The Compare of Weightlifter Upper-Limb Muscle Strength in EMG

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Received 5 Aug 2009; Accepted 28 Nov 2009

Abstract

The purpose of this study was to examine the upper-limb muscle strength of 8 weightlifters (aged 18.75 ± 1.13 years old) in 6 directions during maximal voluntary contraction (MVC). The average number of years that the subjects had been practicing weightlifting was 5.25 ± 1.77 years. A Biodex isokinetic measurement instrument was used to compare the differences in 6 directions of 6 100% MVCs measured using muscle electromyography (EMG). Data collection was performed using EMG electrodes attached to the skin overlying 6 upper limb muscles, and data were processed using a Biovision system, with DASY lab software as the filter. Root-mean-square (RMS) EMG values were used to represent the 6 upper limb muscles tested in 6 different directions of isometric MVC. A repeated 1-way analysis of variance (ANOVA; direction, muscle) was performed. SPSS 10.0 was used for the statistical analysis. In the different directions of upper-limb muscle motor unit recruitment (MUR), shoulder extension showed greater MUR than the other muscles. In elbow extension, MUR was less than that for other muscles. In shoulder flexion, RMS for the pectoralis major and middle deltoid was significantly greater than that for other muscles, indicating that weightlifters have stronger MUR in the anterior deltoid, pectoralis major, and middle deltoid. This result may be attributed to increased MUR, which generates more power to resist weight, due to muscle adaptation occurring over long periods of high-strength training. In the different directions of upper limb activity, elbow flexion in weightlifters was significantly greater than the other directions tested. The force produced by pectoralis major was significantly greater than that produced by other upper limb muscles.

Keywords: Specific strength, Isometric contraction, Shoulder extension

Introduction

Weightlifting can be both a form of exercise in which humans manipulate barbells and a competitive sport demonstrating power and technique. Participants in the sport attempt a maximum-weight single lift of a barbell loaded with weight plates. The current rules for competition include 2 lifts: the “clean and jerk” and the “snatch” [1].

Weightlifting requires a combination of power (strength and speed), technique, flexibility, and consistency. A weightlifter’s strength comes primarily from the legs, specifically the muscles of the quadriceps and posterior chain, and secondarily from the muscles of the back, anterior core, and the shoulders, as well as all-around ratio development.

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Weightlifting is a full-body activity that involves even the minor muscles, though these muscles receive emphasis over the others within the body. The upper extremities play an important role in weightlifting, not only by adjusting the direction of the weight and body posture to fit the center of gravity but also by producing the force required for whole-body strength and movement.

The main factors affecting muscle strength are the neuromuscular excitability of motor units, the frequency of nerve impulses, the number of working muscle fibers, muscle volume, and speed ratio [2]. Tesch & Larsson (1982) [3] studied the relationship between outstanding achievement, strength, and power in weightlifters and then explored different ways of relating isotonic contraction in the best weightlifters to compare strength-training studies. The results indicated that athletes increase their muscle strength faster with high-intensity exercise training than with general (low-intensity, high-volatility) training. Resistance training also has been shown to increase the number of muscle fibers per muscle [3]. Increases in the number of muscle fibers appear to be due to the high levels of stress exerted on the working muscle. Although there is evidence of a high muscle-fiber in extremely hypertrophied muscle, the increase in fiber may be a result of the training regimen or genetic predisposition [4].

Muscle action and nerve activity are essentially electrical in nature. Contraction of muscle fibers is associated with an electrical discharge that can be detected by electrodes or brought about by electrical stimulation. Electromyography (EMG) is a technique for evaluating and recording the activation signals in muscles. It is most often used when people have symptoms of weakness and examination shows impaired muscle strength. In weightlifting, EMG can be used to evaluate muscle action and nerve activity during exercise. The EMG testing of upper limb muscle fibers performed in this study provides potentially useful information that can be used in coaching and further study.

The purpose of this study was to explore the upper-limb muscle strength of weightlifters in 6 directions during MVC.

Methods

Subjects

Eight male weightlifters participated in this study. The average age, weight, height, and years of weightlifting for the subjects were 18.75 ± 1.13 years, 68 ± 7.52 kg, 168.13 ± 6.16 cm, and 5.25 ± 1.77 years, respectively. Each participant in the study was fully informed of all risks and the testing protocol.

Materials

The extreme muscle strength of upper limb extensors and flexors was tested in 6 directions during MVC. A Biodex isokinetic dynamometer was used to compare the differences in 6 100% MVCs measured using 6-muscle EMG. Differentiated EMG (CED 1902 amplifier, CED, UK) was recorded from 6 upper limb muscles throughout each protocol using bipolar electrodes 2 cm in diameter (Arbo neonatal ECG electrodes, Kendall, Germany). The skin was cleaned using alcohol pads, after which electrode pads were placed on the skin overlying the anterior deltoid (Ant_Del), middle deltoid (Med_Del), posterior deltoid (Post_Del), pectoralis major (Pec), biceps (Bi), and triceps (Tri) [5].

Data were collected using the EMG electrodes attached to the skin. On analysis, the raw EMG amplitude was rectified and then smoothed as part of the root-mean-square (RMS) process (5-ms time interval) during each MVC effort [6]. The data were normalized by subtracting resting noise from the RMS. Subsequently, the RMS EMG values were used to represent the isometric MVCs of the 6 upper limb muscles in 6 different directions. A repeated 1-way analysis of variance (ANOVA; direction, muscle) was performed. SPSS 10.0 (SPSS Inc., Chicago, IL, USA) was used to derive statistics.

Testing Procedure

Biodex Isokinetic dynamometer EMG tests were performed in this study. Based on a study by Delagi, Perotto, Iazzetti & Morrison (1981) [7], which suggests electrodes tapering the position at the motor point, an EMG electrode was attached to the skin overlying each of the 6 upper limb muscles (Ant_Del, Med_Del, Post_Del, Pec, Bi, and Tri, Figure 1).

Results

Different directions of upper-limb muscle motor unit recruitment (MUR) during 100% MVC EMG

There was a significant difference in the direction of motor unit recruitment (MUR) in the 6-muscle 100% MVC EMG (Table 1, Figure 2, Figure 3): Ant_Del (right arm, F = 11.20, $p < .05$; left arm, F = 11.18, $p < .05$); Med_Del (left arm, F = 0.23, $p < .05$); Pec (left arm, F = 19.67, $p < .05$); and Bi (left arm, F = 5.77, $p < .05$). After ANOVA analysis, least significant difference (LSD) post hoc analysis showed that, in shoulder abduction, the left Ant_Del (4.66 ± 1.33 μV) was significantly greater than elbow flexion (1.48 ± 1.72 μV) and elbow extension (2.68 ± 1.27 μV). In the left Ant_Del, shoulder flexion (1.98 ± 1.14 μV), shoulder extension (3.52 ± 1.92 μV), shoulder abduction (3.58 ± 1.76 μV), and horizontal adduction (2.43 ± 1.66 μV) were significantly greater than elbow flexion (1.02 ± 0.06 μV).

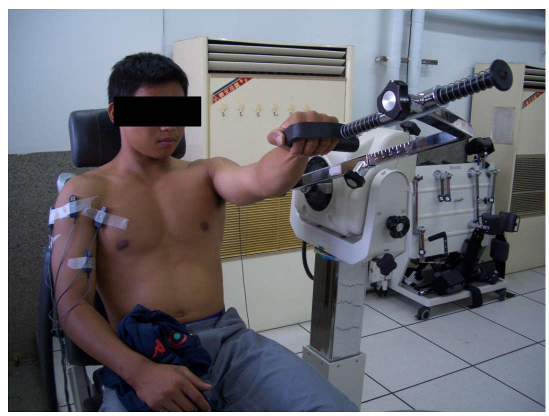

Figure 1. Biodex isokinetic EMG tests Six EMG electrodes attach at the upper limb muscles that was anterior deltoid, Ant_Del; middle deltoid, Med_Del; posterior deltoid, Post_Del; pectorals major, Pec; biceps, Bi and triceps, Tri.

In the right Med_Del, shoulder flexion (6.50 ± 4.97 μV) was significantly greater than shoulder extension (3.92 ± 2.64 μV), horizontal adduction (2.59 ± 0.27 μV), elbow flexion (2.81 ± 1.27 μV), and elbow extension (3.23 ± 2.90 μV). In the left Med_Del, shoulder flexion shoulder abduction (4.47 ± 2.88 μV) was significantly greater than elbow flexion (2.34 ± 1.66 μV). In the left Pec and Bi, shoulder flexion (10.09 ± 2.96 μV) was significantly greater than shoulder flexion (5.58 ± 2.10 μV), horizontal adduction (4.08 ± 2.74 μV), elbow flexion (3.78 ± 2.39 μV), and elbow extension (3.93±2.05 μV); F = 19.67, $p > .05$. In the Bi, shoulder extension (4.47 ± 3.32 μV) was greater than shoulder abduction (3.32 ± 2.18 μV) .

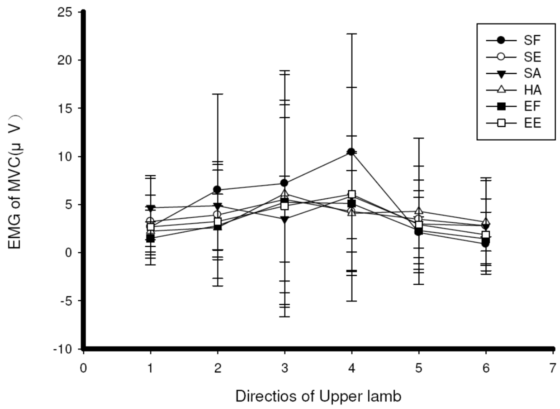

Figure 2. The difference directions of right upper limb actives Six difference directions: SF: shoulder flexion, SE: shoulder extension, SA: shoulder abduction, HA: horizontal adduction, EF: elbow flexion, EE: elbow extension; (1). anterior deltoid, Ant_Del, (2). middle deltoid, Med_Del, (3). posterior deltoid, Post_Del, (4). pectorals major, Pec, (5). biceps, Bi and (6).triceps, Tri.

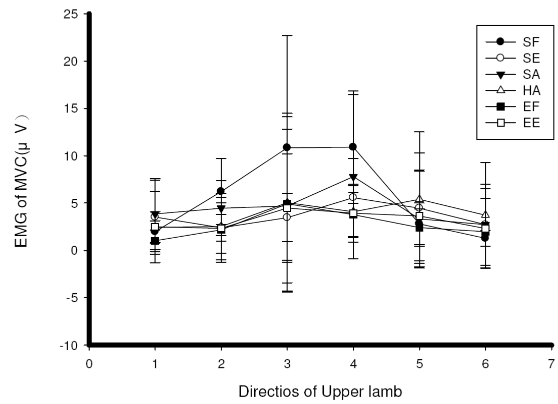

Figure 3. The difference directions of left upper limb actives Six difference directions: SF: shoulder flexion, SE: shoulder extension, SA: shoulder abduction, HA: horizontal adduction, EF: elbow flexion, EE: elbow extension; (1). anterior deltoid, Ant_Del, (2). middle deltoid, Med_Del, (3). posterior deltoid, Post_Del, (4). pectorals major, Pec, (5). biceps, Bi and (6).triceps, Tri.

Table 1. Comparison of EMG at different directions, right & left hands

Muscle		(1)		(2)		(3)		(4)		(5)		(6)			
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	*F*	Post-hoc
A	R	2.67	1.06	3.23	2.50	4.66	1.33	2.24	1.17	1.48	1.72	2.68	1.27	11.20*	3 > 5,6;4 > 5
	L	1.98	1.14	3.52	1.92	3.85	1.76	2.43	1.66	1.02	0.06	2.49	1.78	11.18*	1,2,3,4 > 5
B	R	6.50	4.97	3.92	2.64	4.87	2.60	2.59	0.27	2.81	1.27	3.23	2.90	5.26	1 > 2,4,5,6 3 > 5
	L	6.22	2.46	2.40	1.39	4.47	2.88	2.52	1.51	2.19	1.45	2.34	1.66	0.23*	
C	R	7.18	4.32	5.53	3.47	3.49	3.45	6.13	2.78	5.24	2.62	4.85	2.50	2.53	
	L	10.84	4.86	3.47	2.55	4.70	2.12	5.04	2.44	4.92	2.21	4.48	2.72	4.29	
D	R	10.42	2.28	4.27	2.23	5.87	2.44	4.08	2.43	5.10	2.04	6.06	2.10	5.40	1 > 2,4,5,6
	L	10.90	2.96	5.58	2.10	7.80	2.69	4.08	2.74	3.78	2.39	3.93	2.05	19.67*	
E	R	2.10	1.63	3.46	2.51	2.98	1.49	4.29	2.59	2.30	2.45	2.91	2.64	04.18	2 > 3
	L	2.81	1.19	4.47	2.84	3.32	2.18	5.40	2.12	2.42	1.97	3.65	1.72	05.77*	
F	R	0.89+	0.74	2.78	2.00	2.78	2.00	3.17	4.31	1.43	2.77	1.85	3.74	4.56	
	L	1.28+	0.84	2.72	2.28	2.72	2.28	3.72	5.54	1.98	3.52	2.31	4.20	4.09	

Note: * p<0.05, n=8 significantly between six difference directions: (1) shoulder flexion, (2) shoulder extension, (3) shoulder abduction, (4) horizontal adduction, (5) elbow flexion, (6) elbow extension.

+ p<0.05, significantly between right and left hands. A. anterior deltoid, Ant_Del, B. middle deltoid, Med_Del, C. posterior deltoid, Post_Del, D. pectorals major, Pec, E. biceps, Bi and F. triceps, Tri.

Comparison of right and left arms' EMG

Comparison of the right and left arms revealed significant a difference for the Tri: 0.89 ± 0.74 versus 1.28 ± 0.84; t=–3.467, p=.01, p >.05, Table 1). No other significant differences were observed.

Discussion

This study observed 8 weightlifters at upper-limb 100% MVC contraction. Interpretation of EMG signals necessitates knowledge of using RMS to represent muscle activity under 100% MVC. During Biodex Isokinetic dynamometer EMG testing, RMS represents muscle activity under 100% MVC and is often used to assess the extent of recruitment of motor units [7]. Therefore, RMS represents the degree of MUR. In the present study, the greatest difference in RMS value for 6-direction activity EMG was for SE (shoulder extension). This may have been caused by the protocol because the study subjects may have had more strength during SE, i.e., the first test position, as compared to subsequent test positions. In Ant_Del MUR, SE was significantly greater than muscle activity in other directions, indicating that the weightlifters had more strength in SE. Increases in muscular strength are often attributed to hypertrophy [8]. In the present study, however, strength gains were not accompanied by additional muscle mass. Instead, the higher MUR, which generates more power to resist weight, can be attributed to muscle adaptation over long periods of high-impact strength training.

Previous studies with animals and humans have indicated that training increases the number of fibers recruited and brings about a more synchronous firing of motor units [9,10]. Results of muscle EMG tests conducted using healthy subjects and dystrophy patients were similar to those obtained in this upper limb study (listed here in order of descending strength: Pec, Med_Del, and Post_Del). In terms of SF(shoulder flexion) and SE movements, the results for Pec were significantly greater than for the other upper limb muscles (Table 1). Comparing the 6 directions of upper limb muscle activity, our results revealed that, for SF and SE, there were significant differences among the 6 upper limb muscles. The post hoc test showed that the RMS of SF for Pec was significantly greater than for the other upper limb muscles. In SE, the RMS of both Ant_Del and Tri were significantly smaller than for the other upper limb muscles. Comparing each weightlifter's upper limb muscles in 6 different directions revealed that the RMS of Med_Del was significantly greater in SF than in SE, and that results for Pec were the same as those for Med_Del. Furthermore, our results showed differences in RMS for SF and SE for the 6 upper limb muscles. In SF, RMS for Pec was significantly greater than for the other 5 muscles, meaning that the Pec will strengthen more than the other muscles in SF. Thus, by using specific training to increase strength, athletes should be able to enhance their skill in barbell lifting.

Conclusion

In different directions of upper limb activity, weightlifter elbow flexion was significantly greater than that of other weightlifters. In addition, Pec generated significantly greater force than the other muscles of the upper limb. Finally, there were no significant differences in right- and left-arm EMG results in the weightlifter athletes tested.

References

[1] International Weightlifting Federation (IWF). (2009). Technical Rules 1.1.1. Retrieved Aug 7, 2009 from the World Wide Web: http://www.iwf.net/doc/handbook/Handbook.

[2] Baechle, T.R., & Earle, R.W. (2004). *Fitness weight training*. Champaign, IL: Human Kinetics.

[3] Tesch, P.A., & Larsson, L. (1982). Muscle Hypertrophy in Bodybuilders. *European Journal of Applied Physiology and Occupational Physiology,* 49, 301-306.

[4] Abernathy, P.J., Jürimäe, J., Logan, P.A., Taylor, A.W., & Thayer, R.E. (1994). Acute and Chronic Response of Skeletal Muscle to Resistance Exercise. *Sports Medicine.* 17 (1), 22-38.

[5] Cram, J.R., & Kasman, G.S. (1998). *Introduction to Surface Electromyography*. Aspen Publishers Inc, USA.

[6] Delagi, E.F., Perotto, A., Iazzetti, J., & Morrison, D. (1981). Section II: Forearm. In E.F. Delagi, A. Perotto (Eds.), *Anatomic guide for the electromyography* (pp. 28-62). Springfield, Illinois: Charles C Thomas.

[7] Perry, S.R., Housh, T.J., Johnson, G.O., Ebersole, K.T., Bull, A.J., Evetovich, & T.K., Smith, D.B. (2001). Mechanomyography, electromyography, heart rate, and ratings of perceived exertion during incremental cycle ergometry. *Journal of Sports Medicine & Physical Fitness.* 41, 183-188.

[8] Clarke, D. H. (1973). Adaptations in strength and muscular endurance resulting from exercise. In J. H. Wilmore (Ed.), *Exercise and sport sciences review.1*, (pp.73–102). New York: Academic Press.

[9] Burke, R., & Edgerton, V. R. (1976). Motor unit properties and selective involvement in movement. *Exercise and sport science review,* 11, 73-102.

[10] Edgerton, V. R. (1976). Neuromuscular adaptations to power and endurance work. *Canadian Journal Applied Sports Science,* 1, 49-58.