Medicina Sportiva (2014), vol. X, no 4, 2452-2456
Journal of Romanian Sports Medicine Society

Electromyographic analysis of bench press in paralympic athletes

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Abstract. The aim of the study was to analyze the percentage of muscle activation by surface electromyography (sEMG) at different intensities in bench press execution, in the pectoralis major muscle, anterior deltoid, serratus anterior, biceps brachii and triceps brachii of paralympic weightlifters. Six male paralympic weightlifting athletes were evaluated, aged 32.7 ± 3.50years, with a body mass of 78.3 ± 14.35kg, during a national Weightlifting Circuit held in Natal/RN, Brazil. Two tests were performed: on Test 1, the athlete performed the bench press movement with 50% of the maximum load lifted on the competition. The test 2 was performed, with the lifting of the maximum load (100%). The analysis of variance (ANOVA) was used to evaluate the effect of the exercise performed. The pectoralis major muscle was more active in both tests and the only one showed a statistically significant difference, with percentage of activation 19.9±3.19 on test 1 and 27.6±2.91 on test 2. The percentage of activation muscles in test 1 and test 2, respectively, was Serratus anterior (16.9±2.43 vs. 21.0±6.83); Triceps brachii (16.3±4.63 vs 19.6±4.93); Anterior deltoid (14.3±6.24 vs. 20.2±6.21) and biceps brachii (16.0±5.18 vs. 17.3±6.35) ($p < 0.05$). In conclusion, the percentage of activation in all muscles analyzed during the execution of the bench press was greater with increasing intensity, suggesting that training with heavier loads lead to a greater muscle activation in paralympic weightlifters.
Key words: *weightlifting, paralympic, electromyography, bench press.*

Introduction

The interest in competitive sports has increased dramatically, and many individuals have been seeking sporting success. In the field of adapted high performance sport, it is no different.

With the emergence of the Paralympics, paralympic sports have become an option for disabled people leading sedentary lifestyles, in rehabilitation, or as an initiation to adaptive sports (1, 2). Weightlifting first appeared in the Paralympics in 1964, and now the competition is open to all athletes with cerebral palsy, spinal cord injuries, lower limb amputees etc (3). With the growth of sports, human movement studies have also increased, serving as a support for fitness or high performance training programs (4, 6). Thus, the motion analysis technique is very important to identify the factors that influence movement and the individual diagnosis of motor-technical failures recorded in motion and evaluate the performance, since the description of many specific exercises for a sport is still determined from visual, theoretical and anatomical observations, which may be often incomplete (5, 6). Biomechanics, the field of study that deals with the physical analysis of biological systems, is an important parameter for quantitative evaluation of the variables of motion (5,6). Electromyography, being a parameter related to biomechanics, performs the recording and analysis of electrical signals generated by cell membranes (7-10). Thus, electromyography should be used as a method for providing scientific support required for plans and programs for sports training (11).

Therefore, this study analyzes the percentage of muscle activation at different intensities in bench press execution, in the pectoralis major muscle, anterior deltoid, serratus anterior, biceps and triceps of paralympic weightlifters in order to contribute to weightlifting training programs, mainly paralympic.

Material and Method

Subjects. Six male paralympic weightlifting athletes were evaluated, aged 32.7±3.50 years, with a body mass of 78.3±14.35kg and sum skinfold thickness of pectoral, midaxillary, subscapular, triceps, biceps, suprailiac, supraspinal and abdomen of 152.8mm ± 44.08, during the Caixa Lotteries Brazil Weightlifting Circuit held in Natal/RN. All athletes in the competition were invited to participate in the study; however, the sample was randomly composed by athletes who agreed to participate in the research voluntarily and signed an informed consent form (ICF).The athletes who consented to be subjects in this study were evaluated during the event during their rest period, between 12 and 24 hours after participating in the competition.

The present study was approved by the ethics committee of the Federal University of Rio Grande do Norte, duly recognized by the National Research Ethics Committee under protocol 576/11 and Resolution CNS196/96, according to the Declaration of Helsinki 1975 and addendum 2000.

Experimental design. The athletes underwent body composition assessment through the skinfold measurement method using Lange - John Bull, British Indicators Ltd. skinfold calipers with jaw pressure of $10g/m^2$ performed by a trained evaluator with technical error rate of 3.9%. Pectoral, midaxillary, subscapular, triceps, biceps, suprailiac, supraspinal, and abdomen skinfolds were evaluated. The Lohman skinfold evaluation protocol was used (12), and all measurements were taken in triplicate and averaged.

The test analysis was the bench press, which was carried out following the IPC Powerlifting Rules and Regulations 2011-2012 manual (10). The athletes performed the tests with the official equipment used in the competition. The official bench (ELEIKO brand, adopted by the International Paralympic Committee) (3) has a stable and strong surface, with a total length of 210cm, divided into two parts: the headrest, with dimensions of 70.5x30.5cm and the main part with dimensions of 61x38.5cm. Its height is between 48/50cm, starting from the ground to the top of the flat surface of the bench. The barholder measures between 70/110cm, from the ground, with an inner width of 110cm. The IPC powerlifting olympic bar is serrated and has grooves on its surface. It has a total length of 220cm, inner distance between 131/132cm, diameter between 2.8cm (preferably) and 2.9cm, outside of 41.5cm with a diameter between 5/5.2cm and weighs 20kg.N. There are markings on the bar to indicate the narrower and wider grips (minimum and maximum limits according to the official rules 2011-2012 IPC (13), ranging from 42cm to 81cm. The athlete's grip may vary according to his or her preferences in relation to the ease of movement, which can be related to the technique used, due to the type of injury, or bench press technique bad habits. However, the wider grip technique, within the limits, is used by more experienced athletes, because it shortens the range of motion (3).

The exercise was performed in supine position with extended knees, which were, however, fastened to the bench with a specific belt for the sporting discipline. The test was performed at least 24 hours after the athletes competed and consisted of a single repetition with full execution of the exercise at 50% and 100% of the maximum load lifted by athletes during competition. The athletes received aid for the detachment of the bar and auxiliary monitoring, if biomechanical failure occurred during the execution of the concentric and eccentric stages. This procedure is part of the security measures adopted by the IPC powerlifting (3, 13).

Electromyographic Analysis and Data Processing. The evaluation was carried out at the athletes' competition site, where they were subjected to analysis of surface electromyography (sEMG) of the following muscles: serratus anterior, pectoralis major, biceps brachii, triceps brachii, and anterior deltoid during the bench press movement. Two tests were performed: on Test 1, the athlete performed the bench press movement with 50% of the maximum load lifted on the competition. After four minutes Test 2 was performed, with the lifting of the maximum load (100%), i.e. the maximum load lifted in the competition. The athletes were not categorized by their pathology, but by body mass, according to the official competition rules (3, 13). The grip on the bar varied according to the preference of each individual, being the same used in the event.

Active, bipolar disposable 3M® surface electrodes were used. They were placed in accordance with the recommendations of SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) of the Biomedical Health and Research Program (BIOMED II) of the European Union (14), in the average distance between the motor point and distal tendon of the muscle and parallel to the fibers of the muscles evaluated.With the distance between the poles of 20mm. A reference electrode fixed to the olecranon was also used (14, 9). The

skin was prepared with trichotomy (hair removal), removal of dead epidermal layers, and asepsis with alcohol. There was an interval of 2 to 3 minutes prior to the placement of the electrodes.
All cables were secured with micropore tape to avoid mechanical artifacts and exaggerated movement of the cables. Before beginning the evaluation, the channels of EMG were calibrated.
A MiotecMiotool® electromyograph with a frequency of 400Hz was used for the analysis of the electromyographic signal (sEMG). Data were analyzed in the Miograph® 2.0 software. The sEMG signals obtained in microvolts (uV) with bandwidth *(bandpassfilter)* between 20Hz and 500Hz. *Notchfilter* frequency (FFT) was added in signal acquisition. The percentage of activation was determined from the average of peaks in each test (load percentage 50% and 100%).
Statistical analyses. Statistical analysis was performed using the SPSS 20 package (IBM Corporation, Inc., New York, USA). All descriptive statistics presented in the text and tables are mean values±standard deviation (SD). The data met the assumptions of normality, visually evaluated by normal distribution graph and the Shapiro-Wilk test, and statistical analysis for parametric data was performed. Analysis of variance (ANOVA) was used to evaluate the effect of the exercise performed. The averages of Test 1 and Test 2 were then compared. Percentage change from Test 1 to Test 2 was also calculated. For all statistical analyses, a p-value <0.05 was accepted as significance level.

Results

The results of the percentage of activation of each muscle in the bench press are described in Table I. Comparing the percentage of activation of test 1 and test 2 obtained the following values of p: serratus anterior (p value=0.196); biceps brachii (p value=0.713); triceps brachii (p value=0.249), anterior deltoid (p value=0.13) and pectoralis major that showed a statistically significant difference (p value=0.001).

Table I. Average percentage of activation
of the serratus anterior, triceps, biceps, anterior deltoid and pectoralis major

Percentage of Load		Confidence interval 95%		
		Average ± SD	Minimum	Maximum
50% Maximum Load (Test 1)	Serratus anterior	16.9 ± 2.43	15.1	18.7
	Triceps	16.3 ± 4.63	13.0	20.1
	Biceps	16.0 ± 5.18	11.9	20.2
	Anterior deltoid	14.3 ± 6.24	9.5	18.8
	Pectoralis	19.9 ± 3.19	17.7	22.6
100% Maximum Load (Test 2)	Serratus anterior	21.0 ± 6.83	15.5	26.6
	Triceps	19.6 ± 4.93	15.8	23.6
	Biceps	17.3 ± 6.35	12.1	21.8
	Anterior deltoid	20.2 ± 6.21	15.5	25.4
	Pectoralis	27.6 ± 2.91	25.0	29.6*

**There was significant difference at p <0.05 in the percentage of activation of the pectoralis (sig. = 0.001).*

Discussion

The pectoralis major muscle, which is the primary responsible for the movement, was more active in both tests and the only one that showed a statistically significant difference. From Test 1 to Test 2 the pectoralis major underwent a major change in the percentage of activation (7.8%), which corroborates prior studies that describe that as exercise intensity increases, it generates a greater motor unit recruitment and thus greater electromyographic signal amplitude (15-17). The anterior deltoid obtained an increase of 5.9% from the first test to the second, with the second major change in the percentage of activation, confirming the evidence obtained from the pectoralis major (the higher the intensity, the greater muscle activation) (15- 17).

According to the study of Júnior (18), the pectoralis major and anterior deltoid had a similar muscle recruitment in the bench press exercise, indicating that both muscles are equally activated during exercise; however, since the pectoralis major is the primary responsible for the movement, it has a slightly higher percentage of activation, as shown in our study. It has been reported in literature that in the conventional bench press (fitness) the anterior deltoid may have a higher activation than the pectoralis major muscle, due to the angle of the bench in the execution of the exercise or the increase in load (19-21).

The second most active muscle in both tests was the serratus anterior, with a variation of 4.1% from Test 1 to Test 2. This variation can be attributed to the anatomical position of the athletes at the time of competition, when they lift the maximum load. Athletes perform a technique (chest bridge) in which they arch the thorax and inflate the chest, causing a pre-stretch of the serratus muscles and stimulating a greater activation of this muscle with the increase of the load (21). By observing the technique, one notes that it is a way for the athlete to make the movement more effective, by shortening the range of motion.

In Test 1, the EMG activation was lower than in Test 2, probably due to a comfort zone encountered by athletes (bar above the nipple line), and lower load lifted (15-17) which can also be observed in the triceps muscles that had a variation of 3.4% in the percentage of activation from Test 1 to Test 2.In the study of Wattanaprakornkul (21), the serratus anterior was very active in the execution of the bench press with a load of 50% and 70% of the maximum load, and the study suggests that during exercise, the serratus anterior assists in the abduction strength of the scapula. This can also be justified by the axial direction of the load that is subsequently transmitted to the scapulothoracic joint and counterbalanced by the stabilizing action of the serratus anterior (21-23). Thus, a higher activity of this muscle is needed to ensure adequate attachment of the scapula to the chest (22).

The biceps brachii muscle had a smaller variation in the percentage of activation (1.3%), demonstrating a lower electromyographic amplitude when compared with other muscles. The low activation of this muscle can be justified by the fact that there is no need for stabilization or primary motor action, in the bench press movement (22). Also, it may be related to the maximum bone congruence and joint stability of the elbow due to the position of the upper arm in neutral rotation and full extension of the elbow (22, 23), thus, with the results found in this study, the exercise evaluated is not the most suitable to activate the biceps brachii muscle.

Conclusion

The percentage of muscle activation in the pectoralis major, anterior deltoid, serratus anterior, biceps and triceps during the execution of the bench press was greater with increasing intensity, suggesting that training with heavier loads lead to a greater muscle activation in paralympic weightlifters.

Conflict of interest. The authors declare they have no conflict of interest.

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Received: October 30, 2014
Accepted: November 30, 2014