial improvement in vertical jump height and peak power. The length of the post training recovery period does not influence jump performance, presumably due to the tapering inherent in periodized plyometric training. Thus, the performance of the subjects was optimal within 2 days of training and performance adaptations were sustained for at least 10 days after training.

This performance increases in this study were greater than those that demonstrated either no increase in countermovement jump height (Vescovi, et al., 2008) or increases that ranged from 2.8 to 10.2 % (Chimera et al., 2004, Fatouros et al., 2000, Gehri et al., 1998, Markovic et al., 2007). In the present study, the periodized program design including exercises of known increasing intensity (Ebben et al., 2008; Jensen and Ebben, 2007) and decreasing training volumes in the recommended range (Potach and Chu, 2008) were more optimal compared to other studies. Most other plyometric programs used no systematic increase in exercise intensity or decrease in volume. In fact, some studies included plyometric volumes that increased up to 480 foot contacts per session over the course of the training program (Chimera et al., 2004).

Results of this study confirm that tapered programs with a 41-60 % decline in volume, enhances performance (Bosquet et al., 2007). The present study showed that performance improved with no difference between recovery periods of 2, 4, 6, 8, or 10 days, indicating that periodized programs may peak athletes after training and prior to competition without the need for a post training recovery phase.

Previous research comparing a non-training recovery period to a tapering period of reduced volume demonstrated superior performance in strength and power measures after training with reduced volume tapering than with a non-training recovery period of 10 days (Gibala, et al., 1994) or 4 weeks (Izquierdo et al., 2007). Thus, results of the present study add to the body of literature indicating that systematic volume reduction, and not a non-exercising recovery period, may be more ideal for performance enhancement.

Results of the present study call into question the previously held belief that training programs should be longer than 10 weeks to be highly effective (De Villarreal et al., 2009).

CONCLUSION: The present study demonstrates that a brief, moderate volume periodized mesocycle of plyometric training produces large improvements in countermovement jump compared to the pretest performance, without the need for and regardless of the length of the recovery period at the end of the training cycle.

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