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Manual Resistance as a Tool to Increase Muscle Activity and Time under Tension in a Strength Exercise

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ABSTRACT

Reiser FC, Bonuzzi GMG, Lira JLO, Bonfim BMA, Durante BG, Santos Filho SJA, Cardoso JMD, Soares MAA, Miotto H, Tavares LD. Manual Resistance as a Tool to Increase Muscle Activity and Time under Tension in Strength Exercises. **JEPonline** 2018;21(2):139-149. The purpose of this study was to investigate the muscle activity of Dumbbell Fly with and without Manual Resistance (MR) in isometric conditions of shoulder flexor muscles: (a) anterior deltoid (AD); (b) pectoralis major clavicular fibers (PMC); and (c) sternocostal fibers (PMS) muscles. Twenty health well trained men volunteered for the study (age: 27.2 ± 6.6 yrs; stature: 1.83 ± 0.08 m; mass: 87.9 ± 9.2 kg; with 6.4 ± 3.2 yrs of lifting experience). Muscle activation of the AD, PMC and PMS was higher on Dumbbell Fly (DF) plus MR (DFMR) in all conditions compared with the Dumbbell Fly without MR (DFW). The AD demonstrated an increase of muscle activation in the Incline plane when compared with Horizontal, while the PMS showed an inverted pattern. The changes in planes did not promote a change in PMS activation. The manual resistance potentialized muscle activation of shoulder flexors when compared with only the dumbbell.

Key Words: Dumbbell Fly, Load Increment, Manual Resistance

INTRODUCTION

Coaches and rehabilitation professionals promote changes in exercises to modify muscle recruitment and induce different neuromuscular adaptations along with strength training periodization (1-9,22-34,37), degrees-of-freedom such as Smith machines in comparison to barbell weight (29,34). In fact, muscle activity and postural stability modifications seem to be an effective strategy to provide different muscle long-term adaptations (6,17,23,26,28-30,33-35,37). In this sense, these different conditions are created by several varieties of surface or different load types. In the first one, the use of gym balls, boards, and balance cones diminishes overall force production while maintaining similar levels of muscle activity. The strategy is to challenge proprioception and overall stability that are fundamental to sports goals (3,7,27,29,31,32).

On the other hand, the management of different load settings (e.g., unstable barbells, dumbbells, free-cable machines, kettlebells, elastics cords, and chains put on barbells) creates another environment. The muscular requirements are modified, thus affecting power production with implications for sports and/or other performance activities (1,6,16,19,20,26, 27,28-30), by augmenting the force or even creating a similar attempt at reproducing playing conditions. These devices can also use to create an environment that is useful for rehabilitation purposes (2,3). In this sense, an issue to be considered in the strategies of load management, given the fact that the traditional free weight exercises have a constant load characteristic, which induces a production of force along the range of movement that is not equal due to the lever arm that can act by the joint angle position (14,15,18,24).

To overcome this situation coaches and rehabilitation professionals have used isokinetic and variable resistance exercise machines to break up the constant load characteristic of free weights with the purpose of addressing a single muscle or a group of muscles throughout a complete joint range of motion (18,24). However, it is well-known that the machines are expensive, being exclusive in general to academic or elite physical training programs. Concerning the Manual Resistance (MR) incorporated in strength programs, some investigations have highlighted its application. For example, Dombroski and Henderson (13) demonstrated that after a protocol of 14 wks using soldiers as subject, the MR training was superior when compared to calisthenics in parameters assessed by a medicine ball throw, grip dynamometer strength, and maximal pushups performed in 120 sec.

Recently, Dorgo et al. (14) investigated two groups of subjects separated by an MR training protocol or a Weight Resistance Training (WRT) program after 14 wks. Their results showed that both groups improved force production in the squat and the bench press exercises. Other studies have reported positive improvements on general force production results in adolescents and in the elderly population after the application of the MR protocol (15,36). However, despite the studies that have reported an interesting applicability of MR methods, the mechanisms that are related to MR that provide the beneficial effects remain unclear. To our knowledge, no study has quantified the MR applied in a traditional strength training exercise. Hence, the purpose of this study was to investigate the muscle activity of Dumbbell Fly with and without MR in different angles and planes on isometric conditions.

METHODS

Subjects

Twenty health well-trained men volunteered for the study (age, 27.2 ± 6.6 yrs; stature, 1.83 ± 0.08 m; mass, 87.9 ± 9.2 kg; with 6.4 ± 3.2 yrs of lifting experience; total dumbbell load of 36.4 ± 4.2 kg for both angles, based on the familiarization sessions testing loads). All the subjects reported no injury on the upper limbs in the last 6 months. The study was approved by the University Ethics committee (415.333), and all subjects were asked to read and sign an informed consent about the tests. Also, the subjects were asked to avoid performing any upper body exercise other than activities of daily living for at least 48 hrs before testing.

Procedures

Before data collection, the subjects were asked to identify their preferred arm for writing, which was then considered their dominant arm. All subjects were right-arm dominant. The subjects attended for 4 sessions in the laboratory, with the 1st meeting and the 3rd used for familiarization with loads, the range of motion, bench inclination, Maximal Voluntary Contraction (MVC) tests, and MR, and in the 4th session for experimental design. All subjects performed a dynamic warm-up in DF exercise with 2 sets of 15 repetitions each, using a 6 kg dumbbell in both hands with a 2-min rest interval. All four sessions were preceded by a warm-up.

Experimental Protocol

The subjects performed the DF exercise with the load in both hands on two different bench angles: (a) a horizontal position of 0º (DH); and (b) a 30º inclination (DI). They were tested at isometric angles of shoulder horizontal flexion at 90º, 60º, and 30º of abduction, respectively (Figure 1). A “0 angle” was considered when the dumbbell sets were perpendicular with the floor with the shoulder joint-angle positions evaluated by a goniometer (CARCI®). The conditions of only DF Without manual resistance (DFW) and DF plus Manual Resistance (DFMR) tests were randomly assigned. The subjects’ tested condition DFMR with an external force applied on the wrists level was performed by a strength training coach that used this technique with athletes.

The EMG was captured during 6 sec of every isometric condition separately with a 3-min interval rest between each angle tested with or without manual resistance. A 3-sec window (i.e., between 2 to 5 sec) was used to evaluate muscle activation.

Figure 1. Angles Analyzed in the Present Study. From the Left to the Right: 90º, 60º, and 30º Angles.

Electrodes Placement
All electrodes were fixed on the right side of the subject's shoulder muscles. The skin was prepared by shaving the subject and cleaning with soap before attachment of the electrode. Two electrodes Ag/AgCl with a 20-mm inter-electrode distance (Miotrace® 100) were placed midline of the Anterior Deltoid (AD): 4.0 cm below the clavicle, parallel to the muscle fibers at an oblique angle to the arm, the Pectoralis Major Clavicular fibers (PMC): 2.0 cm below the anterior border of clavicle along the longitudinal axis that crosses the middle point of the clavicle, and the Pectoralis Major Sternocostal head (PMS): 2.0 cm medial from the axillary fold, parallel to the muscle fibers via a marginal oblique angle with a reference electrode placed close to the right clavicle.

Following previous work recommendation (5,8,10,12,28,30,38), a raw EMG signal was recorded with a four-channel electromyography Miotool400® (Miotec, Biomedical Equipment, Porto Alegre/Brazil). Sampling was at 1 Hz, amplified 2,000 times at a fixed gain of 100 with a maximum intraelectrode impedance of 1010 Ohm, using a differential amplification of Common Mode Rejection at 110 dB, with a 14-bit resolution. All signals were filtered at 60 Hz for notchfilter and harmonics, a High-Pass of 20 Hz and a Low-Pass of 400 Hz cut-off frequency, with a fourth-order Butterworth filter. Surface electromyography amplitude in the time domain was quantified using the Root Mean Square at a 200-ms window.

MVC determine the normalization of the EMG signal during exercises conditions using the previous recommendations for muscle testing (21,30,35). Miography Software Package ® (Miotec, Biomedical Equipment, Porto Alegre/Brazil) ran all the signal processing. For the AD, the measurement position required the subject to sit and flex the shoulder into a 90º angle without rotation or horizontal movement while the elbow was extended. A manual resistance was applied over the humerus distal position just above the elbow joint. For the PMS, the subject was lying in a supine position with the shoulder at 130º-angle abduction with the elbows flexed, and then the subject was asked to move diagonally down in the contralateral direction. A manual resistance was applied over the wrist in the opposite direction. For the PMC, the subject was lying in a supine position with the shoulder at 60º-angle abduction with the elbows flexed, and then the subject was asked to move diagonally up in the contralateral direction. A manual resistance was applied over the humerus around the forearm just proximal to the wrist. After the warm-up, the subjects were asked to make an MVC augmenting the force to reach a maximum effort that was held for 10 sec before slowly reducing strength, in the positions previously described. This procedure was repeated three times for each muscle within a 90-sec rest interval between sets, and the mean value of the three MVC was used for following exercise comparison. Reliability of MVC was calculated by Intraclass Correlation Coefficient (ICC) between 0.83 and 0.91 for the muscles analyzed.

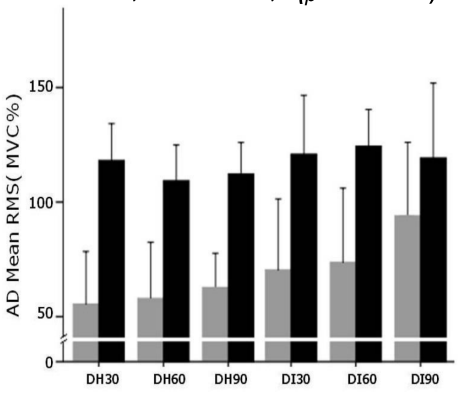
Statistical Analysis

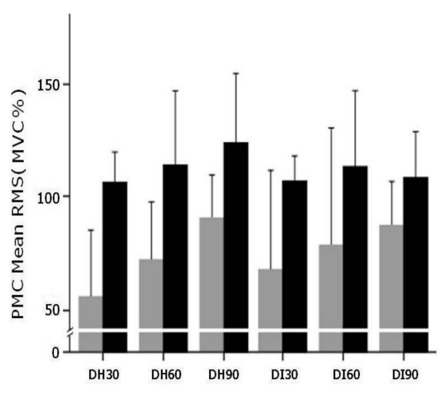
All results are presented as means ± SD. A multiple analysis of variance 3 angles x 2 plans x 2 resistances was used to assess differences in the activity of each muscle measured during the exercises. Individual one-way analysis of variance was used to determine differences between only plans and angles with and without manual resistance with Tukey HSD *post hoc* correction employed in the case of statistically significant differences. Statistical analysis was made with SPSS version 22.0 with significance set at $P \leq 0.05$.

RESULTS

Dumbbell Only (DFW) vs. Dumbbell Plus Manual Resistance Applied (DFMR)

The EMG activity of each muscle was expressed as mean ± SD bars on Figures 2 to 4, showing a descriptive analysis of RMS (MVC) values for each muscle and condition. All muscles demonstrated an increase of muscle activity with significant differences in favor of DFMR $_X$ DFW for angles and plan analyzed: (a) **AD:** Anterior Deltoid ($F_{(1,228)}$ =915.3; $P<0.001$; η_p^2=0.80); (b) **PMC:** Pectoralis Major Clavicular fibers ($F_{(1,228)}$ =349.3; $P<0.001$; η_p^2=0.60); and (c) PMS: Pectoralis Major – Sternal head ($F_{(1,228)}$ =409.5; $P<0.001$; η_p^2=0.68). Significant interactions between Resistance $_X$ Plan $_X$ Angles for AD ($F_{(2,228)}$ =4.50; $P=0.012$; η_p^2=0.038) and PMS ($F_{(2,228)}$ =8.17; $P<0.001$; η_p^2=0.073) were found, but not for PMC ($F_{(2,228)}$ =0.168; $P=0.845$; η_p^2=0.001).





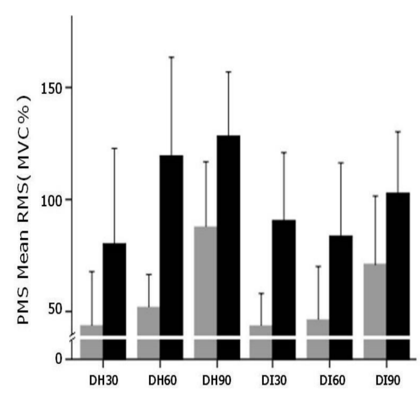


Figure 2 (Left to Right). Anterior Deltoid (AD) Muscle Activity Expressed in RMS (MVC) Means ± SD Bars (colors – grey: dumbbell fly without manual resistance; black: dumbbell fly with manual resistance). **Figure 3. Pectoralis Major – Clavicular Fibers (PMC) Muscle Activity Expressed in RMS (MVC) Means ± SD Bars (**colors – grey: dumbbell fly without manual resistance; black: dumbbell fly with manual resistance). **Figure 4. Pectoralis Major – Sternal Fibers (PMS) Muscle Activity Expressed in RMS (MVC) Means ± SD Bars Bars** (colors – grey: dumbbell fly without manual resistance; black: dumbbell fly with manual resistance).

Incline x Horizontal Plan

Individual plan for DFW analysis demonstrated a significant difference for AD ($F_{(1,114)}$ =67.3; P<0.001; η_p^2=0.371). The incline plan elicited a greater muscle activation than the horizontal plan (P<0.001). An inverse pattern was observed in the PMS ($F_{(1,114)}$ =11.29; P=0.001; η_p^2=0.09) with more muscle activation in the horizontal plan compared to the incline plan (P<0.001). No significant differences were found for the PMC ($F_{(1,114)}$ =2.5; P=0.12; η_p^2=0.02) activity. Individual plan for DFMR condition analysis demonstrated a significant difference for AD ($F_{(1,114)}$ =17.65; P<0.001; η_p^2=0.134). The incline plan elicits greater muscle activation than the horizontal plan (P<0.001). An inverse pattern was observed in PMC ($F_{(1,114)}$ =4.81; P =0.03; η_p^2= 0.041) activity and PMS ($F_{(1,114)}$ =27.35; P<0.001; η_p^2=0.2), with more muscle activation in horizontal plan compared to the incline plan, respectively (P=0.03 and P<0.001).

Range of Motion

Horizontal condition DFW analysis showed that no significant differences were found for AD between all angles ($F_{(2,57)}$ =2.32; P=0.10). However, significant differences were found for PMC ($F_{(2,57)}$ =36.77; P<0,001; η_p^2=0.56) with muscle activity at 90º (P<0.001) greater than 60º and 30º, followed by 60º (P<0.001) greater than 30º. And significant differences were found for PMS ($F_{(2,57)}$ =76.6; P<0.001; η_p^2=0.73), with greater muscle activity in 90º (P<0.001) compared with 60º and 30º, but no differences between 60º and 30º (P=0.085). For the incline DFW, differences were found for AD between angles ($F_{(2,57)}$ =12.24; P<0.001; η_p^2=0.30), with muscle activity in 90º (P<0.001) greater than 60º and 30º, but not between 60º and 30º (P=0.785). Significant differences were found for PMC ($F_{(2,57)}$ =4.35; P=0.017; η_p^2=0.13) with muscle activity at 90º (P=0.013) greater than 30º but not between 60º (P=0.380), with no differences between 60º and 30º (P=0.250).

Significant differences were found for PMS ($F_{(2,57)}$ =31.3; P<0.001; η_p^2=0.52) with greater muscle activity at 90º (P<0.001) compared with 60º and 30º, but no differences between 60º and 30º (P=0.768). For the DFMR condition in the horizontal plan, significant differences were found in the AD between all angles ($F_{(2,57)}$ =6.65; P=0.003; η_p^2=0.189), with muscle activity in 30º greater than 60º (P=0.02) and 90º (P=0.05), with no differences between 60º and 90º (P=0.459). Significant differences were found for PMC ($F_{(2,57)}$ =8.10; P=0.001; η_p^2=0.22); with muscle activity in 90º (P=0.001) greater than 30º but not greater than 60º (P=0.07), and no differences were found between 60º and 30º (P=0.189). For PMS ($F_{(2,57)}$ =33.1; P<0.001; η_p^2=0.53), there was greater muscle activity in 90º and 60º greater than 30 (P<0.001), but no differences between 90º and 60º (P=0.341). For DFMR in the incline plan only significant differences were found on the PMS ($F_{(2,57)}$ = 7.83; P=0.01; η_p^2=0.21), with greater muscle activity in 90º compared with 60º (P=0.001) and 30º (P=0.041), but no differences between 60º and 30º (P=0.339). No significant differences were found for AD (P=0.451) and for PMC (P=0.223) between all angles in the incline condition.

DISCUSSION

The purpose of this study was to investigate the muscular activation levels of the Anterior Deltoid and the two heads of the Pectoralis Major (Sternal and Clavicular) while performing an isometric Dumbbell Fly (Dumbbell only: DFW or dumbbell plus manual resistance applied: DFMR). This study used two different angles of bench inclination, with three distinct angles of shoulder horizontal adduction for analysis. The most notable finding was the difference in favor of DFMR vs. DFW for all conditions analyzed. Despite a frequently nonlinear relation between force and the electromyography signal, this increase of muscle activation may be due to the augmented recruitment of motor units, the firing rate of motor units, or even a combination of these two factors (12).

Although the findings indicate a relationship with the horizontal plane and a recruitment of the sternal portion of the Pectoralis Major, it shows a relationship between the inclination and a greater recruitment of the AD. In fact, the AD is a stronger glenohumeral abductor than a horizontal adductor while PMS works better as a glenohumeral horizontal adductor than abductor. This result is highly reproducible in the literature. da Silva et al. (11) observed an increased activation of the PMC muscle, especially in the eccentric phase of the movement of the Dumbbell Bench Press (BP), when compared to PMS. This result may be related to the stabilization of the glenohumeral joint, given that the PMC fibers are perpendicular to the humeral head. Thus, it is likely the PMC also work as a secondary shoulder stabilizer due to its resultant force.

Barnett et al. (2) assessed the AD, PMS, and PMC during BP repetitions on several planes. They found no differences for the PMC between the horizontal position and the incline position. The PMS muscle activity was higher on flat versus slope conditions, while the AD followed an inverse pattern to the PMS between the same circumstances. This finding is corroborated by other studies for AD and PMS with some controversial results for PMC (22, 37). Recently, Lauver et al. (23) found an increase in activity of the PMC during incline planes (30° and 45°) for a quarter part of the concentric phase (25 to 50% of the movement cycle vs. other changing conditions, i.e., 0 and -15°).

Other studies from Reiser et al. (28,30) and Saeterbakken et al. (33) found no significant differences between incline and flat conditions for the Pectoralis Major muscles during DF and BP exercises. The present study partially agrees with the earlier findings for PMC both, but not for the PMS portion. Several reasons may explain the conflicting results, such as the subjects' weight training experience, weight loads, and bench inclinations.

The findings in the present study support the notion that the AD muscle increases its activation with plane modification; whereas, the PMS is more active on horizontal conditions, and the PMC's activity remains constant regarding the bench slope because the fibers have a stabilization function as well. It is important to point out that a major finding of this study is the maintained muscle activation during the range of motion analyzed via DFMR vs. DFW. Despite significant differences, the muscle activation of the AD and the PMC during all angles and planes was higher than 100% of MVC, and for the PMS it was greater than 80% of MVC for the DFMR condition. When manual resistance was applied together with the dumbbell load, a consistent increase in muscle activity was displayed. In consonance with this perspective, analyzing the range of motion and the differences of muscular recruitment between DFMR and DFW, it was verified that the MR induced an extra demand of torque to perform the movement.

This study identified in the inclined condition with DFMR that there was an equal recruitment of the AD (which is the primary muscle in this state) during all range of motion that does not happen in the DFW condition. This finding leads us to believe that the MR may be the recourse to ensuring a superior and longer muscular activation during the performance of traditional free weight exercises. In this sense, some studies have not verified differences between the partial or full range of motion of execution of the BP for force and power development (9,26). Thus, the fact that there is a constant load applied in the traditional BP that induces the equality between both methods, maybe MR increases the effects of a full range of movement. Future investigations of MR in isotonic contractions to assess the chronic effects of this training may be a good direction to explore.

To our understanding, this is the first study to evaluate the effects of MR on the electromyography of a traditional strength exercise. Other investigations have examined Maximal Voluntary Contractions (38) and/or plus the body weight resistance (39). Our data suggest that MR is a possible mechanism of accommodating resistance that breaks the constant load, which is a general characteristic of free weights. Hence, it is reasonable to expect that exercise physiologists and strength training coaches may use this strategy to increase the athlete's performance with lower costs (14,15,18,36).

CONCLUSIONS

The use of manual resistance during strength training may benefit individuals who are responsible for optimizing time under tension during the athlete's training session. Lever arms may be lower when the weight load is more perpendicular to the joint axis, thus diminishing torque production. The application manual resistance at this point may benefit athletes in reaching their maximal muscle effort. It is also likely that these basic principles of training are applicable to individuals who are undergoing rehabilitation of their musculoskeletal system.

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REFERENCES

1. Baker DG, Newton RU. Effect of kinetically altering a repetition via the use of chain resistance on velocity during the bench press. ***J Strength Cond Res.*** 2009;23:1941-1946.

2. Barnett C, Kippers V, Turner P. Effects of variations of the bench press exercise on the EMG activity of five shoulder muscles. ***J Strength Cond Res.*** 1995;9:222-227.

3. Behm DG, Leonard AM, Young WB, Bonsey WAC, MacKinnon, SN. Trunk muscle electromyographic activity with unstable and unilateral exercises. ***J Strength Cond Res.*** 2005;19:193-201.

4. Behm D, Colado, JC. The effectiveness of resistance training using unstable surfaces and devices for rehabilitation. ***Int J Sports Phys Ther.*** 2012;7:226-241.

5. Bull, ML, Ferreira, MI, Vitti M. Electromyographic validation of the muscles deltoid (anterior portion) and pectoralis major (clavicular portion) in military press exercises with middle grip. ***J Morphol Sci.*** 2011;28:240-245.

6. Cacchio A, Don R, Ranavolo A, Guerra E, McCaw ST, Procaccianti R, Camerota F, Frascarelli M, Santilli V. Effects of 8-week strength training with two models of chest press machines on muscular activity pattern and strength. ***J Electromyogr Kinesiol.*** 2008;18:618-627.

7. Carvalheiro Reiser F, Gonçalves Durante B, Cordeiro de Souza W, Paulo Gomes Mascarenhas L, Márcio Gatinho Bonuzzi G. Paraspinal muscle activity during unstable superman and bodyweight squat exercises. ***J Funct Morphol Kinesiol.*** 2017;2:1-9

8. Chopp JN, Fischer SL, Dickerson, CR. On the feasibility of obtaining multiple muscular maximal voluntary excitation levels from test exertions: A shoulder example. ***J Electromyogr Kinesiol.*** 2010;20:896-902.

9. Clark RA, Humphries B, Hohmann E, Bryant AL. The influence of variable range of motion training on neuromuscular performance and control of external loads. ***J Strength Cond Res.*** 2011;5:704-711.

10. Criswell E. ***Introduction to Surface Electromyography****.* (2nd Edition). Sulisbury, MA: Jones & Bartlett Publishers, 2010.

11. da Silva SRD, Gonçalves M, de Almeida Leme MA, Bérzin, F. Supino Plano com Halteres: Um Estudo Eletromiográfico. ***Motriz.*** 2001;7:1-5.

12. De Luca, CJ. The use of surface electromyography in biomechanics. ***J Appl Biomech.*** 1997;13:135-163.

13. Dombroski RT, Henderson JM. Partner resistance exercises versus calisthenics for upper body strength improvement. ***Third Annu Mtng Am Med Soc Sports Med.: Rancho Mirage, CA****,* 1994.

14. Dorgo S, King GA, Rice CA. The effects of manual resistance training on improving muscular strength and endurance. ***J Strength Cond Res.*** 2009;23:293-303.

15. Dorgo S, King GA, Candelaria N, Bader JO, Brickey GD, Adams, CE. The effects of manual resistance training on fitness in adolescents. ***J Strength Cond Res.*** 2009;23: 2287-2294.

16. Dunnick DD, Brown LE, Coburn JW, Lynn SK, Barillas SR. Bench press upper body muscle activation between stable and unstable loads. ***J Strength Cond Res.*** 2015; 29:3279-3283.

17. Fonseca RM, Roschel H, Tricoli V, de Souza EO, Wilson JM, Laurentino GC, Aihara AY, de Souza Leão AR, Ugrinowitsch C. Changes in exercises are more effective than

in loading schemes to improve muscle strength. ***J Strength Cond Res.*** 2014;28: 3085-3092;

18. Fleck SJ, Kraemer WJ. ***Designing Resistance Training Programs***. (4nd Edition). Champaign, IL: Human Kinetics, 2014.

19. García-López D, Hernández-Sánchez S, Martín E, Marín PJ, Zarzosa F, Herrero AJ. Free-weight augmentation with elastic bands improves bench-press kinematics in professional rugby players. ***J Strength Cond Res.*** 2016;30:2493-2499.

20. Ghigiarelli JJ, Nagle EF, Gross FL, Robertson RJ, Irrgang JJ, Myslinski T. The effects of a 7-week heavy elastic band and weight chain program on upperbody strength and upper-body power in a sample of division 1-AA football players. ***J Strength Cond Res.*** 2009;23:756-764.

21. Hislop H, Montgomery J. ***Daniels and Wortingham's Muscle Testing: Techniques of Manual Examination.*** Philadelphia, PA: WB Saunders, 2002.

22. Lauver JD, Cayot TE, Scheuermann BW. Influence of bench angle on upper extremity muscular activation during bench press exercise. ***Eur J Sport Sci.*** 2016;16:309-316.

23. Lusk SJ, Hale BD, Russell DM. Grip width and forearm orientation effects on muscle activity during the lat pull-down. ***J Strength Cond Res.*** 2010;24:1895-1900.

24. Manning RJ, Graves JE, Carpenter DM, Leggett SH, Pollock ML. Constant vs. variable resistance knee extension training. ***Med Sci Sports Exerc.*** 1990;22:370-375.

25. Massey CD, Vincent J, Maneval M, Moore M, Johnson JT. An analysis of full range of motion vs. partial range of motion rraining in the development of strength in untrained men. ***J Strength Cond Res.*** 2004;18:518-521.

26. McGill SM, Marshall LW. Kettlebell swing, snatch, and bottoms-up carry: Back and hip muscle activation, motion, and low back loads. ***J Strength Cond Res.*** 2012;26:16-27.

27. Nairn BC, Sutherland CA, Drake JD. Location of instability during a bench press alters movement patterns and electromyographical activity. ***J Strength Cond Res.*** 2015;29: 3162-3170.

28. Reiser FC, de Moura JAR, Cardoso JMD, Grzelczak MT, de Souza WC, Mascarenhas LPG. Eletromiografia do exercício de crucifixo em diferentes planos e angulações de movimento. ***Rev Bra Prescr Fisiol Exer.*** 2014;8:864-870.

29. Reiser FC, de Souza WC, Mascarenhas LPG. Cinética e cinemática do agachamento na coluna vertebral: estudo de revisão. ***Rev UNIANDRADE.*** 2015;16:7-13.

30. Reiser FC, Lira JLO, Bonfim BMA, Santos Filho SJA, Durante BG, Cardoso JMD, Miotto H, Soares MAA, Bonuzzi GMG, Tavares LD. Electromyography of dumbbell fly exercise using different planes and labile surfaces. ***JEPonline.*** 2017;20:31-40.

31. Saeterbakken AH, Fimland MS. Electromyographic activity and 6RM strength in bench press on stable and unstable surfaces. ***J Strength Cond Res.*** 2013;27:1101-1107.

32. Saeterbakken AH, Fimland MS. Muscle force output and electromyographic activity in squats with various unstable surfaces ***J Strength Cond Res.*** 2013;27:130-136.

33. Saeterbakken AH, et al. The effects of bench press variations in competitive athletes on muscle activity and performance. ***J Human Kinet.*** 2017;57:61-71.

34. Schick EE, Coburn JW, Brown LE, Judelson DA, Khamoui, AV, Tran TT, Uribe BP. A comparison of muscle activation between a Smith machine and free weight bench press. ***J Strength Cond Res.*** 2010;24:779-784.

35. Schoenfeld B, Sonmez RGT, Kolber MJ, Contreras B, Harris R, Ozen S. Effect of hand position on emg activity of the posterior shoulder musculature during a horizontal abduction exercise. ***J Strength Cond Res.*** 2013;27:2644-2649.

36. Tokumaru K, Taniguchi C, Morikawa S, Yamasaki Y, Shimada T. The effects of manual resistance training on improving muscle strength of the lower extremities of the community ewelling elderly: A clinical intervention study with a control group. ***J Phys Ther Sci.*** 2011;23:237-242.

37. Trebs AA, Brandenburg JP, Pitney WA. An electromyography analysis of 3 muscles surrounding the shoulder joint during the performance of a chest press exercise at several angles. ***J Strength Cond Res.*** 2010;24:1925-1930.

38. Vera-Garcia FJ, Moreside JM, McGill SM. MVC techniques to normalize trunk muscle EMG in healthy women. ***J Electromyogr Kinesiol.*** 2010;20:10-16.

39. Youdas JW, Hartman JP, Murphy BA, Rundle AM, Ugorowski JM, Hollman, JH. Electromyographic analysis of gluteus maximus and hamstring activity during the supine resisted hip extension exercise versus supine unilateral bridge to neutral. ***Physi Theory Pract.*** 2017;33:124-130.

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