

ABSTRACT

One of the critical parameters for achieving adequate muscle stimulation throughout the range of motion has been addressed as the choice of equipment which must be accommodative with the torque generating capability of muscle group activated. Inefficiency of conventional weight training devices, due to providing constant external force (e.g. dumbbell (DB)), in creating maximal muscle stimulation in some segments of joint angle has propounded the idea of using variable external resistance training (VRT) among athletes and recreational lifters. Among various VRT exercises Nautilus Machine (NM) and Elastic Resistance (ER) has gained considerable popularity among athletes. However, to best of our knowledge, there is no documented research which has compared the torque production and muscle activation pattern among conventional free weight, NM and ER training within performing high intensity resistance exercises. The importance of addressing this issue is underlined by the fact that elastic resistance has long been accepted as a cost-effective and portable exercise device compared expensive and cumbersome weight-stock machines and free weights.

The issue was studied throughout three investigations. In the first research, Resultant Muscle Torque (RMT) and electromyographic activation (EMG) pattern were quantified and compared within performing 8 repetitions maximum (8 RM) biceps curl using ER and DB. Sixteen male and female recreationally active subjects completed 8 RM biceps curl by: (i) DB, (ii) elastic tubing with original un-stretched length at the commencement of contraction (E0), and (iii) elastic tubing with 30% decrement of original length (E30) at the commencement of contraction. The magnitude of muscle activation, external force, acceleration as well as range of motion (ROM) were quantified and synchronized by specific software. The first (initial), the 5th (middle) and the 8th (last) repetitions were selected for further data analysis. Each selected repetition was partitioned into a concentric and eccentric phase and then each phase was further divided into 3 equal segments (3 concentric and 3 eccentric). The EMG and RMT data demonstrated a bell-shaped muscle activation and muscle torque production pattern for the three modes of exercise. The E30 resulted in 15.40% and 14.89% higher total EMG as well as 36.85% and 17.71% higher RMT (N.m) than E0 and DB, respectively (all $P < 0.05$). These findings support the contention that an elastic resistance device (E30) has the capacity to provide an appropriate high resistance stimulus to meet the training requirement of elite athletes.

In the second investigation, the same methodology as the first research was used to compare the pattern of EMG activity and torque production between ER and NM while performing 8 RM seated knee extensions. In this study sixteen males and females completed 8 RM seated knee extension by E0, E30 and NM. A series of pair sample *t-tests* among the Total Average force applied during the three modes of training (3 reps \times 6 segments) indicated a trend in which NM > E30 > E0 (all $p < .001$). In the 1st, 5th and 6th segments significantly higher external force was applied during NM and E30 compared with E0 and during NM compared with E30. However, in the 3rd and 4th segment no significant difference was observed between three modes of training (all $p < .05$). These findings supported the contention that developing external recoil of force in ER device by reducing 30% of initial length of elastic material can offer similar neuromuscular activation compared with NM.

The third 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 (LC) following repeated near maximal contractions by ER/NM. In a counterbalance cross-over study, nine male (21.08 ± 6.2 yrs) recreationally active subjects completed 5 sets of 10-RM knee extension exercise by ER and NM with three weeks “wash-out” period between experiments. Blood sampling, maximum voluntary contraction (MVC) and EMG were recorded before, immediately, 15, 30, and 60-min after termination of the exercise bout. The average of applied forces in NM was significantly higher than ER (362 ± 34.2 N vs 266.73 ± 58.56 N) across the 5 sets of dynamic exercises. However, the average force and mean amplitude of MVC as well as the blood concentration of GH, T and LC demonstrated no significant difference between the two types of exercise either in the pretest or during the recovery period (all $p > .05$). Based on the observation of similar neuromuscular and anabolic hormonal responses for ER and NM, it can be anticipated that similar longer term training adaptations (muscle strength and muscle hypertrophy) will result from employing either training device. In conclusion, contrary to the clinical application of ER for rehabilitation purposes, the findings of the three research investigations suggest that the ER device (30% reduced in initial length and supported with additional elastic units in parallel) is an acceptable exercise device for high intensity resistance training.

ABSTRAK

Salah satu daripada parameter kritikal untuk mencapai stimulasi otot yang mencukupi sepanjang julat pergerakan telah dikenalpasti sebagai peralatan pilihan yang akomodatif dengan kebolehan penjana torque oleh otot yang diaktifkan. Kelemahan alatan latihan beban konvensional disebabkan penjana daya eksternal yang konstan (contohnya dumbbell (DB)) dalam menghasilkan stimulasi otot maksimum dalam sebahagian daripada segmen sudut sendi telah mencetuskan idea penggunaan latihan beban eksternal boleh-ubah (*variable external resistance training*) (VRT) di kalangan atlet biasa dan atlet rekreasi. Antara pelbagai eksesais VRT, *Nautilus Machine* (NM) dan *Elastic Resistance* (ER) telah mendapat populariti di kalangan atlet. Namun demikian, setakat pengetahuan kami, tiada lagi penyelidikan didokumentasikan yang membanding penghasilan *torque* dan corak pengaktifan otot antara latihan beban bebas konvensional, NM dan ER semasa melakukan eksesais beintensiti tinggi. Keperluan memberi perhatian kepada isu ini adalah bersandarkan fakta bahawa penggunaan eksesais *elastic resistance* telah lama diterima sebagai kos-efektif dan alatan mudah-alih berbanding dengan alatan latihan beban serta beban bebas yang lebih mahal dan rumit.

Isu-isu ini dikaji dalam tiga siasatan. Dalam siasatan pertama, Hasil Torque Otot (*Resultant Muscle Torque*) (RMT) dan corak aktivasi elektromiografi (*electromyographic activation*) (EMG) telah dikira dan dibandingkan semasa perlakuan 8 repetisi maksimum (8 RM) *biceps curl* menggunakan ER dan DB. Enam belas subjek lelaki dan perempuan aktif secara rekreasi melakukan 8 RM *biceps curl* dengan menggunakan: (i). DB, (ii) tubing elastik dengan keadaan panjang asalan tanpa regangan pada permulaan kontraksi (E0), dan (iii) tubing elastik dalam keadaan regangan 30%, panjang pada permulaan adalah 30% kurang daripada panjang asalan (E30). Magnitud pengaktifan otot, daya eksternal, pecutan serta julat pergerakan (*range of motion*) (ROM) dikuantifikasi serta disinkronisasi dengan perisian pilihan Repitisi pertama (permulaan), ke-lima (pertengahan) dan ke-lapan (terakhir) dipilih untuk penganalisaan lanjut. Setiap repitisi yang terpilih telah diasingkan kepada fasa konsentrik dan esentrik, dan, setiap fasa ini dibahagikan lagi kepada 3 segmen yang beramaan (3 konsentrik dan 3 esentrik). Data EMG dan RMT menunjukkan pengaktifan otot dan corak penghasilan *torque* bentuk-loceng dalam 3 mod eksesais. Keputusan E30 menunjukkan kelebihan 15.4% dan 14.89% dalam jumlah EMG serta kelebihan 36.85% dan 17.71% dalam RMT (N.m) berbanding dengan E0 dan DB, (semuanya $p < 0.05$). Dapatan ini menyokong pendapat bahawa alatan *elastic resistance* (E30)

mempunyai kebolehan menghasilkan rangsangan tinggi yang setara dan cukup untuk memenuhi keperluan latihan atlet elit.

Dalam siasatan kedua, metodologi yang sama seperti siasatan pertama telah digunakan untuk membandingkan corak aktiviti EMG dan penghasilan *torque* antara ER dan NM semasa perlakuan 8 RM ekstensi lutut dalam keadaan duduk (*seated knee extensions*). Dalam siasatan ini, enam belas orang lelaki dan perempuan melakukan 8 RM ekstensi lutut dalam kedudukan duduk menggunakan E0, E30 dan NM. Satu siri ujian sampel *t*-berpasangan (*paired t-test*) pada Jumlah Purata Daya (*Total Average force*) yang dikenakan semasa 3 mod latihan (3 repetisi x 6 segmen) menunjukkan satu trend di mana $NM > E30 > E0$ (semuanya $p < 0.001$). Di dalam segmen-segmen pertama, ke-5 dan ke-6, lebih daya eksternal dikenakan secara signifikan semasa NM dan E30 berbanding dengan E0 dan semasa NM berbanding dengan E30. Namun demikian, dalam segmen ke-3 dan ke-4, tiada perbezaan yang signifikan diperhatikan antara ketiga-tiga mod latihan tersebut (kesemuanya $p < .05$). Dapatan ini menyokong pendapat bahawa penghasilan daya lenting dalam alatan ER dengan mengurangkan 30% daripada panjang asal akan memberikan pengaktifan neuromuskular yang hampir serupa dengan NM.

Siasatan ketiga diolah untuk mengukur dan membandingkan respon akut dalam isyarat EMG dan konsentrasi Hormon Tumbesaran (Growth Hormone), Testosteron (T) dan Laktat (LC) sebaik sahaja selepas melakukan kontraksi ulangan hampir-maksima menggunakan ER/NM. Dalam satu ujian *counterbalance cross-over*, sembilan lelaki (21.08 ± 6.2 tahun) yang aktif secara rekreasi melakukan 5 set 10-RM ekstensi lutut menggunakan ER dan NM dengan 3 minggu jangkamasa *wash-out* antara ujian. Persampelan darah, kontraksi maksimum bawah kawalan (*maximum voluntary contraction*) (MVC) dan EMG direkodkan sebelum, pada penamatan, 15, 30 dan 60-minit selepas tamat eksesai. Purata daya yang dikenakan dalam NM adalah lebih tinggi daripada ER (362 ± 34.2 N lwn 266.73 ± 58.56 N) secara signifikan sepanjang 5 set eksesai dinamik yang dinyatakan. Namun demikian, purata daya dan min amplitud MVC serta paras GH, T dan LC dalam darah tidak menunjukkan sebarang perbezaan yang signifikan antara kedua jenis eksesai tersebut sama ada sebelum eksesai atau semasa tempoh pemulihan (kesemuanya $p > .05$). Berdasarkan pemerhatian yang hampir serupa dalam respon neuromuskular dan hormon anabolik untuk ER dan NM, kami berpendapat bahawa latihan menggunakan kedua-dua alatan akan menghasilkan adaptasi jangka panjang yang hampir serupa (kekuatan dan hipertrofi otot). Secara

kesimpulannya, aplikasi klinikal ER yang lazimnya untuk rehabilitasi sahaja adalah tidak tepat; dapatan daripada ketiga-tiga siasatan ini mencadangkan bahawa alatan ER (diregang 30% daripada panjang asal, dan disokong dengan tambahan unit elastik secara selari) adalah satu alatan ekseesais yang sesuai untuk latihan resistan berintensiti tinggi.

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