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Comparison of Repetition Number between Uni-Joint and Multi-Joint Exercises with 1-Min and 2-Min Rest Intervals

Marcelo Ricardo Cabral Dias[1,2], Dihogo Gama de Matos[1], Mauro Lucio Mazini Filho[1], Osvaldo Costa Moreira[5], Robert C. Hickner[6], Diogo Cardozo[2], Hugo Barbosa Alves[2], Luis Guilherme Reis[2], Felipe José Aidar[1,3,4]

[1]Department of Sport Sciences, Exercise and Health, University of Trás-os-Montes and Alto Douro (UTAD), Portugal, [2]Laboratory of Exercise Physiology and Evaluation Morphofunctional Granbery Methodist University, Juiz de Fora, Minas Gerais, Brazil, [3]Fire Brigade of Minas Gerais, 5th Battalion Fire Military Fire Brigade of the State of Minas Gerais, Uberlandia, Minas Gerais, Brazil, [4]Triangle University Center - UNITRI, Uberlândia, Minas Gerais, Brazil, [5]Institute of Biological Sciences and Health - Federal University of Viçosa - Campus Florestal - Florestal - Minas Gerais – Brazil, [6]Departments of Kinesiology, and Physiology, Center for Health Disparities Research, Human Performance Laboratory, East Carolina University, Greenville, USA

ABSTRACT

Dias MRC, de Matos DG, Mazini Filho ML, Moreira OC, Hickner RC, Cardozo D, Alves HB, Reis LG, Aidar FJ. Comparison of Repetition Number between Uni-Joint and Multi-Joint Exercises with 1-Min and 2-Min Rest Intervals. **JEPonline** 2014;17(4):93-101. The aim of this study was to compare the maximum number of repetitions performed using uni-joint and multi-joint exercises with either a 1-min or a 2-min rest interval. Eighteen male subjects subjected to two types of resistance exercise: peck deck fly and bench press. Four tests were performed in random order (exercise x recovery interval): Peck deck fly and bench press with either a 1-min or a 2-min rest interval between sets. The tests consisted of 3 sets with a load equal to the individual's 10 repetition maximum (10 RM), each set performed to failure. The amount of work performed for all sets was significantly higher for the 2-min recovery intervals when compared to the 1-min recovery intervals. The maximum number of repetitions with the 1-min interval was statistically higher for the peck deck fly and bench press

compared to the 2nd and 3rd sets. However, a greater absolute number of repetitions tended to be performed during the 1st set of peck deck fly as compared to the 2nd and 3rd sets. With the 2-min recovery, no differences were found between the number of repetitions achieved between the peck deck fly and bench press exercises. However, the trend remained for a higher number of repetitions for the peck deck fly than the bench press. It was concluded that the 2-min interval was more effective for the multi-joint exercises because it minimizes the drop in the total number of repetitions performed.

Key Words: Maximum Repetitions, Interval, Recovery, Strength Training

INTRODUCTION

Resistance training (RT) can be used to improve muscular endurance, hypertrophy, strength, and muscle power (3,21). Thus, there are several variables that influence a program of RT. Among the variables that are altered for effective training are the load, the number of repetitions, the order of exercises, the weekly frequency, the interval between sets and sessions, and the number of sets (3). Periodization of training is also used to maximize the training effect while changing these variables (7,11,12,14).

Ahtiainen et al. (2) and Willardson and Burkett (25) have demonstrated a relationship between the exercise total recovery time interval and the total volume completed in a sequence of exercises on strength and muscle hypertrophy. The recovery time interval used in RT influences the acute metabolic response (16), chronic responses on muscle strength, and the performance of subsequent sets (15,16,25). According to Fleck and Kraemer (8), the manipulation of RT is very important when determining the best approach to training.

Another important point in RT is the influence of the order of different exercises on resultant increases in muscle strength, where the multi-joint exercises should be performed before the uni-joint exercises to not impair force production (22,26). Yet, Simão et al. (23) found no influence of exercise order on the development of strength in small and large muscle groups. An additional consideration according to Shimano and colleagues (20) is the number of repetitions during RT (especially in regards to the increase in muscle mass).

Thus, it is reasonable to state that while much is known about the best procedures to benefit from RT, there are still unanswered questions about RT that are likely to interfere with recovery between sets. Since only a few studies have investigated the influence of recovery time between sets of uni-joint compared to multi-joint exercises of similar muscle groups, this study was designed to investigate the influence of 1-min and 2-min recovery intervals on the performance of uni-joint and multi-joint RT exercises.

METHODS

Subjects

The study consisted of 18 men (age, 23.4 ± 3.5 yrs; height, 177.2 ± 6.0 cm; weight, 75.0 ± 5.8 kg). All subjects had experience in RT for at least 12 months with a frequency of ≥3 days·wk^{-1}. Exclusion criterion included: (a) musculoskeletal limitations that would disrupt the mechanics of motion; and (b) use of any supplements or ergogenic aid. The subjects responded negatively to all questions in the

Questionnaire of Physical Activity Readiness (PAR-Q) (24). The study was approved by the Ethics Committee on Human Research of the Federal University of Juiz de Fora, Minas Gerais, Brazil.

Procedures

Exercise performance was standardized using the High On Righetto® (Righetto, Brazil). When the subjects performed the peck deck fly, they maintained a sitting position with horizontal adduction movement of the arm with the elbow at a 90° angle. In both exercises, the subjects completed a range of motion of 90° that was measured by a goniometer (Trident, Brazil) with a record of 360 (increments of 1 and 1). Both arms measured 18 cm with a maximum margin of error of 4° (18).

The maximum number of repetitions achieved in the uni-joint exercise (peck deck fly) and multi-joint exercise (bench press) (5) with the two different recovery intervals (1 min and 2 min) was determined across 3 days. Initially, there was a familiarization session and two sessions to determine the load for the 10 repetition maximum (10 RM). The bench press 10 RM was determined on the first 10 RM testing day. The peck deck fly 10 RM was determined on the second 10 RM testing day. Then, the subjects performed 4 tests (peck deck fly and bench press for 1 min and 2 min) ordered randomly by lottery. An interval of 48 hrs was adopted for each session. Hence, with two familiarization sessions and two test sessions, the methodology allowed for: (a) the determination of the number of repetitions between the exercises in each recovery interval; and (b) the time interval between each exercise.

Maximum repetitions test

The 10 RM test was conducted with each subject beginning attempts at a weight that he believed could be lifted once using maximum effort. If the subject could not complete 10 repetitions, the weight was removed (decreased) and another attempt at 10 repetitions was made. The subjects rested 5 to 10 min between attempts (5). All subjects underwent two test sessions of 10 RM testing with a range of 48 to 72 hrs between each session to assess muscle strength.

The 10 RM tests were preceded by a warm-up set of 10 to 12 repetitions with ~50% load used in the first attempt. The testing started 2 min after the conclusion of the warm-up. The load in which the subject could complete with only 10 repetitions was recorded as the 10 RM for that exercise. The transition interval between the exercises was 5 to 10 min. Note that the form and technique for each exercise were standardized and continuously monitored in an attempt to ensure the quality of the execution and data collection. Furthermore, the subjects performed the tests in the same period of the day and did not practice physical exercises during the experimental period. It was recommended that all subjects would not perform any strength training of muscle groups involved in the study for a period of 24 hrs before each test session.

To identify the reliability of 10 RM tests, the coefficient of intra-class correlation was calculated, which were: peck deck fly ($r = 0.93$); and bench press ($r = 0.96$). Using paired Student *t*-tests there was no difference between the test and the re-test 10 RM. If the difference between the test and the re-test did not exceed 5%, the higher value of 10 RM was used or otherwise the test was repeated. The test and re-test was conducted with the same subject.

Intervention

Forty-eight hrs after having obtained values of 10 RM, the subjects underwent 3 sets of 10 RM in 4 specific tests chosen randomly by lottery (days x subjects): (a) peck deck fly with 1-min interval between sets, (PD1); (b) peck deck fly with 2-min interval between sets, (PD2); (c) bench press with 1-min interval between sets, (BP1); and (d) bench press with 2-min interval between sets, (BP2). The rest intervals between sets were measured using a digital timer and the tests were performed with an

interval of 48 hrs between them. Before each session, the subjects performed a specific warm-up on the test device with 10 repetitions at 50% of the 10 RM load.

Statistical Analyses

Descriptive statistics of the sample are presented as mean and standard deviation. Tests of normality, using Shapiro-Wilk, and homogeneity, using Barltett, were conducted given the sample size. All variables were normally distributed and achieved homoscedasticity. For each exercise, the paired Student *t*-test was used to compare the difference in the volume of total work (sets x resistance x repetitions per set) between the trials with the 1-min and the 2-min rest. To investigate the differences between the variables (recovery interval x repetitions), a two-way ANOVA for repeated measures was used. It was followed by *post hoc* test of Tukey for verification of the number of repetitions performed using rest intervals of 1-min and 2-min for each exercise. To verify the difference between sets with each rest interval, a two-way MANOVA was used with Bonferroni *post hoc*. The significance level was set at $P<0.05$. Statistical analysis was conducted using SPSS for Windows, version 17.0.

RESULTS

Table 1 shows the volume of total work (sets x resistance type x load per set) for each exercise with 1-min and 2-min rest intervals between sets. The volume of work achieved for all sets was higher for the 2-min rest interval compared to the 1-min recovery intervals for both types of exercise ($P<0.05$). The repetitions reached in each set in each type of exercise are shown in Table 2.

Table 1. Volume of Total Work (Sets x Repetitions x Load Per Set) with the 1-Min and the 2-Min Recovery between Sets.

	Peck Deck Fly (kg)	Bench Press (kg)
1-Min Rest Interval	2304.8 ± 541.1	966.3 ± 150.9
2-Min Rest Interval	2587.7 ± 554.7 *	1220.2 ± 233.0 *

* $P<0.05$ (paired *t*-test compared to 1 Min)

Table 2. Maximum Number of Repetitions Achieved in the Peck Deck Fly and Bench Press with the 1-Min Recovery Interval.

	1st Set	2nd Set	3rd Set	P
Peck Deck Fly	10.0 ± 0.0	7.9 ± 2.1	4.9 ± 1.9 *	0.015
Bench Press	10.0 ± 0.0	5.7 ± 2.8 *	3.3 ± 2.2 *	0.004

* $P<0.05$ for Bench Press vs. Peck Deck Fly (two way ANOVA with Tukey *post hoc*)

Although the first set with the 1-min recovery was not different between the exercise types, the subjects performed a greater number of repetitions in the peck deck than in the bench press for sets two and three. Thus, they executed a greater absolute number of repetitions in peck deck fly than in bench press. There were no significant differences in the number of repetitions performed between the uni-joint (peck deck fly) and the multi-joint (bench press) exercise sets when 2-min intervals were used (Table 3). Table 4 shows the data for the peck deck fly with 1-min and 2-min rest between the sets. When the repetitions achieved in the peck deck fly with 1-min and 2-min recovery intervals between sets were compared, the number of repetitions was higher with the 2-min recovery intervals than with the 1-min intervals in the 3rd set.

Table 3. Maximum Number of Repetitions Achieved in the Peck Deck Fly and Bench Press with the 2-Min Recovery Interval.

	1st Set	2nd Set	3rd Set	P
Peck Deck Fly	10.0 ± 0.0	8.4 ± 2.1	6.4 ± 1.8	0.915
Bench Press	10.0 ± 0.0	7.9 ± 2.4	5.2 ± 2.9	1.112

No significant differences by two way ANOVA with Tukey *post hoc*

Table 4. Maximum Number of Repetitions Performed in Peck Deck Fly with the 1-Min or the 2-Min Recovery Intervals.

Interval	1st Set	2nd Set	3rd Set	P
1-Min Recovery	10.0 ± 0.0	7.9 ± 2.1	4.9 ± 1.9	0.002
2-Min Recovery	10.0 ± 0.0	8.4 ± 2.1	6.4 ± 1.8 *	0.003

* P<0.05 (two way ANOVA with Tukey *post hoc*)

In the bench press exercise (Table 5), repetitions achieved with the 2-min recovery intervals were higher in the 2nd set (P=0.007) and the 3rd set (P=0.004) than when the 1-min recovery intervals were used.

Table 5. Maximum Number of Repetitions Reached in Bench Press with the 1-Min or the 2-Min Recovery Interval.

	1st Set	2nd Set	3rd Set	P
1-Min Recovery	10.5 ± 1.1	5.7 ± 2.8	3.3 ± 2.2	0.007
2-Min Recovery	11.2 ± 1.5	7.9 ± 2.4 *	5.2 ± 2.9 *	0.004

* P<0.05 (two way ANOVA with Tukey *post hoc*)

DISCUSSION

The main finding of this study was that more work was achieved (sets x resistance x repetitions per set) with the 2-min rest interval between sets compared to the 1-min rest interval. As the resistance was constant in all sets of exercises, the resulting difference in workload can be explained by the greater number of repetitions achieved in absolute terms with the 2-min rest interval. There are several investigations of the maximum number of repetitions achieved in single RT sessions (9,20). However, in relation to the volume of training, Drinkwater et al. (7) observed no differences in strength gain when they compared the different number of repetitions and sets. This is because the number of repetitions is inversely proportional to the load. The higher the percentage of load, the lower the maximum number of repetitions achieved (21). In this sense, the purpose of this study was to verify the total workload and the maximum number of repetitions achieved in the two types of common exercises (uni-joint and multi-joint) with 1-min and 2-min intervals between sets.

Both 1-min and 2-min recovery intervals were not sufficient to maintain the repetitions throughout every set with a load equal to 10 RM. However, the 2-min interval allowed performance of a greater number of repetitions per set, mainly for the 2nd set of peck deck fly. It is clear that the 1-min recovery is not sufficient time for recovery of the required energy systems. This drop in the number of repetitions has been shown in other studies. In the study by Willardson et al., (27) intervals of 30 sec, 1-min, and 2-min between sets were compared with subjects performing 5 sets of 15 RM bench press and squat (with the bar on the back). The number of repetitions in each set was not sustained with any of the rest intervals. However, the achieved maximum repetitions were different for the bench press but not for the squat. Thus, it seems that the kind of muscle mass involved influences the number of repetitions performed in relation to the rest interval between sets.

The ratio of different types of prescriptive RT has been the subject of many discussions. Simão et al. (22) compared the effect of exercise order on the number of repetitions achieved. They found that performance decreased each set in both uni-joint and multi-joint exercises. In another study, Senna et al. (19) found that for the leg press, leg extension, and leg curl exercises, regardless of the time interval analyzed (2 min), there was a reduction of repetitions achieved along the sets of exercises. In addition, there was a significant decrease in repetitions for multi-joint exercise (leg press) compared to uni-joint exercises (e.g., knee extension and knee curl).

In this present study, the peck deck fly with either recovery interval used (i.e., 1-min or 2-min) showed a trend for a higher number of repetitions when compared to bench press. This may be due to a neural adaptation of force production to produce a lighter absolute load (1,10). It seems likely as well that the bench press, which recruits more muscle groups, has a lower need for recovery of energy-yielding substrates compared to the peck deck fly because the force production is spread out over more muscle fibers (13,17).

These findings are contradictory to those of Shimano et al. (20), who found a greater number of repetitions performed in the squat and bench press than the curl. It seems that large muscle groups (such as the chest, back, and thigh) have the capacity to perform more repetitions than small muscle groups (biceps brachii and triceps brachii). But, still, more repetitions can be performed with uni-joint exercises than the multi-joint exercises using the same muscle group.

The 2-min rest interval between sets was better for recovery in the multi-joint bench press exercise, although the 1-min recovery was sufficient to maintain the uni-joint peck deck fly exercise. These findings are in agreement with the position of the American College Sports Medicine (4) that calls for 1-min to 2-min recovery periods for uni-joint exercises and 2-min to 3-min recovery periods for multi-

joint muscle training. Interestingly, this appears to be the case despite the lack of substantial evidence to clearly support the different exercise prescriptions for the two types of RT (4,6).

CONCLUSIONS

For the pectoralis major and related shoulder flexors muscles (e.g., biceps brachii, coracobrachialis, and anterior deltoid), the findings in the present study indicate that the 2-min rest interval between sets was more effective than the 1-min rest interval in relation to the maximum number of repetitions performed for the multi-joint bench press exercise. Also, the findings indicate that the 1-min rest interval was sufficient to minimize a decrease in the number of repetitions in the uni-joint exercise peck deck fly exercise. However, there was a tendency for more repetitions to be performed with the peck deck fly than the bench press. These findings suggest that it is necessary to continue the research involving different muscle groups and rest intervals to establish an appropriate prescription for RT exercises and desired outcomes.

Address for correspondence: Dihogo Gama de Matos, MD, Department of Sport Sciences, Exercise and Health, University of Trás-os-Montes and Alto Douro (UTAD), Portugal. Phone (+55)9112-6169; Email: dihogogmc@hotmail.com

REFERENCES

1. Aagaard P, Simonsen EB, Andersen JL, Magnusson P, Dyhre-Poulsen P. Increased rate of force development and neural drive of human skeletal muscle following resistance training. ***J Appl Physiol.*** 2002;93:1318-1326.

2. Ahtiainen JP, Pakarinen A, Alen M, Kraemer WJ, Häkkinen K. Short vs. long rest period between the sets in hypertrophic resistance training: Influence on muscle strength, size, and hormonal adaptations in trained men. ***J Strength Cond Res.*** 2005;19:572-582.

3. American College of Sports Medicine (ACSM). Position stand: Progression models in resistance training for healthy adults. ***Med Sci Sports Exer.*** 2002;34(2):364-380.

4. American College of Sports Medicine. Progression models in resistance training for healthy adults. ***Med Sci Sports Exer.*** 2009;41:687-708.

5. Baechle TR, Earle RW. ***Essential of Strength Training and Conditioning***. Champaign: IL. Human Kinetics, 2000.

6. Carpinelli RN, Otto RM, Winett RA. A Critical analysis of the ACSM position stand on resistence training: Insufficient evidence to support recommended training protocols. ***JEPonline.*** 2004;7:1-60.

7. Drinkwater EJ, Lawton TW, Mckenna MJ, Lindsell RP, Hunt PH, Pyne DB. Increased number of forced repetitions does not enhance strength development with resistance training. ***J Strength Cond Res.*** 2007;21(3):841-847.

8. Fleck SJ, Kraemer WJ. ***Designing Resistance Training Programs***. Champaign: IL. Human Kinetics, 2004.

9. Halet KA, Mayhew JL, Murphy C, Fanthorpe J. Relationship of 1 repetition maximum lat-pull to pull-up and lat-pull repetitions in elite collegiate women swimmers. ***J Strength Cond Res.*** 2009;23:1496-1502.

10. Kirk EP, Washburn RA, Bailey BW, Lecheminant JD, Donnelly JE. Six months of supervised high-intensity low-volume resistance training improves strength independent of changes in muscle mass in young overweight men. ***J Strength Cond Research.*** 2007;21:151-156.

11. Kraemer WJ, Fleck SJ, Dziados JE, Harman EA, Marchitelli LJ, Gordon SE. Changes in hormonal concentrations after different heavy-resistance exercise protocols in woman. ***J Appl Physiol.*** 1993;75:594-604.

12. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: Progression and exercise prescription. ***Med Sci Sports Exer.*** 2004;36(4):674-688.

13. Lambert CP, Flynn MG. Fatigue during high-intensity intermittent exercise: Application to bodybuilding. ***Sports Med.*** 2002;32:511-522.

14. Miranda H, Fleck SJ, Simão R, Barreto AC, Dantas EHM, Novaes J. Effect of two differents rest periods lengths on the number of repetitions performed during resistance training. ***J Strength Cond Res.*** 2007;21:1032-1036.

15. Rahimi R. Effect of different rest intervals on the exercise volume completed during squat bouts. ***J Sports Sci Med.*** 2005;4:361-366.

16. Ratamess NA, Falvo MJ, Mangine GT, Hoffman JR, Faigenbaum AD, Kang J. The effect of rest interval length on metabolic responses to the bench press exercise. ***Eur J Appl Physiol.*** 2007;100:1-17.

17. Richmond SR, Godard MP. The effects of varied rest periods between sets to failure using the bench press in recreationally trained men. ***J Strength Cond Res.*** 2004;18:846-849.

18. Sabari JS, Maltzev I, Lubarsky D, Liszkay E, Homel R. Goniometric assessment of shoulder range of motion: Comparison testing in supine and sitting positions. ***Arch Phys Med Rehabil.*** 1998;79:647-651.

19. Senna G, Salles BF, Prestes J, Mello RA, Simão R. Influence of two different rest interval lengths in resistance training sessions for upper and lower body. ***J Sports Sci Med.*** 2009;8: 197-202.

20. Shimano T, Kraemer WJ, Spiering BA, Volek JS, Hatfield DL, Silvestre R. Relationship between the number of repetitions and selected percentages of one repetition maximum in free weight exercises in trained and untrained men. ***J Strength Cond Res.*** 2006;20:819-823.

21. Simão R, Farinatti PTV, Polito MD, Maior AS, Fleck SJ. Influence of exercise order on the number of repetitions performed and perceived exertion during resistive exercises. ***J Strength Cond Res.*** 2005;11(8):152-156.

22. Simão R, Farinatti PTV, Polito MD, Viveiros L, Fleck SJ. Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercise in women. ***J Strength Cond Res.*** 2007;21:23-28.

23. Simão R, Spineti J, Salles BF, Oliveira LF, Matta T, Miranda F. Influence of exercise order on maximum strength and muscle thickness in untrained men. ***J Sports Sci Med.*** 2010;9:1-7.

24. Thomas S, Reading J, Shephard RJ. Revision of the physical activity readiness questionnaire (PAR-Q). ***Canadian J Sport Sci.*** 1992;17:338-345.

25. Willardson JM, Burkett LN. A comparison of 3 different rest intervals on the exercise volume completed during a workout. ***J Strength Cond Res.*** 2005;19:23-26.

26. Willardson MJ, Burkett NL. The effect of different rest intervals between sets on volume components and strength gains. ***J Strength Cond Res.*** 2008;22:146-152.

27. Willardson MJ, Burkett NL. The effect of rest interval length on the sustainability of squat and bench press repetitions. ***J Strength Cond Res.*** 2006;20:400-403.