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## The optimal complex training rest interval for athletes from anaerobic sports

Item Type	Article
Authors	Comyns, Thomas M.;Harrison, Andrew J.;Hennessy, Liam K.;Jensen, Randall L.
Citation	Journal of Strength and Conditioning Research;20 (3), pp. 471-476
Publisher	Lippincott, Williams & Wilkins
Download date	2026-05-14 10:02:24
Item License	<a href="https://creativecommons.org/licenses/by-nc-sa/1.0/">https://creativecommons.org/licenses/by-nc-sa/1.0/</a>
Link to Item	<a href="https://hdl.handle.net/10344/5673">https://hdl.handle.net/10344/5673</a>

1 **TITLE:** THE OPTIMAL COMPLEX TRAINING REST INTERVAL FOR  
2 ATHLETES FROM ANAEROBIC SPORTS  
3

4 **AUTHORS:** Thomas M. Comyns<sup>1</sup>, Andrew J. Harrison<sup>1</sup>, Liam K. Hennessy<sup>2</sup> and  
5 Randall L. Jensen<sup>3</sup>.  
6

7 **AFFILIATIONS:**  
8

9 <sup>1</sup>Department of Physical Education and Sport Sciences, University of  
10 Limerick, Limerick, Ireland;

11 <sup>2</sup>Irish Rugby Football Union, 62 Lansdowne Road, Dublin 4, Ireland;

12 <sup>3</sup>Department of Health, Physical Education and Recreation, Northern  
13 Michigan University, Marquette, Michigan 49855, USA.  
14

15

16 **CONTACT INFORMATION:**  
17

18 Dr Drew Harrison

19 Senior Lecturer

20 Department of Physical Education and Sport Sciences,

21 University of Limerick,

22 Limerick

23 IRELAND

24 Tel: +35361202809

25 Mobile: +353863467611

26 Fax: +35361202814

27 Email: [drew.harrison@ul.ie](mailto:drew.harrison@ul.ie)  
28  
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1 **TITLE: THE OPTIMAL COMPLEX TRAINING REST INTERVAL FOR**  
2 **ATHLETES FROM ANAEROBIC SPORTS.**  
3

1 **ABSTRACT**

2

3 Complex training research has indicated that 3-4 minutes may be an optimum  
4 intracomplex rest interval. The purpose of this study was to determine if a heavy  
5 resistive exercise causes performance enhancement of a slow stretch-shortening cycle  
6 exercise and if there is an optimal rest interval. Eighteen subjects performed  
7 countermovement jumps before and after a 5RM back squat lifting protocol. This  
8 procedure was repeated 4 times over 2 days using rest intervals of 30 seconds, 2, 4  
9 and 6 minutes. Flight time and peak ground reaction force were the dependent  
10 variables. All jumps were performed on a specially constructed sledge and force  
11 platform apparatus. Repeated measures ANOVA found a significant reduction in  
12 flight time at the 30 second and 6 minute interval ( $p < 0.05$ ). No significant difference  
13 was found between men and women. Only the men showed an enhancement in jump  
14 performance after the 4 minute interval. The improvement window was different for  
15 each subject and an analysis of the greatest increase and decrease in flight time and  
16 peak ground reaction force was conducted, showing a significant decrease for men  
17 and women and a significant increase in flight time for men and peak ground reaction  
18 force for women. The results suggest that complex training can benefit and/ or inhibit  
19 countermovement jump performance depending on the rest interval. The individual  
20 determination of the intracomplex rest interval may be necessary in the practical  
21 setting.

22

23 **Keywords:** countermovement jump, stretch-shortening cycle, sledge, resistance  
24 exercise, plyometrics.

25

## 1 INTRODUCTION

2

3 Alternating a high-load resistance exercise with a biomechanically similar plyometric  
4 exercise has been referred to as complex training and it is thought that the resistance  
5 exercise will have a performance enhancing effect on the plyometric exercise (8).

6 Recent research has sought to investigate the optimal rest interval between the  
7 strength training and the plyometric training components of complex training (16,  
8 18). This interval has been referred to as the intracomplex rest interval (16). The  
9 traditional view, based on anecdotal evidence, is that this rest period should be  
10 minimal (8, 21) in order to take advantage of the heightened neural stimulation gained  
11 by completing the resistance set. More recently, research has altered this view and  
12 Ebben (6) noted that it may be necessary to take three or four minutes rest between  
13 the resistive and plyometric components.

14

15 The rest interval used in complex training research has ranged from 10 seconds (16)  
16 up to 20 minutes (18). Research examining the effects of the bench press on force  
17 production and motor unit recruitment during the medicine ball power drop using a  
18 short rest interval (10 seconds) has shown no enhancement for the plyometric exercise  
19 (7, 17). In contrast to this, upper-body complex training research (9) and lower-body  
20 research (12, 19, 22) that used intracomplex rest intervals of 3 to 4 minutes revealed  
21 improvement effects for the plyometric exercise. Only one study (16) has specifically  
22 investigated the optimal intracomplex rest interval. Jensen & Ebben (16) had subjects  
23 perform a countermovement jump (CMJ), a set of 5RM squats, and 5 trials of CMJ at  
24 rest intervals of 10 seconds, and 1, 2 and 3 and 4 minutes after the squat. Results  
25 revealed no significant difference in jump height from pre to post-squat for any of the  
26 rest intervals. The jump performance, however, at the 10 seconds interval was reduced

1 but not significantly. A non-statistically significant trend of improvement in jump  
2 height occurred from 10 seconds up to 4 minutes. This implied that up to 4 minutes  
3 might provide optimal intracomplex rest. The authors also found the effect of complex  
4 training was similar for men and women as well as athletes with varying strength  
5 levels. The study did not isolate each of the rest intervals although a pilot study found  
6 no cumulative learning effects on vertical jump performance due to the consecutive  
7 completion of vertical jumps at the different rest intervals. It may still be difficult to  
8 know if the improvement trend was due to the 5RM squat or the completion of the  
9 post-squat CMJs at the different rest intervals or a combination of both. In addition,  
10 the completion of the CMJs at the rest intervals could have had a fatiguing effect and  
11 masked any potential improvements. The present study addresses this by having the  
12 subjects perform a 5RM squat before each rest interval.

13

14 Jones and Lees (18) adopted a similar approach to Jensen & Ebben (16) by  
15 manipulating the length of the rest interval. They investigated the effect of 5RM back  
16 squatting on CMJs and drop jumps (DJs) that were performed immediately, 3, 10 and  
17 20 minutes post-lifting. While no statistical significance was found, suggesting that  
18 complex training did not enhance plyometric performance, it was also noted that no  
19 adverse effects occurred. No added benefit existed for conducting the plyometric  
20 jumps 20 minutes after the back squatting. Both Jensen and Ebben (16) and Jones and  
21 Lees (18) found no performance advantage due to 5RM back squatting. One possible  
22 reason for this could be that the improvement window may differ for individuals (3, 4,  
23 12, 20) and thus mask any ergogenic response at the different intervals. The present  
24 study accommodated for this by analysing the greatest improvement and reduction in

1 the dependent variables' scores compared to the baseline scores regardless of when  
2 they occurred.

3

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

14

15 From previous research it would seem that the optimal recovery time between the  
16 resistive and plyometric components of complex training is an important factor in  
17 ensuring an enhancing effect from the resistive exercise. A short interval may take  
18 advantage of the heightened stimulation of the neuromuscular system (8, 21) and this  
19 is why past research employed a protocol where the plyometric exercise was  
20 performed immediately after the high-load resistance exercise (7, 17). The heavy  
21 resistance exercise, however, has a fatiguing effect on the muscles. Adequate rest is  
22 needed to allow recovery of the phosphagen system (15). Researchers hypothesise  
23 that there is an optimal rest period that allows for partial recovery and utilisation of  
24 the heightened stimulation of the neuromuscular system. The purpose of this  
25 investigation was to assess if there is performance enhancing response for a slow

1 stretch shortening cycle (SSC) exercise that is performed after a high-load resistance  
2 exercise. Secondly it sought to determine if there is an optimal intracomplex rest  
3 interval. The effect of complex training for men and women was also evaluated.

4

## 5 **METHODS**

6

### 7 **Experimental design and approach to the problem**

8 This study involved the subjects performing three single-legged CMJs on a specially  
9 constructed sledge and force platform apparatus before and after a 5RM back  
10 squatting protocol. This procedure was repeated using four different intracomplex rest  
11 intervals. The complex pairs of five squats followed by three CMJs were completed  
12 four times over two different testing sessions utilising four intracomplex rest intervals  
13 of 30 seconds, 2, 4 and 6 minutes. The pre-squat (baseline) CMJs acted as a control  
14 and were compared with the post-squat jumps at the different rest intervals.  
15 Independent variables included rest interval and gender. Dependent variables included  
16 peak ground reaction force (GRF) and duration of the airborne phase (flight time, FT)  
17 during the test jump (CMJ). To investigate if the 5RM had an enhancing and/ or  
18 inhibiting effect on CMJ performance, the greatest improvement and reduction in FT  
19 and GRF were selected for each subject. A repeated measures ANOVA was used to  
20 analyze the effect of the rest intervals on the dependent variables and to see if the  
21 greatest improvement and reduction in FT and GRF values were significantly  
22 different from the baseline FT and GRF values.

23

24

25

## 1 **Subjects**

2 Eighteen subjects, 9 men and 9 women (see table 1) from predominantly anaerobic  
3 sports, namely athletics (sprinters and jumpers) and rugby, took part in this study. All  
4 subjects had experience of weight lifting and plyometric training. They were  
5 proficient with the technique of the back squat exercise and countermovement  
6 jumping and could back squat in excess of 1.5 times bodyweight (Women mean [SD]  
7 = 1.9 [0.3]; Men = 2.1 [0.2]). Ethical approval for this study was granted from the  
8 University research ethics committee and written consent was obtained from all  
9 subjects. Prior to participation in the testing procedure, the subjects completed a  
10 Physical Activity Readiness Questionnaire (PAR-Q).

11

## 12 **Instrumentation**

13 All CMJs were performed on a specially built sledge apparatus as described by  
14 Harrison et al. (13). The apparatus consisted of three main components: a sledge  
15 frame, a sliding chair and a force platform (see figure 1). The sledge frame was  
16 constructed from box steel with sledge rails inclined at 30°. The chair was mounted on  
17 the rails on low-friction steel rollers. The force platform (AMTI OR6-5) was mounted  
18 at right angles to the sledge apparatus and sampled at 1000 Hz to give values for  
19 vertical ground reaction force. The subject was secured to the chair with a harness and  
20 Velcro straps at the waist and shoulders to prevent any upper body movement during  
21 the jumps. The vertical GRF data was inspected to obtain peak GRF and FT for each  
22 jump.

23

24 The baseline (pre-test) FT and GRF data was analysed to establish the reliability of  
25 the CMJ sledge testing. Three baseline CMJs trials were performed on both testing

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

8

### 9 **Test Procedure**

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

1 into a crouch position and immediately propel the sledge chair up the rails by fully  
2 extending the leg with maximal effort.

3

4 The procedures for the second and third testing sessions were identical. The same  
5 warm-up procedure as session one was completed, but it also included an activity  
6 specific warm-up of 2 sets of 3 CMJs. This was followed by the 3 pre-squat CMJs.  
7 These jumps were done on each day of testing and served as a baseline for examining  
8 the influence of the set of 5RM squats on the jumps performed after the squats on that  
9 particular testing day. According to the percentage of 1RM-repetition relationship  
10 outlined by Baechle, Earle & Wathen (2), the load for the 5 repetitions of the back  
11 squat was 87% of the 1RM. This load and repetition number was consistent with  
12 previous research (7, 9, 14, 16, 17, 18, 19, 20, 22). A back squat warm-up was  
13 performed prior to any heavy lifting and this consisted of 8 repetitions of the back  
14 squat at 50% of 1RM and then 6 repetitions at 70%. Once warmed-up, the subjects  
15 performed a 5RM squat followed by 30 seconds, 2, 4 or 6 minutes rest before  
16 completing 3 CMJs. This was considered to be one complex pair. The order of the rest  
17 intervals was randomly assigned to each subject. This procedure was done four times  
18 in total to accommodate the four rest intervals. In order to avoid fatigue affecting the  
19 results, two of the complex pairs were done on each day of testing. Based on the  
20 guidelines of Ebben and Watts (8), ten minutes rest was allowed between each  
21 complex pair. On completion of the tests the subjects did a cool-down consisting of  
22 light jogging and static stretching.

23

24

25

## 1 **Statistical Analyses**

2 All statistical analysis was conducted using a software package (SPSS for Windows,  
3 Release 11.0.1). Differences between the baseline scores and the scores after the  
4 different intracomplex rest intervals for each dependent variable were evaluated using  
5 a 2-way analysis of variance (ANOVA) with repeated measures. The analysis was  
6 carried out separately for each rest interval. The GLM ANOVA had 1 between-  
7 subjects factor, namely gender with 2 levels (men and women), and 2 within-subjects  
8 factors, namely condition with 2 levels (baseline and rest interval) and trials with 3  
9 levels. The data was also split, based on gender, to examine the differences between  
10 the baseline scores and the various rest interval scores for men and women separately.  
11 The GLM ANOVA in this case had 2 within-subject factors, namely condition with 2  
12 levels (baseline and rest interval), and trials with 3 levels.

13

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

## 1 RESULTS

2

3 Figure 3 illustrates the mean differences in the FT for each rest interval and the  
4 baseline FT. The x-axis represents the baseline FT and data for the entire group, men  
5 and women are shown separately. For the entire group, the GLM ANOVA results  
6 indicated a significant difference in FT between the baseline jumps and those jumps  
7 done at the 30 second and 6 minute intervals ( $p < 0.01$ ). While no rest interval for the  
8 women produced an enhancement in CMJ performance following the back squats,  
9 there were significant reductions ( $p < 0.05$ ) in FT at the 30 second and 6 minute  
10 intervals. For men, there were no significant reductions or enhancements in FT  
11 following back squats at any rest interval; however, the general trend in the mean FT  
12 scores with respect to rest interval follows a similar pattern to the entire group and the  
13 women, although a slight non-significant enhancement was seen at the 4 minute  
14 interval.

15

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

20

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

1 A GLM ANOVA was performed to determine whether the subjects' greatest decrease  
2 and increase in FT and GRF were significantly different from their baseline values.  
3 Table 4 shows the difference in FT for men, women and the entire group between the  
4 baseline values and the rest interval that showed the greatest decrease in FT. These  
5 data show that the back squat exercise elicited a significant reduction in FT scores  
6 compared to the baseline measures. When the maximum increase in FT performance  
7 was examined there was a significant improvement in FT for the entire group ( $p <$   
8  $0.05$ ) and for men ( $p < 0.01$ ), see table 4. For women however, GLM ANOVA  
9 indicated no significant improvement in FT compared with the baseline values.

10

11 A similar trend was evident for peak GRF. Table 5 shows the maximum increase and  
12 decrease in GRF for men, women and the entire group. The GLM ANOVA indicated  
13 the decreases in GRF compared with the baseline values were significant for men,  
14 women ( $p < 0.01$ ) and the group as a whole ( $p < 0.001$ ). Significant increases in peak  
15 GRF were observed for the entire group ( $p < 0.01$ ) and for the women ( $p < 0.05$ ). For  
16 the men, while the mean maximum GRF was higher than the baseline GRF, this was  
17 not statistically significant ( $p \geq 0.05$ ).

18

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

23

24

25

## 1 **DISCUSSION**

2

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

10

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

25

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

18

19 High inter-individual differences can exist with intracomplex rest interval. Previous  
20 research has noted that in the applied setting the time period between the resistance  
21 and plyometric sets should be determined individually (3, 4, 12, 20). Güllich &  
22 Schmidtbleicher (12) commented that in order to guarantee the highest possible  
23 effectiveness it is necessary to determine individually the optimal interval between  
24 treatment MVCs and the subsequent speed-strength performances. The high inter-  
25 individual differences may explain why a significant performance enhancement effect

1 was not evident in this study. Subjects had their greatest improvement and reduction  
2 in FT and GRF performance at different rest intervals. The subjects' optimal recovery  
3 time for improvement varies and this could explain why no single rest interval showed  
4 a significant advantage for the plyometric performance. Consequently, the subjects'  
5 greatest improvement and reduction in FT and GRF were grouped together, regardless  
6 of when they occurred, and the statistical analysis revealed that complex training can  
7 inhibit and/ or enhance CMJ performance depending on the amount of recovery.  
8 Other studies that examined the rest interval, Jensen & Ebben (16), Jones & Lees (18)  
9 did not investigate this and thus may have missed the true effects of the resistive  
10 exercise on plyometric performance. Finding an appropriate individual rest interval  
11 may be paramount to optimising the effectiveness of complex training.

12

13 The present study used the CMJ as the criterion plyometric exercise. The CMJ is an  
14 example of a slow or long SSC exercise. The CMJ was also used by Jensen & Ebben  
15 (16), Radcliffe & Radcliffe (19), Young et al. (22). The findings observed here are  
16 relevant to slow SSC activities. Whether similar findings exist for fast SSC activities,  
17 such as a DJ, would need to be investigated further as only a small number of acute  
18 studies have used such an approach (10, 12, 18). Two of these studies, French et al.,  
19 (10) and Güllich & Schmidtbleicher (12) used MVCs as the stimulus so it may not be  
20 appropriate to apply their findings to the training environment. Future research should  
21 investigate the effective of a resistance exercise on fast SSC performance.

22

### 23 **Practical Applications**

24 Results from the current study suggest that in the applied training setting it may be  
25 beneficial for the intracomplex rest interval to be individually determined. The

1 improvement window seems to differ between subjects and it would be important to  
2 individually determine this window of opportunity, as this study illustrates that  
3 complex training can be detrimental and/ or favourable to slow SSC performance  
4 depending on the amount of recovery. Certain trends were evident in this study.  
5 Performing a slow SSC exercise, such as a CMJ, either 30 seconds or 6 minutes post-  
6 lifting will be disadvantageous on performance. The effect of complex training is  
7 similar for men and women, although a slight improvement was shown in flight time  
8 after 4 minutes rest for men. The evidence presented would support the use of  
9 complex training in a practical setting for male and female athletes from anaerobic  
10 sports, where the plyometric exercise is a slow SSC activity and when the  
11 intracomplex rest interval is individually assigned.  
12

1 **REFERENCES:**

2 1. ATKINSON, G. and T. REILLY. Circadian variation in sports performance.  
3 *Sports Med.* 21:292 - 312. 1996.

4

5 2. BAECHLE, T.R., R.W. EARLE, and D. WATHEN. Resistance Training. In:  
6 *Essentials of Strength Training and Conditioning (2nd Ed.)*. T. R. Baechle  
7 and R.W. Earle, eds. Champaign, IL: Human Kinetics, 2000.

8

9 3. DOCHERTY, D., D. ROBBINS and M. HODGSON. Complex training  
10 revisited: A review of its current status as a viable training approach. *Strength*  
11 *and Cond.* 26(6):52 - 57. 2004.

12

13 4. DUTHIE, G.M., W.B. YOUNG and D.A. AITKEN. The acute effects of  
14 heavy loads on jump squat performance: An evaluation of the complex and  
15 contrast methods of power development. *J. Strength Cond. Res.* 16(4):530 -  
16 538. 2002.

17

18 5. EARLE, R.W. Weight training exercise prescription. In: *Essentials of*  
19 *Personal Training Symposium Workbook*. Lincoln, NE: NSCA Certification  
20 Commission, 1999.

21

22 6. EBBEN, W.P. Complex training: A brief review. *J. Sports Sci. Med.* 2:42 - 46.  
23 2002.

24

- 1       7. EBBEN, W.P., R.L. JENSEN, and D.O. BLACKARD. Electromyographic and  
2       kinetic analysis of complex training exercise variables. *J. Strength Cond. Res.*  
3       14:451 - 456. 2000.
- 4
- 5       8. EBBEN, W.P., and P.B. WATTS. A review of combined weight training and  
6       plyometric training modes: Complex training. *Strength and Cond.* 20(5):18 -  
7       27. 1998.
- 8
- 9       9. EVANS, A.K., T.D. HODGKINS, M.P. DURHAM, J.M. BERNING, and K.J.  
10       ADAMS. The acute effects of a 5RM bench press on power output. *Med. Sci.*  
11       *Sport Exerc.* 32(5):S311. 2000.
- 12
- 13       10. FRENCH, D.N., W.J. KRAEMER, and C.B. COOKE. Changes in dynamic  
14       exercise performance following a sequence of preconditioning isometric  
15       muscle actions. *J. Strength Cond. Res.* 17(4):678 - 685. 2003.
- 16
- 17       11. GOURGOULIS, V., N. AGELOUSSIS, P. KASIMATIS, G. MAVROMATIS,  
18       and A. GARAS. Effect of a submaximal half-squats warm-up program on  
19       vertical jumping ability. *J. Strength Cond. Res.* 17(2):342 - 344. 2003.
- 20
- 21       12. GÜLLICH, A., and D. SCHMIDTBLEICHER. MVC-induced short-term  
22       potentiation of explosive force. *New Studies in Athletics.* 11(4):67 - 81. 1996.
- 23

- 1 13. HARRISON, A.J., S.P. KEANE, and J. COGLAN. Force-velocity relationship  
2 and stretch-shortening cycle function in sprint and endurance athletes. *J.*  
3 *Strength Cond. Res.* 18(3):473 - 479. 2004.  
4
- 5 14. HRYMOMALLIS, C., and D. KIDGELL. Effect of heavy dynamic resistive  
6 exercise on acute upper-body power. *J. Strength Cond. Res.* 15(4):426 - 430.  
7 2001.  
8
- 9 15. HULTMAN, E., J. BERGSTORM, and N. MCLENNAN-ANDERSON.  
10 Breakdown and resynthesis of phosphorylcreatine and adenosine triphosphate  
11 in connection with muscular work in man. *Scand. J. Clin. Invest.* 19:56 - 66.  
12 1967.  
13
- 14 16. JENSEN, R.L., and W.P. EBBEN. Effect of complex training rest interval on  
15 vertical jump performance. *J. Strength Cond. Res.* 17:345 - 349. 2003.  
16
- 17 17. JENSEN, R.L., W.P. EBBEN, D.O. BLACKARD, B.P. MCLAUGHLIN, and  
18 P.B. WATTS. Kinetic and electromyographic analysis of combined strength  
19 and plyometric training in women basketball players (Abstract). *Med. Sci.*  
20 *Sports Exerc.* 31:S19. 1999.  
21
- 22 18. JONES, P., and A. LEES. A biomechanical analysis of the acute effects of  
23 complex training using lower limb exercises. *J. Strength Cond. Res.* 17(4):694  
24 - 700. 2003.  
25

- 1       19. RADCLIFFE, J.C., and J.L. RADCLIFFE. Effects of different warm-up  
2           protocols on peak power output during a single response jump task. *Med. Sci.*  
3           *Sport Exerc.* 38(5):S189. 1996.
- 4
- 5       20. SCOTT, S.L., and D. DOCHERTY. Acute effects of heavy preloading on  
6           vertical and horizontal jump performance. *J. Strength Cond. Res.* 18(2):201 -  
7           205. 2004.
- 8
- 9       21. VERKHOSHANSKY, Y., and V. TATYAN. Speed-strength preparation of  
10          future champions. *Logkaya Atletika.* 2:2 - 13. 1973.
- 11
- 12      22. YOUNG, W.B., A. JENNER, and K. GRIFFITHS. Acute enhancement of  
13          power performance from heavy load squats. *J. Strength Cond. Res.* 12:82 - 84.  
14          1999.
- 15

## 1 **ACKNOWLEDGEMENTS**

2 The authors would like to thank the Irish Rugby Football Union and Energia for  
3 providing funding to support this research project.

4

1 **FIGURE LEGENDS**

2

3 **Figure 1.** Photograph of the set-up of the sledge and force platform apparatus  
4 showing a subject about to perform a single-legged CMJ.

5

6 **Figure 2.** Difference between the baseline FT values and the FT values at the  
7 different rest intervals for a male subject. The maximum decrease and increase values  
8 are illustrated.

9

10 **Figure 3.** Mean with 95% confidence interval FT difference between the baseline  
11 jumps and the jumps done after the different rest intervals.

12 \*Significant difference between the rest interval and baseline jumps ( $p < 0.05$ )

13 \*\* Significant difference between the rest interval and baseline jumps ( $p < 0.01$ )

14

15 **Figure 4.** Mean with 95% confidence interval GRF difference between the baseline  
16 jumps and the jumps done after the different rest intervals.

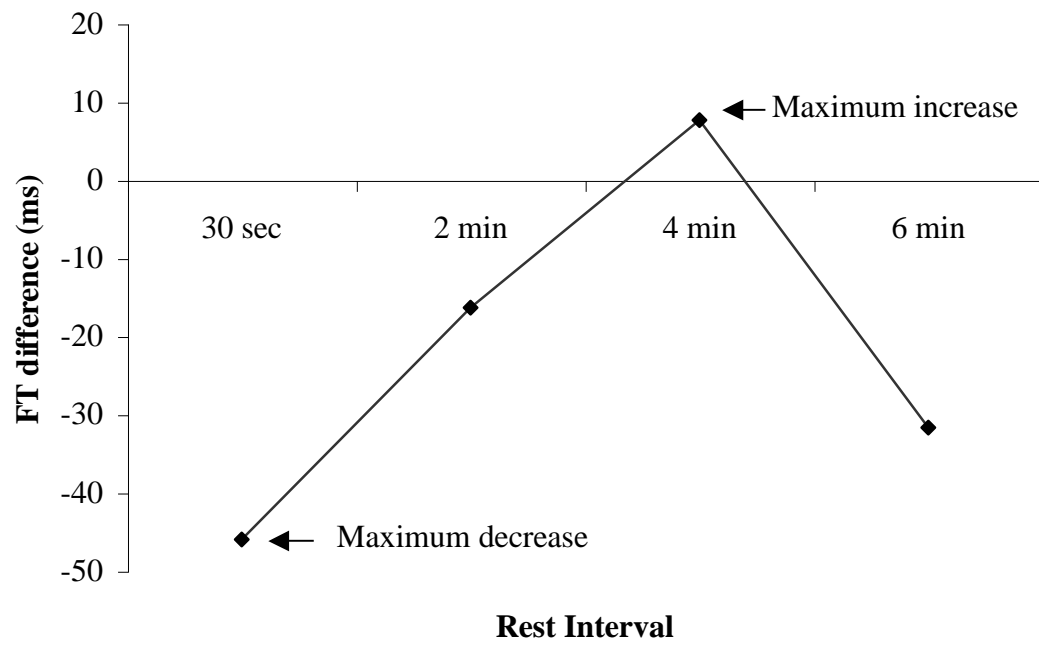
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3 **Figure 1.**

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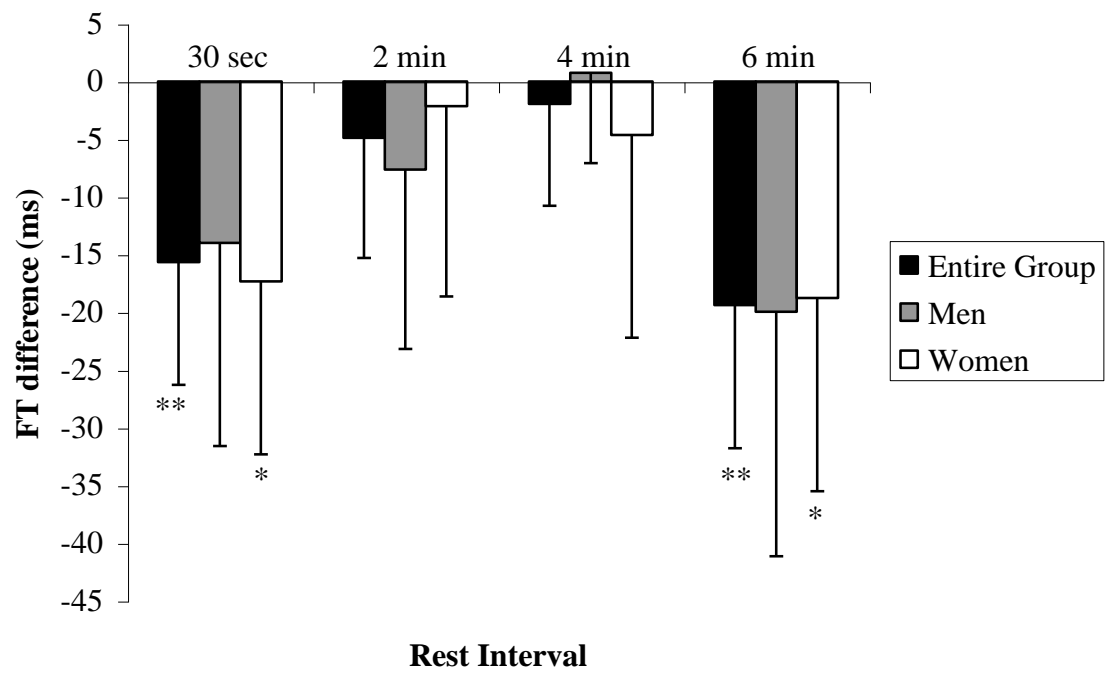


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3 **Figure 2.**

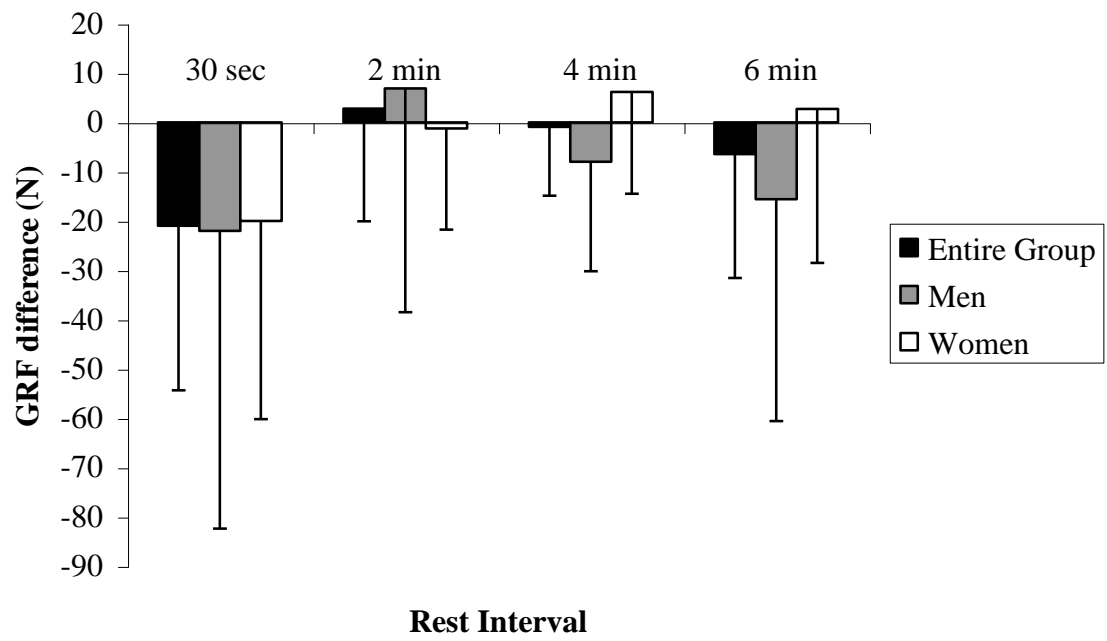
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4 **Figure 3.**

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3 **Figure 4.**

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6

1 **Table 1.** Physical characteristics of the subjects.

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

2

1 **Table 2.** Number of subjects with the greatest reduction (maximum decrease) and  
2 improvement (maximum increase) in FT at the different rest intervals.

3

	FT Maximum Decrease		FT Maximum Increase	
	(Number of subjects)		(Number 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

4

5

6

1 **Table 3.** Number of subjects with the greatest reduction (maximum decrease) and  
 2 improvement (maximum increase) in GRF at the different rest intervals.

3

	GRF Maximum Decrease (Number of subjects)		GRF Maximum Increase (Number 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

4

1 **Table 4.** Mean  $\pm$  95% confidence interval FT difference between the baseline and the  
 2 greatest reduction (maximum decrease) and improvement (maximum increase) in FT.  
 3 Percentage change in the FT maximum decrease and increase values compared to the  
 4 corresponding baseline values is given.

5

	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%

6

7 \*Significantly different from the corresponding baseline values ( $p < 0.05$ ).

8 \*\* Significantly different from the corresponding baseline values ( $p < 0.01$ ).

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

10

1 **Table 5.** Mean  $\pm$  95% confidence interval GRF difference between the baseline and  
 2 the greatest reduction (maximum decrease) and improvement (maximum increase) in  
 3 GRF. Percentage change in the GRF maximum decrease and increase values  
 4 compared to the corresponding baseline values is given.

5

	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*	3.56%

6

7 \*Significantly different from the corresponding baseline values ( $p < 0.05$ ).

8 \*\* Significantly different from the corresponding baseline values ( $p < 0.01$ ).

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