The effects of interset rest duration on performance and muscle activation during resistance training

Mohamad Shahrul Azzfar Mohamad Azzeme, Kevin Tan, Muhammad Hannan Sazali, Siti Jameelah Md Japilus, Ebby Waqqash & Ali Md Nadzalan

1 Faculty of Sports Science and Coaching, Sultan Idris Education University, MALAYSIA
2 Faculty of Sports Science and Recreation, Universiti Teknologi MARA, Arau Campus, MALAYSIA
3 Centre for Sport and Exercise Sciences, University of Malaya, MALAYSIA

Abstract. The purpose of this study was to compare the effects of different rest intervals on performance and muscle activation during multi-joint (bent over row) and single-joint (biceps curl) exercises. Fifteen trained men that have experienced at least one year in resistance training were instructed to perform both exercises using three protocols in a randomized crossover design; each consisting of three sets with three different rest intervals; i) 60 seconds, ii) 90 seconds and iii) 120 seconds rest interval between sets. Each set was performed with hypertrophy designed loading (75% of 1RM) until fatigue. Results showed performing bent over row with 120 seconds rest interval produced higher number of repetitions and greater latissimus dorsi muscle activation compared to 60 seconds and 90 seconds rest interval. For biceps curl exercise, results showed 90 seconds and 120 seconds rest interval produced higher number of repetitions and greater biceps brachii muscle activation compared to 60 seconds rest interval. In conclusion, performing bent over row with 120 seconds rest interval interset and 90 seconds and 120 seconds rest interval during biceps curl exercise allow participants to produce greater lifting performance while recruiting more motor unit for activating the muscles in every set. The findings of this study is hoped to be used as a guideline for resistance training design planning in order to achieve optimum benefit while been time-effective.

Keywords: bent over row, biceps curl, repetitions, rest interval

1. Introduction

Resistance training is carried out for many purposes such as to increase muscle strength, power, muscular endurance and cardiorespiratory fitness [1, 2]. Apart from these, hypertrophy is also one of the resistance training objectives. In hypertrophy training, rest interval between sets is one of the variables that need to be taken into consideration [3]. This is because muscles that were recruited during resistance training will fatigue and will need time to recover before continue the training. The length of rest interval must be enough to recover energy sources (e.g., adenosine triphosphate [ATP] and phosphocreatine [PCr]), clear fatigue producing substances, and restore force production. Hence, it can be concluded that rest interval in training is important to recover the muscle that fatigue. Not enough rest between sets will cause the muscle not able to recover thus cannot sustain the force production as the earlier sets. In contrast, too long rest period might cause the muscle too relaxed and...
not having enough stimuli for hypertrophy adaptation. Stimuli for hypertrophy adaptation can be obtained through the muscle activation analysis during the movement.

The American College of Sports and Medicine recommends 2 to 3 minute rest intervals between sets for multi-joint (core) exercises and around 1 to 2 minutes rest for the single-joint (assistance) exercises [4]. Furthermore, the chosen of rest period between set must take into consideration on the complexity of movement and the load that being lifted.

Schoenfeld et al. [5] classified length of rest interval between sets into three categories that are short (30 seconds or less), moderate (60-90 seconds), and long (3 minute or more). Based on these three categories, moderate rest interval can enhance the body’s anabolic environment to a greater extent than longer rest interval. Besides that, greater hypoxia that increases the potential for better muscular growth is also evoked by moderate rest intervals [6]. Moderate rest intervals are also being related with a better metabolic accumulation, catalysing a huge hike in anabolic hormonal concentrations post exercise [7].

This current study examined the effects of various moderate rest interval on muscle activation during multiple joint exercise. The exercise of interest in current study is bent over row. Through several previous literature review, bent over row was found to be less adopted and studied. Bent over row is an exercise that targeted the upper back muscles, mainly latissimus dorsi and rhomboids as agonists and biceps brachii as the assistant muscles. Without machines such as lat pull down and back rowing, bent over row is undoubtedly among the main exercise for the upper back. The exercise of interest for single-joint is the bicep curl. Biceps curl is among the most popular exercise due to its simple movement and concentration to the biceps brachii muscle.

Overall, the objective of this study is to compare the effects of 60 second, 90 second and 120 second rest interval on muscle activation and number of repetitions completed during bent over row and biceps curl exercises.

2. Methodology

2.1. Participants
Fifteen trained men (n=15) were recruited as participants in this study. Before participating in this study, they were required to sign a consent form and were asked to fill out the Physical Activity Readiness Questionnaire (PAR-Q). Participants were all males and aged between 20-25 years old based on their year of birth. Participants had been selected in accordance to their experience in resistance training. The minimum involvement was one year of participation with three times of training per week, particularly before this study was carried out. All participants have displayed good technique in bent over row and biceps curl exercises.

2.2. Equipment
Calibrated barbell, weight plates and electromyogram (EMG) were the tools used in the data collection. All the equipment had been set up and tested before the study was carried out in the biomechanics laboratory. In this study, Olympic standard 20 kg barbells (Ivanko OB, USA) and weight plates (Ivanko rubber E-Z Lift® plate, USA) were used as the loadings to be lifted. Wireless electromyogram (EMG) (Trigno, Delsys, USA) was used to detect and analyse maximum voluntary isometric contraction (MVIC) and mean of muscles activation while performing the bent over row and biceps curl exercises. Electrodes were placed at right latissimus dorsi and right biceps brachii.
2.3. Procedures
During the first session, participants’ anthropometric profile were measured. After that, participants were required to enter familiarization phase. Familiarization phase was necessary to give information on the objectives and procedures of the study. Participants were also required to perform bent over row and biceps curl exercises with minimal loadings just so that the techniques can be observed.

2.4. Determination of One Repetition Maximum (RM)
After familiarization session and resting for 72 hours, participants underwent one repetition maximum (1RM) test to identify the maximum load that can be lifted in bent over row and biceps curl exercises. The 1RM testing procedure followed the guidelines provided by National Strength and Conditioning Association [8]. 1RM test started with participants were asked to warm up with light resistance. After series of lifting 2 to 5 repetitions, participants were required to try for the 1RM lift. All the loads lifted were based on the participants’ experience with the agreement of the researcher. Any success or failure will cause the loads to be increased or decreased by 4 to 10 kg and 5 minutes rest was given before participants were asked to do the next attempt. The amount of repetitions would not be considered if participants did the exercises with wrong technique. Failure was defined as the time point when the participant paused more than 2 seconds during lifting load or if the participant was unable to complete each repetition in a full range of motion. To avoid errors and bias during the 1RM test, a brief explanation about the test procedures were given by researcher during the familiarization session and again before the test was carried out.

2.5. Muscle Activation Procedure
Electromyography (EMG) signals have been recorded from latissimus dorsi during the bent over row and biceps brachii during bicep curl exercises by using wireless electrodes (Trigno, Delsys, USA). The study by Park and Yoo [9] was used as guideline to determine location of electrode placement for latissimus dorsi. The Surface EMG for Non-Invasive Assessment of Muscles (SENIAM) was used as guideline to determine the location for biceps brachii electrode placement [10]. In order to get a good electrode-skin contact, the hair that covered the skin surface at the electrode placement location was shaved, particularly where the electrodes have to be placed in order to avoid reading error. Participants’ skins were then cleansed by using alcohol swab and the alcohol was allowed to vaporise first so that the skin would be dry before the electrodes were placed. After the skin preparation, the participants were required to be in the starting posture (depends on the respective muscle) to determine the proper location of the electrodes on the muscle. Palpation was done to determine the muscle and the anatomical landmarks were marked clearly as a way to determine a proper electrode positioning.

Maximum voluntary isometric contraction (MVIC) is important for this study to identify maximal contraction of muscle against pressure. Every participant performed three times of trials with rest of two minutes length between each trial. Five seconds was given for participant to perform the MVIC for each trial.

To determine the latissimus dorsi electrode placement, the researcher asked participants to be in seated position with shoulder adducted, extended, and internal rotated. The electrodes were placed at 25° of oblique angle over the latissimus dorsi on the right side, which was approximately 4 cm below the inferior tip of the scapula and midway between the spine and lateral edge of the torso. The MVIC test for latissimus dorsi muscle was carried out according to Hislop and Brown [11]. For the biceps brachii electrode placement, participants were required to be in a seated position with 90° right elbow flexion and the dorsal side of the right forearm pointing downwards. A single-channel surface electrode was placed on the line between the medial acromion and the fossa cubit at one-third (1/3) from the fossa cubit. Before the MVIC test was conducted, right hand of participant was placed on the bench with supination of forearm. The MVIC test for this muscle was conducted according to SENIAM guidelines [12].
Raw Electromyography (EMG) signals were recorded at an analogue-to-digital conversion rate of 2000 Hz and 16-bit resolution after being amplified at 1000×. Recorded signals were full-wave rectified and filtered by using a dual-pass of sixth-order, 10 to 500 Hz band-pass Butterworth filter, and then a linear envelope was created by using a low-pass, second-order Butterworth filter with a cut-off frequency of 6 Hz. For each muscle, the EMG signals were collected from the beginning of the movement upon the completion of the movement for three sets. The recorded muscle activity was converted to percentage of MVIC and was presented in mean to be compared between sets and between rest interval duration.

2.6 Experimental Protocol
The experimental session took place after the participants rest about 72 hours after 1RM test. Participants were required to perform six different testing sessions. In each training session, participants performed exercise with randomized rest intervals of 60 seconds, 90 seconds and 120 seconds over 3 repetitions and 75% of 1RM loading. This session started with participants warming up with light loads. Two minutes rest was given before the data collection started. Participants performed bent over row exercise and followed by the biceps curl exercise after 5 minute rest in between exercises. Movement velocity was controlled 4 seconds per repetitions (2 seconds concentric and 2 seconds eccentric) and same verbal encouragement was used to all participants.

2.7 Bent Over Row
Participants lifted the loaded barbell from the ground, flexed the trunk over the hips, and were instructed to keep a neutral spine while they pulled the barbell to their upper abdomen, bending their arms at the elbows. Participants then straightened the elbow back to the starting position until the elbow reach almost full extension. This was considered as one full repetition. The body and knee position were maintained during the movement.

2.8 Biceps Curl
Participants grasped the barbell with the wrist in neutral position. Participants lifted the barbell through full elbow flexion. Participants’ body should be stationary (minimum movement) and not swung during the movement.

2.9 Statistical Analysis
In this study, Statistical Package for the Social Sciences (SPSS) version 20 was used to analyse the data. Descriptive statistics were presented through the calculation of mean and standard deviation (SD). Repeated measure Analysis of Variance (ANOVA) was used to compare three different rest intervals between sets on number of repetitions and muscle activation during bent over row and biceps curl exercises. Statistical significance was accepted in this study at an alpha level of p ≤ 0.05.

3. Results
Table 1 showed the anthropometry profile of participants involved in this study.

| Variables       | Minimum | Maximum | Mean ± SD     |
|-----------------|---------|---------|---------------|
| Age (years)     | 20      | 25      | 21.20 ± 1.146 |
| Height (cm)     | 161     | 180     | 170.93 ± 5.049 |
| Body Mass (kg)  | 60      | 77      | 65.13 ± 5.854 |
Table 2 showed the number of repetitions performed during bent over row exercise. Results showed that total number of repetitions of bent over row exercise with 120 seconds rest interval between sets was significantly higher than 90 seconds, $F(1,14) = 54.827; p = 0.000$ and 60 seconds, $p = 0.027$. Bent over row with 90 seconds rest interval also showed significantly higher number of repetitions than 60 seconds, $p = 0.027$.

The number of repetitions during bent over row with 60 seconds rest interval were showed to have significant reduction started in set 2, ($p = 0.000$) and continued reduction in set 3 ($p = 0.000$). Bent over row with 90 seconds rest interval were showed to significantly decrease also in set 2 ($p = 0.000$) and set 3 ($p = 0.000$). Bent over row with 120 seconds rest interval showed no significant different between set 1 and set 2 ($p = 0.493$) and only significantly decrease in set 3 ($p = 0.001$).

The number of repetition in set 1 showed no significant different exist between all rest interval. In set 2, bent over row with 120 seconds rest interval showed significantly higher number of repetition than 60 seconds, ($p = 0.000$) and 90 seconds, ($p = 0.000$). However, no significant difference found between 60 seconds and 90 seconds rest interval, ($p = 0.058$). In set 3, bent over row with 120 seconds rest interval also showed significantly higher than 60 seconds ($p = 0.000$) and 90 seconds, ($p = 0.000$) and result showed 90 seconds rest interval significantly higher on number of repetitions than 60 seconds, ($p = 0.004$).

| Set  | 60 seconds | 90 seconds | 120 seconds |
|------|------------|------------|-------------|
| Set 1| 9.47 ± 0.64| 9.93 ± 0.72| 9.67 ± 0.61 |
| Set 2| 7.40 ± 0.74| 8.07 ± 0.80| 9.53 ± 0.64 |
| Set 3| 5.60 ± 0.91| 6.87 ± 0.80| 8.80 ± 0.78 |
| Total| 22.47 ± 1.69| 24.27 ± 2.05| 28.00 ± 1.85 |

Table 3 showed the muscle activation of latissimus dorsi during bent over row. Results showed that muscle activation reduced in set 2 ($p = 0.000$) and set 3 ($p = 0.000$) in both 60 and 90 seconds rest interval. During 120 seconds rest interval, the muscle activation only reduced significantly during the third set ($p = 0.002$).

In the first set, there was no significant difference of muscle activation between all the rest interval protocols. In set 2, muscle activation during 120 seconds were showed to be significantly higher than 60 seconds ($p = 0.000$) and 90 seconds, ($p = 0.031$). Result also showed that 90 seconds rest interval had higher muscle activation compared to 60 seconds rest interval, ($p = 0.012$). In set 3, muscle activation during 120 seconds rest interval were showed to be significantly higher than 60 seconds ($p=0.000$) and (90 seconds, $p = 0.002$). Result also showed that the muscles were more activated during 90 seconds compared to 60 seconds rest interval ($p = 0.017$).

| Set  | 60 seconds | 90 seconds | 120 seconds |
|------|------------|------------|-------------|
| Set 1| 50.12±4.421| 49.418±7.211| 48.791±7.061 |
| Set 2| 37.855±5.788| 40.590±5.770| 45.593±4.687 |
| Set 3| 28.201±5.733| 30.373±5.083| 36.279±3.674 |

Table 4 showed the number of repetitions performed during biceps curl exercise. The results showed the total number of repetition of biceps curl exercise with 120 seconds rest interval was significantly higher than 60 seconds, ($p = 0.000$) and 90 seconds, ($p = 0.015$). Result also showed total number of repetitions during 90 seconds rest interval was significantly higher than 60 seconds ($p = 0.000$).
Looking at the comparison between set, result showed number of repetitions during 60 seconds rest interval was significantly reduced started in set 2 (p = 0.000) and continued reduction in set 3 (p = 0.000). For 90 and 120 seconds rest interval, the number of repetitions only significantly reduced during the third set (both p = 0.000).

No significant differences exists for the number of repetition in set 1 between all rest intervals. In set 2, number of repetitions during 60 seconds protocols showed lower number of repetitions compared to 90 seconds, (p = 0.000) and 120 seconds, (p = 0.000). No significant difference on number of repetitions between 90 seconds and 120 seconds, (p = 1.000). In set 3, biceps curl exercise with both 90 and 120 seconds rest interval showed significantly higher number of repetitions compared to 60 seconds, (both p = 0.000). Again, no significant differences between 90 and 120 seconds protocols (p = 0.21).

Table 4. Number of repetitions during biceps curl exercise

|       | Set 1     | Set 2     | Set 3     | Total number repetitions |
|-------|-----------|-----------|-----------|--------------------------|
| 60 seconds | 9.87 ± 0.35 | 8.067 ± 0.70 | 5.87 ± 1.06 | 23.80 ± 1.86 |
| 90 seconds  | 9.73 ± 0.46 | 9.40 ± 0.74 | 7.27 ± 0.73 | 26.40 ± 1.60 |
| 120 second | 9.80 ± 0.41 | 9.60 ± 0.74 | 8.73 ± 0.80 | 28.13 ± 1.81 |

Table 5 showed the muscle activation of biceps brachii during biceps curl. The result indicated muscle activation of biceps brachii during biceps curl exercises with 60 seconds rest interval was significantly decrease in set 2 (p = 0.000) and continued decrease in set 3 from set 2 p=0.001. During 90 seconds rest interval, results showed that muscle activation only significantly reduced in set 3 (p = 0.000). The same were seen during 120 seconds protocols.

The result in set 1 showed no significant difference of muscle activation between all rest interval protocols. In set 2, 60 seconds protocols showed significantly lower muscle activation than 90 seconds, (p=0.022) and 120 seconds, (p = 0.004), while no significant difference between 90 seconds and 120 seconds, (p=0.546). The same condition were also found during set 3.

Table 5. Biceps brachii muscle activation during biceps curl

|       | Set 1     | Set 2     | Set 3     |
|-------|-----------|-----------|-----------|
| 60 seconds | 71.139±10.327 | 60.574±8.748 | 43.146±18.953 |
| 90 seconds  | 73.458±8.892  | 70.480±7.442  | 55.561±10.366  |
| 120 seconds | 75.977±11.007  | 73.603±8.062  | 67.477±5.300  |

4. Discussions

This acute study was done to compare three different rest intervals between sets which were 60 seconds, 90 seconds and 120 seconds on the number of repetitions and muscle activations during bent over row and biceps curl exercises among the people that were experienced in resistance training.

Based on the finding of this current study, the best rest interval between sets for maintaining the number of repetitions while performing bent over row was 120 seconds and for biceps curl exercise is at least 90 seconds rest between sets. Bent over row exercise is a type of exercise that involves more than one joint and demands more energy to lift the load while biceps curl is a single joint exercise. Exercises in hypertrophy mode were high intensity types that need optimal rest interval that is not too long and not too short. In this current study, short rest interval such as 60 seconds and 90 seconds gave the negative effect on the number of repetitions. Hypertrophy training is high intensity training that needed fast-twitch muscle fibres to lift the load for generated the sufficient force. Force will re-exist when there is enough recovery time to produce energy. 60 seconds and 90 seconds rest length between
sets was not enough for the bent over row exercise and 60 seconds for biceps curl to recover and re-produce energy through anaerobic glycolytic system. The synthesis of adenosine triphosphate (ATP) would increase the acidic content and produce more hydrogen ions (H⁺) which causes muscle fatigue. The rest period would give the opportunity to remove lactic acid proceeding with devolution of hydrogen (H⁺) ion from energy metabolism and replenishment of the ATP-CP system [13].

This finding was strongly supported by the American College of Sports Medicine (ACSM) that recommends 2 minute rest interval is suitable for those who want to achieve optimum level in strength and hypertrophy. In addition, the study by Goessler and Polito [14] was carried out to compare the rest interval of 1 minute, 2 minutes and self-suggested rest interval with average (157±37 seconds). The finding presented that 2 minutes of rest interval between sets can most likely to help maintaining and providing more repetitions with each set of exercise. Furthermore, more repetitions would increase mechanical tension caused by force generation and stretch that may help muscle growth [15]. Moreover, 2 minutes of rest interval also helped to increase the body’s anabolic environment to be on higher level than 3 minutes of rest interval. Apart from that, 2 minutes rest interval between sets also increase muscle growth resulting from encouraged production of higher hypoxia [6], greater metabolic build up and sudden increase anabolic hormonal concentration after workout [16].

This current finding for biceps curl exercises was supported by the statement of ACSM that stated at least 1 minute to 2 minute rest interval was enough to increase strength development during single-joint exercise.

Looking at the muscle activation data, the length of resting period with 120 seconds was enough for the bent over row activity and 90 seconds and 120 seconds while doing biceps curl. Resting period length of 60 seconds somehow decreased in muscle activation on Latissimus Dorsi and Biceps Brachii where muscle cannot produce higher force when doing exercises. The amount of force depends on the amount of muscles fibres that were required. Hypertrophy training depends on anaerobic glycolysis system because it was an effective system to produce energy quickly with short rest interval in between sets. However, the rest length of 60 seconds and 90 seconds on bent over row activity and 60 seconds on biceps curl caused higher accumulation of hydrogen ions (H⁺) and it may interrupt in the concentration gradients of other ions such as sodium ions (Na⁺), potassium ions (K⁺), calcium ions (Ca²⁺), magnesium ions (Mg²⁺) and chloride ions (Cl⁻) [17]. Furthermore, inadequate rest time will give negative effect to clear the hydrogen (H⁺) ions and may easily cause muscle fatigue. Muscle fatigue causing the ability to restore motor neuron firing rate to be stunned [17, 18]. Therefore, exercises with inadequate rest interval length between sets cannot generate force maximally to increase muscle activation on the next sets.

5. Conclusion
Rest interval between sets was one of the variables in resistance training that is crucial because it has a great influence on resistance training programme especially hypertrophy training. Based on the findings of this study, performing bent over row with 120 seconds rest interval interset and at least 90 seconds rest interval during biceps curl exercise allow participants to produce greater lifting performance while recruiting more motor unit for activating the muscles in every set. The findings of this study is hoped to be used as a guideline for resistance training design planning in order to achieve optimum benefit while been time-effective.

References
[1] Mahfudz, N.N., et al., The effects of HIIT on physical abilities among special education students. International Journal of Recent Technology and Engineering (IJRTE), 2019. 8(1): p. 1276-1278.
[2] Firdaus, W., G. Kuan, and O. Krasilshchikov, The effects of using complex training method on muscular strength among male weightlifters. Jurnal Sains Sukan dan Pendidikan Jasmani, 2018. 7(1): p. 1-12.

[3] Haff, G.G. and N.T. Triplett, Essentials of strength training and conditioning 4th edition. 2015: Human kinetics.

[4] Schoenfeld, B.J., The mechanisms of muscle hypertrophy and their application to resistance training. The Journal of Strength & Conditioning Research, 2010. 24(10): p. 2857-2872.

[5] Toigo, M. and U. Boutellier, New fundamental resistance exercise determinants of molecular and cellular muscle adaptations. European journal of applied physiology, 2006. 97(6): p. 643-663.

[6] Ratamess, N.A., et al., The effect of rest interval length on metabolic responses to the bench press exercise. European journal of applied physiology, 2007. 100(1): p. 1-17.

[7] Baechle, T.R. and R.W. Earle, Essentials of strength training and conditioning. 2008: Human kinetics.

[8] Park, S.-y. and W.-g. Yoo, Comparison of exercises inducing maximum voluntary isometric contraction for the latissimus dorsi using surface electromyography. Journal of Electromyography and Kinesiology, 2013. 23(5): p. 1106-1110.

[9] Stegeman, D. and H. Hermens, Standards for surface electromyography: The European project Surface EMG for non-invasive assessment of muscles (SENIAM). Enschede: Roessingh Research and Development, 2007: p. 108-12.

[10] Hislop, H., D. Avers, and M. Brown, Daniels and Worthingham's muscle Testing-E-Book: Techniques of manual examination and performance testing. 2013: Elsevier Health Sciences.

[11] Hermens, H.J., et al., Development of recommendations for SEMG sensors and sensor placement procedures. Journal of electromyography and Kinesiology, 2000. 10(5): p. 361-374.

[12] Ratamess, N.A., et al., The effects of rest interval length on acute bench press performance: The influence of gender and muscle strength. The Journal of Strength & Conditioning Research, 2012. 26(7): p. 1817-1826.

[13] Goessler, K.F. and M.D. Polito, Effect of fixed and self-suggested rest intervals between sets of resistance exercise on post-exercise cardiovascular behavior. Revista Brasileira de Cineantropometria & Desempenho Humano, 2013. 15(4): p. 467-475.

[14] Hornberger, T.A. and S. Chien, Mechanical stimuli and nutrients regulate rapamycin-sensitive signaling through distinct mechanisms in skeletal muscle. Journal of cellular biochemistry, 2006. 97(6): p. 1207-1216.

[15] Kraemer, W.J., et al., Hormonal and growth factor responses to heavy resistance exercise protocols. Journal of Applied Physiology, 1990. 69(4): p. 1442-1450.

[16] de Salles, B.F., et al., Rest interval between sets in strength training. Sports medicine, 2009. 39(9): p. 765-777.

[17] Martin, P.G., et al., Fatigue-sensitive afferents inhibit extensor but not flexor motoneurons in humans. Journal of Neuroscience, 2006. 26(18): p. 4796-4802.