Comparison Between Constant and Decreasing Rest Intervals: Influence on Maximal Strength and Hypertrophy

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[1]*Faculty of Physical Education of Santos, Metropolitan University of Santos, Santos, Brazil;* [2]*Faculty of Physical Education, State University of Campinas, Campinas, Brazil;* [3]*Sport Science Department, Colorado College, Colorado Springs, Colorado;* [4]*School of Physical Education and Sports, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil;* [5]*Department of Physiology, São Paulo Federal University, São Paulo, Brazil;* [6]*School of Physical Education and Sports, University of São Paulo, São Paulo, Brazil; and* [7]*Department of Radiology, State University of Campinas, Campinas, Brazil*

Abstract

de Souza Jr, TP, Fleck, SJ, Simão, R, Dubas, JP, Pereira, B, de Brito Pacheco, EM, da Silva, AC, and de Oliveira, PR. Comparison between constant and decreasing rest intervals: influence on maximal strength and hypertrophy. *J Strength Cond Res* 24(7): 1843–1850, 2010—Most resistance training programs use constant rest period lengths between sets and exercises, but some programs use decreasing rest period lengths as training progresses. The aim of this study was to compare the effect on strength and hypertrophy of 8 weeks of resistance training using constant rest intervals (CIs) and decreasing rest intervals (DIs) between sets and exercises. Twenty young men recreationally trained in strength training were randomly assigned to either a CI or DI training group. During the first 2 weeks of training, 3 sets of 10–12 repetition maximum (RM) with 2-minute rest intervals between sets and exercises were performed by both groups. During the next 6 weeks of training, the CI group trained using 2 minutes between sets and exercises (4 sets of 8–10RM), and the DI group trained with DIs (2 minutes decreasing to 30 seconds) as the 6 weeks of training progressed (4 sets of 8–10RM). Total training volume of the bench press and squat were significantly lower for the DI compared to the CI group (bench press 9.4%, squat 13.9%) and weekly training volume of these same exercises was lower in the DI group from weeks 6 to 8 of training. Strength (1RM) in the bench press and squat, knee extensor and flexor isokinetic measures of peak torque, and muscle cross-sectional area (CSA) using magnetic resonance imaging were assessed pretraining and posttraining. No significant differences ($p \leq 0.05$) were shown between the CI and DI training protocols for CSA (arm 13.8 vs. 14.5%, thigh 16.6 vs. 16.3%), 1RM (bench press 28 vs. 37%, squat 34 vs. 34%), and isokinetic peak torque. In conclusion, the results indicate that a training protocol with DI is just as effective as a CI protocol over short training periods (6 weeks) for increasing maximal strength and muscle CSA; thus, either type of program can be used over a short training period to cause strength and hypertrophy.

Key Words resistance training, rest periods, weight training

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Introduction

Rest period length between sets and exercises is an important acute resistance training program variable. Decreasing rest period length (3–5 minutes vs. 2 minutes to 30 seconds) results in a decreased number of repetitions per set using the same resistance indicating increased fatigue (9,11,12) and is one method of making sets more difficult to complete with the prescribed number of repetitions (4). The decreased number of repetitions per set with short rest periods results in a decreased total training volume that could compromise maximal strength increases. This may in part explain why most longitudinal training studies (11,12) have shown greater strength increases with long (2–5 minutes) compared to short (30–40 seconds) rest period lengths. However, short rest periods also increase the metabolic and hormonal response to resistance training (6,7,8,11,12). The increased hormonal response (growth hormone, IGF-1) with short rest periods indicates a more anabolic environment that could result in increased muscle hypertrophy.

Longitudinal studies (11,12) have used rest periods between sets and exercises of a constant length throughout the duration of training. However, during some resistance training programs, rest period length is decreased as the training progresses. The authors are not aware of any study examining the effect of decreasing rest period length between sets and exercises as resistance training progresses. The present study's purpose was to compare during 8 weeks of training the effect on strength and hypertrophy of a resistance training program using constant rest intervals (CIs, 2 minutes) and one using decreasing rest intervals (DIs, 2 minutes decreasing to 30 seconds) as the 8 weeks of training progresses. It is hypothesized that the increased hormonal response with short rest periods will counteract any decreases in training volume because of decreasing rest period length resulting in similar strength and hypertrophy increases with the constant and decreasing rest period training protocols.

Methods

Experimental Approach to the Problem

The study was a randomized control design. Subjects performed 3 1 repetition maximum (1RM) test familiarization sessions on Monday, Wednesday, and Friday for 2 weeks. Seventy-two hours (Monday) after the last 1RM familiarization session, muscle cross-sectional area (CSA) was measured using magnetic resonance imaging (MRI) followed by isokinetic peak torque determination. Forty-eight and 96 hours later (Wednesday and Friday) pretraining 1RM tests for the squat and bench press were performed. During the following 8 weeks, 2 training programs were performed, one program used constant rest periods or intervals (CIs) of 2 minutes between sets and exercises throughout the 8 weeks of training and the other rest periods that decreased (DI) from 2 minutes to 30 seconds as the 8 weeks of training progressed. Posttesting took place using the following timetable: Seventy-two to 96 hours (Monday or Tuesday) after the last training session, muscle CSA and isokinetic peak torque measures were determined. Forty-eight and 96 hours (Wednesday and Friday) after these measures, 1RM tests for the squat and bench press were performed. All training and testing sessions for individual subjects were conducted at the same time of day.

Subjects

Twenty young men recreationally trained in strength training were randomly assigned to 2 training groups of 10 subjects: CI group age, 20.5 ± 1 years; body mass, 74.3 ± 9.4 kg; height, 178 ± 4.2 cm and DI group age, 22 ± 4.8 years; body mass, 70.8 ± 12.9 kg; height, 175.5 ± 9.8 cm. All subjects performed a strength training program for at least a year with a minimum training frequency of 3 times per week before the study, had no functional limitations to strength training or the testing procedures, upon questioning had not used anabolic–androgenic steroids or similar substances and negatively answered the PAR-Q questionnaire (13). Subjects with previous resistance training experience were chosen because this should help minimize the neural effects on initial strength gains. The experimental procedures were approved by the Ethics Committee of the UNICAMP Medical Science College (Project: 260/2005–CAAE: 0078.0.146.000-05), and informed written consent was obtained from all subjects before their participation in the study.

One Repetition Maximum Testing

Pre and posttesting 1RMs for the free-weight squat and bench press were determined on 2 occasions separated by 48 hours with no exercise allowed during the time between tests. The heaviest resistance achieved on either of the test days was considered the pre and posttraining 1RM. Pre and posttraining the 1RM bench press ($r = 0.94$, $r = 0.96$) and squat ($r = 0.92$, $r = 0.92$) tests showed high intraclass correlation coefficients, respectively, and paired t-tests showed no significant difference between the 2 pre or posttraining 1RM tests.

These 2 exercises were used for strength testing because they were common exercises performed by the subjects before participation in the study and the study-training program trained muscle groups used when performing these 2 exercises. The 1RM testing protocol has been described previously (15). Briefly, 1RMs were determined in fewer than 5 attempts with a rest interval of 5 minutes between attempts. The bench press 1RM was determined first and then a rest interval no shorter than 10 minutes was allowed before beginning determination of the squat 1RM.

Isokinetic Peak Torque Evaluation

Knee extensor and flexor isokinetic peak torque evaluations were conducted using an isokinetic dynamometer (Cybex 6000 model, Division of Lumex, Inc. Ronkonkoma, NY, USA). Subjects were positioned and stabilized in accordance with the manufacture's recommendations (3). Before determination of the isokinetic peak torques, subjects performed a warm-up of 2 muscle actions at $60°\cdot s^{-1}$ at approximately 50% of maximum effort. After the warm-up and a rest period of 2 minutes, subjects performed a concentric action of the knee extensors followed by a concentric action of the knee flexors for 5 maximal repetitions at the angular velocity of $60°\cdot s^{-1}$. The same testing protocol was used for both the right and left legs to determine peak torque irrelevant of knee angle.

The test–retest reliability of the isokinetic tests was evaluated by retesting each subject 6 hours after the initial isokinetic test both pre and posttraining. Pre and posttraining isokinetic peak torque evaluation of the knee extensor ($r = 0.96$, $r = 0.96$) and flexor ($r = 0.94$, $r = 0.96$) tests showed high intraclass correlation coefficients, respectively, and paired t-tests showed no significant difference between the 2 pre or posttraining isokinetic peak torque evaluations. The greatest value obtained during either test during both pre and posttraining was used for the statistical analysis.

Magnetic Resonance Imaging Muscle Cross-Sectional Areas Measurements

Magnetic resonance imaging of the right thigh and upper arm was performed using a standard body coil and a 2.0-T Scanner (Elscint Prestige, Haifa, Israel) to determine muscle CSA. The

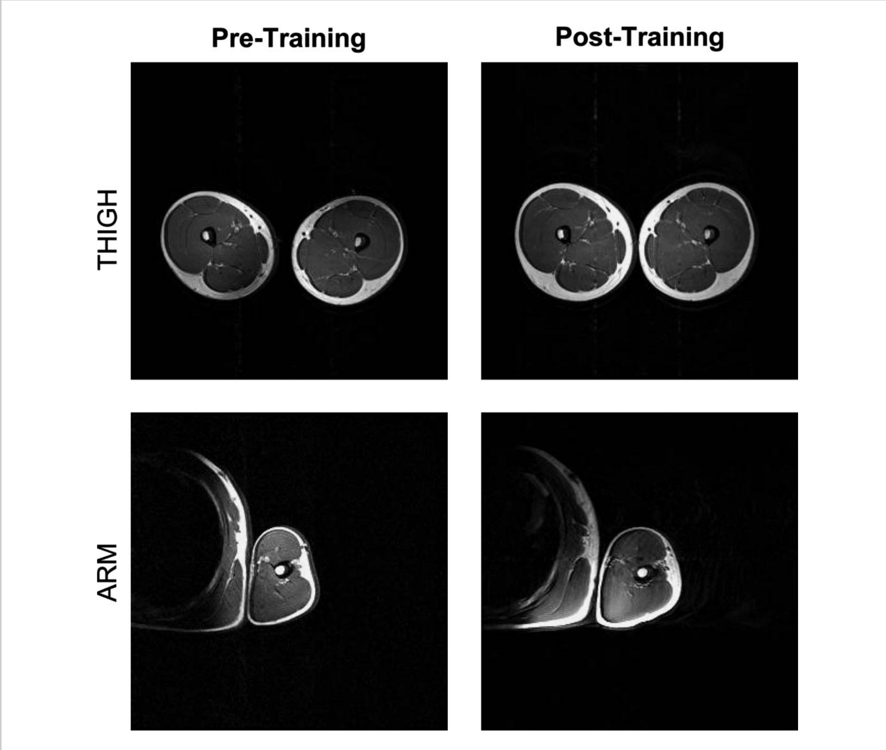

Figure 1. Magnetic resonance images of thigh and arm for the same individual pre and posttraining.

MRI equipment was calibrated before CSA determination of the first subject on each testing day using the manufacture's procedures. The right thigh and upper arm were scanned with subjects in a supine position. During the thigh scan, the legs were relaxed and straight, feet parallel to each other, and legs immobilized with pads and straps around both feet. For the upper arm scan, the arm was placed as close as possible to the magnetic isocenter aligned at the subject's side palm up and taped in position to the scanner bed surface.

Both the thigh and arm scans were obtained using axial T1-weighted spin-echo images with a repetition time of 750 milliseconds, echo time of 20 milliseconds, 230 × 290 matrix resolution, and number of excitations of 2. Thigh images were obtained perpendicular to the femur starting at the proximal femoral epiphysis (tangential to its proximal end) and proceeding distally toward the knee joint. The slice thickness was 8 mm with no gap (40 slices) with a 45 × 45-cm field of view (FOV). Upper arm images were obtained perpendicular to the humerus starting at the proximal humeral epiphysis (tangential to its proximal end) proceeding distally toward the elbow joint. The slice thickness was 6 mm with a 1.2-mm interslice gap (40 slices) with an FOV of 40 × 32 or 40 × 40 cm depending on the arm's size. Scan time for both scans was 3 minutes and 18 seconds. The MRI images from each site were saved in a DICOM format on an optical disc and sent to a central imaging facility for analysis.

The muscle CSA of the thigh and arm was determined by manually tracing the margins of the muscles (all muscle compartments were included) and the external margin of the bone (periosteal border). The muscle CSA was obtained by subtracting the total bone area from total muscle area (Figure 1). Analyses were performed by the same investigator using public domain software–Image J 1.33u (National Institutes of Health, Bethesda, MD, USA).

Cross-sectional areas of 2 slices per site were determined with the mean of the 2 slices used for statistical analyses. The slices were selected from the midpoint of the thigh and the midpoint of the arm (just distal to the deltoid insertion). To ensure that the slices analyzed pre and posttraining were taken from the same section of the thigh, the slice tangentially to the femoral head was used as an anatomical marker (first slice) and then numbered slice-by-slice distally. Two images midthigh were selected from each subject and their numbers recorded and used to locate the same slice during posttesting. The ninth and tenth axial slices of the thigh were selected for most subjects. The same procedure was used for the arm with the slice tangentially to the humeral head used as an anatomical marker (first slice). The 12th and 13th axial slices of the arm were selected for most subjects. In 2 subjects, where the number of slices between the first slice and the pretraining selected slices did not match (different anatomical position) during pre and posttesting, images from the pretraining were compared to the posttraining scans until an identical anatomical match was found.

The reproducibility of CSA measurements was evaluated by analyzing each subject's arm and thigh image 2 times within 4 months. The precision of the CSA measurements was good for both the thigh (coefficient of variation = 0.8%; intraclass correlation coefficient = 0.97) and arm (coefficient of variation = 0.8%; intraclass correlation coefficient = 0.99).

Training Procedures

The CI and DI groups between sets and exercises performed the same exercises, repetitions per set, and sets during an 8-week monitored training period. For both groups, the resistance was changed when necessary to stay within the desired RM training zone.

Table 1. Rest period length used by the decreasing rest interval group.

Training week	Rest (s)
1–2	120
3	105
4	90
5	75
6	60
7	45
8	30

During the first 2 weeks, 3 sets of 10–12 RM, with 2-minute rest intervals between sets and exercises were performed by both groups. Training was performed 6 $d \cdot wk^{-1}$. Three days per week (Monday, Wednesday, Friday) program A was performed (free-weight bench press, free-weight incline bench press, machine wide grip front lat pull down, leg extension machine, and leg curl machine) and 3 $d \cdot wk^{-1}$ (Tuesday, Thursday, Saturday) program B was performed (free-weight front military press, dumbbell shoulder lateral raises, biceps barbell curls, triceps extension on a pulley machine with a v shaped handle, lying triceps extension with a barbell, and abdominal crunches).

After the first 2 weeks of training, the CI group continued to use 2-minute rest periods and trained the next 6 weeks (weeks 3–8) 6 $d \cdot wk^{-1}$ using 4 sets of 8–10RM for each exercise. During weeks 3–8, different exercises were performed on Monday and Thursday (free-weight bench press, free-weight incline bench press, machine wide grip front lat pull down, and machine seated row), Tuesday and Friday (free-weight front military press, dumbbell shoulder lateral raises, biceps barbell curls, alternating biceps curl with dumbbells, triceps extension on a pulley machine with a v shaped handle, and lying triceps extension with a barbell), and Wednesday and Saturday (free-weight back squat, leg extension machine, leg curl machine, and abdominal crunches).

After the second week of training, the DI group's training program consisted of the same exercises, days of training per week, and number of sets and repetitions as the CI group. The only difference in the training programs was as training progressed, rest period intervals were gradually decreased with the DI training (Table 1). The gradual reduction in rest period length was to allow the subjects time to adapt to and tolerate the low rest period length between sets and exercises.

The mass of all weight plates and bars used for training was determined with a precision scale (Filizola Balanças Industriais S.A., São Paulo, Brazil). The machine exercises were performed using resistance training machines (Life Fitness Inc., Franklin Park, IL, USA).

Statistical Analyses

A 2 (pre–post) by 2 (groups) way analysis of variance (time [baseline vs. 8 weeks training] × group (CI vs. DI) with repeated measures followed by Tukey's post hoc test when appropriate were used to analyze for significant differences ($p \leq 0.05$) between groups for dependent variables: 1RMs, muscle CSAs, isokinetic peak torques, total training volume (sets × resistance for all training sessions), and weekly training volume (sets × resistance for all sessions in 1 week)

Table 2. Total training volume of the bench press during the 8 weeks of training.*†‡

Group	Week	Training volume (kg)	Group	Week	Training volume (kg)
CI	1	2,003.7 ± 433.6	DI	1	2,075.0 ± 300.9
CI	2	2,024.5 ± 437.0	DI	2	2,096.2 ± 304.7
CI	3	2,066.7 ± 446.7	DI	3	2,138.9 ± 311.7
CI	4	2,137.1 ± 471.3§	DI	4	2,138.7 ± 301.8
CI	5	2,196.9 ± 433.7§‖	DI	5	2,106.7 ± 305.8
CI	6	2,291.6 ± 417.8§‖¶#	DI	6	2,082.6 ± 341.4
CI	7	2,410.8 ± 490.8§‖¶#**	DI	7	2,118.5 ± 319.0
CI	8	2,446.5 ± 519.4§‖¶#**††	DI	8	2,094.1 ± 314.4

*CI = constant rest interval group; DI = decreasing rest interval group.
†Values are given as mean ± *SD*.
‡All significant differences are $p \leq 0.05$.
§Significant difference from first week.
‖Significant difference from second week.
¶Significant difference between the groups.
#Significant difference from third week.
**Significant difference from fourth week.
††Significant difference from fifth week.

Table 3. Total training volume for the squat during the 8 weeks of training.*†‡

Group	Week	Training volume (kg)	Group	Week	Training volume (kg)
CI	1	2,752.1 ± 469.6	DI	1	2,566.1 ± 373.1
CI	2	2,766.0 ± 472.9	DI	2	2,579.0 ± 375.1
CI	3	2,794.0 ± 477.7	DI	3	2,606.6 ± 377.3
CI	4	2,836.4 ± 449.7	DI	4	2,664.1 ± 378.4
CI	5	2,984.9 ± 443.3§	DI	5	2,590.7 ± 355.3
CI	6	3,019.0 ± 476.1§‖¶	DI	6	2,591.9 ± 357.4
CI	7	3,162.8 ± 468.1§‖¶#	DI	7	2,595.3 ± 345.9
CI	8	3,253.8 ± 498.2§‖¶#**††	DI	8	2,619.4 ± 335.5

*CI = constant rest interval group; DI = decreasing rest interval group.
†Values are given as mean ± *SD*.
‡All significant differences are $p \leq 0.05$.
§Significant difference from the first week.
‖Significant difference between the groups.
¶Significant difference from the second week.
#Significant difference from the third week.
**Significant difference from the fourth week.
††Significant difference from the fifth week.

of the free-weight bench press and squat. Statistica version 7.0 (Statsoft, Inc., Tulsa, OK, USA) statistical software was used for all statistical analyses.

Results

There were no significant differences between the groups pretesting anthropometric, strength or muscle CSA measures. All subjects had a compliance of 100% to the experimental procedures and training. Neither group showed a significant change in total body mass from pre to posttraining.

The total training volume (sets × resistance for all training sessions) during the 8 weeks of training for the bench press by the CI group (21,257.9 ± 172.7 kg) was significantly greater (p = 0.043) than the DI group (19,250.4 ± 343.8 kg). Similarly, total training volume in the squat performed by the CI group (27,248.2 ± 293.8 kg) was significantly greater (p = 0.000) than the DI group (23,453.6 ± 299.4 kg). Weekly training volume of the CI group for the bench press and squat showed significant increases beginning in weeks 4 and 5, respectively, compared to previous weeks (Tables 2 and 3). The CI group's weekly training volume was significantly greater than that of the DI group for the bench press and squat during weeks 6–8. The DI group showed no significant change in bench press and squat weekly training volume between any weeks during the 8 weeks of training.

Both groups showed significant increases in bench press and squat 1RM (Table 4), muscle CSAs (Table 5), and knee extensor and flexor isokinetic peak torque pre to posttraining, except for the right knee extensor peak torque of the CI group pre to posttraining (Table 6). One RM, isokinetic peak torque or muscle CSAs showed no significant differences between the CI or DI groups.

Table 4. One repetition maximum pre and posttraining.*†

	Bench press		Squat	
Groups	Pre (kg)	Post (kg)	Pre (kg)	Post (kg)
CI	93.6 ± 12	120 ± 10‡	126.8 ± 10	169 ± 14‡
DI	95.9 ± 14	132 ± 15‡	120.9 ± 12	162 ± 22.5‡

*CI = constant rest interval group; DI = decreasing rest interval group.
†Values are given as mean ± *SD*.
‡Statistically significant difference ($p \leq 0.0001$) between pretraining and posttraining.

Table 5. Muscle CSAA and CSAT pre and posttraining.*†

	CSAA (cm^2)		CSAT (cm^2)	
Variables	Pre	Post	Pre	Post
CI	63.6 ± 8.0	72.4 ± 9.8‡	172.2 ± 19.6	200.8 ± 27.1‡
DI	65.2 ± 5.8	74.7 ± 7.2‡	168.7 ± 16.8	196.2 ± 26.6‡

*CI = constant rest interval; DI = decreasing rest interval; CSAA = cross-sectional area of the arm; CSAT = cross-sectional area of the thigh.
†Values are given as mean ± *SD.*
‡Statistically significant difference ($p \leq 0.0001$) between pretraining and posttraining.

Table 6. Isokinetic knee flexor and extensor peak torque (N·m) pre and posttraining.*†

	CI group		DI group	
Variables	Pre (N·m)	Post (N·m)	Pre (N·m)	Post (N·m)
Knee flexor				
Right	130.6 ± 27	140 ± 34‡	118.5 ± 19	127 ± 29‡
Left	131.5 ± 25	140.4 ± 38‡	118.5 ± 15	126.2 ± 27‡
Knee extensor				
Right	267.4 ± 31	271.5 ± 9	240.2 ± 22	258 ± 25‡
Left	242.3 ± 32	254.5 ± 12‡	231.7 ± 16	245.4 ± 24‡

*CI = constant rest interval group; DI = decreasing rest interval group.
†Values are given as mean ± *SD.*
‡Statistically significant difference ($p \leq 0.0001$) between pretraining and posttraining.

Discussion

To our knowledge, this was the first study to compare the chronic effects of a training program using decreasing rest periods between sets and exercises to a program using constant rest periods. The constant rest interval program (CI) used constant rest periods (2 minutes) between sets and exercises for 8 weeks of training and the DI program used constant rest period lengths (2 minutes) for 2 weeks followed by 6 weeks with decreasing rest periods between sets and exercises (2 minutes decreasing to 30 seconds). The results showed no significant differences in strength or muscle CSA gains because of the different training protocols. No differences between groups was shown even though the DI group's total training volume for the 8 weeks of training and weekly training volume beginning in week 6 was lower for the bench press and squat exercises than that of the CI group.

For programs emphasizing muscular strength in novice and intermediate weight trainers, the American College of Sports Medicine (11) recommends 2- to 3-minute rest periods between sets when performing multijoint exercises, and 1- to 2-minute rest periods between sets for single-joint exercises. While for programs emphasizing muscular hypertrophy in novice and intermediate weight trainers 1–2 rest periods are recommended for both multijoint and single-joint exercises. The need for longer rest periods when emphasizing strength is supported by the results of Pincivero et al. (10) for isokinetic training with either 40 or 160 seconds rest between sets. One leg of each subject was assigned to a 4-week, 3 $d{\cdot}wk^{-1}$ isokinetic protocol that involved concentric knee extension and flexion muscle actions performed at $90°{\cdot}s^{-1}$. The 160-second rest group demonstrated significantly greater increases in quadriceps and hamstring peak torque ($60°{\cdot}s^{-1}$), average power ($60°{\cdot}s^{-1}$), and total work (30 repetitions at $180°{\cdot}s^{-1}$).

In the present study, both groups showed significant increases pre to posttraining in knee extensor and flexor isokinetic peak torque except for the right knee extensor peak torque of the CI group. No significant difference between the DI and CI groups in peak torque at an angular velocity of $60°{\cdot}s^{-1}$ was shown indicating that isokinetic peak torque is equally increased with both CI or DI training groups.

Willardson and Burkett (16) compared squat strength gains and training volume using 2-minute vs. 4-minute rest between sets over 13 weeks of training. The same squat training program using either 2- or 4-minute rest between sets was performed 2 d·wk^{-1}. The squat training sessions varied in intensity, number of sets, and repetitions performed per set in a nonlinear periodized manner. Differences in strength gains and volume measures (resistance used per set, repetitions performed per set, intensity per set, and volume performed per workout) were compared between groups. During the entire training period, training using 4-minute rest periods demonstrated significantly higher total training volumes during training sessions using higher intensities (70–90% 1RM for 3–15 repetitions per set). However, the groups showed no significance difference in squat strength gains (18% for 2-minute rest and 21% for 4-minute rest). These findings suggest that there may be a threshold for training volume necessary to gain maximal strength. Resting 2 minutes between sets although resulting in less total volume did result in the same maximal strength gains as resting 4 minutes between sets indicating sufficient volume was performed with 2-minute rest to achieve maximal strength gains. The present study's design resulted in the DI group compared to the CI group performing lower total training volume and lower volume in weeks 6–8 in the squat and bench press, which is in agreement with previous research demonstrating exercise volume decreases with shorter rest periods (9). However, the groups showed no significant difference in maximal squat or bench press strength despite lower training volumes performed by the DI group, which is in agreement with the study of Willardson and Burkett (16) that the same maximal strength gains can be achieved with a lower training volume.

The squat and bench press were performed 2·d·wk^{-1} in a 6-d·wk^{-1} training program during weeks 3–8 when the rest period was gradually shortened in the training program of the DI group. These exercises in this study were chosen to represent training volume because they are common exercises for which training volume is tracked during resistance training programs. Additionally, these exercises when performed were the first exercise of a training session, and previous research indicates the volume of exercises performed first in a session are the least affected by exercise order (14,15). Thus, for these exercises, changes in volume would accurately reflect the difference in rest periods between sets and exercises and not changes in exercise order.

It is interesting to note that in the present study squat strength gains were very similar between CI (34%) and DI (34%) training. However, in the bench press, the 1RM gain in the DI group was 10% (38% vs. 28%) greater compared to the CI group indicating DI training may be more effective for the upper body than CI training although further research is needed to substantiate this hypothesis.

Using a crossover design so that all subjects trained 3 months with both 2- and 5-minute rest periods, Ahtiainen et al. (1) concluded that the maximal strength and hypertrophic responses with these 2 different rest periods were not significantly different in experienced strength trained men (mean training experience of 6.6 ± 2.8 years). Training using 5-minute rest periods did result in using approximately a 15% higher intensity than training using 2-minute rest intervals. Although using the 5-minute rest interval resulted in a higher intensity, the volume of training was significantly greater with the 2-minute condition because of the performance of more sets. However, maximal strength of the leg extensors and quadriceps CSA determined by MRI was not significantly different between the 2 training protocols. The results indicate that the same gains in strength and hypertrophy can be achieved with a program of a higher volume and lower intensity or a program of lower volume and a higher intensity. In the present study, the resistance used by the DI and CI groups was adjusted to stay within the 8–10RM training zone during weeks 3–8 of training when rest period length was decreased with the DI training. Thus, the only manner in which the CI training could result in a higher volume was an increase in the resistance or intensity. The present study's results for maximal strength, arm (CSAA) and thigh (CSAT) CSA indicate that training volume can be lower for a portion of training (weeks 6–8 in the present study) and still result in similar strength gains as a higher volume program. Although not measured in the present study the effect of decreased volume on strength and muscle CSA may have been compensated for by an increase in the metabolic and hormonal response to shorter rest periods as the training progressed (6,7,8,11,12).

One possible limitation of the present study is the use of medial CSAs to determine muscle size gains. However, according to Kawakami et al. (5), muscle CSA of the triceps brachii increases predominantly at the medial portion of the muscle, whereas the distal and proximal portions show little change. Indicating if the CI and DI training protocols did result in different changes in CSA it should have been apparent at the arm and thigh medial CSAs examined in the present study. The use of medial CSAs to examine muscle size changes does not rule out as suggested by Antonio (2) that muscle fibers in different regions of a muscle or in different muscles and even in the same muscle may adapt with varying magnitudes to the same training protocol.

In conclusion, this is the first study to the author's knowledge to demonstrate that similar strength and muscle CSA increases can be achieved with either constant (2 minutes) or decreasing (2 minutes decreasing to 30 seconds) rest periods between sets and exercises over short training periods. This conclusion appears to be true for both upper and lower body exercises (bench press and squat) and muscle groups (arm and thigh). In that this is the first study to examine the effects of decreasing rest period length between sets and exercises as training progresses further studies should be performed to substantiate these conclusions.

Practical Applications

The results of this study showed no significant differences in maximal strength (1RM; isokinetic torque) or muscle size

(CSA) over 8 weeks of training using either a constant rest period length (2 minutes) between sets and exercises or a decreasing rest period length (2 minutes decreased to 30 seconds). Thus, a weight training program using decreasing rest periods between sets and exercises for at least short training periods can be used to bring about the same adaptations in strength and muscle hypertrophy as a constant rest period resistance training program.

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