EFFECTS OF SHORT AND LONG INTER-SET REST ON MAXIMAL ISOKINETIC STRENGTH AT SLOW AND FAST ANGULAR VELOCITIES IN TRAINED YOUNG MALES AFTER EIGHT WEEKS OF RESISTANCE TRAINING

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Abstract:

Resistance training is a widely used method to enhance muscle strength, with acute program variables influencing muscle adaptations. This study focused on the often-neglected variable of inter-set rest interval duration and its impact on muscle strength gains. Existing literature presents conflicting findings, with some studies advocating for longer rest intervals, while the others show comparable strength increases with shorter rests. Methodological differences in prescription and sample groups contributed to these inconsistencies. This study investigated the effect of short and long inter-set rests on maximal isokinetic strength gains of the upper and lower extremities during slow and fast angular velocities after eight weeks of resistance training. The research involved 26 healthy strength-trained males (age=20±1 year, body mass=81.5±8.8 kg, body height=184.4±6.1 cm) randomly assigned to G1m (1-minute rest) or G3m (3-minute rest). The resistance training programs were matched for all acute program variables, emphasizing the rest interval as the primary difference. Isokinetic dynamometry pre- and post-training assessed knee and elbow extensor and flexor maximal strength at 60º/s and 120º/s. The training program consisted of seven exercises performed at 70% 1RM until muscle failure three times per week over eight weeks. The most important result was that G3m, in contrast to G1m, led to a higher increase in peak torque of the knee (p=.037) and elbow extensors (p=.007) as well as the elbow flexors (p=.045) at 60º/s. Furthermore, G3m and G1m similarly increased the peak torque of the knee and elbow extensors and flexors at 120º/s and of the knee flexors at 60º/s (p>.138). In conclusion, the study suggests that strength training with longer inter-set rest intervals may lead to similar strength gains as strength training with shorter inter-set rest intervals. Nonetheless, individuals who prioritize maximizing their strength gains are advised to utilize longer rest intervals. However, shorter rest intervals may still yield significant strength enhancements, particularly for those who are limited by time.

Keywords: *strength training, rest intervals, muscle strength, isokinetic dynamometry*

Introduction

Resistance training is commonly used to increase muscle strength. The proper manipulation of acute program variables can influence these muscle adaptations (American College of Sports Medicine, 2009; Longo, et al., 2022). However, the rest interval duration is a significant acute program variable that is often neglected when designing resistance training programs. Currently, there are only a limited number of studies that have looked at how different inter-set rest intervals affect muscle strength, and their findings are inconsistent.

Resistance training guidelines recommend inter-set rest of long (>2 min) rather than short (<1 min) duration to increase muscle strength (Hill-Haas, Bishop, Dawson, Goodman & Edge, 2007; Schoenfeld, Pope, et al., 2016; Schoenfeld, Wilson, Lowery & Krieger, 2016). However, some studies show similar strength increases regardless of the inter-set rest (Ahtiainen, Pakarinen, Alen, Kraemer & Häkkinen, 2005; Buresh, Berg & French, 2009; Fink, Schoenfeld, Kikuchi & Nakazato, 2017; MacInnis, McGlory, Gibala & Phillips, 2017), but others show higher strength increases when using short inter-set rests (Villanueva, Lane & Schroeder, 2015). Such inconsistencies could be due to differences in the prescription of training variables and sample groups. Regarding training variables, studies exclusively investigated different durations of short (20 seconds to 1 min) and long (80 seconds to 5 min) rest intervals (Ahtiainen, et al., 2005; Fink, et al., 2017; Hill-Haas, et al., 2007) and differed between conditions for relative load, proximity to muscle failure and volume load (Buresh, et al., 2009; Fink, et al., 2017; Schoenfeld, Pope, et al., 2016). Regarding sample groups, some studies investigated physically inactive elderly persons (Villanueva, et al., 2015) or resistance-untrained individuals (Buresh, et al., 2009; Fink, et al., 2017; Piirainen, et al., 2011).

Another difference in the experimental designs is evident in the various methods used to assess muscle strength. Previous studies have laid the groundwork by employing diverse approaches to measure strength, each with its unique advantages and limitations, ranging from direct 1RM measurements to formula-based estimations and isokinetic dynamometer assessments (Buresh, et al., 2009; De Salles, et al., 2016; Piirainen, et al., 2011). The advantage of utilizing an isokinetic dynamometer lies in its capacity to measure muscle performance across various angular velocities, offering a more nuanced and practical comprehension. Incorporating assessments at both slow and fast angular velocities and evaluating both the flexors and extensors in the upper and lower extremities contributes to a thorough evaluation of muscular strength. This approach extends and combines insights from previous studies, providing a more holistic understanding of muscular strength.

Thus, studies investigating the effects of inter-set rest on muscular strength should compare short versus long intervals, last at least eight weeks, and match conditions for relative load, proximity to muscular failure, and volume load in resistance-trained individuals.

Therefore, the present study aimed to investigate the effect of short (one minute) and long (three minutes) inter-set rest on maximal isokinetic strength gains of the upper and lower extremities during slow (60º/s) and fast (120º/s) angular velocities after eight weeks of resistance training in trained young males. We hypothesized that two almost identical resistance training programs, with the only difference being the rest interval duration between sets, should have a similar impact on strength gains of the upper and lower extremities in young trained men.

Methods

Participants

An *a priori* analysis of statistical power performed with the G*Power program (Germany, Duesseldorf, version 3.1.9.7), based on a two-way analysis of variance with repeated measures, determined a required sample size of 22 participants. The minimum practically significant standardized effect size was set at 0.25, with an alpha level of 0.05, a statistical power of 0.80, and a correlation between repeated measures of 0.7.

The final sample consisted of young, healthy, and physically active male individuals (N = 26). Inclusion criteria for participants were the following: minimal knowledge and experience in resistance training, general health with no existing neurological or musculoskeletal disorders, and absence of injury history (with "hidden" or residual pain symptoms) to the trunk, upper, and/or lower extremities. Participants' age, body mass, height, and training experience are presented in Table 1.

Table 1. The age, body mass, height, and strength training experience of participants in G1m and G3m

	G1m	G3m
Age (year)	20.3 ± 1.0	19.5 ± 0.7
Body mass (kg)	82 ± 9.9	81 ± 7.8
Height (cm)	185.3 ± 5.6	183.5 ± 6.7
Training experience (year)	3.7 ± 1.4	4.2 ± 1.9

All participants were familiarized with the research objectives and risks and then gave informed consent to participate in the experiment. The research fully complied with the Declaration of Helsinki, and the experimental protocol was approved by the Scientific and Ethical Committee of the Faculty of Kinesiology University of Zagreb. Participants were instructed not to take any medications, consume any dietary supplements, or engage in any other systematic training during the experiment.

Participants were randomly assigned (using the random number generator function in Microsoft Excel, i.e., "=RAND()") to two equally sized groups: (1) resistance training with short rest intervals of one minute (G1m; n = 14) and (2) resistance training with long rest intervals of three minutes (G3m; n = 14).

Study design

The experimental design lasted 10 weeks, with the first and last weeks dedicated to testing and the remaining eight weeks were for the training program implementation. All tests (the initial and final condition) were performed at the same time of day for each participant to avoid possible influences of circadian rhythm fluctuations on strength (Grgic, et al., 2019) in the Laboratory for Motor Control and Performance at the Faculty of Kinesiology, University of Zagreb. Participants were instructed not to perform strenuous exercise 48 hours prior to the measurements. Each participant was trained and familiarized with the measurement protocol prior to the initial testing.

The first tests were administered to all participants during the first week. They aimed to determine baseline anthropometric characteristics, maximum concentric strength of the dominant arm and leg on an isokinetic dynamometer, and 1RM for all exercises included in the training program. For the next eight weeks, participants completed the training program three times per week. Final testing was performed in week ten, 3-5 days after the last training session. During the last week, participants were instructed not to do any other exercises or intense activities that could affect the final research results.

Procedure

Maximal isokinetic strength

The maximum concentric strength (peak torque and peak torque normalized to body mass) of the extensor and flexor muscles of the knee and elbow was measured using an isokinetic dynamometer (System 4, Biodex Corporation, Shirley, New York, USA) at two angular velocities—first at 60°/s and then, after a one minute rest, at 120°/s.

Measurement of the maximum concentric strength of the knee extensors and flexors was preceded by a standardized warm-up program consisting of three minutes of light jogging, dynamic stretching of the front and back thigh muscles, and ten forward and ten reverse lunges with each leg.

After the warm-up, participants were secured with straps in the dynamometer seat. The adjustment of the seat backrest distance was made to accommodate the positioning of the lateral femoral condyle's axis of rotation, as an anatomical reference point, in line with the dynamometer head's axis of rotation. For each participant, the dynamometer arm pad was individually adjusted proximally to the lateral malleolus. The range of motion ranged from 90° knee flexion to 10° knee extension, where 0° corresponded to a complete knee extension. Adjustments related to the effect of gravity on the shin and foot were made by weighing at a knee angle of 30°.

After two submaximal knee extension and flexion trials, participants performed three maximal repetitions. All measurements were accompanied by loud verbal encouragement.

The maximum concentric strength of the elbow extensors and flexors was measured after a break of approximately 20 minutes. The participants underwent a standardized warm-up again, which included a three-minute run, dynamic stretching of the arm muscles, and unilateral flexion and extension of the elbow (10 repetitions for each arm) with an elastic band.

The dynamometer was set up according to the manufacturer's instructions. Specifically, participants sat in the dynamometer seat with their shoulders, pelvis, and the upper arm of their dominant hand secured with straps. A 30° lateral angle was established between the upper arm and the trunk, and the dynamometer head height was aligned with the elbow rotation axis. The participants grasped the dynamometer arm pad handle with a hammer grip and performed elbow extensions and flexions within the range of 10-130° at the elbow joint (where 0° represented a complete extension of the elbow) at angular velocities of 60°/s and 120°/s. After two trial submaximal attempts, participants performed three maximal elbow extensions and flexions with the dominant arm. Loud verbal encouragement was provided throughout all measurements.

Maximal dynamic strength (1RM)

Prior to the training intervention period, all participants underwent one-repetition maximum (1RM) testing for each exercise following the guidelines established by the National Strength and Conditioning Association (Haff, et al., 2016) to determine individual initial training loads for each exercise. All exercises were tested in a single session with the testing order mirroring the exercise sequence used during the training program, with a 5-minute rest interval between exercises.

Before testing, participants participated in a general warm-up, including a three-minute run with tasks and brief dynamic stretching. Then, a specific warm-up set for the targeted exercise was performed, consisting of five repetitions at 50% of the estimated 1RM, followed by 1-2 sets of 2-3 repetitions with a load approximately corresponding to 60-80% of the estimated 1RM. The weight was gradually increased in subsequent one-repetition sets until the participants were still capable of performing the concentric muscle action through the full range of motion. The obtained 1RM was considered to be the highest weight lifted with a proper technique. A 3-minute rest was allowed between each consecutive attempt. All 1RM values for each exercise were determined within five attempts. The average 1RM values for groups G1m and G3m are presented in Table 2.

All testing was supervised by the research team to ensure consensus on the successful execution of each attempt.

Training program

The resistance training program was designed following all the aforementioned recommenda-

Table 2. 1RM (kg) in G1m and G3m

Group	Incline leg press	EZ bar French press	Barbell bicep curl	Leg extension	Prone leg curl	Cable triceps extension	Dumbbell Scott curl
G1m	211.5 ± 40.3	28.9 ± 10.7	34.0 ± 5.5	87.7 ± 12.2	75.0 ± 14.4	46.9 ± 11.1	28.1 ± 8.8
G3m	226.2 ± 21.8	28.5 ± 6.9	35.8 ± 7.3	96.2 ± 15.0	82.3 ± 10.9	46.6 ± 8.9	27.7 ± 5.5

tions about training program variables, and most of them were matched between the conditions, except the number of sets, which was increased in G1m to match the volume load of G3m. Specifically, each training session consisted of seven exercises (multi-joint and single-joint, using free weights and/or a machine) performed in the same sequence. However, to eliminate the influence of exercise order on dependent variables, participants began each session with a different exercise (i.e., 1234567, 2345671, 3456712…).

Two exercises were selected for each tested muscle group, and they were performed in the following sequence: 1) incline leg press, 2) Barbell Bicep Curl, 3) EZ bar French press, 4) leg extension, 5) dumbbell Scott curl, 6) cable triceps extension, and 7) prone leg curl.

The program included a general standardized warm-up, consisting of a three-minute run with tasks, followed by a brief dynamic full-body stretching routine (using a wooden stick), and, before the working sets, a specific warm-up involving one 10-repetition set of each exercise at 30% 1RM. All exercises were directly supervised to ensure correct execution and technique.

Further, the training intensity was individualized and corresponded to 70% of 1RM in each exercise. All sets were performed to the point of momentary concentric muscle failure, i.e., till the moment when it was no longer possible to perform the next concentric repetition while maintaining proper technique (Zaroni, et al., 2019). The predetermined load allowed an average of 12 repetitions per set in both groups (range: 10-14 repetitions). Therefore, the weight was adjusted so that the repetitions remained in the pre-established range regardless of changes in 1RM. However, due to the longer rest intervals between sets, G3m participants were able to perform sets of all exercises using heavier weights than G1m ($p<.004$).

Furthermore, the volume load relative to 1RM, calculated as the number of sets × repetitions × %1RM (Scott, Duthie, Thornton & Dascombe, 2016), was progressively increased by one set per exercise after the second and fifth weeks in both groups. By calculating the volume load for each exercise after each training session, it was found that the volume load was higher for G3m compared with G1m due to lifting heavier weights (Faraji, Vatani & Arazi, 2011). Therefore, it was necessary to precisely equalize the volume load of G1m concerning G3m. This was achieved originally and uniquely by adding one set per exercise in group G1m to the last training of each week.

In the first two weeks, G3m performed three sets, whereas from the third to the fifth week, four sets were performed, and from the sixth to the eighth week, five sets were performed per exercise per week (Table 3). Specifically, participants completed 24 training sessions over a total of eight weeks, with G3m performing a total of 99 sets and G1m performing 106 sets for each of the exercises.

Repetition tempo was also controlled, with concentric and eccentric muscle actions lasting ~1.5 seconds each on average, resulting in a total repetition time of approximately three seconds. Therefore, the only acute program variable that was expected to make a difference between the training groups was the rest interval between sets. Group G1m strictly adhered to a one-minute rest interval between sets, while group G3m had a three-minute rest interval.

Statistical analysis

All statistical procedures were conducted using the Statistical Package for the Social Sciences (IBM Corp. Released 2016; IBM SPSS Statistics for Macintosh, Version 24.0. Armonk, NY: IBM Corp.) and spreadsheet software (Microsoft Corporation. (2018). Microsoft Excel. Retrieved from: https://office.microsoft.com/excel).

Means and standard deviations were calculated for all variables, and the normality of distributions was assessed using the Shapiro-Wilk's test. To determine whether the groups differed in baseline values of all the measured variables before the training program, t-tests for independent samples were performed.

Table 3. Training protocol for both experimental groups

				Average repetitions × average weight (kg)						
	Week	Sets		Incline leg press	Barbell bicep curl	EZ bar French press	Leg extension	Dumbbell Scott curl	Cable triceps extension	Prone leg curl
G1m	1-2	3	+1 each week	13 × 174	12 × 18	12 × 19	12 × 67	12 × 18	12 × 29	12 × 58
	3-5	4		12 × 215	12 × 23	12 × 24	12 × 81	13 × 20	12 × 32	12 × 60
	6-8	5		12 × 234	12 × 23	12 × 26	12 × 86	13 × 21	12 × 33	12 × 63
G3m	1-2	3		13 × 210	12 × 20	12 × 20	13 × 80	12 × 17	12 × 31	12 × 59
	3-5	4		12 × 241	12 × 22	12 × 23	12 × 92	12 × 19	12 × 35	12 × 68
	6-8	5		13 × 261	12 × 24	12 × 25	12 × 97	12 × 21	12 × 37	12 × 72

Training effects within experimental groups were assessed using a series of paired t-tests with Bonferroni correction. Treatment effects within groups were assessed using Cohen's effect size index (ES; the difference between the final and initial condition divided by the standard deviation of the initial condition). An effect size of 0.2 was considered small, 0.5 moderate, and 0.8 large (Cohen, 1988). Effects were also expressed as percent change (the difference between the final and initial condition divided by the initial condition and multiplied by 100).

Differences in the effects of the program with different rest intervals for all dependent variables were tested with a series of two-way repeated-measures analysis of variance (Split-plot ANOVA or Mixed Design ANOVA) with a within-subjects factor (time) and another between-subjects factor (groups).

Partial eta squared (η2) was used as a measure of effect size and was classified as small (0.02 ≤ η2 ≤ 0.12), medium (0.13 ≤ η2 ≤ 0.25), or large (η2 ≥ 0.26). The level of statistical significance was set at p<.05.

Table 4. Peak torque (Nm) of knee and elbow extension and flexion at angular velocities of 60 and 120°/s in the pre- and post-training of experimental groups (G1m and G3m). Effect size (Cohen's d), percentage change (%), the statistical significance of within-group differences between the pre- and post-training, and the statistical significance of group × time interaction

PEAK TORQUE (Nm)				**G1m**			**G3m**			
				M ± SD	**ES**	**%**	**M ± SD**	**ES**	**%**	**F (p)**
KNEE	**60 °/s**	**EXTENSION**	Initial	204.18 ± 19.36	1.48	14.07	200.31 ± 40.72	**1.58***	32.06	4.88 **(0.037**)**
			Final	232.91 ± 43.44			264.53 ± 31.91			
		FLEXION	Initial	109.17 ± 18.24	**1.53***	25.59	118.06 ± 21.21	**1.75***	31.45	1.56 (0.223)
			Final	137.11 ± 22.01			155.19 ± 22.11			
	120 °/s	**EXTENSION**	Initial	164.38 ± 18.65	**1.26***	14.33	161.99 ± 20.37	**1.67***	21.03	1.31 (0.264)
			Final	187.95 ± 20.79			196.06 ± 30.02			
		FLEXION	Initial	92.92 ± 13.19	**1.74***	24.76	101.42 ± 19.62	**1.75***	33.94	2.36 (0.138)
			Final	115.93 ± 23.19			135.85 ± 22.71			
ELBOW	**60 °/s**	**EXTENSION**	Initial	69.12 ± 14.13	0.28	5.65	67.58 ± 11.13	**1.25***	20.62	8.85 **(0.007**)**
			Final	73.02 ± 17.87			81.52 ± 11.82			
		FLEXION	Initial	59.09 ± 13.31	0.03	0.76	51.25 ± 11.80	**0.54***	12.37	4.48 **(0.045**)**
			Final	59.54 ± 10.61			57.58 ± 14.18			
	120 °/s	**EXTENSION**	Initial	55.92 ± 13.04	**0.74***	17.27	56.82 ± 9.02	**1.21***	19.24	.23 (0.635)
			Final	65.57 ± 15.09			67.75 ± 12.61			
		FLEXION	Initial	49.06 ± 11.39	0.20	4.53	45.34 ± 11.55	**0.48***	12.15	1.31 (0.264)
			Final	63.89 ± 11.22			63.49 ± 10.24			

Note. **p<.05; *p<.025; bolded results are statistically significant; G1m = group with a one-minute rest interval; G3m group with a three-minute rest interval; M ± SD = mean and standard deviation; ES = effect size; % = percent change.

Table 5. Normalized peak torque (Nm) of knee and elbow extension and flexion at angular velocities of 60 and 120°/s in the pre- and post-training of experimental groups (G1m and G3m). Effect size (Cohen's d), percentage change (%), the statistical significance of within-group differences between the pre- and post-training, and the statistical significance of group × time interaction

NORMALIZED PEAK TORQUE (Nm/kg)				G1m			G3m			
				M ± SD	**ES**	**%**	**M ± SD**	**ES**	**%**	**F (p)**
KNEE	**60 °/s**	**EXTENSION**	Initial	2.56 ± 0.37	0.86	12.35	2.53 ± 0.31	**2.49***	30.33	3.97 (0.058)
			Final	2.87 ± 0.58			3.30 ± 0.37			
		FLEXION	Initial	1.36 ± 0.25	**1.37***	25.45	1.50 ± 0.22	**1.95***	28.52	0.64 (0.430)
			Final	1.71 ± 0.21			1.93 ± 0.28			
	120 °/s	**EXTENSION**	Initial	2.05 ± 0.32	**0.88***	13.72	2.06 ± 0.21	**1.89***	19.18	0.99 (0.331)
			Final	2.34 ± 0.34			2.46 ± 0.28			
		FLEXION	Initial	1.16 ± 0.18	**1.39***	22.06	1.29 ± 0.21	**1.92***	31.90	3.49 (0.074)
			Final	1.42 ± 0.21			1.70 ± 0.21			
ELBOW	**60 °/s**	**EXTENSION**	Initial	0.86 ± 0.19	0.22	4.87	0.86 ± 0.10	**1.58***	18.42	8.71 **(0.007**)**
			Final	0.91 ± 0.20			1.02 ± 0.12			
		FLEXION	Initial	0.74 ± 0.17	0.01	0.23	0.65 ± 0.10	**0.67***	10.86	3.85 (0.061)
			Final	0.74 ± 0.12			0.72 ± 0.11			
	120 °/s	**EXTENSION**	Initial	0.70 ± 0.17	**0.68***	16.54	0.72 ± 0.09	**1.38***	17.93	0.17 (0.676)
			Final	0.81 ± 0.19			0.85 ± 0.14			
		FLEXION	Initial	0.61 ± 0.15	0.20	4.69	57.34 ± 11.09	**0.55***	10.73	0.87 (0.362)
			Final	0.64 ± 0.11			0.64 ± 0.10			

Note: **p<.05; *p<.025; bolded results are statistically significant; G1m = group with a one-minute rest interval; G3m group with a three-minute rest interval; M ± SD = mean and standard deviation; ES = effect size; % = percent change.

Results

Out of all the participants involved in the study, 93% actively participated in all training sessions as well as pre- and post-testing assessments. Specifically, two participants dropped out of the experiment: one from group G1m due to illness and one from group G3m due to personal reasons. Thus, the total number of participants analyzed who completed the study was 26, with 13 participants in each group. The initial states of peak torque and normalized peak torque (p>.125), 1RM (p>.128), and the volume loads (p=.372) were similar between groups for all the exercises. All variables were normally distributed (p>.098).

Values of the maximum concentric muscle strength of the knee and elbow extensors and flexors on the isokinetic dynamometer at two angular velocities of 60 and 120°/s, expressed as peak torque

(Nm) and peak torque normalized to body mass (Nm/kg) in the initial and final conditions of the tested groups G1m and G3m, effect size (Cohen's d), percentage change, statistical significance of the within-group differences between the initial and final conditions and statistical significance of the changes between the initial and final conditions are presented in Tables 4 and 5.

Discussion and conclusions

This study investigated the effect of short (one minute) and long (three minutes) inter-set rests on maximal isokinetic strength gains of the upper and lower extremities during slow (60º/s) and fast (120º/s) angular velocities after eight weeks of resistance training in trained young males. The programs were matched in all acute program variables except for the inter-set rest interval duration.

The main finding of this study was that three instead of one minute of inter-set rest resulted in higher increases in peak torque of the knee and elbow extensors and elbow flexors at 60º/s. Furthermore, three minutes and one minute of inter-set rest seem to have similarly increased the peak torque of the knee and elbow extensors and flexors at 120º/s and of the knee flexors at 60º/s.

However, considering effect sizes and changes from an applied standpoint, it is important to emphasize that even though a clear increase in peak torques is observed in both groups, these increases are more pronounced in G3m in all conditions. Specifically, large effect sizes and percent changes were found in G3m (21-34%) compared to G1m (14-26%) during knee extension and flexion, and 12-20% versus 0-17% in G3m compared to G1m during elbow extension and flexion. Although statistically insignificant, it appears that participants in G3m experienced a greater increase in strength than those in G1m. One reason for this could be that, although both groups trained to muscle failure using the same relative load, 3-minute rest between sets allowed a higher rate of weight progression throughout the intervention. The increased workload in G3m is, therefore, a direct consequence of the longer rest interval duration, which resulted in a faster recuperation and the sustained upkeep of a higher training intensity compared to a shorter rest interval (Willardson, 2006).

The results of our study are in concordance with the results of the study by Bemben, Fetters, Bemben, Nabavi & Koh (2000), showing a similar trend in strength increase across various but not all muscle groups. However, they are also in line with previous studies showing that training with higher loads causes a greater increase in muscle strength than training with lower loads (Carvalho, et al., 2022). Furthermore, these results appear to follow a dose-response relationship where the highest loads produce the greatest strength-related benefits. Studies by Campos et al. (2002), Fatouros et al. (2005, 2006), Jenkins et al. (2016), Jessee et al. (2018), Kubo, Ikebukuro & Yata (2021), Lasevicius et al. (2018, 2022), and Schoenfeld et al. (2014) have found a greater increase in muscle strength with higher weights, in contrast to Barcelos et al. (2015), Hortobágyi, Tunnel, Moody, Beam & DeVita (2001), Lopes et al. (2017), Taaffe, Pruitt, Pyka, Guido & Marcus (1996), and Vincent et al. (2002), who found no differences in the effect of the magnitude of weight on the development of muscle strength.

The only differences between the groups in terms of peak torque and normalized peak torque gains were found in four out of sixteen conditions, favoring the longer rest interval between sets, especially at lower angular velocities, with the differences decreasing as angular velocity increased. One possible reason for this is that G3m, due to a longer rest interval, recovered more, and started the next set with higher external loads, which, according to the force-velocity relationship, resulted in slower muscle contractions which are specific to testing with lower angular velocities.

The results confirm the effectiveness of both resistance training programs in developing muscle strength. Training programs that maintain similarity across all variables except for the duration of inter-set rest intervals demonstrate similar effects on the mechanical properties of muscles, regardless of body size. Therefore, the recommendation to use longer rest intervals in strength training for muscle strength development is questionable, given that shorter rest intervals can be just as effective as programs with longer rest intervals. Furthermore, results suggest that irrespective of training volume, the greatest influence on muscle strength enhancement is attributed to the magnitude of the training load, specifically the intensity. This can enhance the number of activated motor units, cause higher motor unit activation frequency, and greater changes in agonist-antagonist coactivation rate in comparison to lower intensities (Walker, 2021).

To summarize, the duration of rest intervals in resistance training programs does not have a significant impact on the development of muscle strength. Such generalizations should, however, be approached with caution. Although there were no statistically significant differences between the two groups of participants, a noticeable trend of greater increases was evident in the group with a longer rest interval for all the measured variables.

The changes that were observed can be practically applied, confirming their authenticity and observability. When examining the impact of rest interval duration on the peak torque and normalized peak torque, it is clear that a three-minute rest interval results in higher outcomes with greater effects and changes compared to a one-minute rest interval. Therefore, for individuals seeking to maximize muscle strength gains during resistance training, consider employing rest intervals of at least three minutes between sets. This duration proved effective in sustaining higher performance during the training session and contributed to notable increases in strength.

Based on the findings, it can be inferred that the acute program variables play a vital role in enhancing muscle strength. The changes that occur due to training are largely dependent on the specific training regimen, primarily in terms of training volume and intensity. While rest intervals play a role, prioritize training volume and intensity in resistance programs. Heavier weights have a direct correlation with increased muscle strength, emphasizing the importance of load management in training protocols. However, strength gains can still be achieved even with relatively lighter weights. The extent to which these gains are sufficient for improving sports performance or daily activities depends on individual needs and capabilities.

Additionally, the results of the study suggest that rest interval duration plays a secondary but still important role in muscle strength development. Shorter rest intervals are a more time-efficient approach, making it easier for individuals with busy schedules to stick to a regular training plan. This is especially important as lack of time is a common obstacle for people who want to participate in various training programs.

It is important to point out several methodological aspects. Firstly, the study was conducted solely on young males, which means that the findings cannot be applied to other populations, such as women, older individuals, or those with significant resistance training experience. Secondly, the researchers did not take into account the dietary intake of the participants, which could have influenced the outcomes in various ways. However, the participants were instructed to maintain their usual dietary habits and avoid consuming any additional sources of energy throughout the entire research process. And thirdly, it is important to highlight that the participants' maximum strength was determined using an isokinetic dynamometer. The challenge is that in natural movements of the human body, the angular velocity varies throughout the range of joint motion. In natural movements, the muscles undergo a cycle of stretching and shortening where the eccentric stretching of the muscle-tendon unit is followed by concentric contraction and the angular velocity changes as the joint angle changes. Despite this, with familiarity with the specific measurement nuances, isokinetic dynamometry is a reliable and valid tool for assessing the maximum strength of the participants.

Future studies could benefit from examining different participant groups such as women, untrained individuals, elderly, or clinical populations. It would also be helpful to monitor their food intake. Additionally, analyzing the mean velocity of set repetitions could provide clarity on why longer inter-set rest intervals improve isokinetic strength, particularly at lower angular velocities. This could also help in assessing fatigue, i.e., recovery levels.

In conclusion, although no statistically significant differences were observed between the groups, the study results suggest that longer inter-set rest intervals may lead to greater strength gains. It is essential to recognize the significance of rest intervals when it comes to individualizing training based on personal goals and needs. For individuals seeking to maximize their strength gains, longer rest intervals are recommended to maintain higher intensity. Nonetheless, for individuals who are under time constraints, shorter rest intervals may still result in significant improvements in strength gains.

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