Electromyographic Activity Using Elastic Resistance and Nautilus Machine Exercises

Saied Jalal Aboodarda, Sport Center, University Malaya, Malaysia

Dr Ahmad Munir Che Muhamed, Sport Center, University Malaya, Malaysia

Assoc. Prof. Fatimah Binti Ibrahim, Dept of Biomedical Engineering, University Malaya, Malaysia

Dr. Mohamad Shariff Bin A Hamid, Faculty of Medicine, University Malaya, Malaysia

Abstract

The purpose of this study, therefore, was to quantify and compare Integrated Electromyography (I-EMG) within perfuming 8-RM seated knee extension in contribution of Elastic Resistance and Nautilus Machine exercises. All data were collected within one testing session. Subjects completed 8-RM seated knee extension by three modalities of resistance exercises comprised of Nautilus Machine (NM), elastic tubing with original elongation (E0%) and elastic tubing with 30% decrement of original elongation (E30%). Electromyographic muscle activation and range of motion were collected and synchronized from Vastus Lateralis (VL). Results: manipulating the resting length of elastic resistance resulted in significantly higher I-EMG for E30% in compare with E0% (25% increasing muscle activation); however, no significant difference observed between E30% and NM (P = 0.443). Based on these results, it seems that shortened form of elastic exercise (E30%) and NM exercises offer equivalent muscle activation. Thus, they could be used interchangeably for lower body strength development.

Introduction

The variability of external moment of force and ability to provide maximal muscular tension within various segments of range of motion have been addressed as critical parameters in introducing a superior resistance exercise type [1, 2]. Based on some considerations such as accessibility and price of accommodative exercise devices (e.g. Cybex Isokinetic dynamometer) and mechanical disadvantages of traditional free weight exercises(known as sticking point; Behm, [3], Variable Resistance Training (VRT) has been proposed as reliable modes of contraction for achieving further muscular adaptation [4-6]. Among many modalities of VRT, Elastic Resistance and CAM-Nautilus Machine exercises seems to be more applied among athletes and recreational lifters [5, 7, 8]. However, the debate over differences in rate of neuromuscular activity between these two modes of exercise is not proposed by any direct investigation.

Electromyography (EMG) has been introduced as an experimental technique which provides the most direct assessment of neuromuscular activation and adaptation [9, 10]. Measuring the integrated EMG signal (IEMG) is comprised of quantifying the amount of motor unit activation in the muscle from electrodes place over the belly of the muscle [11]. McBride [12] stated that "…surface EMG may not identify any specific neural mechanism but can serve as a cross measure of the amount of muscle activity changes that may occur as a result of given stimulus". Although, some previous investigations have been concentrated on scrutinizing the proficiency of elastic resistance training via measuring EMG [6, 13], no study to date has attempted to quantify and compare muscle activation and torque production in contribution of elastic material and nautilus machine within performing 8-RM knee extension exercise.

This study is based on this speculation that if the magnitude of electromyographical activation during varies segments of range of motion in elastic resistance is not significantly different from Nautilus machine exercises it might be more likely to introduce elastic resistance as a viable mode of exercise in athletic setting. The purpose of this study, therefore, was to quantify and compare Integrated Electromyography (I-EMG) within perfuming 8-RM seated knee extension in contribution of elastic resistance and nautilus machine exercises.

Method

Experimental Approach to the Problem

All data were collected within one testing session. Subjects completed 8-RM seated knee extension by three modalities of resistance exercises comprised of nautilus machine (NM), elastic tubing with original elongation (E0%) and elastic tubing with 30% decrement of original elongation (E30%). Electromyographic muscle activation and kinematic values such as range of motion were collected and synchronized from Vastus Lateralis (VL). Thus, I-EMG was quantified and compared as dependent variables and independent variables were three aforementioned resistance exercises.

Subjects. Nine male (age= 24.0± 2.6 years; height= 179 ± 2 cm; weight= 85.14 ± 7.2 kg) and five female (age= 24.7 ± 2.2 years; height= 157 ± 5 cm; weight= 56,2 ± 5.02 kg) recreationally active university students gave their consent to voluntarily participate in the study which was approved by the ethical committee of University Malaya. None of the subjects had had experience of regular resistance training. They were asked not contribute in any resistance training 48 hours before data collection.

Instrumentation. EMG muscle activity values were collected with a sample rate of 1000 Hz using a 16 bit acquisition mode with an eight channel TeleMyo™ 2400T G2 (Noraxon, Scottsdale, Arizona, USA) EMG system. Pre-gelled silver/silver chloride adhesive disk surface electrodes (Meditrace, Canada) were used to detect electromyographic signals. All EMG signals were passed through preamplifier leads to a frequency-modulation transmitter. Range of motion in dominant knee was monitored using a 2D electrogoniometer in 200 uv and a two dimension accelerometer (10g) was places at the lateral side of the shank to measure linear acceleration of the shank and foot (Noraxon, Scottsdale, Arizona, USA). A PC-Interface receiver (Noraxon, Scottsdale, Arizona, USA) which could receive WiFi based telemetry data was used to forward the data from transmitter to a notebook (ASUS 3F3 China) via USB. We collected the EMG data with data acquisition package Myoresearch-XP, Master Edition (Noraxon, Scottsdale, Arizona, USA). Data were collected from all 8-RM while the first, 4^{th} plus 5^{th} and 8^{th} repetitions has been selected for data analyze. Various color code of Thera-Band elastic tubing (Hygienic Corporation, Akron, OH) were used to provide elastic resistance.

Data Collection. All data were collected within one testing session and the order of the measurement was randomized across 3 exercise modalities. Following the warm up comprised of static stretching and 5 minutes biking on an ergometer with desired pace, the subjects were allowed at least 5 minutes of rest, during which time the electrogoniometer and accelerometer were strapped to the subject`s dominant knee and ankle respectively. The load cell were placed in series with nautilus machine cable (between cable and weight stock) to measure MVIC. Before placement of electrodes subject`s skin was prepared by shaving hair and removing dead-skin from the surface with a roughing pad and cleansing the surface with alcohol. Based on scientific recommendation (Alkner, Tesch and Berg, 1999) surface electrodes were placed over Vastus Lateralis (VL) as representer of Quadriceps muscle group. Electrodes were placed on the longitudinal axis over VL muscle 2/3 on the line from the anterior spina iliaca superior to the lateral side of the patella. The ground electrode was placed on the patella bone (SENIAM).

After electrodes placement, subject were seated on the leg extension nautilus machine chair. The shin lever arm pat of the nautilus machine was adjusted to put the knee in the 60° of extension which has been indicated the best angle for MVIC of the knee [14]. A 5-second baseline signal was collected to ensure that no artifact was observed. Then, the subject performed three MVIC trials on the dominant limb. Each MVIC trial was lasted 5 second and 90 second rest intervals were assigned between the trials to prevent fatigue [14]. After completion of 3 trials, the highest value automatically was selected by Myoresearch-XP as MVIC and this value were establish as a EMG reference value for EMG data collection throughout the study.

Following measuring MVIC, the subjects completed 8-RM tests with 3 modes of resistance exercise in a random order. In all 3 modes of exercises, subjects were instructed and asked to perform the exercise within 80° to 180° of knee extension. The cadence of performing the exercise was 2 second concentric and 2 second eccentric set by a metronome. A second pause between every repetition was assigned to avoid interference of stretch shortening cycle in potential of movement in early concentric. Counting the number of repetitions in all modes of exercises was continued until subject could perform 8-RM without any compromise in the correct style and range of motion. Lifting more than 8 repetitions with the current resistance in the assigned range of motion, subject performed next trial with heavier weight in nautilus exercise or adds up more tubing until the subject was no longer able to perform more than 8 repetitions.

The Myoreseach-XP software is capable of calculating IEMG value by integration of the full wave rectified signals and synchronize the data with other 3 sensors. After collecting the data, based on the electrogoniometer traces each repetition was divided into concentric and eccentric phases by putting markers on the peak and lowest place in the beginning and end of each repetition. Then, the record mean value of concentric or eccentric phase of contraction was manually divided by three; which ultimately separated each phase of contraction to 3 equal segments (totally 6 segments: 3 segments concentric and 3 segments eccentric). Saved EMG data were preceded for full waved rectified and smoothness. Then, the software automatically translated the Mean EMG and Area of Each Segment to I-EMG values transferable into excel software.

Statistical Analyses

Differences in mean EMG value and resultant muscle torque of biceps brachii within various segments (1 to 6), repetitions (1, 4+5 and 8) and modalities of exercise (NM, E0% and E30%) were examined using a 3 × 3 × 6 repeated measure analyze of variance (ANOVA) across the factors (segments, repetitions, exercise modalities). Since repeated measure ANOVA doesn't monitor differences across every couple of values, pair t-tests were used to examine the effects of various modes of exercises in I-EMG within segments in analogous repetitions.

Results

The ensemble I-EMG values for 3 exercise types comprised of Average of I-EMG (average of all 6 segments within every repetition) and Total of Average I-EMG (average of all 6 segments × 3 repetitions) in addition to I-EMG value within various segments are listed in table 1. Total of Average I-EMG demonstrated no significant difference between E30% and NM ($P = 0.443$); while, both modes of exercise attained significantly higher value than E0% ($P = 0{,}011$ and $P = 0.00$ for M and E30%, respectively; all $P < 0.05$).

Examining similar repetitions within various modes of exercise in Average of I-EMG level also advocated aforementioned finding (all P < 0.05). The data in this level demonstrated, except in first repetition which E30% displayed slightly higher value than nautilus machine (P = 0.996), NM exercise generated non-significantly higher value than E30% (P = 0.155 and P = 0.570 in repetition 4 and 8 respectively) and statistically higher value than E0%. The comparison between elastic resistance exercises also exhibited significantly higher value in favor of E30% (all P < 0.05). In segmental level, the differentiations of muscle activation in similar phases between various exercise types are exhibited in table 1. These results indicated that in the early concentric and late eccentric segments (i.e. first and 6^{th} segments) NM generated significantly higher muscle activation than both elastic modalities; E30% also attained higher value than E0% (all p < 0.05). In the mid-concentric and mid-eccentric segments both nautilus and E30% show significantly higher muscle activity than E0%, though no

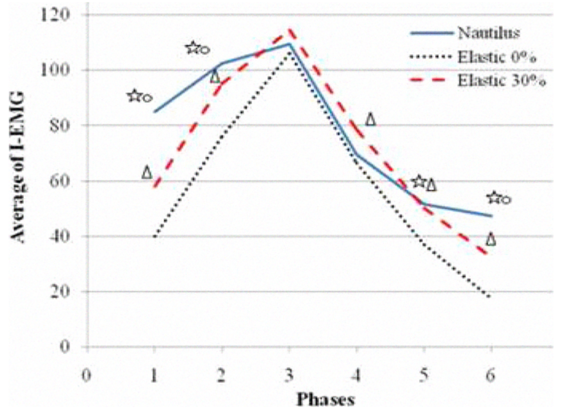

Figure 1. Ensemble of all 3 repetitions representing the value of every segment. ☆ = Nautilus is significantly higher than Elastic 0%. Δ = Elastic 30% is significantly higher than Elastic 0%. ○ = Nautilus is significantly higher than Elastic 30%

significant differences displayed between E30% and NM. Finally, in late concentric and early eccentric phases, no significant differences has been observed between 3 types of exercises; except, E30% which demonstrated significantly higher Mean I-EMG value than E0% in 4^{th} phase.

TABLE1 I-EMG Values Within Various Levels of Exercise Modalities

I-EMG																	
Nautilus Machine "Total Average Of All 3 Repetitions × 6 Phases"						Elastic Band 0% " Total Average Of All 3 Repetitions P× 6 hases"						Elastic Band 30% " Total Average Of All 3 Repetitions × 6 phases"					
77,36 * (35,52)						57,02 (19,67)						71,28 Δ (23,40)					
Average of all 6 phases within every repetition						Average of all 6 phases within every repetition						Average of all 6 phases within every repetition					
repetition 1		repetition 4		repetition 8		repetition 1		repetition 4		repetition 8		repetition 1		repetition 4		repetition 8	
62,44* (32,59)		77,32 * ▲ (33,72)		92,31 * ● (42,46)		45,30 (15,72)		58,09 ▲ (18,74)		67,67 ● (25,53)		62,48 Δ (21,21)		72,94 Δ ▲ (25,6)		78,43Δ● (24,07)	
Mean and SD of IEMG values of every segments (N=14)																	
1	55,70 * (25,76)	1	83,22*† (43,39)	1	116,12*† (68,54)	1	31,70 (18,42)	1	39,28 (12,50)	1	48,65 (20,08)	1	54,67Δ (17,63)	1	53,36Δ (20,37)	1	65,90 Δ (23,12)
2	76,37 (49,39)	2	102,73 * (45,15)	2	127,80 * (64,81)	2	54,93 (19,19)	2	75,89 (26,96)	2	97,14 (43,81)	2	84,20 Δ (32,48)	2	88,50 (37,98)	2	112,62Δ (35,44)
3	99,27 (66,83)	3	106,68 (52,71)	3	122,42 (53,56)	3	86,36 (31,10)	3	109,54 (41,61)	3	122,65 (52,46)	3	100,34Δ (40,47)	3	113,74 (51,35)	3	129,03 (47,75)
4	59,24 (35,45)	4	68,71 (29,04)	4	80,28 (38,91)	4	56,13 (27,70)	4	67,05 (27,81)	4	76,43 (27,25)	4	64,48 (25,14)	4	86,89 Δ ♦ (36,34)	4	83,92 Δ (27,43)
5	43,87* (18,61)	5	51,59 * (20,96)	5	59,02* (21,92)	5	29,66 (11,07)	5	37,39 (12,34)	5	43,45 (15,17)	5	42,05Δ (12,40)	5	56,39 Δ (21,41)	5	51,70 Δ (16,83)
6	42,59 *† (16,39)	6	51,00 *† (19,35)	6	48,22 *† (18,79)	6	15,62 (5,88)	6	19,38 (7,30)	6	17,69 (8,63)	6	31,46 Δ (11,71)	6	38,75 Δ (13,14)	6	27,39 Δ (15,59)

* NM is significantly higher than E0%. Δ E30%) is significantly higher than E0%. † NM is significantly higher than E30%. ♦ E30% is significantly higher than NM. ▲Significantly higher than repetition 1.● Significantly higher than repetition 1 and 4.

Discussion.

This investigation speculated whether various modalities of elastic resistance (E0% and E30%) could generate as much muscle activation as NM exercises. The present findings implied that decreasing 30% of resting elongation and matching various color code of elastic tubing, has successfully developed muscle activation and torque production in Total Average I-EMG values (ensemble of all 6 segments × 3 repetitions) throughout elastic resistance exercises. More specifically, utilizing aforementioned strategies resulted in 25% increasing muscle activation in E30% in compare with E0%.

Average of I-EMG. Examining Inter-exercise I-EMG values within similar repetitions supported preceding findings based on insignificant difference between E30% and NM. However, Intra-exercise I-EMG values demonstrated a general trend in which within all types of exercise higher I-EMG was achieved while approaching to the last repetitions of 8-RM (figure 2). This increase in magnitude of muscle activation could be attributed to neuromuscular fatigue. The results are in line with previous findings indicating that motor unit activation was increased with fatigue in last few repetition of a set [15, 16]. In advocate of this explanation, Behm [3] suggested that following fatigue, stronger neural drive is generated to conquer some of the effects of fatigue to make the muscle able to produce required tension.

However, the visual inspection of figure 2 demonstrated various slops for muscle activation curves within 3 exercise modalities. Interestingly, the more repetitions were completed, the more distinction has been observed between NM and elastic resistance. For example, E30% and NM demonstrated 0.06% differentiation in repetition 1 (in favor of E30%), while, 17.69% in repetition 8 (in favor of NM). These alterations could be attributed to various loading profile of 3 exercise types [11] and could indicate the higher efficiency of nautilus exercises in generating muscle activation within performing 8-RM. In the other hand, differentiations between elastic resistance exercises exhibited a downward range from 37.2% in repetition 1, to 25.56% in repetition 4 and 15.90% in repetition 8 (all in favor of E30%). The possible explanation might be attributed to more constant near maximal recoil of force within entire range of motion in E30%. This sub-maximal muscle activation from initiation of the set might slow down further increase motor unit recruitment in repetition 4 and 8. However, the finding cannot be interpreted as a disadvantage for E30% because it still statistically showed higher values within all 3 repetitions.

I-EMG. The present finding in segmental level displayed an ascending-descending I-EMG profile for knee extensors which completely supports previous research outcomes recommended ball-shaped loading profile of VRT. Utilizing these modes of exercises is characterized by increasing muscle tension progressively throughout concentric phase and decreasing tension throughout eccentric phase of contraction. Therefore, the linear increment of external moment of force in elastic resistance and nautilus machine exercises within the concentric phase of contraction has met the torque requirement of quadriceps muscles.

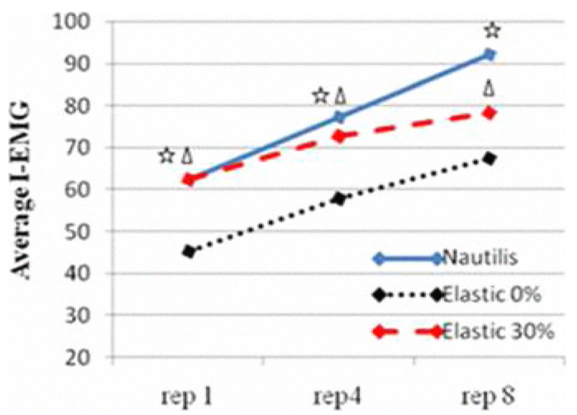

FIGURE 2. Ensemble of all 6 phases representing the value of every repetition. ☆ NM is significantly higher than E30%. Δ E30% is significantly higher than E0%

In the early concentric and late eccentric segments, NM generated significantly higher muscle activation than both E0% and elastic 30%. Greater provided external resistance as well as concomitant higher inertia of force in these two segments is the reason for observing higher I-EMG value in NM. However, 66.57% increasing I-EMG in phase 1 and

85.20% in phase 6 for E30% in compared with E0% supported effectiveness of two applied strategies in developing muscle tension in elastic resistance exercises.

In the mid-concentric and mid-eccentric segments, NM displayed 34.62% and E30% showed 35.82% significantly higher muscle activity than E0% in phase 2 and 5; although no significant differences observed between E30% and NM (2.89% in favor of NM). Regarding that nautilus machine is being designed to provide required muscular tension in all range of motion itself, the merit of applying elastic 30% become more obvious when it reached the tension generated in nautilus machine within these two segments.

In late concentric phase (third segment), although E30% showed slightly higher I-EMG value than NM (4.48%), no statistical differences has been observed between three modes of training. In the early eccentric phase (4th segment), E30% demonstrated significantly (17.88%) higher I-EMG value than E0%. Based on these results, it seems that shortened form of elastic exercise (E30%) and NM exercises offer equivalent muscle activation. Thus, they could be used interchangeably for lower body strength development; while, E0% exercises might not be considered as a reliable mode of exercise for achieving further neuromuscular adaptation for quadriceps since it couldn't elicit adequate muscle activation. However, this is not to say that E0% is not an effective lift, but rather that it may be applied in various levels of rehabilitation or primary level of training period.

References

[1]. Fleck SJ, William J Kraemer. Designing Resistance Training Program: Human Kinetics; 2004.

[2]. Wallace BJ, Winchester JB, McGuigan MR. Effects of Elastic Bands on Force and Power Characteristics during the Back Squat Exercise. The Journal of Strength & Conditioning Research. 2006; 20(2):268-72.

[3]. Behm DG. Surgical tubing for sport and velocity specific training. . NCSA J. 1988; 10(4):66-70.

[4]. Hodges GN. The effect of movement strategy and elastic starting strain on shoulder resultant fount moment during elastic resistance exercise: Manitoba; 2006.

[5]. Anderson CE, Sforzo GA, Sigg JA. The Effects of Combining Elastic and Free Weight Resistance on Strength and Power in Athletes. The Journal of Strength & Conditioning Research. 2008; 22(2):567-74 10.1519/JSC.0b013e3181634d1e.

[6]. Ebben WE, Jensen RL. Electromyographic and Kinetic Analysis of Traditional, Chain, and Elastic Band Squats. The Journal of Strength & Conditioning Research. 2002; 16(4):547-50.

[7]. Page PA, John Lamberth, Ben Abadie, Robert Boling, Robert Collins, Robert Collins. Posterior Rotator Cuff Strengthening Using Theraband® in a Functional Diagonal Pattern in Collegiate Baseball Pitchers. J Athl Train. 1993 28.(4):346-54.

[8]. Treiber FA, Lott J, Duncan J, Slavens G, Davis H. Effects of Theraband and Lightweight Dumbbell Training on Shoulder Rotation Torque and Serve Performance in College Tennis Players. The American Journal of Sports Medicine. 1998 July 1998; 26(4):510-5.

[9]. SALE D. Neural Adaptation to Resistance Training. Medicine and science in sport and exercise. 1988 20 (5):135-45.

[10]. Konrad P. The ABC of EMG: Noraxon Company; 2005.

[11]. Welsch EA, Bird M, Mayhew JL. Electromyographic Activity of the Pectoralis Major and Anterior Deltoid Muscles during Three Upper-Body Lifts. The Journal of Strength & Conditioning Research. 2005; 19(2):449-52.

[12]. McBride J, Blaak JB, T. T-M. Effect of resistance exercise volume and complexity on EMG, strength, and regional body composition. Eur J Appl Physiol 2003 90(5-6):626-32

[13]. Lim Y, Chow J. Electromyographic Comparison of Biceps Curls Performance Using a Dumbbell and an Elastic Tubing. north American congress on biomechanics waterloo, Canada; 1998.

[14]. Matheson JW, Kernozek TW, Fater DCW, Davies GJ. Electromyographic activity and applied load during seated quadriceps exercises. Medicine & Science in Sports & Exercise. 2001;33(10):1713-25.

[15]. KREAMER WJ, RATAMESS NA. Hormonal Response and Adaptation to Resistance Exercise and Training. Jounal of Sport Medicine. 2005;35(4):339-61.

[16]. Hortobagyi T, Barrier J, Beard D, Braspennincx J, Koens P, Devita P, et al. Greater initial adaptations to submaximal muscle lengthening than maximal shortening. J Appl Physiol. 1996 October 1, 1996; 81(4):1677-82.