

THE OPTIMAL COMPLEX TRAINING REST INTERVAL FOR ATHLETES FROM ANAEROBIC SPORTS

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ABSTRACT. Comyns, T.M., A.J. Harrison, L.K. Hennessy, and R.L. Jensen. The optimal complex training rest interval for athletes from anaerobic sports. *J. Strength Cond. Res.* 20(3):471–476. 2006.—Complex training research has indicated that 3–4 minutes may be an optimum intracomplex rest interval. The purpose of this study was to determine if a heavy resistive exercise causes performance enhancement of a slow stretch–shortening cycle exercise and if there is an optimal rest interval. Eighteen subjects performed countermovement jumps (CMJs) before and after a 5 repetition maximum back squat lifting protocol. This procedure was repeated 4 times over 2 days using rest intervals of 30 seconds and 2, 4, and 6 minutes. Flight time and peak ground reaction force (GRF) were the dependent variables. All jumps were performed on a specially constructed sledge and force platform apparatus. Repeated measures analysis of variance found a significant reduction in flight time at the 30-second and 6-minute interval ($p < 0.05$). No significant difference was found between men and women. Only the men showed an enhancement in jump performance after the 4-minute interval. The improvement window was different for each subject, and an analysis of the greatest increase and decrease in flight time and peak GRF was conducted, showing a significant decrease for men and women and a significant increase in flight time for men and peak ground reaction force for women. The results suggest that complex training can benefit or inhibit CMJ performance depending on the rest interval. The individual determination of the intracomplex rest interval may be necessary in the practical setting.

KEY WORDS. countermovement jump, stretch–shortening cycle, sledge, resistance exercise, plyometrics

INTRODUCTION

Alternating a high-load resistance exercise with a biomechanically similar plyometric exercise has been referred to as complex training, and it is thought that the resistance exercise will have a performance-enhancing effect on the plyometric exercise (8). Recent research has sought to investigate the optimal rest interval between the strength training and the plyometric training components of complex training (16, 18). This interval has been referred to as the intracomplex rest interval (16). The traditional view, based on anecdotal evidence, is that this rest period should be minimal (8, 21) in order to take advantage of the heightened neural stimulation gained by completing the resistance set. More recently, research has altered this view, and Ebben (6) noted that it may be necessary to take 3–4 minutes' rest between the resistive and plyometric components.

The rest interval used in complex training research has ranged from 10 seconds (16) up to 20 minutes (18). Research examining the effects of the bench press on

force production and motor unit recruitment during the medicine ball power drop using a short rest interval (10 seconds) has shown no enhancement for the plyometric exercise (7, 17). In contrast to this, upper-body complex training research (9) and lower-body research (12, 19, 22) that used intracomplex rest intervals of 3–4 minutes revealed improvement effects for the plyometric exercise. Only one study (16) has specifically investigated the optimal intracomplex rest interval. Jensen and Ebben (16) had subjects perform a countermovement jump (CMJ), a set of 5 repetition maximum (5RM) squats, and 5 trials of CMJ at rest intervals of 10 seconds and 1, 2, 3, and 4 minutes after the squat. Results revealed no significant difference in jump height from presquat to postsquat for any of the rest intervals. The jump performance, however, at the 10 seconds interval was reduced but not significantly. A nonstatistically significant trend of improvement in jump height occurred from 10 seconds up to 4 minutes. This implied that up to 4 minutes might provide optimal intracomplex rest. The authors also found the effect of complex training was similar for men and women as well as athletes with varying strength levels. The study did not isolate each of the rest intervals, although a pilot study found no cumulative learning effects on vertical jump performance due to the consecutive completion of vertical jumps at the different rest intervals. It may still be difficult to know if the improvement trend was due to the 5RM squat or the completion of the postsquat CMJs at the different rest intervals or a combination of both. In addition, the completion of the CMJs at the rest intervals could have had a fatiguing effect and masked any potential improvements. The present study addresses this by having the subjects perform a 5RM squat before each rest interval.

Jones and Lees (18) adopted a similar approach to Jensen and Ebben (16) by manipulating the length of the rest interval. They investigated the effect of 5RM back squatting on CMJs and drop jumps (DJs) that were performed immediately, 3, 10, and 20 minutes post-lifting. While no statistical significance was found, suggesting that complex training did not enhance plyometric performance, it was also noted that no adverse effects occurred. No added benefit existed for conducting the plyometric jumps 20 minutes after the back squatting. Both Jensen and Ebben (16) and Jones and Lees (18) found no performance advantage due to 5RM back squatting. One possible reason for this could be that the improvement window may differ for individuals (3, 4, 12, 20) and thus mask any ergogenic response at the different intervals. The present study accommodated for this by analyzing

the greatest improvement and reduction in the dependent variables' scores compared to the baseline scores regardless of when they occurred.

Past complex training investigations that used CMJs as the test jump (11, 12, 16, 18, 20) have failed to control factors that could contribute to the jump performance. For example, the use of the arms and upper body in a swinging motion during the performance of CMJs could enhance jump height. Some of the studies attempted to control these factors by instructing the subjects to place their hands on their hips during the performance of the jumps (18, 20). These instructions alone cannot fully eliminate the contribution of the arm and upper-body movement to jump height and subsequently to influencing the results of the studies. For these reasons this study used a protocol where the subjects performed all CMJs on a sledge apparatus as described by Harrison et al. (13).

From previous research it would seem that the optimal recovery time between the resistive and plyometric components of complex training is an important factor in ensuring an enhancing effect from the resistive exercise. A short interval may take advantage of the heightened stimulation of the neuromuscular system (8, 21), and this is why past research employed a protocol where the plyometric exercise was performed immediately after the high-load resistance exercise (7, 17). The heavy resistance exercise, however, has a fatiguing effect on the muscles. Adequate rest is needed to allow recovery of the phosphagen system (15). Researchers hypothesize that there is an optimal rest period that allows for partial recovery and utilization of the heightened stimulation of the neuromuscular system. The purpose of this investigation was to assess if there is performance-enhancing response for a slow stretch-shortening cycle (SSC) exercise that is performed after a high-load resistance exercise. Second, it sought to determine if there is an optimal intracomplex rest interval. The effect of complex training for men and women was also evaluated.

METHODS

Experimental Approach to the Problem

This study involved the subjects performing 3 single-legged CMJs on a specially constructed sledge and force platform apparatus before and after a 5RM back squatting protocol. This procedure was repeated using 4 different intracomplex rest intervals. The complex pairs of 5 squats followed by 3 CMJs were completed 4 times over 2 different testing sessions utilizing 4 intracomplex rest intervals of 30 seconds, 2, 4, and 6 minutes. The presquat (baseline) CMJs acted as a control and were compared with the postsquat jumps at the different rest intervals. Independent variables included rest interval and gender. Dependent variables included peak ground reaction force (GRF) and duration of the airborne phase (flight time, FT) during the test jump (CMJ). To investigate if the 5RM had an enhancing or inhibiting effect on CMJ performance, the greatest improvement and reduction in FT and GRF were selected for each subject. A repeated-measures analysis of variance (ANOVA) was used to analyze the effect of the rest intervals on the dependent variables and to see if the greatest improvement and reduction in FT and GRF values were significantly different from the baseline FT and GRF values.

TABLE 1. Physical characteristics of the subjects. Mean \pm SD.

Gender	Age (y)	Height (cm)	Mass (kg)
Women	24.9 \pm 3.8	170.5 \pm 6.0	61.0 \pm 4.2
Men	22.1 \pm 3.9	184.6 \pm 8.6	83.8 \pm 8.8



FIGURE 1. Photograph of the setup of the sledge and force platform apparatus showing a subject about to perform a single-legged CMJ.

Subjects

Eighteen subjects, 9 men and 9 women (Table 1) from predominantly anaerobic sports, namely athletics (sprinters and jumpers) and rugby, took part in this study. All subjects had experience of weight lifting and plyometric training. They were proficient with the technique of the back squat exercise and countermovement jumping and could back squat in excess of 1.5 times bodyweight (women mean [\pm SD] = 1.9 [0.3]; men = 2.1 [0.2]). Ethical approval for this study was granted from the University research ethics committee and written consent was obtained from all subjects. Prior to participation in the testing procedure, the subjects completed a Physical Activity Readiness Questionnaire.

Instrumentation

All CMJs were performed on a specially built sledge apparatus as described by Harrison et al. (13). The apparatus consisted of 3 main components: a sledge frame, a sliding chair, and a force platform (Figure 1). The sledge frame was constructed from box steel with sledge rails inclined at 30°. The chair was mounted on the rails on low-friction steel rollers. The force platform (AMTI OR6-5; Advanced Medical Technology, Inc., Watertown, MA) was mounted at right angles to the sledge apparatus and sampled at 1000 Hz to give values for vertical GRF. The subject was secured to the chair with a harness and Velcro straps at the waist and shoulders to prevent any upper body movement during the jumps. The vertical GRF data was inspected to obtain peak GRF and FT for each jump.

The baseline (pretest) FT and GRF data was analyzed to establish the reliability of the CMJ sledge testing. Three baseline CMJ trials were performed on both testing

days. Intraclass correlation coefficients (ICC R) were obtained for trial-to-trial reliability and for day-to-day reliability. An ICC (absolute agreement) of $R = 0.981$ for FT and $R = 0.988$ for GRF were obtained for the trial-to-trial analysis. The day-to-day analysis reported ICCs of $R = 0.983$ for the FT and $R = 0.987$ for the GRF data. This indicates that the CMJ sledge testing was a reliable test and thus variations in results are due to the acute intervention as opposed to the CMJ testing protocol and instrumentation.

Test Procedure

The experiment involved 3 testing sessions at equal intervals during a 3-week period. The same day of the week and time were used for reliability reasons and to control for circadian variation (1). The subjects were required to refrain from any high-intensity exercise, particularly strength training, on the day before each test day. Güllich and Schmidtbleicher (12) reported that fatigue negatively affects neural activation responses. They commented that high anaerobic loads on the previous day lead to a reduction of the maximum voluntary contraction (MVC) effect on speed-strength performance. Testing session 1 included a warm up of 3 minutes of low-intensity jogging and static stretching including 1 exercise for each of the quadriceps, hamstrings, gastrocnemius, soleus, gluteals, and hip adductors, with stretches held for 15 seconds. The subjects' 1RM was tested using the procedure outlined by Earle (5) and then they completed familiarization trials of the single-legged CMJ (test jump). The subjects were allowed to choose the leg they were most comfortable with in performing all jumps. The subjects were instructed to begin the action from a straight leg position with their arms held across the chest, move rapidly into a crouch position, and immediately propel the sledge chair up the rails by fully extending the leg with maximal effort.

The procedures for the second and third testing sessions were identical. The same warm up procedure as session 1 was completed, but it also included an activity-specific warm up of 2 sets of 3 CMJs. This was followed by the 3 presquat CMJs. These jumps were done on each day of testing and served as a baseline for examining the influence of the set of 5RM squats on the jumps performed after the squats on that particular testing day. According to the percentage of 1RM-repetition relationship outlined by Baechle, Earle, and Wathen (2), the load for the 5 repetitions of the back squat was 87% of the 1RM. This load and repetition number was consistent with previous research (7, 9, 14, 16–20, 22). A back squat warm up was performed prior to any heavy lifting, consisting of 8 repetitions of the back squat at 50% of 1RM and then 6 repetitions at 70%. Once warmed up, the subjects performed a 5RM squat followed by 30 seconds or 2, 4, or 6 minutes of rest before completing 3 CMJs. This was considered to be 1 complex pair. The order of the rest intervals was randomly assigned to each subject. This procedure was done 4 times in total to accommodate the 4 rest intervals. In order to avoid fatigue affecting the results, 2 of the complex pairs were done on each day of testing. Based on the guidelines of Ebben and Watts (8), 10 minutes of rest was allowed between each complex pair. On completion of the tests, the subjects did a cool-down consisting of light jogging and static stretching.

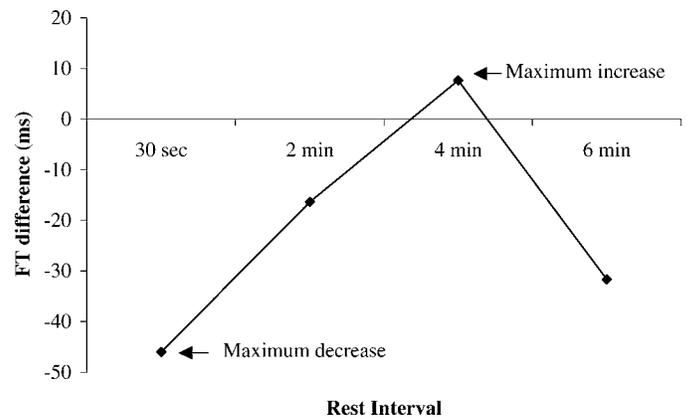


FIGURE 2. Difference between the baseline flight time (FT) values and the FT values at the different rest intervals for a male subject. The maximum decrease and increase values are illustrated.

Statistical Analyses

All statistical analysis was conducted using a software package (SPSS for Windows, version 11.0.1; SPSS, Inc., Chicago, IL). Differences between the baseline scores and the scores after the different intracomplex rest intervals for each dependent variable were evaluated using a 2-way ANOVA with repeated measures. The analysis was carried out separately for each rest interval. The general linear model (GLM) ANOVA had 1 between-subjects factor, namely gender with 2 levels (men and women), and 2 within-subjects factors, namely condition with 2 levels (baseline and rest interval) and trials with 3 levels. The data were also split, based on gender, to examine the differences between the baseline scores and the various rest interval scores for men and women separately. The GLM ANOVA in this case had 2 within-subject factors, namely condition with 2 levels (baseline and rest interval), and trials with 3 levels. Statistical significance was accepted at $p \leq 0.05$.

Individuals respond to complex training in different ways, and it has been noted previously that the optimal intracomplex rest interval may differ for participants, and in a practical training setting, it should be determined individually (3, 4, 12). To determine if complex training was beneficial to CMJ performance, the mean FT and GRF scores for the rest intervals were examined and the scores that showed the greatest decrease and greatest increase in FT and GRF were selected for each subject (Figure 2). When there was no increase or decrease in FT and GRF, the values closest to the baseline were selected. A second GLM ANOVA was performed on these data to determine if significant differences existed between the baseline scores and greatest decrease and greatest increase scores. It was hypothesized that significant decreases and increases from baseline scores would indicate the existence of fatigue and improvement effects.

RESULTS

Figure 3 illustrates the mean differences in the FT for each rest interval and the baseline FT. The x -axis represents the baseline FT, and data for the entire group, men and women, are shown separately. For the entire group, the GLM ANOVA results indicated a significant difference in FT between the baseline jumps and those

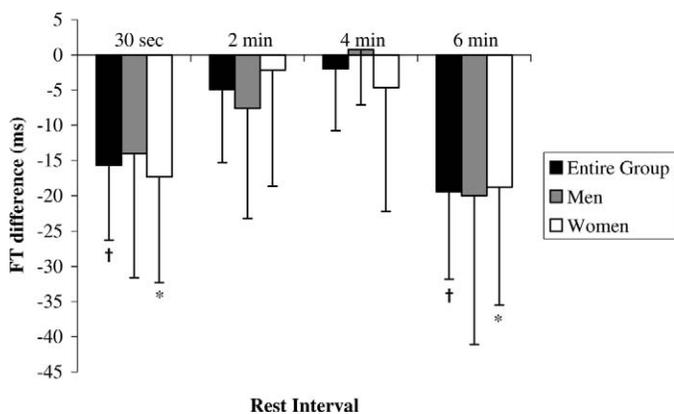


FIGURE 3. Mean with 95% confidence interval flight time (FT) difference between the baseline jumps and the jumps done after the different rest intervals. * Significant difference between the rest interval and baseline jumps ($p < 0.05$). † Significant difference between the rest interval and baseline jumps ($p < 0.01$)

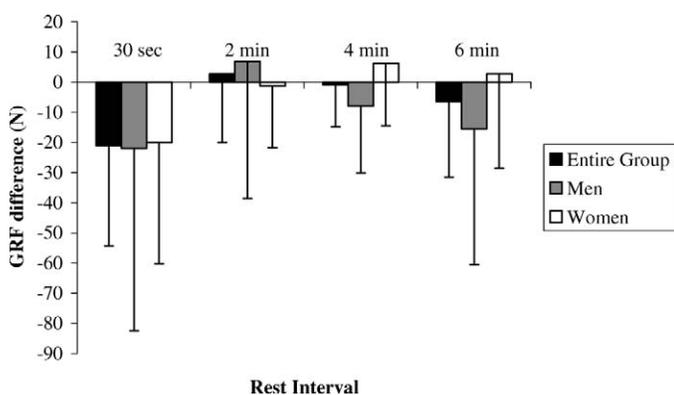


FIGURE 4. Mean with 95% confidence interval peak ground reaction force (GRF) difference between the baseline jumps and the jumps done after the different rest intervals.

jumps done at the 30-second and 6-minute intervals ($p < 0.01$). While no rest interval for the women produced an enhancement in CMJ performance following the back squats, there were significant reductions ($p < 0.05$) in FT at the 30-second and 6-minute intervals. For men, there were no significant reductions or enhancements in FT following back squats at any rest interval; however, the general trend in the mean FT scores with respect to rest interval follows a similar pattern to the entire group and the women, although a slight nonsignificant enhancement was seen at the 4-minute interval.

For GRF, while the general trend of increase and decrease in scores with respect to rest intervals was similar to the FT trends, no significant difference was evident between the rest interval jumps and the baseline jumps for the entire group or for men and women separately (Figure 4).

Tables 2 and 3 provide a breakdown of when the greatest increase and greatest decrease in FT and GRF respectively occurred for the subjects. The tables illustrate the individual variation in results. The subjects had their greatest increase and decrease in FT and GRF at different rest intervals, thus indicating the possible need for the individual assessment of the intracomplex rest interval.

TABLE 2. Number of subjects with the greatest reduction (maximum decrease) and improvement (maximum increase) in flight time (FT) at the different rest intervals.

	FT maximum decrease (No. of subjects)		FT maximum increase (No. of subjects)	
	Men	Women	Men	Women
30-sec interval	4	5	2	2
2-min interval	0	0	2	5
4-min interval	1	0	3	2
6-min interval	4	4	2	0

TABLE 3. Number of subjects with the greatest reduction (maximum decrease) and improvement (maximum increase) in ground reaction force (GRF) at the different rest intervals.

	GRF maximum decrease (No. of subjects)		GRF maximum increase (No. of subjects)	
	Men	Women	Men	Women
30-sec interval	4	4	1	1
2-min interval	1	1	5	2
4-min interval	1	1	1	3
6-min interval	3	3	2	3

TABLE 4. Mean \pm 95% confidence interval flight time (FT) difference between the baseline and the greatest reduction (maximum decrease) and improvement (maximum increase) in FT.*

	FT maximum decrease		FT maximum increase	
	Time (ms)	% change	Time (ms)	% change
Entire group	-31 \pm 10†	4.5	9 \pm 8‡	1.3
Men	-35 \pm 14†	4.8	14 \pm 8§	1.9
Women	-28 \pm 15§	4.4	3 \pm 16	0.5

* Percentage change in the FT maximum decrease and increase values compared to the corresponding baseline values is given.

† Significantly different from the corresponding baseline values ($p < 0.001$).

‡ Significantly different from the corresponding baseline values ($p < 0.05$).

§ Significantly different from the corresponding baseline values ($p < 0.01$).

A GLM ANOVA was performed to determine whether the subjects' greatest decrease and increase in FT and GRF were significantly different from their baseline values. Table 4 shows the difference in FT for men, women and the entire group between the baseline values and the rest interval that showed the greatest decrease in FT. These data show that the back squat exercise elicited a significant reduction in FT scores compared to the baseline measures. When the maximum increase in FT performance was examined, there was a significant improvement in FT for the entire group ($p < 0.05$) and for men ($p < 0.01$) (Table 4). For women, however, GLM ANOVA indicated no significant improvement in FT compared with the baseline values.

A similar trend was evident for peak GRF. Table 5 shows the maximum increase and decrease in GRF for men, women, and the entire group. The GLM ANOVA indicated the decreases in GRF compared with the base-

TABLE 5. Mean \pm 95% confidence interval ground reaction force (GRF) difference between the baseline and the greatest reduction (maximum decrease) and improvement (maximum increase) in GRF.*

	GRF maximum decrease		GRF maximum increase	
	Force (N)	% change	Force (N)	% change
Entire group	-48.7 \pm 19.7 [†]	4.6	34.0 \pm 21.4 [‡]	3.3
Men	-57.4 \pm 34.1 [‡]	4.7	36.1 \pm 40.1	3.0
Women	-40.1 \pm 25.9 [‡]	4.4	31.8 \pm 23.8 [§]	3.6

* Percentage change in the GRF maximum decrease and increase values compared to the corresponding baseline values is given.

[†] Significantly different from the corresponding baseline values ($p < 0.001$).

[‡] Significantly different from the corresponding baseline values ($p < 0.01$).

[§] Significantly different from the corresponding baseline values ($p < 0.05$).

line values were significant for men, women ($p < 0.01$) and the group as a whole ($p < 0.001$). Significant increases in peak GRF were observed for the entire group ($p < 0.01$) and for the women ($p < 0.05$). For the men, while the mean maximum GRF was higher than the baseline GRF, this was not statistically significant ($p \geq 0.05$).

With regard to the comparison of men and women on the changes in FT and GRF at the different rest intervals and on the maximum increase and decrease, the gender \times condition interaction was not significant ($p \geq 0.05$), indicating that men and women respond to complex training in a similar manner.

DISCUSSION

The results of this study are consistent with the findings of Jensen and Ebben (16), who found a reduction in performance when minimum rest (10 seconds) was given between the resistance and plyometric components of complex training. A significant reduction in FT was observed when a 30-second intracomplex rest interval was used. The GRF data also showed a similar reduction at this rest interval. This refutes earlier complex training research, which advocated performing the plyometric exercise immediately postlifting (8, 21).

Using the GLM ANOVA with repeated measures at 30 seconds and 2, 4, and 6 minutes, no significant advantage was evident in GRF or FT at any of the rest intervals; this is consistent with findings from other studies (18, 20). From the FT data it is evident that 4 minutes of rest produced scores closest to the baseline values. Ebben (6) stated that 3 or 4 minutes might be an optimal intracomplex rest interval. Evans et al. (9), Radcliffe and Radcliffe (19), and Young (22) used 4 minutes of rest and found ergogenic effects for the plyometric exercise. While Jensen and Ebben (16) did not see a significant improvement in performance after lifting, their results did suggest that 4 minutes of rest might be most optimal for complex training. The significant reduction in FT after 6 minutes of rest is of particular interest. Such a drop-off in performance at this stage has not been evident in previous research. It supports the view that heavy weight lifting causes a heightened stimulation of the neuromuscular system. The muscles would have recovered from fa-

tigue induced by the heavy resistance exercise, but any stimulation of the neuromuscular system may have elapsed.

The statistical analysis showed that there was no significant difference in the changes in FT and GRF at the different rest intervals for men and women and for the maximum FT and GRF increase and decrease, indicating that the effect of complex training is similar for men and women. Similar findings with regard to gender were found by Ebben et al. (7), Jensen and Ebben (16), and Jensen et al. (17). A different trend in FT results, however, is seen for men and women. Women were closest to the baseline FT data after 2 minutes of rest, while men showed a slight enhancement in performance at the 4-minute rest interval. Both showed a decrease in performance after 30 seconds and 6 minutes rest, with the FT decreases being significant for women. These results indicate that 2 minutes intracomplex rest may be necessary for women, and 4 minutes for men. In addition, the women, unlike the men, showed no significant maximum increase in FT. It is not clear why the women did not improve. Possible reasons for this may include a lack of potentiation or coordination problems. The significant maximum increase in the women's GRF values indicates that it could be a coordination problem, but future research should use electromyography to see if the nonsignificant improvement in FT is related to a lack of potentiation.

High interindividual differences can exist with intracomplex rest interval. Previous research has noted that in the applied setting, the time period between the resistance and plyometric sets should be determined individually (3, 4, 12, 20). Güllich and Schmidtbleicher (12) commented that in order to guarantee the highest possible effectiveness, it is necessary to determine individually the optimal interval between treatment MVCs and the subsequent speed-strength performances. The high interindividual differences may explain why a significant performance enhancement effect was not evident in this study. Subjects had their greatest improvement and reduction in FT and GRF performance at different rest intervals. The subjects' optimal recovery time for improvement varies, and this could explain why no single rest interval showed a significant advantage for the plyometric performance. Consequently, the subjects' greatest improvement and reduction in FT and GRF were grouped together, regardless of when they occurred, and the statistical analysis revealed that complex training can inhibit or enhance CMJ performance depending on the amount of recovery. Other studies that examined the rest interval, by Jensen and Ebben (16) and Jones and Lees (18), did not investigate this and thus may have missed the true effects of the resistive exercise on plyometric performance. Finding an appropriate individual rest interval may be paramount to optimizing the effectiveness of complex training.

The present study used the CMJ as the criterion plyometric exercise. The CMJ is an example of a slow or long SSC exercise. The CMJ was also used by Jensen and Ebben (16), Radcliffe and Radcliffe (19), and Young et al. (22). The findings observed here are relevant to slow SSC activities. Whether similar findings exist for fast SSC activities, such as a DJ, would need to be investigated further, as only a small number of acute studies have used such an approach (10, 12, 18). Two of these studies, by French et al. (10) and Güllich and Schmidtbleicher (12),

used MVCs as the stimulus, so it may not be appropriate to apply their findings to the training environment. Future research should investigate the effective of a resistance exercise on fast SSC performance.

PRACTICAL APPLICATIONS

Results from the current study suggest that in the applied training setting it may be beneficial for the intracomplex rest interval to be individually determined. The improvement window seems to differ between subjects and it would be important to individually determine this window of opportunity, as this study illustrates that complex training can be detrimental or favorable to slow SSC performance depending on the amount of recovery. Certain trends were evident in this study. Performing a slow SSC exercise, such as a CMJ, either 30 seconds or 6 minutes postlifting will be disadvantageous on performance. The effect of complex training is similar for men and women, although a slight improvement was shown in flight time after 4 minutes of rest for men. The evidence presented would support the use of complex training in a practical setting for male and female athletes from anaerobic sports, where the plyometric exercise is a slow SSC activity and when the intracomplex rest interval is individually assigned.

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