Journal of Exercise Physiology**online**

December 2012
Volume 15 Number 6

JEPonline

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

Acute Neuromuscular and Hormonal Responses to Resistance Exercise Using Variable External Resistance Loading

Saied Jalal Aboodarda[1], Fatimah Ibrahim[2], A. Halim Mokhtar [3], Martim W. Thompson[4], David G. Behm [5]

[1]Sports Center, University of Malaya, Malaysia, [2]Dept of Biomedical Engineering, Faculty of Engineering, University Malaya, Malaysia [3]Sports Medicine Unit, Faculty of Medicine, University of Malaya, Malaysia, [4]Discipline of Exercise and Sport Science, The University of Sydney, Sydney, Australia, [5]School of Human Kinetics and Recreation, Memorial University of Newfoundland, St. John's, Newfoundland, Canada

ABSTRACT

Aboodarda SJ, Ibrahim F, Mokhtar AH, Thompson MW, Behm DG. Acute Neuromuscular and Hormonal Responses to Resistance Exercise Using Variable External Resistance Loading. **JEPonline** 2012;15(6):1-12. Variable resistance training (VRT) such as that employed by equipment that utilizes asymmetrical cams or pulleys (ASYM CAM) (e.g., Nautilus Machines) and elastic resistance (ELASTIC) are commonly used by athletes and fitness enthusiasts. However, the use of ELASTIC in high intensity training protocols has been controversial due to the limitation of providing a relatively low external force. The purpose of this study was designed to quantify and compare the acute responses in electromyogram signals (EMG) and the concentration of serum growth hormone ([GH]), testosterone ([T]), and lactate ([LA]) following fatiguing knee extension exercise with ELASTIC and ASYM CAM. In a counterbalanced cross-over study, nine male (21.08 ± 6.2 yrs) recreationally active subjects completed 5 sets of 10-RM knee extension exercise with ELASTIC and ASYM CAM with 3 wks of no training between experimental conditions. Blood sampling, maximum voluntary contraction (MVC) and EMG were recorded before, immediately, 15, 30, and 60 min after the termination of the exercise bout. The average of applied forces with ASYM CAM was significantly higher than ELASTIC (362 ± 34.2 N vs. 266.73 ± 58.56 N; P = .00) across the 5 sets of dynamic exercises.

However, the average force and mean amplitude of MVC as well as the [GH], [T] and [LA] demonstrated no significant difference between the two types of exercise either in the pretest or during the recovery period (all P>0.05). Contrary to the traditional approach of using ELASTIC, which is for early rehabilitation purposes, the findings of the present study suggest ELASTIC is an acceptable exercise device for high intensity resistance training in the final stages of rehabilitation as well as athletic conditioning.

Key Words: Resistance Training, Elastic Tubing, Variable Exercises, Multiple Repetitions Maximum

INTRODUCTION

Acute neuromuscular and hormonal responses have been used extensively to compare resistance training protocols of various intensities (7,22) and types of muscle contraction (8,9,23). The relatively short term responses at the outset of a resistance training program may potentially provide insight to the longer term adaptations. However, we are unaware of any published research that has focused on the neuromuscular and hormonal responses to variable external resistance training (VRT) such as elastic resistance (ELASTIC) and resistance equipment using asymmetrical cams or pulleys (ASYM CAM; e.g., Nautilus™ Universal™ and others). Manning and colleagues (20) define VRT as training devices, which attempt to provide varying external resistance based on the muscle force production capability throughout the range of motion (ROM).

During the past two decades ASYM CAM and ELASTIC have gained considerable popularity among therapist, recreational resistance trainers and athletes (1,26,27,30). However, there is some controversy in the research literature concerning the use of ELASTIC with the prevailing view that “an elastic device cannot provide adequate external force” (9,12,25). It is worth noting that elastic device (Tubing or Therabands) are produced in different color codes and each color denotes a specific resistance (15). Accordingly, the lower resistive ELASTIC has been used primarily for pain impairment, increased range of motion after trauma and improvement in functional scales and disabilities in the early and the middle phases of rehabilitation protocols (13,21,23) while the more resistive ELASTIC has been used for development of muscle endurance, balance, and proprioception enhancement in healthy trained individuals (4,26,30).

The proponents of ELASTIC (4,21,24) suggest that the elastic device is a suitable alternative to the use of conventional resistance training equipment for development of muscle strength, if a similar external force is provided by the ELASTIC. Behm (4) demonstrated similar strength increases with a 10 wk training program compared to elastic tubing, Universal™ (isotonic), and Hydragym™ (VRT) resistance devices. Nevertheless the efficacy of ELASTIC as an appropriate resistance training device does not have widespread acceptance. The question that needs to be addressed is: “whether using an ELASTIC device can result in similar acute neuromuscular and anabolic hormonal responses as ASYM CAM?”

In order to enhance external force in ELASTIC, some investigators have recommended using additional elastic bands in parallel (26) as well as reducing the initial length of the elastic material (12). We hypothesized that by applying these two strategies, equal external force and consequently similar acute neuromuscular and anabolic hormonal responses can be achieved with ELASTIC compared with ASYM CAM exercise. Thus, the purpose of this investigation was to study the magnitude of external force as well as the acute responses of electromyogram signals (EMG) and the responses of growth hormone ([GH]), testosterone ([T]) and plasma lactate concentration ([LA]) following intensive resistance training protocols employing ELASTIC and ASYM CAM devices.

METHODS

Subjects

Ten recreationally active male students (age: 21.08 ± 6.2 yrs, weight: 74.58 ± 7.2 kg, height: 172 ± 6 cm) participated in the study, which was approved by the Human Ethics Committee of the Sports Center, University of Malaya. Subjects had not participated in any regular resistance training program or competitive sport in the past 12 mo. The sample-size in the study was estimated according to the statistical power calculations method recommended by Hopkins (13) and Vincent (32). Accordingly, if the P=0.05 and statistical power =0.80, 10 subjects were required to participate in the study, and with a crossover study design, one half undertook the ELASTIC training first and the other half undertook the ASYM CAM first. One subject was excluded from the experiment due to incomplete data. All participants provided their informed consent following explanation of the possible risks and discomfort and subsequently completed a Medical Screening Questionnaire. None of the participants had a history of taking medications and there were no reports of musculoskeletal injuries or metabolic disease. All subjects refrained from vigorous physical activity during their involvement in the study though they were allowed to continue their low intensity physical activities such as jogging or swimming.

Procedures

The experimental protocol consisted of a counterbalance cross-over design where all subjects completed two modalities of exercise with a 3-wk "wash-out" period between experiments (Figure 1). The participants undertook 5 sets of 10 repetition maximum (RM) with ELASTIC and ASYM CAM exercises. Average external force and electromyographic muscle activation (EMG) were measured and blood samples were obtained before, immediately post (IP), 15 min, 30 min, and 60 min after termination of either the 10 RM ELASTIC or ASYM CAM exercise testing session.

Figure 1. The Experimental Design of the Study. ? = preliminary testing session; ? = performance test (MVC, submaximal isometric) + EMG, blood sampling for T, GH and [LA] before, immediately post, 15, 30, and 60 min following the dynamic sets; ? = one set of 10RM knee extension + EMG.

Basic anthropometric measurements such as height and body mass for each subject were undertaken at the outset of the initial testing session. To ensure the positioning of the subject was the same for the ELASTIC test and ASYM CAM test, a Nautilus machine knee extension chair (Nautilus, Vancouver, WA) was also used for the ELASTIC exercise test session. The resting unstretched length of elastic material (Hygienic Corporation, Akron, OH) was determined for each subject by measuring the distance from the origin of the elastic device (base of the Nautilus machine chair) to the axis (a custom made ankle cuff). In addition, 30% of resting length of elastic device was reduced to provide additional tensile force throughout the entire ROM, particularly at the beginning of the concentric phase (12).

Each experiment had 3 phases. The pre-exercise phase commenced at 8:00 a.m. with inserting a flexible indwelling catheter into the antecubital vein to collect the baseline blood samples from each subject after an 8-h fast. An exercise “warm-up” was performed, which included 5-min of cycling on a stationary cycle ergometer at a self-selected cadence. Following the “warm-up” period, a 2-D electrogoniometer (Noraxon, Scottsdale, Arizona, USA) was strapped on the lateral side of the knee and a pair of pre-gelled surface electrodes (Meditrace, Canada) were located parallel to the direction of the muscle fibers (20 mm interelectrode distance) on the skin overlying the vastus lateralis (VL), vastus medialis (VM), and rectus femoris (RF) of the dominant leg using the protocol outlined by SENIAM (11). The ground electrode was placed on the patella bone. The location of the electrodes was carefully marked on the skin to ensure the same position of the electrodes for the next test session.

The baseline measurement of maximal knee extension force was assessed using maximal voluntary isometric contractions (MVIC) based on the method reported by Arendt-Nielsen and Mills (3). The lever arm of the isokinetic dynamometer (Biodex USA) was equipped with a force transducer (Noraxon, Scottsdale, Arizona, USA). Three trials of 5 sec unilateral MVIC were completed with 2 min rest intervals to prevent fatigue. In addition, 5-sec submaximal isometric contractions were undertaken at 50% of the pre-exercise MVIC load to record the EMG at a constant level of external force.

The EMG signals were recorded with a sample rate of 1000 Hz using an eight channel TeleMyo™ 2400T G2 (Noraxon, Scottsdale, Arizona, USA). The signals were passed through built-in preamplifier leads (Input impedance of 500 M? common mode rejection ratio of 130 dB). A receiver unit collected the telemetry signals, filtered (10 Hz to 500 Hz) and saved the data on a computer. The Myoresearch-XP software (Noraxon, Scottsdale, Arizona, USA) was used to calculate mean amplitude and median frequency of EMG signals and to synchronize the data of the electrogoniometer, force cell, and EMG.

Subjects completed the second phase of the experiment, which was comprised of 5 sets of 10 RM (ELASTIC or ASYM CAM) knee extension throughout the assigned range of motion (80º to 180º of knee extension) with a 90-sec rest period between sets. The lever arm of the ASYM CAM (Nautilus™) machine and the insertion of Elastic (the point which elastic tubing was attached to the ankle cuff) were equipped with the force transducer to measure the magnitude of applied force while performing 5 sets of knee extension exercises. The subject’s body was secured in the ASYM CAM machine via hip and shoulder straps, along with a leg strap located around both thighs. The axis of rotation of the knee during Elastic exercise was similar as the axis of rotation, which was used for the ASYM CAM machine exercise. Each participant`s seat was adjusted to align the axis of rotation of the knee with the spot that was marked on the ASYM CAM machine by the manufacturer as the axis of rotation of knee.

During each mode of exercise the external load was either added or removed so that the subject was able to just complete 10 RM with extreme effort (30). This goal for Elastic was achieved by examining different combinations of elastic tubing that were color-coded according to extensibility and resistance to meet the actual number of repetitions. The 10 RM protocol was selected for this study because it is commonly used for inducing hypertrophy and strength development (18,19). All repetitions were completed based on the rhythm of a metronome at the cadence of 2 sec per repetition. Based on

Linnamo et al. (16), the average of the 2nd, 3rd, and 4th repetitions of the first set, and the average of the 4th, 5th, and 6th repetitions of the 2nd, 3rd, and 4th sets and the average of the 7th, 8th and 9th repetitions of the fifth sets were used for computing the magnitude of external force and electromyographic parameters.

During the third phase (recovery), which was identical to the pretest phase, the MVC was determined along with a repeat of the submaximal isometric contractions, and blood samples were collected immediately post 15, 30, and 60 min following the dynamic sets outlined in the second phase. Blood samples were analyzed for [GH], [T] and [LA]. The blood samples were stored in vacutainers and centrifuged for 10 min at 3000 rpm. Serum plasma was stored at –20° C until assayed. [GH] and [T] were determined using a sensitive radioimmunoassay (RIA) and reagent kit from Diagnostic Products Corporation (Los Angeles, CA). The blood samples were analyzed for lactate using an enzymatic colorimetric method (Sigma Chemical, St. Louis, MO).

Statistical Analyses

Statistical analyses were computed using SPSS software (Version 15.0, SPSS, Inc, Chicago, IL). A two way repeated measure ANOVA (2 × 5) was used to identify the effect of training mode (ELASTIC and ASYM CAM) and the time course of testing (before × IP × 15 min × 30 min × 60 min) on the EMG, applied force and blood parameters. If significant results were obtained from main effects of ANOVA, a series of pair sample t-tests were used to compare identical time course of intervals between ELASTIC and ASYM CAM. Significance was defined as $P<0.05$. Test–retest reliability was evaluated by intraclass correlation coefficient (ICC).

RESULTS

The ICC for force production for ASYM CAM and ELASTIC during the 10-RM dynamic trials was 0.93 and 0.85, respectively.

Inter-Training Modes Comparison

The average of applied forces during 5 sets of ASYM CAM was significantly higher than ELASTIC (362 ± 34.2 N vs. 266.7 ± 44.6 N, F (1,8) = 27.20, P=0.00). However, the main effects for mean amplitude (F (1,8) = 0.68, P=0.43) and median frequency (F (1,8) = 0.05, P=0.82) of EMG signals during dynamic contractions showed no significant difference between the two modes of training (Table 1). In addition, after completion of 5 sets of dynamic contractions, the magnitude of applied force during the MVC test (F (1,8) = 0.31, P=0.59), mean EMG amplitude of the MVC (F (1,8) = 0.004, P=0.95), median frequency (F (1,8) = 0.95, P=0.35) and mean amplitude (F (1,8) = 0.067, P= 0.80) of the submaximal isometric contraction tests did not show any significant difference between the two modes of training (Table 2). The data presented in Table 2 also did not show any significant difference between the two modes of exercise for [GH] (F (1,8) = 0.002, P=0.96), [T] (F (1,8) = 0.10, P=0.75) and [LA] (F (1,8) = 0.42, P=0.53).

Intra-Training Mode Changes

The results addressing the changes in force production and EMG parameters following ELASTIC and ASYM CAM are presented in Table 2. Analysis of variance demonstrated that neither types of training caused any significant changes in force (F (4,32) = 1.70, P=0.17) and EMG amplitude (F (4,32) = 1.19, P=0.33) of the MVC and EMG median frequency (F (4,32) = 1.80, P=0.15) of the submaximal isometric contraction test. However, the submaximal isometric test demonstrated statistically greater EMG mean amplitude in IP, 15, 30 and 60 min after both ELASTIC and ASYM CAM exercises (Table 2, F (4,32) = 20.75, P=0.00).

Table 1. The EMG Measures during 5 Sets of Dynamic Exercises.

Variable	Groups	1st set	2nd set	3rd set	4th set	5th set
Average Force (N)	**ASYM** **ELASTIC**	341.6 ± (53.6)† 268.4 ± (81.6) (P = 0.00)	363.6 ± (48.9)† 292.7 ± (69.9) (P = 0.00)	368.2 ± (27.8)† 279.9 ± (56.4) (P = 0.00)	371.0 ± (34.6)† 262.1 ± (29.6) (P = 0.00)	365.6 ± (44.9)† 230.6 ± (28.3) (P = 0.00)
MA (µV)	**ASYM** **ELASTIC**	86.2 ± (21.3) 79.5 ± (15.9) (P = 0.256)	89.6 ± (15.6) 86.6 ± (13.8) (P = 0.802)	92.3 ± (21.5) 82.7 ± (15.1) (P = 0.768)	95.2 ± (39.1) 90.2 ± (21.3) (P = 0.914)	98.3 ± (21.4) 96.9 ± (22.6) (P = 0.777)
MDF (Hz)	**ASYM** **ELASTIC**	60.2 ± (9.6) 61.8 ± (7.4) (P = 0.50)	60.6 ± (9.3) 61.1 ± (8.9) (P = 0.925)	59.5 ± (9.5) 59.6 ± (7.2) (P = 0.574)	59.8 ± (9.1) 57.7 ± (7.6) (P = 0.826)	57.5 ± (9.3) 53.3 ± (6.9) (P = 0.717)

Note: Mean (±SD) of Average of Applied Force (N), Mean Amplitude (MA, µV) and Median Frequency (MDF, Hz) during performing 5 sets of dynamic exercises. The precise P values from comparison of the two modes of training are presented for each variable in various intervals. † = ASYM CAM demonstrated significantly greater value than ELASTIC. ASYM = ASYM CAM device; ELASTIC = Elastic Resistance. Each EMG value includes the average of three muscles analyzed (Vastus Medialis, Vastus Lateralis, and Rectus Femoris).

Table 2. The Magnitude of Maximal Force and the EMG Measures within MVC and Submaximal Isometric Tests.

Variables	Groups	Before	IP	15-min	30-min	60-min
Average force MVC (N)	**ASYM** **ELASTIC**	951.78 ± (195.4) 1004.05 ± (193.0) (P=0.623)	778.67 ± (109.02) 828.00 ± (224.9) (P=0.602)	864.81 ± (178.5) 803.63 ± (193.4) (P=0.452)	888.95 ± (151.4) 813.73 ± (152.3) (P=0.314)	893.26 ± (202.9) 856.19 ± (332.3) (P=0.878)
MA (MVC, µv)	**ASYM** **ELASTIC**	94.5 ± (3.96) 97.1 ± (2.4) (P=0.355)	95.6 ± (3.62) 94.4 ± (2.9) (P=0.551)	94.2 ± (2.7) 93.2 ± (2.2) (P=0.203)	95.6 ± (4.6) 94.0 ± (4.3) (P=0.442)	94.5 ± (4.7) 95.8 ± (3.5) (P=0.893)
MA (SMIT, µv)	**ASYM** **ELASTIC**	56.4 ± (15.1) 53.9 ± (26.4) (P=0.231)	77.8 ± (18.1)‡ 79.8 ± (28.6)‡ (P=0.346)	106.0 ± (23.9)‡ 104.4 ± (19.1)‡ (P=0.916)	89.0 ± (28.1)‡ 95.0 ± (21.3)‡ (P=0.737)	90.5 ± (23.9)‡ 93.1 ± (22.3)‡ (P=0.756)
MDF (SMIT, Hz)	**ASYM** **ELASTIC**	53.5 ± (9.1) 55.9 ± (7.8) (P=0.973)	57.0 ± (10.6) 53.8 ± (8.0) (P=0.460)	58.1 ± (9.7) 54.7 ± (5.9) (P=0.420)	58.6 ± (8.5) 56.7 ± (6.7) (P=0.360)	55.5 ± (8.5) 54.1 ± (3.7) (P=0.225)
GH (mlU/L)	**ASYM** **ELASTIC**	0.14 ± (0.03) 0.28 ± (0.13) (P=0.156)	1.65 ± (0.44)‡ 1.52 ± (0.46)‡ (P=0.731)	2.91 ± (0.90)‡ 3.82 ± (1.52)‡ (P=0.395)	3.56 ± (1.72)‡ 3.52 ± (1.93)‡ (P=0.971)	2.66 ± (1.43)‡ 1.88 ± (0.66)‡ (P=0.408)
Testosterone (nmol·L^{-1})	**ASYM** **ELASTIC**	22.55 ± (2.8) 21.09 ± (3.9) (P=0.456)	20.97 + (2.3) 20.19 ± (4.2) (P=0.684)	20.12 ± (1.7) 20.34 ± (4.2) (P=0.907)	18.7 ± (2.5) 18.5 ± (4.7) (P=0.917)	16.24 ± (2.1) * 16.66 ± (4.6) (P=0.840)
LACTATE (mmol·L^{-1})	**ASYM** **ELASTIC**	2.08 ± (0.55) 1.97 ± (0.41) (P=0.705)	6.83 ± (2.02) ‡ 7.78 ± (1.05) ‡ (P=0.290)	7.08 ± (3.01) ‡ 6.34 ± (2.06) ‡ (P=0.601)	6.30 ± (1.81) ‡ 5.73 ± (2.14) ‡ (P=0.597)	4.64 ± (2.19) 3.40 ± (1.13) (P=0.207)

Note: Mean (±SD) average of MVC (N), Mean Amplitude (MA, µV) and Median Frequency (MDF, Hz) within performing MVC (Maximal Voluntary Contraction) and SMIT (submaximal Isometric Test at 50% of MVC) tests. The precise *P* values from comparison of the two modes of training are presented for each variable in various intervals. Each EMG value includes the average of three muscles analyzed (Vastus Medialis, Vastus Lateralis, and Rectus Femoris). ASYM = ASYM CAM device; ELASTIC = Elastic Resistance. ‡ = significantly higher than pretest value. * = significantly smaller than pretest value.

The results addressing the changes in concentration of blood hormones are presented in Table 2. Serum [T] decreased significantly 60 min after ASYM CAM (F (4,32) = 19.19, P=0.00), while there was no significant change in serum [T] following ELASTIC. The [GH] however showed a significant increase throughout the recovery period after both ASYM CAM and ELASTIC (Table 2, F (4,32) = 43.85, P=0.00). The concentration of blood [LA] also significantly increased for both modes of exercise IP and remained high until 30 min after termination of the dynamic contractions (F (4,32) = 62.65, P=0.00).

DISCUSSION

The present study was designed to address the question of “whether using ELASTIC device can provide an equal magnitude of external force and result in similar acute neuromuscular and anabolic hormonal responses as ASYM CAM?” The importance of resolving this debate is underlined by the fact that elastic resistance has long been accepted as an affordable, portable and versatile training device compared with other resistance training apparatus (27). The results in the present study indicated that ELASTIC did not provide similar external force as ASYM CAM. Interestingly however, similar acute neuromuscular and anabolic hormonal responses were observed with ELASTIC compared with ASYM CAM exercises.

Hughes et al. (15) reported the resistance of an elastic device (Hygienic Corporation, Akron, Ohio) ranging from of 3.3 N (yellow) to 80.1 N (silver) when elastic materials were at 18% (minimum) and 250% (maximum) of deformation from resting length (unstretched), respectively. These data indicate that one unit of the commercially produced elastic tubing cannot possibly provide adequate external force necessary to accomplish high exercise resistance training. Accordingly, in the present study to achieve adequate tensile force for performing 10 RM, 30% of the resting unstretched length of an elastic device was reduced and various elastic color codes were used in parallel to meet actual 10 RM.

The results however indicated that, despite implementing a similar exercise intensity (10-RM) and observing equal EMG amplitude and frequency discharge between ASYM CAM and ELASTIC (Table 1), a significantly greater load (26.31%) was employed during ASYM CAM compared with ELASTIC (Figure 2). The reason underlying this discrepancy is not clear. However, a potential explanation possibly centers on the need for more control over the movement during ELASTIC. Since the ankle had a greater degree of freedom during the ELASTIC knee extension (compared with restricted-unidirectional ASYM CAM lever arm), perhaps greater muscle activation was also required to keep the lower leg motion aligned in the sagittal plane. This proposition is consistent with the findings of Richards and Dawson (29), who observed a significant alteration in rate of motor unit recruitment due to performing exercises in a multiaxial direction. Although Behm et al. (5) reported a decrease in muscle activation with a high degree of instability, a moderate degree of instability resulted in impaired force output although with no change in muscle activation when compared to a stable resistance exercise. Related to the present experiment, a multiaxial elastic resistance exercise would be considered more unstable than a uniaxial ASYM CAM machine lever and, therefore, the lack of difference in muscle activation could be partially attributed to the need for greater stabilization functions for the muscles with ELASTIC (3). It seems a reasonable propose that such a difference in external force (26.31%) between ELASTIC and ASYM CAM would be reflected in differences in the acute neural and anabolic hormonal responses.

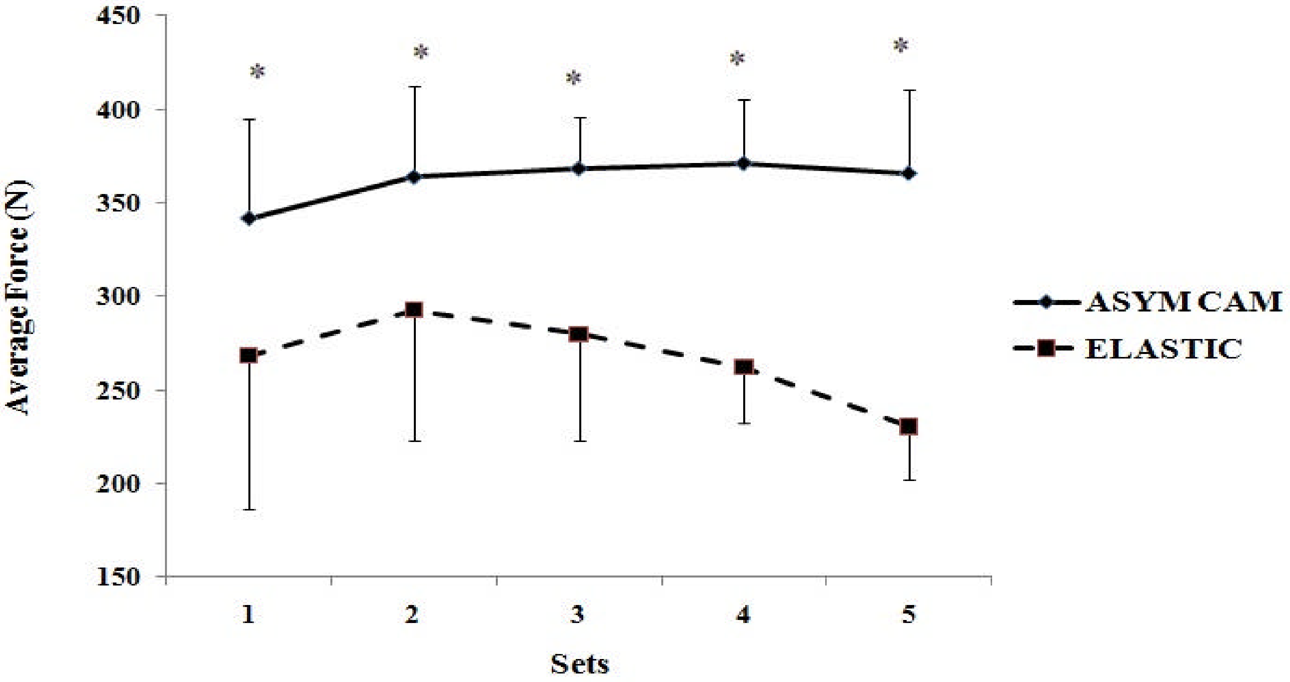

Figure 2. Average of External Force Employed during Dynamic Exercises (ELASTIC and ASYM CAM). * = significantly greater magnitude of external force lifted during NM in compared with ER (P<0.001).

Neuromuscular Responses

The maximal voluntary contractile force (MVC) and corresponding average muscle activation did not decrease to any significant extent after both modes of dynamic exercise (Table 2). Bosco et al. (7) have attributed such phenomenon to increased activation of the tonic motor units (slow-twitch, ST), which possess a lower action potential. Since fast-twitch fibers (FT) are more susceptible to muscle fatigue (16), Bosco et al. (7) suggested a tendency towards recruitment of ST muscle fibers. In addition, previous investigations demonstrated an increase in effectiveness of the afferent volley, increased liberation of transmitters from Ia terminals and a decrease in the presynaptic inhibition of the Ia afferents following a high intensity volitional muscle activations. This phenomenon, known as neural potentiation, has been shown to offer positive feedback onto the motoneurons to contribute more to the neural drive as the muscle is activated during maximal resistance exercise (31).

However, the mean amplitude of the submaximal isometric test demonstrated a significant increase after both ELASTIC and ASYM CAM training (Table 2). The data are in accordance with the findings in previous investigations (6,10). In fact, since the submaximal isometric test was performed against 50% of MVC, rotation of motor units and inclusion of fresh motor units could have resulted in achieving higher mean amplitude. In other words, given that during the pre-test MVC, there is an attempt to activate all motor units, recruitment of new motor units immediately after the dynamic exercise is unlikely. Based on Arendt-Nielsen and Mills (3), recruitment of fresh motor units above 60% of maximal force is improbable.

The median frequency of EMG signals also exhibited a reduction during both the dynamic (Table 1) and submaximal isometric exercise bouts (Table 2). Numerous research studies have shown a reduction in the frequency component of EMG signals after fatiguing dynamic exercise (16). This has been attributed to the accumulation of metabolic by-products such as lactate with the implication that this is an indicator of peripheral muscle fatigue. In support of this thinking, the present data demonstrated a significant increase in the concentration of blood lactate following both modes of exercise (Table 2).

Endocrine responses

The rate of hormonal discharge has been shown to be sensitive to the relative stress of exercise (8,22,28). Previous research studies reported a positive relationship between total amount of work (load × repetitions) and the magnitude of increase in anabolic hormonal levels (14,17). However, the present data surprisingly exhibited equal concentration of serum [T] and [GH], despite the fact that considerably less total external work was completed during ELASTIC compared with ASYM CAM (load × 10 reps × 5 sets). The underlying mechanism for these findings is not known. However, perhaps the most plausible explanation was presented by Richards and Dawson (29). They found greater adaptive responses following exercises with multiaxial loading patterns. On this basis, they speculated on the presence of an alternative signaling pathway which could be responsible for achieving higher muscle adaptation. In line with this assumption, Durand et al. (8) proposed the inclusion of proprioceptive feedback pathway (Golgi tendon organs and muscle spindles) as one of the major modulators of the hormonal response. Thus, it could be speculated that a higher degree of freedom of the leg segment of the lower limb during ELASTIC training stimulated a proprioceptive pathway and/or changed the motor unit activation pattern that then resulted in similar discharge of [T] and [GH] when compared with ASYM CAM. Overall, the data support the conclusion of Bosco et al. (7) that the intensity should be defined as the rate of work performed rather than the classical view, which defines the intensity as the magnitude of load employed.

The time course of hormonal secretion also exhibited a trend towards a decrease in serum [T] and an increase in [GH] following both modes of dynamic exercises. The increased serum [GH] was in accordance with the findings in the previous studies, which have suggested a high volume of training (repetitions × sets) combined with short rest periods between sets as the main cause of GH secretion (28). Likewise, Linnamo and colleague (16) explained that the decrease in blood pH following high intensity and moderate volume exercises (5 sets × 10-RM) was one of the underlying mechanisms for increasing GH. With the decrease in pH a significant increase in [LA] following both modes of training was observed.

The level of serum [T] decreased systematically during resting period for both modes of exercise. This response could be due to reducing production or increasing utilization of testosterone. Several researchers have attributed the decrement in serum [T] to an increased role in remodeling muscle tissue following intensive training as well as increases in the blood concentration of other hormones such as sex hormone-binding globulin [SHBG] (10). However, Bosco et al. (7) suggested a negative relationship between changes in concentration of serum [T] and the amplitude of electromyogram signals. In this proposition, the dissipation of testosterone has been suggested to compensate for muscle fatigue via enhanced the neuromuscular efficiency of FT muscle fibers. Bosco et al. (7) speculate that perhaps serum testosterone is partially consumed to compensate for disturbances in excitation-contraction coupling through a Ca²? handling mechanism.

The limitation of the current study is the possibility of differences in torque-angle relationship between ELASTIC versus ASYM CAM, due to differences in line of external resistance that might have affected the pattern and rate of muscle activation. In this regard, in order to minimize biomechanical variables affecting the line of external resistance, we used similar axis of rotation for the knee extension with the two modes of exercise. More investigations are required to study torque-angle relationship between ELASTIC and ASYM CAM.

CONCLUSIONS

Contrary to the clinical application of ELASTIC for rehabilitation purposes, the findings of the present study suggest an ELASTIC device (30% reduced in initial length and supported with additional elastic units in parallel) is an acceptable exercise device for high-intensity resistance training. Furthermore, based on the observation of similar neuromuscular and anabolic hormonal responses for ELASTIC and ASYM CAM, it can be anticipated that similar longer term training adaptations (muscle strength and muscle hypertrophy) could result from employing either training device. However, an unusual finding regarding the ELASTIC device compared with the ASYM CAM was that less force was required to elicit an exercise intensity of 10 RM. This observation requires further research to determine the underlying mechanism(s) contributing to this apparent difference between the ELASTIC and ASYM CAM devices. Notwithstanding the need for further research we consider the two devices to be capable of eliciting similar training adaptations. In some certain sports we need a combination of strength and proprioceptive control rather than absolute muscle strength. The findings indicate that due to employing less external force and to requiring more control over movement Elastic could be more advantageous than ASYM CAM.

Address for correspondence: Aboodarda SJ, (PhD), Sports Center, University of Malaya, Kuala Lumpur, Malaysia, 50603; Email. saiedjalal1980@gmail.com

REFERENCES

1. Anderson CE, Sforzo GA, Sigg JA. The effects of combining elastic and free weight resistance on strength and power in athletes. ***J Str Cond Res.*** 2008;22(2):567-574.

2. Anderson K, Behm DG. Maintenance of EMG activity and loss of force output with instability. ***J Str Cond Res.*** 2004;18(3):637-640.

3. Arendt-Nielsen L, Mills K. Muscle fibre conduction velocity, mean power frequency, mean EMG voltage and force during submaximal fatiguing contractions of human quadriceps. ***Eur J Appl Physiol.*** 1998;58(1-2):20-25.

4. Behm, DG. An analysis of intermediate speed exercises for velocity specific strength gains. ***J Appl Sport Sci Res.*** 1991;5:1-5.

5. Behm DG, Anderson K, Curnew RS. Muscle force and activation under stable and unstable conditions. ***J Str Cond Res.*** 2002;16(3):416-422.

6. Bigland-Ritchie B, Furbush F, Woods J. Fatigue of intermittent submaximal voluntary contractions: central and peripheral factors. ***J Appl Physiol.*** 1986;61(2):421-429.

7. Bosco C, Colli R, Bonomi R, Von Duvillard SP, Viru A. Monitoring strength training: neuromuscular and hormonal profile. ***Med Sci Sports Exerc.*** 2000;32(1):202-208.

8. Durand RJ, Castracane VD, Hollander DB, Tryniecki JL, Bamman MM, O'Neal S, et al. Hormonal responses from concentric and eccentric muscle contractions. ***Med Sci Sports Exerc.*** 2003;35(6):937-943.

9. Ebben WE, Jensen RL. Electromyographic and kinetic analysis of traditional, chain, and elastic band squats. ***J Str Cond Res.*** 2002,16(4):547-550.

10. Häkkinen K, Pakarinen A, Alén M, Kauhanen H, Komi PV. Neuromuscular and hormonal responses in elite athletes to two successive strength training sessions in one day. ***Eur J Appl Physiol.*** 1988;57:133-139.

11. Hermens H, Feriks B, Merletti R, Stegeman D, Blok J, Rau G, et al. ***European Recommendations for Surface Electromyography.*** *SENIAM*. 1999.

12. Hodges GN. ***The Effect of Movement Strategy and Elastic Starting Strain on Shoulder Resultant Joint Moment During Elastic Resistance Exercise.*** Master Thesis. University of Manitoba, Canada. 2006.

13. Hopkins WG. ***Estimating Sample Size for Magnitude-Based Inferences.*** Sport science 2006*;*10,63-70. http://sportsci.org/resource/stats/ssdetermine.html.

14. Hortobagyi T, Hill JP, Houmard JA, Fraser DD, Lambert NJ, Israel RG. Adaptive responses to muscle lengthening and shortening in humans. ***J Appl Physiol.*** 1996;80(3):765-772.

15. Hughes CJ, Hurd K, Jones A, Sprigle S. Resistance properties of Thera-Band® tubing during shoulder abduction exercise. ***J Orthop Sports Phys Ther****.* 1999*;*29:413-420.

16. Linnamo V, Newton RU, Häkkinen K, Komi PV, Davie A, McGuigan M, et al. Neuromuscular responses to explosive and heavy resistance loading. ***J Electromy Kines****.* 2000;10:417-424.

17. Linnamo V, Pakarinen A, Komi P, Kraemer W, Häkkinen K. Acute hormonal responses to submaximal and maximal heavy resistance and explosive exercises in men and women. ***J Str Cond Res.*** 2005;19(3):566-571.

18. Kraemer W, Gordon S, Fleck S, Marchitelli L, Mello R, Dziados J, et al. Endogenous anabolic hormonal and growth factor responses to heavy resistance exercise in males and females. ***Int J Sports Med.*** 1991;12(2):228-235.

19. Kraemer WJ, Hakkinen K, Newton RU., McCormick M., Nindl, BC., Volek, JS., et al. Acute hormonal responses to heavy resistance exercise in young and older men. ***Eur J Appl Physiol.*** 1998;77:206-211.

20. Manning RJ, Graves JE, Carpenter DM, Leggett SH, Pollock ML. Constant vs variable resistance knee extension training. ***Med Sci Sports Exerc.*** 1990;22(3):397-401.

21. Matheson JW, Kernozek TW, Fater DC, Davies GJ. Electromyographic activity and applied load during seated quadriceps exercises. ***Med Sci Sports Exerc.*** 2001;33(10):1713-1725.

22. McCaulley G, McBride J, Cormie P, Hudson M, Nuzzo J, Quindry J, et al. Acute hormonal and neuromuscular responses to hypertrophy, strength and power type resistance exercise. ***Eur J Appl Physiol.*** 2009;105(5):695-670.

23. Morrissey MC, Harman EA, Johnson MJ. Resistance training modes: Specificity and effectiveness. ***Med Sci Sports Exerc.*** 1995;27(5):648-660.

24. Muhitch L. ***Electromyographic Investigation of Free Weights and Thera-Band.*** State Uiniversity of New York College at Cortlad, New York. 2006.

25. Newsam C, Leese C, Fernandez-Silva J. Intratester reliability for determining an 8-repetition maximum for 3 shoulder exercises using elastic bands. ***J Sports Rehab.*** 2005;14(1):35-47.

26. Page P, Lamberth J, Abadie B, Boling R, Collins R. Posterior rotator cuff strengthening using theraband® in a functional diagonal pattern in collegiate baseball pitchers. ***J Athl Train****.* 1993;28(4):346-354.

27. Page P, Ellenbecker T. ***The Scientific and Clinical Application of Elastic Resistance***. Champaign, IL: Human Kinetics. 2003.

28. Raastad T, Bjøro T, Hallén J. Hormonal responses to high- and moderate-intensity strength exercise. ***Eur J Appl Physiol.*** 2000;82(1-2):121-128.

29. Richards JA, Dawson TA. Optimizing exercise outcomes: The efficacy of resistance training using conventional vs. novel movement arcs. ***J Str Cond Res.*** 2009;23:2015-2024.

30. Treiber FA, Lot 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. ***American J Sports Med.*** 1998;26(4):510-515.

31. Trimble MH, Scott SH Postexercise potentiation of the H-reflex in humans. ***Med Sci Sports Exerc.*** 1998;30(6):933-941.

32. Vincent W.J. ***Statistics in Kinesiology***. 3rd Edition, Champaign, IL: Human Kinetics. 2005;147-151.

Disclaimer