Resultant muscle torque and electromyographic activity during high intensity elastic resistance and free weight exercises

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Introduction

Resistance training employing free weights or specially designed machines with pulley weights or hydraulics is a widely practised form of physical activity for stimulating skeletal muscle hypertrophy and strength (Baechle & Earle, 2000; Fleck & Kraemer, 2004). This equipment is both cumbersome and costly. Among various strength training modalities, Elastic Resistance (ER) is known as a safe and affordable mode of exercise which can be adapted to meet the needs of diverse populations (Page & Ellenbecker, 2003). Numerous research studies have recommended ER for regeneration of muscle strength in rehabilitation settings (Hostler et al., 2001; Kluemper, Uhl, & Hazelrigg, 2006; Schulthies, Ricard, Alexander, & Myrer, 1998). However, tensile force of elastic material offers an ascending external resistance curve which has been acknowledged by sport scientists (Anderson, Sforzo, & Sigg, 2008; Wallace, Winchester, & McGuigan, 2006).

The benefits of this ascending elastic force can be substantiated in exercises such as biceps curl and shoulder abduction. In this category of exercises, the torque generating capacity of prime movers is greater at the beginning of the concentric phase (Harman, 2000). However when using a conventional constant external resistance (e.g. free weights), muscles accelerate the force and create a moment of torque which shifts to the late concentric phase and reduces muscle stimulation (Hodges, 2006). In contrast to using free weights, the increment of provided external force by elastic material (due to further elongation) requires the active muscle to develop tension over the entire concentric phase (Hodges, 2006). While providing an ascending resistance curve, an elastic device has been shown to provide a bell-shaped torque curve which is compatible with torque generating capability in many human movements including the biceps curl (Hughes, Hurd, Jones, & Sprigle, 1999; Simoneau, Bereda, Sobush, & Starsky, 2001).

Although these findings validate using ER for this category of exercises, the practical difficulty of providing a high elastic resistance, particularly at the beginning of the concentric phase, has limited the use of ER in high intensity training protocols (Ebben & Jensen, 2002). Accordingly, two strategies are recommended for increasing resistance of the elastic device; 1) reducing the initial length of the elastic material (Treiber, Lott, Duncan, Slavens, & Davis, 1998); and 2) using additional elastic bands in parallel to the current elastic device (Page et al., 1993). We hypothesised that by applying these two strategies, significantly higher muscle activation and muscle torque production could be achieved with an ER device compared with conventional free weights when performing high resistance exercises.

This study, was thus undertaken to investigate the electromyographic muscle activity (EMG) and Resultant Muscle Torque (RMT) profile during the performance of an eight repetition maximum (8 RM) biceps curl exercise using free weights and elastic devices.

Methods

Experimental approach to the problem

In this investigation, subjects completed a series of 8-RM biceps curl by three modalities of resistance exercises comprising: (i) free weights-dumbbell (DB), (ii) elastic tubing with initial length (E0) and (iii) elastic tubing with 30% decrement of initial elongation (E30). The level of muscle activation and kinetic and kinematic values such as external force, linear acceleration and range of motion (ROM) were collected and synchronised by data acquisition package Myoresearch-XP (Noraxon, Scottsdale, USA, Master Edition). The first (initial), the fifth (middle) and the eighth (last) repetitions were selected for further analysis. characteristics are presented in Table I. The subjects had no experience of resistance training in the past 12 months and were requested to abstain from any exercises involving arm muscles 48 hours before the main testing session. They had no history of injury or surgery, and were not currently receiving medical treatment.This experimentwas approved by theEthics Committee of the Sport Centre, University Malaya.

Equipment

The neuromuscular activation pattern during 8-RM Biceps curl exercise was measured via electromyography (EMG) of the biceps brachii muscle with a sample rate of 1000 Hz using a 16-bit acquisition mode with an eight-channel TeleMyo$_{TM}$ 2400T G2 EMG system (Noraxon, Scottsdale, Arizona, USA). The EMG signals were passed through inbuilt preamplifier leads with Input impedance_100MV with common mode rejection ratio_80 dB. A receiver unit collected the telemetry signals from the receiver and amplified and filtered (15 Hz to 1000 Hz) the signals. The range of motion of the dominant elbow was monitored using a 2-D electrogoniometer (Noraxon, Scottsdale, Arizona, USA). A 2-D accelerometer (10g; Noraxon, Scottsdale, Arizona, USA) was placed over the lateral side of the wrist to measure linear acceleration of the forearm and hand in the X and Y axis. The external resistance of the elastic device was measured using a force transducer (Noraxon, Scottsdale, Arizona, USA) placed in series with the elastic device. Data were collected and synchronised using the data acquisition package Myoresearch-XP, Master Edition (Noraxon, Scottsdale, Arizona, USA). Before testing, sensors were calibrated based on the recommended instructions of the manufacturer. The elastic tubing (yellow, red, green, blue, black and silver; Hygienic Corporation, Akron, OH) and standard dumbbell (MuJo Products) were used as training apparatuses.

Experimental protocol

Physical characteristics of subjects. All subjects attended a preliminary testing session where anthropometric measurements including height, body mass and the length of the subject's dominant forearm (distance from the elbow joint to the wrist joint) and forearm plus hand (tip of middle finger of the hand to the elbow) were undertaken and recorded from the subjects. The percentage of body fat was assessed using a four-skinfold site (thigh, triceps, suprailiac, and abdomen) equation (Jackson & Pollock, 1978).

Elastic resistance device. The resting un-stretched length of E0 was determined for each subject by measuring the distance from the origin (ground) to the axis (distal end of the load cell attached to the handle of the elastic device held by the subject standing in anatomical position). The resting length of E30 was therefore calculated as the length of E0 _ 30%. The subjects were then familiarised with the testing procedure by practising maximal voluntary isometric contractions (MVICs) and dynamic exercises. The resistance required for 8 RM was assessed by the three types of resistance training devices (dumbbell, the elastic resistance device at E0, and E0 length _ 30%) prior to the day of testing. The 8 RMwas selected for the current study because it has been widely recommended for training protocols designed to develop muscle strength (Fry, 2004; Kraemer et al., 2002). The external load in each mode of training was either added or removed to meet the load required for an actual 8 RM. To achieve this, different combinations of elastic colour codes were examined for E0 and E30 (each colour denotes specific resistance; for a review see Simoneau et al., 2001). Accordingly, the colour codes of E0 and E30 were dictated by the requirement to successfully complete 8 RM and therefore differed between the two modes of training. The actual 8 RM was achieved within the first or second trial.

To avoid inaccurate location of electrodes from day to day testing, all data were collected within one testing session. The test protocol began with a 5-min warm up consisting of 30s to 60s biceps curl exercise with minimal resistance followed by stretching of the upper limb musculature. Subjects then rested for 5 minutes during which time the electrogoniometer and accelerometer were strapped to the subject’s dominant arm. A pair of surface electrodes (20 mm interelectrode distance) was placed on the centre of the muscle belly in the direction of the underlying muscle fibres as recommended by Hermens et al. (1999). The ground electrode was placed at the acromial process. Before placement of electrodes, the area of skin was shaved, abraded to remove dead skin with sandpaper and cleaned with alcohol to decrease skin resistance.

Prior to the dynamic exercises, subjects performed three MVICs for 5s each at 2-min intervals. Measurements were performed while the subject stood on a test platform (height: 30 cm), holding the handle of a non-extensible strap and the elbow was positioned at 908 (Alway, Grumbt, Stray-Gundersen, & Gonyea, 1992). The MVIC was calculated as the average amplitude over a one second window of the highest rectified EMG signals (automatically selected by Myoresearch-XP). This measure became a reference value (100% EMG) for normalising muscle activation data during dynamic actions (% MVIC).

The subjects then completed 8 RM biceps curl exercises in a randomised order across each of the three training modalities. Ten to 15 minutes resting period was assigned between exercise modes. To control the arm position during dynamic contractions, two laser beams connected to an alarm system limited the ROM (20_1408 of flexion) at each extremity. Therefore, an alarm sounded if the subject's hand extended beyond the laser spectrums.
The cadence of performing the bicep curls was 2s concentric and 2s eccentric which was maintained by the auditory signal of a metronome. One second pause between every repetition was assigned to avoid potential stretch-shortening cycle interference. An attempt at 8 RM was deemed successful if all repetitions were performed in accordance with the pace of the metronome without any compromise in ROM, plus failure to complete 9 RM. Ten subjects were randomly selected to perform the same procedures and protocol 5 days following the test day. The test-retest reliability for the magnitude of external force during performance of 8 RM dynamic trials was 0.89, 0.84 and 0.93 for E30, E0 and DB, respectively.

The data were collected from all eight repetitions with the first (initial), the fifth (middle) and the eighth (last) repetitions selected for further data analysis. Each of the assigned repetitions was partitioned into a concentric and eccentric phase based on the end points determined from the electrogoniometer traces. Each concentric and eccentric phase was divided into three equal segments (3 concentric and 3 eccentric_6 segments per repetition). The Root Mean Square (RMS) of rectified EMG signals was computed for each phase of movement. The average of six segments was used to calculate the value of every repetition. Finally, the obtained values from first, fifth and eighth repetitions were used to calculate the 'total average EMG' (average of 6 segments_3 repetitions) for each exercise modality.

Full text is available at :

http://www.tandfonline.com/doi/abs/10.1080/17461391.2011.586438