Distinct Temporal Organizations of the Strength- and Power-Training Loads Produce Similar Performance Improvements

Irineu Loturco,1,2,3 Carlos Ugrinowitsch,2 Hamilton Roschel,2 Alan Lopes Mellinger,4 Filipe Gomes,4 Valmor Tricoli,2 and Juan José Gonzáles-Badillo1

1Faculty of Sport, Pablo de Olavide University, Seville, Spain; 2School of Physical Education and Sport, University of São Paulo, São Paulo, SP, Brazil; 3Pão de Açúcar Group—Nucleus of High Performance in Sport, São Paulo, SP, Brazil; and 4Special Operations Brigade, Brazilian Army, Brazil

ABSTRACT

Loturco, I., Ugrinowitsch, C., Roschel, H., Lopes Mellinger, A., Gomes, F., Tricoli, V., and Gonzáles-Badillo, JJ. Distinct temporal organizations of the strength- and power-training loads produce similar performance improvements. J Strength Cond Res 27(1): 188–194, 2013—This study aimed to compare the effects of distinct temporal organizations of strength and power training loads on strength, power, and speed improvements. Sixty soldiers with at least 1 year in the army volunteered for this study. The subjects were divided into 4 groups: control group (CG: n = 15; age: 20.18 ± 0.72 years; height: 1.74 ± 0.06 m; and weight: 66.7 ± 9.8 kg); successive-mesocycle group (SMG: n = 15; age: 20.11 ± 0.7 years; height: 1.72 ± 0.045 m; and weight: 63.1 ± 3.6 kg); successive-week group (SWG: n = 15; age: 20.36 ± 0.64 years; height: 1.71 ± 0.05 m; and weight: 66.1 ± 8.0 kg); and simultaneous daily group (SDG: n = 15; age: 20.27 ± 0.75 years; height: 1.71 ± 0.068 m; and weight: 64.0 ± 8.8 kg). In the SMG, heavy resistance training (HRT), jump squat (JS), and countermovement jump (CMJ) were performed in successive mesocycles of 3 weeks each. In the SWG, HRT, JS, and CMJ were trained in 1-week blocks into 3 mesocycles of 3 weeks each. In the SDG, HRT, JS, and CMJ were trained daily in all the 3 mesocycles of 3 weeks each. Total volume was equalized between groups. The following dependent variables were analyzed: squat 1RM, CMJ height, 20-m sprint speed, mean power, and mean propulsive power in the squat exercise (60% of the squat 1RM) and in the JS (45% of the squat 1RM). Significant improvements for all the dependent variables were detected from pretraining to posttraining in all the training groups (p ≤ 0.05), without any between-group differences.

Address correspondence to Irineu Loturco Filho, irineu.loturco@terra.com.br.

27(1)/188–194
Journal of Strength and Conditioning Research © 2013 National Strength and Conditioning Association

Our data suggest that the temporal organization of the training load is not critical for performance improvements in this population.

KEY WORDS periodization, squat, plyometrics, jumps

INTRODUCTION

The ability of the neuromuscular system to produce force and power is critical for optimal performance in several sports. As a consequence, researchers have attempted to identify the most appropriate training methods for strength development. Heavy resistance training (HRT), jump squat (JS), and countermovement jump (CMJ) have been described as effective training methods to achieve such goals (14,16,21). Even though a significant amount of research has been dedicated to identify the effects of these methods on performance, less attention has been devoted to understanding the effects of their temporal sequencing within a training program. For instance, several authors have suggested that resistance training should be combined with power training in the same training unit (i.e., complex training) to maximize performance gains (2,8,10).

Accordingly, several authors have reported acute increments in power production when using complex-training units (4,24), in which strength and power exercises are performed within a training unit (i.e., period of time in which training exercises are performed). Therefore, the theory behind the chronic application of complex training relies on a classic exercise physiology paradigm in which the summation of the acute effects produced by each training unit determines the magnitude of the chronic effect of a training program (5). However, no study has attempted to ascertain if using a complex-training regimen over a few mesocycles produces greater performance improvements when compared with distributed training loads.

For instance, a traditional distributed training schedule usually develops a strength foundation (i.e., muscle force production capacity) in the initial phase of the macrocycle,
whereas the power production capacity is emphasized later into the cycle (11). Under this schedule, HRT loads should be followed by progressive lighter resistances and higher-velocity training loads (i.e., HRT, JS, and CMJ). Nonetheless, knowledge about the most appropriate schedule for distributing training loads with distinct orientations along a macrocycle is also equivocal. For example, reports describing if a successive training-load pattern over longer training periods of time (i.e., a mesocycle) is advantageous over weekly changes (i.e., a microcycle) are still scarce. Changing the training content every microcycle may be advantageous over mesocycle changes because it may decrease the probability of detraining (12). Heavy strength training could decrease power production capacity if the latter motor ability is not trained for long periods of time.

On the other hand, several authors have suggested that the total work is the most important variable for producing training adaptations. Candow and Burke (7) reported similar increases in performance and morphological adaptations when the same total volume of resistance training was distributed over a different number of training sessions per week (i.e., twice a week vs. 3 times a week), in untrained individuals. These findings contradict the concept that the temporal organization of training loads with different orientations (i.e., complex or successive training-load schedule) is relevant for performance improvements (18). Therefore, this study aimed at comparing if distinct temporal organizations of strength and power loads equated for total volume differently affect improvements in strength, power, and speed abilities. Based on unpublished data from our laboratory, we hypothesized that the equalization of the total work performed is more important than the temporal sequence of the training load for performance improvements.

**METHODS**

**Experimental Approach to the Problem**

We used 3 training schedules to test if the sequence that HRT, JS, and CMJ is introduced into the training program affects the improvements in functional performance and muscle power production capacity over a 9-week training period, when the total volume is equalized between schedules. In the first protocol, HRT, JS, and CMJ were performed each in separate and successive mesocycles of 3 weeks. In the second protocol, HRT, JS, and CMJ were trained in 1-week microcycles (i.e., week 1: HRT; week 2: JS; week 3: CMJ), in 3 mesocycles of 3 weeks each. Finally, in the third protocol, HRT, JS, and CMJ were trained daily in 3 mesocycles of 3 weeks each.

Back squat exercise 1RM, CMJ height, 20-m sprint average speed were assessed at 0-, 3, 6-, and 9-week time points to track the changes in the functional status of the individuals at the end of each mesocycle and over the whole training period (21). Mean power (MP) and mean propulsive power (MPP) both in the high velocity back squat (60% of the 1RM load) and in the JS (45% of the squat 1RM load) were measured at 0- and 9-week time points to assess lower limbs power production capacity and the ability to accelerate an external load in both exercises (19). Back squat 1RM load was determined 48 hours before the high-velocity squat, JS, CMJ height, and 20-m sprint tests. Similar improvements in functional status and lower limbs power production capacity between the training schedules would suggest that the total work is more important to performance improvements than the temporal distribution of the loads. Figure 1 depicts the sequence of events over the 9-week period.

**Subjects**

Sixty male soldiers of the Brazilian special operations brigade with at least 1 year on the army volunteered for this study. The subjects were divided into a control group (CG: n = 15, age: 20.18 ± 0.72 years, height: 1.74 ± 0.06 m, and weight: 66.7 ± 9.8 kg); a successive-mesocycle group (SMG: n = 15, age: 20.11 ± 0.7 years, height: 1.72 ± 0.045 m, and weight: 63.1 ± 3.6 kg); a successive-week group (SWG: n = 15, age: 20.36 ± 0.64 years, height: 1.71 ± 0.05 m, and weight: 66.1 ± 8.0 kg); and a simultaneous daily group (SDG: n = 15, age: 20.27 ± 0.75 years, height: 1.71 ± 0.068 m;
<table>
<thead>
<tr>
<th></th>
<th>Wk-1</th>
<th>Wk-2</th>
<th>Wk-3</th>
<th>Wk-4</th>
<th>Wk-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMG</td>
<td>Squat</td>
<td>Squat</td>
<td>Squat</td>
<td>Squat</td>
<td>Squat</td>
</tr>
<tr>
<td>Test 1</td>
<td>3 Sessions</td>
<td>3 Sessions</td>
<td>3 Sessions</td>
<td>Test 2</td>
<td>Jump squat</td>
</tr>
<tr>
<td></td>
<td>(S1)(3 x 8/50%)</td>
<td>(S1)(3 x 6/60%)</td>
<td>(S1)(3 x 5/70%)</td>
<td>(S1)(3 x 6/30%)</td>
<td>(S1)(3 x 5/45%)</td>
</tr>
<tr>
<td></td>
<td>(S2)(3 x 8/50%)</td>
<td>(S2)(3 x 6/60%)</td>
<td>(S2)(3 x 5/70%)</td>
<td>(S2)(3 x 6/30%)</td>
<td>(S2)(3 x 5/45%)</td>
</tr>
<tr>
<td></td>
<td>(S3)(3 x 8/50%)</td>
<td>(S3)(3 x 6/60%)</td>
<td>(S3)(3 x 5/70%)</td>
<td>(S3)(3 x 6/30%)</td>
<td>(S3)(3 x 5/45%)</td>
</tr>
<tr>
<td>SWG</td>
<td>Jump squat</td>
<td>CMJ</td>
<td>Test 3</td>
<td>Squat</td>
<td>Jump squat</td>
</tr>
<tr>
<td>Test 1</td>
<td>3 Sessions</td>
<td>3 Sessions</td>
<td>3 Sessions</td>
<td>3 Sessions</td>
<td>Test 4</td>
</tr>
<tr>
<td></td>
<td>(S1)(3 x 8/50%)</td>
<td>(S1)(3 x 6/60%)</td>
<td>(S1)(3 x 5/70%)</td>
<td>(S1)(3 x 6/30%)</td>
<td>(S1)(3 x 5/45%)</td>
</tr>
<tr>
<td></td>
<td>(S2)(3 x 8/50%)</td>
<td>(S2)(3 x 6/60%)</td>
<td>(S2)(3 x 5/70%)</td>
<td>(S2)(3 x 6/30%)</td>
<td>(S2)(3 x 5/45%)</td>
</tr>
<tr>
<td></td>
<td>(S3)(3 x 8/50%)</td>
<td>(S3)(3 x 6/60%)</td>
<td>(S3)(3 x 5/70%)</td>
<td>(S3)(3 x 6/30%)</td>
<td>(S3)(3 x 5/45%)</td>
</tr>
<tr>
<td>SDG</td>
<td>Squat</td>
<td>Squat</td>
<td>Squat</td>
<td>Squat</td>
<td>Squat</td>
</tr>
<tr>
<td>Test 1</td>
<td>3 Sessions</td>
<td>3 Sessions</td>
<td>3 Sessions</td>
<td>3 Sessions</td>
<td>Test 4</td>
</tr>
<tr>
<td></td>
<td>(S1)(3 x 8/50%)</td>
<td>(S1)(3 x 6/60%)</td>
<td>(S1)(3 x 5/70%)</td>
<td>(S1)(3 x 6/30%)</td>
<td>(S1)(3 x 5/45%)</td>
</tr>
<tr>
<td></td>
<td>(S2)(3 x 8/50%)</td>
<td>(S2)(3 x 6/60%)</td>
<td>(S2)(3 x 5/70%)</td>
<td>(S2)(3 x 6/30%)</td>
<td>(S2)(3 x 5/45%)</td>
</tr>
<tr>
<td></td>
<td>(S3)(3 x 8/50%)</td>
<td>(S3)(3 x 6/60%)</td>
<td>(S3)(3 x 5/70%)</td>
<td>(S3)(3 x 6/30%)</td>
<td>(S3)(3 x 5/45%)</td>
</tr>
</tbody>
</table>

*SMG = successive-mesocycle group; SWG = successive-week group; SDG = simultaneous daily group; CMJ = countermovement jump; S1 = session 1; S2 = session 2; S3 = session 3.
and weight: 64.0 ± 8.8 kg). The subjects followed a 5-day on and 2-day off routine in the army living quarter. Besides the experimental training protocol, the subjects performed regular army training (i.e., aerobic exercise—2 week⁻¹, calisthenics—3 week⁻¹, and strength-endurance circuit training—2 week⁻¹) and took the special operations-military coursework. We assumed no differences between groups for nutritional status and macronutrient ingestion, and training time schedule because the subjects were from the same company, and performed all the daily tasks together. The subjects were informed of the experimental risks, and they signed an informed consent form before the investigation. The investigation was approved by an Institutional Review Board for use of human subjects.

Back Squat 1-Repetition Maximum Test

The 1RM test was performed as follows: the participants ran for 5 minutes on a treadmill (Movement Technology, Brudden, São Paulo, Brazil) at 9 km·h⁻¹, followed by 5 minutes of lower limb stretching exercises. Then, they performed 2 parallel back squat warm-up sets. In the first set, the participants performed 5 repetitions with 50% of the estimated 1RM, and in the second set, they performed 3 repetitions with 70% of the estimated 1RM. A 3-minute resting interval was allowed between sets. Three minutes after the warm-up, the participants had up to 5 attempts to obtain the 1RM load (e.g., maximum weight that could be lifted once using proper technique), with a 3-minute interval between attempts (6). Strong verbal encouragement was given throughout the test.

Mean Power and Mean Propulsive Power in the Back Squat Exercise

The subjects were instructed to perform 2 sets of 3 repetitions of the parallel back squat exercise with maximal speed at 60% of the 1RM load in a Smith machine. A linear transducer (T-force, Dynamic Measurement System, Ergotech Consulting S.L., Murcia, Spain) was attached to the Smith machine bar. Bar position data were sampled at a frequency of 1,000 Hz and recorded into a computer. Finite differentiation technique was used to estimate the bar velocity and acceleration. The MP and the MPP on each
repetition of the back squat exercise were obtained multiplying the average force by the average speed, over the entire concentric phase (MP) and positive acceleration region of the concentric phase (MPP), respectively (19).

Mean Power and Mean Propulsive Power in the Jump Squat

This test was performed following the same basic procedures (i.e., number of sets and repetitions) described for the previous test. The subjects were instructed to start from a static squat position (i.e., ~90° of knee flexion) and jump as high as possible without losing contact with the bar, using a load corresponding to 45% of the squat 1RM. Mean power and MPP in the jump squat (MPJ and MPPJ, respectively) were calculated as previously described.

Countermovement Jump Height

The subjects were instructed to maintain their hands on their waist and freely determine the amplitude of the countermovement to avoid changes in jumping coordination (22). They performed 5 jumps with a 15-second interval between attempts. The jumps were executed in a contact platform (Winlaborat, Buenos Aires, Argentine). The best and the worst jumps were discarded, and the average of the remaining jumps was used for data analysis purpose.

20-m Sprint Test

Two pairs of photocells were used to mark a 20-m distance. The subjects accelerated as much as possible for 5 m before crossing the first pair of photocells. They had 2 attempts, and the best one was considered for further analysis.

Training Protocols

The training protocols were composed of regular parallel back squat exercises, JS starting from approximately 90° of knee flexion (i.e., concentric phase only), and CMJ with hands on the waist and autoadjusted countermovement amplitude. The total volume was equated across the training groups. Table 1 depicts the training protocol for each group over the 9-week period.

Statistical Analyses

Data normality was assessed through visual inspection and the Shapiro-Wilk test. All the variables presented a normal distribution. Mixed models having group (i.e., CG, SMG, SWG, and SDG) and time (i.e., pre and post) as fixed factors and subjects as a random factor were used to test for differences in training schedules induced changes in back squat 1RM, CMJ height, and 20-m sprint speed analyses. An initial analysis using a 1-way analysis of variance revealed between-group differences in the initial values for both the MP and MPP in the 60% 1RM high-velocity squat and 45% 1RM JS. Thus, a number of mixed models having groups as a fixed factor, subjects as a random factor, and pretest values of MP and MPP obtained in both in the 60% 1RM high-velocity squat, and 45% 1RM JS were used as covariates for these variables analyses and to test for differences between training schedules in the posttest. The assessment of all these dependent variables is routine in our laboratory, and the interday coefficients of variability between measurements are <5%. In the case of significant F-values, a Tukey adjustment was used for multiple comparison purposes. Significance level was set at \( p \leq 0.05 \).

RESULTS

The SMG, SWG, and SDG significantly increased the back squat 1RM from the previous to next time points \( (p \leq 0.05) \) (Figure 2). Importantly, the increments in the squat 1RM were similar between training groups after the 9-week training period (i.e., SMG: 24.6%; SWG: 25.3%; SDG: 26.1%).

The increment in CMJ was more erratic because jumping height did not increase consistently over the training period for any of the experimental groups (Figure 3). However, the increment in jumping height after the 9-week training period was significant and of a similar magnitude between the training groups (i.e., SMG—34.3%, SWG—38.9%, and SDG—39.1%; interaction effect, \( p \leq 0.05 \)).
The 20-m sprint test results presented a similar behavior than those of the back squat 1RM test (Figure 4). All the 3 training groups increased sprint speed on each test when compared to the previous time point (interaction effect, $p \leq 0.05$). The pretest to posttest percent difference in the 20-m sprint test was 15.2, 11.7, and 13.7% for the SMG, SWG, and SDG, respectively.

Mean power and MPP in both the high-velocity back squat and the JS increased from pretest to posttest for all the training groups (analysis of covariance main effect, $p \leq 0.05$) as they were different from the CG (Figures 5A–D).

**Discussion**

We hypothesized that distinct temporal organizations of the strength and power training loads would produce similar performance improvements. The findings reported herein support our hypothesis that the equalization of total work is more important than the temporal distribution of the training loads as the monthly, weekly, and daily distribution of the strength and power training loads produced similar performance improvements.

The training modes used in this study (i.e., HRT, JS, and CMJ) targeted at developing the strength abilities at both ends of the force-velocity curve. For instance, the HRT would increase muscle-force production capacity, whereas the JS and CMJ would enhance the rate of force development and muscle-power production capacity. Even though we did not perform a standard force-velocity curve test (3), our findings support this concept. The training groups significantly improved maximum strength (i.e., back squat 1RM). These increments indicate that the high-force, low-velocity end of the curve was shifted to the right. Additionally, the improvements in sprinting speed (i.e., 20-m sprint test) and power production (i.e., CMJ height and MPP in the squat and in the JS exercises) strongly suggest changes in the high-velocity, low-force end of the curve.

It has been advocated that gains in maximum strength are necessary to build the foundation for subsequent power development. This proposition is based on 2 factors: (a) morphological adaptations take longer to occur than neural and physiological ones (13); (b) there is a lag time between the strength development and the detection of changes in performance (1). The findings of this study challenge these ideas as all of the training-load distribution regimens improved performance at the same rate (i.e., there were no differences between the training groups throughout the experimental protocol). Additionally, training adaptations do not seem to be as specific as previously reported. For instance, the SMG improved performance at both ends of the force-velocity curve (squat 1RM and 20-m sprint) even when no specific training for power development was performed (i.e., first mesocycle).

Furthermore, the lack of differences between groups in the posttraining tests suggest that the total work performed over a training period may be more important than the temporal distribution of the loads itself. Accordingly, Milahik et al. (17) reported similar improvements in volleyball players’ performance after equated (i.e., same total work load) complex (e.g., strength and power exercises within a training unit) or compound (e.g., strength and power exercises in different training sessions) training regimens. However, it should be emphasized that other studies do not support this suggestion. Regarding strength improvements, Monteiro et al. (18) reported greater gains when using a nonlinear periodization (43.3%), when compared with both a linear and nonperiodized models (13.8 and 8%, respectively). In addition, Maio Alves et al. (15) found that doubling the total volume of a complex training regimen did not produce additional improvements in the 20-m sprint time and CMJ height. The reasons for such differences among studies are not clear. One possible explanation is that researchers standardize the external load among individuals. Thus, it is possible that using external load parameters for training prescription may compromise neuromuscular adaptations and performance increments, because some individuals may train with a nonoptimal training load in research settings. In fact, coaches and trainers usually prescribe individualized loads based on the expected internal load in an actual training setting. It has been shown that experienced coaches can predict the internal load reported by the athletes in the training sessions (23).

The findings of this study also suggest that detraining did not occur throughout the 9-week training period. These results are supported by the constant and similar increments in functional performance variables for all training groups, even when a specific training regimen (i.e., HRT) was not performed in a weekly basis such as for the SMG and SWG schedules. On the other hand, some authors have reported reductions in maximum strength after either training reduction or cessation in trained kayakers (9,20). Similarly, Terzis et al. (20) reported a nonsignificant reduction in 1RM values after 4 weeks of training in healthy young individuals. Thus, our findings suggest that the JS and CMJ training stimuli were efficient in increasing strength levels and detraining should not be considered as an issue when the HRT was discontinued. Accordingly, McBride et al. (16) used light (30% of the squat 1RM) and heavy (80% of the squat 1 RM) loads in an 8-week JS training program for trained individuals. These authors reported increments in maximum strength of 8.2 and 10.2% for the light- and heavy-load groups, respectively. Thus, it is conceivable that HRT is not required to either maintain or increase maximum strength at least for moderately trained individuals.

Nonetheless, caution should be exercised when considering the practical application of our findings. Even though the subjects of this study were members of the Brazilian army special operations brigade, their strength level may be considered low compared to competitive athletes. It is possible that strength-trained athletes are more sensitive to the distribution of the training loads across the training period. Furthermore, the absence of detraining in the SMG and SWG should be carefully considered, because the training period...
Temporal Organization of Strength and Power Training

was relatively short (i.e., 9 weeks). It is reasonable to speculate that detraining may occur under the SMG schedule and longer training periods. Thus, future studies should be performed trying to identify the effects of the training load distribution on performance parameters of high-level athletes.

In summary, our data suggest that moderately trained individuals have similar performance adaptations irrespective of the training load distribution applied.

**Practical Applications**

The findings of this study suggest that the temporal organization (i.e., periodization model) of the training load is not critical, at least for moderately trained individuals, as long as the same total work is performed over the training period. In addition, athletes and physically active individuals do not need to have a maximum strength training phase to achieve peak performance later on in the macrocycle. In fact, strength and power may be trained simultaneously throughout the training period, without hampering performance improvements. Finally, coaches and strength coaches should not be concerned about removing a specific training stimulus (e.g., HRT) for relatively short periods (i.e., ~3 weeks) when other training modes require the expression of strength capabilities such as power production (e.g., JS).

**Acknowledgments**

H.R. is supported by Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP 2010/51428-2). C.U. (470207/2008-6, 303162/2008-2) and V.T. (304814/2010-5) are supported by CNPq.

**References**


