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Review Article

Shoulder Electromyography (Emg) Evaluation During Latissimus-Dorsi Pulldown Variations Following an Accelerated Shoulder Resistance Training Program

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Abstract

Background: The latissimus dorsi-pulldown exercise is used to strengthen the elbow flexors, shoulder adductors, and shoulder horizontal adductors. Evidence indicates that resistance training injuries commonly occur in the shoulder complex.

Objectives: The purpose of this study was to determine peak muscle activation and time to peak activation using shoulder surface electromyography (sEMG) during latissimus-dorsi pulldown variations following an accelerated shoulder resistance training program.

Methods: Thirteen males aged 18 to 35 years participated in the study. The participants completed a five-week, three times weekly supervised intervention program for 60 minutes. The intervention program consisted of a standardized rotator cuff impingement rehabilitation protocol and shoulder stabilizing muscle exercises. Each session commenced with a five-minute arm ergometer warm-up performed at 50 watts with 50-70 revolutions per minute (RPM), followed by five minutes of static upper body musculature. Participants performed three sets of eight to 12 repetitions of floor calisthenics exercises at 50-70% maximal voluntary contraction (MVC) and four sets of 25 repetitions of TheraBand exercises. Each session was concluded with stretching for three sets, with each stretch held for 45 seconds.

Results: Peak muscle activation of the middle trapezius significantly improved during wide grip anterior (WGA) ($p=0.042$). Further, the intervention significantly reduced the time to peak activation of the latissimus-dorsi during WGA ($p=0.000$) and supinated close grip (SCG) ($p=0.000$). Time to peak activation also significantly reduced of the middle trapezius during WGA ($p=0.010$). Similarly, time to peak activation of the triceps long head significantly reduced during WGA ($p=0.002$), wide grip posterior (WGP) ($p=0.045$) and SCG ($p=0.008$). Further, this study demonstrated a significant difference using WGA in the latissimus-dorsi at pre-test, in the lower trapezius using WGP at pre- and post-test, in the middle trapezius using WGA during post-test and using VBG during pre-test and in the triceps long head using WGA at pre- and post-test.

Conclusion: This study's findings are essential in shoulder prevention and rehabilitation programs since the various grips of latissimus dorsi-pulldown exercises are varied in their ability to target specific muscles in the shoulder complex that may need focused attention.

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Keywords: Bodybuilding; Lattisimus-dorsi pulldown; Peak muscle contraction; Surface electromyography; Time to peak contraction.

Introduction

Bodybuilder's weight training regimes aim to achieve muscle hypertrophy, symmetry, density and definition, through consistently training at high intensities with moderate to heavy workloads [1]. Bodybuilding is a unique sport that is not assessed based on the amount of weight that is lifted, nor the period of time taken to complete an event [1]. The lattisimus-dorsi pulldown exercise, in all variations, is widely used by bodybuilders' for strengthening and hypertrophy of the elbow flexors and shoulder adductors [2]. The major muscles activated during these exercises are the latissimus dorsi, teres major, trapezius (middle and lower), triceps long head, pectoralis major and posterior deltoid [3]. These muscles aid in stabilising the glenohumeral joints during these movements [2]. Therefore, the development of these muscles is highly important as they provide functional balance for the shoulder joint and contribute to symmetry, which is a vital aim for athletes, and especially for bodybuilders [3]. Resistance training incorporates exercises that rely on the shoulder for weight bearing, despite it not being a weight bearing joint [4]. Resistance training programs used by bodybuilders usually focus on hypertrophy of the larger, more superficial muscle groups, and very few exercises are incorporated for the stabilising muscles [4]. Muscle sequence and activation during an exercise can be detected using a surface electromyography (sEMG), which records changes in electric activity during muscle activation [5]. Higher peak contractions of a muscle result from greater recruitment of motor units and hence greater electrical activity is displayed on the sEMG [6]. The sEMG records the maximum voluntary contraction (MVC) produced by bilateral contractions for each muscle, and provides baseline data for muscle activation levels during variations of latissimus-dorsi pulldown exercises [2]. Evidence shows that performing a wide-grip latissimus-dorsi pulldown compared to a supinated grip yielded no significant increase in muscle activation of the latissimus-dorsi [7]. Further, a wide grip anterior (WGA) position produced a greatest amount of electrical muscle activation of the latissimus-dorsi and the triceps long head during both the eccentric and concentric phases [3]. However, the range of motion at which an exercise is performed can affect the level of muscle activation and affect the time to peak for muscle contraction [4, 5].

Resistance training injury incidences have been reported with prevalence rates of between 22 and 36% [4], with an anticipated gradual exponential increase of between 25 and 40% over the next decade [4, 8]. Increased risk of injury occurs when resistance training exercises place's the shoulder joint in end-range positions while bearing heavy loads [4]. This is due to the shoulders' high mobility and shallow glenoid cavity [8]. The shoulder complex is more prone to these high rates of injury due to large compressive loads being applied to a traditionally non-weight bearing joint, although contributing risks are attributed to intrinsic and extrinsic factors [4]. Intrinsic risk factors are defined as abnormal joint movement and muscle characteristics that develop in response to resistance training [4]. Such characteristics include muscle strength imbalances, shoulder instability, and decreased mobility [1]. Muscle imbalances between mobiliser and stabiliser muscles in conjunction with end-point resistance loading increases the risk of further injury [4]. As such, it is imperative to ascertain peak contraction levels, time to peak contraction, and muscle activation sequences during latissimus-dorsi pulldown variations in order to appropriately rehabilitate shoulder injuries.

Objectives

The purpose of this study was to determine peak muscle activation and time to peak activation using shoulder surface electromyography (sEMG) during latissimus-dorsi pulldown variations following an accelerated shoulder resistance training program.

Methods

Participants

Twenty-four males aged 18 to 35 years participated in the study. Participants with a body fat percentage greater than 15% were excluded from the study. Out of the initial 24 participants who were eligible to participate in the study, 13 completed the intervention program and were included in the final analysis. Ethical approval was obtained for the University of Zululand's Research Ethics Committee (UZREC 171110-030) prior to conducting the study. Participants completed informed consent forms prior to participating.

Procedures

Prior to participation in the study, participants completed informed consent forms. All participants then underwent anthropometric testing which included body mass, stature, BMI, and body fat percentage [9]. Body mass was measured in kilograms (kg) to the nearest 0.1 kg on a calibrated digital medical scale (Seca 843, Switzerland) with participants dressed in a standard T-shirts and shorts. Stature was measured in centimetres (cm) to the nearest 0.5 cm via a standard wall-mounted stadiometer. Body mass index (BMI) was calculated by dividing body mass by stature squared (weight/height^2) and expressed as kilograms per square meter (kg.m^{-2}). Skinfolds were taken at the bicep, tricep, subscapular, suprailiac, abdominal, thigh and calf using a Harpenden skinfold calliper (Harpenden, HSB-BI, ATICO Medical Pvt. Ltd, UK). Body fat percentage (%BF) was then calculated using the following MOGAP equation: % BF =

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[sum of six skinfolds x 0.105] + 2.585. Each participant then performed a one-repetition maximum (1-RM) latissimus-dorsi pulldown test for each grip variation namely; the v-bar grip (VBG), wide grip anterior (WGA), wide grip posterior (WGP), and supinated close grip (SCG) [2]. All grip distances were standardised using the participants' limb length measurements; the biacromial diameter was used for the SCG (3) and the distance from the seventh cervical vertebra (C7) to the first metacarpophalangeal joint was used for the WGA and WGP [2]. Calculations using 85% of the 1-RM tests were used to determine the eight repetitions maximum (8-RM) weight. During testing, the range of motion of a participant was determined by placing a marker on the weight stack along the structural support of the latissimus-dorsi pulldown machine at each endpoint of motion during one repetition [5]. Self-adhesive electrodes were placed on the middle trapezius (MT), lower trapezius (LT), middle latissimus-dorsi (LD) and the triceps long head (TLH). The participants skin was sterilized with alcohol swabs mostly in areas where the electrodes were placed in order to reduce electronic activity interference when conducting the sEMG assessment [10]. All electrodes were placed parallel to the muscle fibres over the midpoint between the nearest innervation zone and the musculotendinous junction, using maximum voluntary isometric contractions (MVIC's) to determine the midpoint [11]. The participants repeated five seconds of MVIC for each muscle group to normalise the sEMG value [12]. Each participant then performed an 8-RM assessment of each latissimus-dorsi pulldown variation while their muscle activation parameters were recorded using the sEMG. All repetitions were standardized using a metronome set at 30 beeps per minute [13].

Intervention

Thirteen participants completed a five-week, three times weekly supervised intervention program for 60 minutes. The intervention program consisted of a standardized rotator cuff impingement rehabilitation protocol and shoulder stabilizing muscle exercises. Each session commenced with a five-minute arm ergometer warm-up performed at 50 watts with 50-70 revolutions per minute (RPM), followed by five minutes of static upper body musculature stretching [2, 4]. Participants performed three sets of eight to 12 repetitions at 50-70% maximal voluntary contraction (MVC) with two- to three-minute rest between each set of the following floor calisthenics exercises, YTW, prone scapular retraction with thumbs down, prone scapular retraction with thumbs up, 90º shoulder and elbow flexion prone lift and prone shoulder 180º flexion lift [4]. Also, color-coded TheraBand's (The Hygienic Corp, Akron, Ohio); yellow (low), red (medium), green (heavy), blue (extra-heavy) and black (special heavy); were used to perform triceps pushdown, shoulder external rotation, shoulder flexion, D1 and D2 shoulder flexion, 90º shoulder-abduction-external rotation, chest pull, standing rows, standing shoulder extension, military wall walks and seated frontal and lateral raises [3]. The level of tubing resistance was adjusted accordingly for all participants throughout the treatment process. At the first session, the participants were asked to do 10 repetitions of each of the tubing exercises to ascertain difficulty. The appropriate coloured TheraBand was prescribed to a participant based on feedback from the electromyography (EMG) of the target muscles. Each tubing exercise was performed for four sets of 25 repetitions with a 2-minute rest period between each set. At the end of every week, the participants' were evaluated using Kendall's manual strength tests and progressed to the next higher level of resistance. The sessions were concluded with stretching for three sets, with each stretch held for 45 seconds.

Statistical analysis

All statistical analysis was performed using the SPSS for Windows software (version 25.0, SPSS Inc., Chicago, Illinois, USA). Data are presented as means±standard deviation (SD). Subsequent paired t-tests were done for peak contractions and time to peak contractions for pre-testing and post-testing results. The level of significance was set at $p \leq 0.05$.

Results

Eleven participants were excluded from the study as they were unable to complete the required sessions. The mean body fat percentage, body mass and stature were 8.3%, 169.4cm and 76.2kg, respectively. The five-week shoulder resistance training program significantly ($p \leq 0.05$) improved peak muscle activation of the middle trapezius during WGA (p=0.042). Further, the intervention significantly reduced the time to peak activation of the latissimus-dorsi during WGA (p=0.000) and SCG (p=0.000). Time to peak activation also significantly reduced of the middle trapezius during WGA (p=0.010). Similarly, time to peak activation of the triceps long head significantly reduced during WGA (p=0.002), WGP (p=0.045) and SCG (p=0.008). Further, this study demonstrated a significant difference using WGA in the latissimus-dorsi at pre-test, in the lower trapezius using WGP at pre- and post-test, in the middle trapezius using WGA during post-test and using VBG during pre-test and in the triceps long head using WGA at pre- and post-test. The relevant data are presented in Table 1.

Discussion

This study aimed to determine peak muscle activation and time to peak activation using shoulder surface electromyography (sEMG) during latissimus-dorsi pulldown variations following an accelerated shoulder resistance training program. Following the five-week shoulder resistance training program, peak muscle activation of the middle trapezius significantly improved during WGA. The intervention significantly reduced the time to peak activation

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Table 1: Changes in peak muscle activation and time to peak activation of the latissimus- dorsi, lower trapezius, middle trapezius and triceps long head during the lattisimus-dorsi pulldown variations in response to a five-week shoulder resistance training program

Variable	Peak muscle activation					Time to peak activation				
	Pre-test		Post-test		p-value	Pre-test		Post-test		p-value
	x̄ (μV)	σ (μV)	x̄ (μV)	σ (μV)		x̄ (s)	σ (s)	x̄ (s)	σ (s)	
Latissimus-dorsi										
WGA	2053.32^	1086.65	2316.29	1583.56	0.626	1.51	0.26	1.01	0.34	0.000*
WGP	2014.44	1011.2	2282.99	1453.5	0.590	1.4	0.26	1.22	0.25	0.085
VBG	1815.14	1091.7	1848.46	924.44	0.934	1.3	0.25	1.34	0.18	0.644
SCG	2026.87	984.34	2324.86^	1621.26	0.576	1.7	0.23	1.09	0.26	0.000*
Lower trapezius										
WGA	1316.8	585.37	1421.16	683.04	0.680	1.21	0.29	0.938	0.404	0.060
WGP	1687.46^	713.51	2030.65^	1785.95	0.526	1.06	0.33	1.06	0.32	1.000
VBG	1305.41	641.47	1319.86	636.49	0.955	1.06	0.26	1.0	0.4	0.654
SCG	1439.34	798.34	1335.3	663.1	0.721	1.09	0.41	0.96	0.42	0.432
Middle trapezius										
WGA	952.25	444.17	1568.17^	933.74	0.042*	1.25	0.31	0.97	0.18	0.010*
WGP	1088.77	454.86	1465.13	747.29	0.134	1.17	0.27	1.03	0.28	0.207
VBG	1153.91^	387.16	1030.83	417.023	0.443	1.16	0.23	1.12	0.32	0.718
SCG	1002.3	436.03	1303.45	420.89	0.086	1.38	0.33	1.13	0.31	0.058
Triceps long head										
WGA	1380.41^	477.38	1157.21^	479.35	0.245	1.32	0.34	0.94	0.19	0.002*
WGP	1290.05	563.30	1111.03	686.81	0.475	1.26	0.26	1.04	0.27	0.045*
VBG	831.71	389.8	748.56	441.66	0.615	1.05	0.36	0.90	0.28	0.247
SCG	767.92	274.57	1014.34	689.22	0.243	1.27	0.33	0.93	0.27	0.008*

x̄: Average mean; σ: Average standard deviation; μV: Microvolts; s: seconds; WGA: Wide grip anterior; WGP: Wide grip posterior; VBG: v-bar grip; SCG: Supinated close grip; ^: significant differences between grips for a specific muscle; *: significant difference between pre-test and post-test

of the latissimus-dorsi during WGA and SCG, of the middle trapezius during WGA and of the triceps long head during WGA, WGP and SCG. Also, a significant difference was found using WGA in the latissimus-dorsi at pre-test, in the lower trapezius using WGP at pre- and post-test, in the middle trapezius using WGA during post-test and using VBG during pre-test and in the triceps long head using WGA at pre- and post-test. Various studies have examined sEMG responses of latissimus-dorsi pulldown exercises [2, 3, 7, 14]. However, there is limited research on the effect of an intervention program on muscle activation during latissimus-dorsi pulldown variations. This study's reduction in time to peak activation of the latissimus-dorsi during WGA and SCG, of the middle trapezius during WGA and of the triceps long head during WGA, WGP and SCG, may reflect higher production rates of adenosine triphosphate, as well as increased production of calcium during muscle contraction [15]. The lattissimus-dorsi acts as the agonistic muscle, the triceps long head acts as the stabiliser and the lower trapezius and middle trapezius act as synergistic muscles during the lattissimus-dorsi pulldown exercise. Koyama at al. [13] showed that peak sEMG activity occurred in a proximal-to-distal sequence, in the order of the serratus anterior, latissimus dorsi, posterior deltoid, biceps brachii and finally the triceps brachii. However, the present study demonstrated a contrasting muscle activation sequence, with the triceps long head reaching peak contraction before the latissimus dorsi during WGA, WGP and SCG. Therefore, the triceps long head activated faster during these grips allowing the glenohumeral joint to develop stability at a faster rate. The changes in muscle recruitment patterns between pre-testing and post-testing could be attributed by a larger number of muscle fibers being activated during a single contraction which increased motor neuron response [15]. The changes in sequencing and stability activation could be associated with the intervention program. The latissimus-dorsi was found to produce greater levels of electrical activity during the WGA position at pre-test when compared to any other grip variation, and no changes were found at post-test using any of the grip variations. This is in contrast to the findings of previous research [2, 3]. The sample period of exposure to training and physiological differences could have been contributing factors to the differences in the findings [2, 3]. The middle trapezius produced the greatest activity at pre-test when using the VBG, whereas WGA resulted in the greatest activation at post-test. This increase in peak muscle activation could be due to the recruitment of larger motor units as the muscle progressively became fatigued [16, 17, 18]. These

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findings are contrary to previous research, possibly due to the different workload and program design factors used during the latissimus-dorsi pulldown variations [15].

Research has noted that the WGP position increases emphasis on the lower trapezius activation, which is in agreement with the pre- and post-test findings of the present study [3]. In contrast to the present study, which showed that the triceps long head activation was greatest during the WGA for both pre- and post-testing, previous research reported that the triceps long head did not show any significant differences between the hand grip variations [3]. In the current study, time to peak activation of the latissimus-dorsi during WGA and SCG reduced. In this regard, reductions in repetition performance were found for WGA and SCG, respectively. These results are in agreement with Signorile et al. [3] who performed three repetitions of latissimus-dorsi pull-down at a 10-RM weight and Ekberg (9) who performed at 75-100% of MVC. The time to peak activation of the triceps long head significantly reduced during WGA, WGP and SCG. From a clinical point of view, the integrity of the long head of the triceps brachii can be properly assessed in a fully extended shoulder position. In this position, the long head of the triceps brachii is the most dominant muscle which contributes to elbow extension, and the role of both lateral and medial heads are as an adjunct synergic support. Thus, the triceps long head was significantly different during the variations and accounted for the significant reduction of time to peak during the WGA, WGP, and SCG grips.

Limitations

The present study has several limitations. Once such possible limitation may be the relatively small sample size which reduces ecological validity. In addition, this study made use of a male-only population to mitigate physiological and anatomical differences and these findings should be utilized with caution in female populations. While the present study examined the main latissimus dorsi-pulldown grip variations, other grip variations exist that may influence the shoulder musculature in different ways. Also, a multitude of alternate resistance training design variables exist when developing shoulder injury prevention or rehabilitation programs which may produce greater force outputs in specific shoulder muscles.

Conclusion

Since resistance training injuries commonly occur in the shoulder complex it is essential to ascertain which hand grip positions during latissimus dorsi-pulldown exercises could result in optimal peak muscle activation and time to peak activation. This study's findings are essential in shoulder prevention and rehabilitation programs since the various grips of latissimus dorsi-pulldown exercises are varied in their ability to target specific muscles in the shoulder complex that may need focused attention.

Authors contribution

Musa Lewis Mathunjwa and Megan Ellor made a substantial contribution in the design of the study, acquisition, analysis, writing and critically reviewing the article and its intellectual content; final approval of the manuscript; and agreeing to take responsibility for all aspect of the study. Nduduzo Shandu made a substantial contribution in design of the study, acquisition, analysis, writing and critically reviewing the article and its intellectual content. Musa Lewis Mathunjwa, Ina Shaw, Loyiso Maqina, Gudani Goodman Mukoma and Brandon Stuwart Shaw made a substantial contribution in the design of the study, acquisition, analysis, writing and critically reviewing the article and its intellectual content, final approval of the manuscript.

Conflict of Interests

No conflict of interest has been declared by any of the authors.

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