CHAPTER I

INTRODUCTION

1.0 Introduction

Resistance exercises have become an inevitable part of training schedule for distinctive applications from clinical purposes to professional athletic aims. Scientific evidence has advocated a range of applications that encompass strength impairment after injury or surgery (Hintermeister *et al.*, 1998), attenuation of risk factors to enhance the overall quality of life for older adults (Mikesky *et al.*, 1994), promoting beauty and general physical fitness and health (Duncan *et al.*, 1998), preventing musculoskeletal injuries (Myers *et al.*, 2005) and developing various components of physical performance for professional athletes (Treiber *et al.*, 1998). However, it has been emphasized that for developing muscle strength and performance, the act of resistance training itself does not ensure optimal results (Kraemer and Ratamess, 2004). Rather, it is the systemic structuring of training stimuli that ultimately determines the outcomes associated with resistance training. Exercise intensity, training volume, duration of resting period, frequency of training and type of muscle contraction are the elements of a training protocol which must be arranged in an appropriate way to achieve particular purposes.

One of the critical parameters for achieving maximal muscle stimulation throughout the range of motion (ROM) has been addressed as the choice of equipment which must be specific to the muscle group activated (Cabell and Zebas, 1999; Kraemer, Duncan, and Volek, 1998; Morrissey, Harman, and Johnson, 1995). It is well established that the torque generating capability of muscle is dissimilar within various positions of ROM (Baechle and Earle, 2000; Fleck and Kraemer, 2004; Manning *et al.*, 1990; Page and Ellenbecker, 2003). Therefore, the provided external resistance in an ideal training device must be accommodative to be able to take advantage of the muscle length-tension relationship.

The accommodative external resistance is provided using isokinetic dynamometers (e.g. Cybex and Biodex). However, this apparatus is most often used in the rehabilitation setting because it is very costly and not widely available. Accordingly, athletes and coaches have been attracted toward utilizing Variable Resistance Training (VRT). These modes of training relatively demonstrate the characteristics of isokinetic contractions and are introduced as a viable mode of training to overcome the shortcomings of traditional weight training (Ebben and Jensen, 2002; Ghigiarelli, 2006; Starkey *et al.*, 1996). In the other words, inefficiency of conventional weight training devices (free weights and weight machines) in creating maximal muscle stimulation in some segments of joint angle (Elliott, Wilson and Kerr, 1989), due to providing constant external force, has propounded the idea of using VRT among athletes and recreational lifters. Manning and colleagues (1990) noted that VRTs attempt to accommodate the changing level of muscle force output throughout the range of motion by varying the resistance produced.

Among modalities of VRT such as Isoinertia Machines (Matheson *et al.*, 2001; Tracy *et al.*, 1995), Nautiluses Machine (Cabell and Zebas, 1999), Weight-Chain (Ghigiarelli, 2006), Weight-Heavy Elastic Band (Ebben and Jensen, 2002), Thera-Band Elastic Resistance exercises (ER) have recently attracted more applicants among athletes and recreational lifters (Anderson, Sforzo and Sigg, 2008; Treiber *et al.*, 1998). Providing variable external moment of force, practicability of simulating various sport specific skills and ability to perform exercises without the influence of gravity and inertia of free weights are the unique features of ER exercises which introduce it as a viable alternative mode of training instead of conventional free weight exercises. However, to the best of our knowledge, there are very few research studies in the literature that have quantified and compared the proficiency of an ER device in eliciting acute physiological responses as compared with other traditional resistance apparatus such as the Dumbbell (DB) or Nautilus Machine (NM).

1.1 Background of ER Training

Elastic resistance exercise is well established as an effective mode of training in the rehabilitation and fitness setting (Hintermeister *et al.,* 1998; Schulthies *et al.,* 1998). Numerous studies have evaluated the clinical features of utilizing an elastic device; where, patients and older adults have been prescribed with Thera-bands for treatment of strength and pain impairment, balance and proprioception enhancement, increased range of motion after trauma and improvement in functional scales and disabilities (Decker *et al.,* 1999; Mikesky *et al.*, 1994; Myers *et al.*, 2005; Page *et al.*, 1993 ; Swanik *et al.,* 2002).

Thera-bands and tubing are being produced in several color-codes and each color denotes a specific resistance level (Simoneau *et al.,* 2001). Selecting the resistance of elastic material among different applicants depends on the initial state of health and fitness (e.g. injured vs. healthy individual) and the goals of training program (e.g. increase strength, coordination, balance, etc). On the other hand, the actual amount of resistance varies significantly with the amount of stretch applied to the tubing. This is accomplished in the clinical setting most effectively by starting a patient exercising with some initial slack in the tubing, thereby ensuring relatively low resistance. As the patient improves, the exercise is performed with no slack, increasing the resistance gradually and safely. Eventually, the exercise effort progresses to starting with some "pre-stretch," in order to stimulate and activate a more widespread neurological response to the exercise movement. In this way, users are able to advance through their entire joint rehabilitation program with just one piece of exercise tubing.

Hughes (1999) reported the resistance of an elastic device (Hygienic Corporation, Akron, Ohio) from 3.3 N (yellow) to 70.1 N (silver) when elastic materials were at 18% (minimum) and 159% (Maximum) of deformation from resting length (un-stretched), respectively. Hopkins and colleagues (1999) recommended ER training after Anterior Cruciate Ligament (ACL) reconstruction and advocated this mode of exercise as a safe and effective mode of rehabilitation exercise. In another research, based on electromyographic activity pattern of muscle and applied load during shoulder rehabilitation exercise, Hintermeister *et al.*, (1998) concluded that ability to perform movements in a controlled manner and low initial loading of ER could effectively target the rotator cuff muscles. In addition, In separate studies Matheson and colleague (2001) and Tyler and colleagues (2005) recommended ER as an effective mode of training for the initial stage of knee and Superspinatus muscle rehabilitation, respectively. Duncan *et al*., (1998) also prescribed ER training as a part of home-base cardiac rehabilitation protocol for individuals with mild and moderate stroke.

The borders of applying ER have not been confined to the clinical setting. In other words, some characteristics of ER such as ability to perform exercises similar as sport specific pattern (Jakubiak and Saunders, 2008; Page *et al.*, 1993), increases the overload of training in a reasonable slope (Patterson *et al.*, 2001; Simoneau *et al.*, 2001), providing eccentric and concentric resistance regardless of gravity (Hodges, 2006; Hughes *et al.*, 1999), ability to perform quick motion and change the direction (Wallace, Winchester and McGuigan, 2006) are recommending the ER exercises as a unique mode of training for developing athletic performance.

The ER has also been shown to accommodate the ascending-descending strength curve requirement of majority of the joints which have typical bell-shaped strength curves (Hughes *et al.,* 1999). The demonstrated ascending-descending strength curve could partially resolve concerns over using elastic resistance and completion of concentric phase. In fact, some previous investigators had been skeptical in that, because tensile force in an ER device increases with further elongation, the subject may not be able to generate adequate muscle torque to overcome the corresponding force at the end of the concentric phase.

1.2 Statement of Problem

Despite of the fact that scientific evidence supported the idea of utilizing ER exercises in the clinical and fitness setting, since their findings are based on applying moderate exercise intensity (e.g. 20 RM) and a relatively low to moderate ER device, the result may not be extendable to athletic community. In other words, despite the popularity of ER, there is controversy concerning the use of ER for increasing muscle hypertrophy and strength among healthy-trained individuals. This stems from an unfounded assumption that an "elastic device provides a low level of external force" (Ebben and Jensen, 2002; Hodges, 2006; Newsam *et al.,* 2005; Treiber *et al.,* 1998) and therefore is limited in providing an appropriate resistance/stimulus for strength development.

ER devices were originally commercialized as low cost therapeutic aids in muscle rehabilitation where comparatively low resistances are the norm. Reinforcing the assumption that ER devices provide low resistance, Hughes (1999) reported the resistance of an elastic device from 3.3N (yellow) to 70.1N (silver) when elastic materials were at

18% (minimum) and 159% (Maximum) of deformation from resting length (un-stretched), 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 for an elite athlete.

Lack of supportive evidences regarding the proficiency of ER in providing adequate moment of external force have made the athletes and coaches uncertain about utilizing this mode of training to achieve further muscular adaptations. However, there have been some attempts to increase the provided external force by an ER device. A number of investigators have speculated that for developing the resistance of an elastic device, additional elastic units must be applied in parallel to meet the required amount of external force (Page *et al.*, 1993). On the basis of this recommendation, different grades of "stiffness" of elastic material known as elastic color codes must be combined to achieve the required force for performing a given exercise (e.g. 10 repetition maximum (10 RM) biceps curl). However, further investigations are necessary to examine the effectiveness of this strategy in eliciting significant physiological responses.

In addition, failure in providing adequate external resistance by elastic material particularly at the initial segments of lifting (beginning of concentric phase) has been recognized as the major obstacle in applying ER in the athletic community (Wallace *et al.*, 2006; Ghigiarelli, 2006). This concern become more obvious when we review Baechle and Earle (2000) idea that "…development of strength may be retarded under training conditions that do not allow high tension development in the early part of range of motion". In order to work out this shortcoming of ER, Intra-elastic-device alteration comprised of shortening the resting length of the elastic device has been recommended by scientists (Hodges, 2006).

Therefore, to increase the magnitude of elastic force, two strategies have been recommended in the research literature; first, reducing the initial length of the elastic device (Page and Ellenbecker, 2003) and second, using additional elastic bands in parallel to the current elastic unit (Hodges, 2006; Simoneau *et al.*, 2001). These strategies have the potential to further increase the utility of ER devices by enabling significant increases in resistance. Thus ER devices that are often used as a physical therapy aid may be adapted to elicit significant strength gains with a programme of repeated near maximal contractions. However, to the best of our knowledge there is no documented research study which used the two strategies in enhancing provided external resistance in an ER device. In addition, no investigation was found which has quantified and compared the magnitude of muscle activation (measured via electromyography (EMG)) and Torque production, between modified ER training and other modes of free weight exercises like Dumbbell (DB) and VRT exercises such as nautilus machine (NM).

Scientists reported that both coaches and athletes tend to rely on clinical experiences and documentation while they use elastic resistance training (Hughes *et al.*, 1999; Patterson *et al.*, 2001; Page and Ellenbecker, 2003). Accordingly more studies are required to elaborate the effects of a high intensity elastic resistance exercises on physiological aspects of athletic performance. Thus, clarification of the neuromuscular and hormonal responses following an intensive training protocol by ER and NM exercises may present a clearer perspective about benefits and shortcoming of the two modes of training in developing muscle strength and hypertrophy.

1.3 Objectives of study

The controversy of using ER in high intensity training protocols was investigated in a series of three studies. The objectives of each study are discussed in the following.

1.3.1 Objectives of first study. In the first study including a descriptive methodology, the magnitude of resultant muscle torque production (RMT) and EMG activity of elbow flexor muscles were quantified and compared within performing 8 RM biceps curl exercises using ER and dumbbell (DB). Therefore, subjects completed a series of 8-RM biceps curl by three modalities of resistance exercises comprising:

(i) DB

(ii) Elastic tubing with initial length (E0; i.e. elastic resistance device at un-stretched length)

(iii) Elastic tubing with 30% decrement of initial elongation (E30).

The Elbow flexors were selected for this study because:

I. Biceps curl using dumbbells and elastic bands is a popular exercise in recreational and professional athletic setting.

II. Elbow flexion is an exercise which could be performed in an isolated range of motion without interference from other biomechanical interventions (Lim and Chow, 1998; Oliveira and Gonçalves, 2008).

III. A low level of subcutaneous fat exists around the biceps muscle which increases the quality of surface electromyogram signals.

IV. Taking EMG from Biceps Brachii would create reliable results because this is an isolated muscle which is free from interfering electromyographic signals from adjacent muscles.

1.3.2 Objectives of second study. In the second study including similar methodology as the first investigation, the magnitude of torque production and EMG activity of knee extensor muscles were compared while performing 8 RM seated knee extension exercises using ER and NM devices. In this study, subjects completed a series of 8-RM seated knee extension using three modalities of resistance exercises comprising:

(i) NM

(ii) Elastic tubing with initial length (E0; i.e. elastic resistance device at un-stretched length)

(iii) Elastic tubing with 30% decrement of initial elongation (E30).

More specifically, the objectives of the study included:

I. To quantify and compare the magnitude of applied force among NM, E0 and E30 while performing of 8 RM seated knee extensions exercises.

II. To quantify and compare the level and pattern of muscle activation (EMG) among NM, E0 and E30 while performing of 8 RM seated knee extensions exercises.

III. To quantify and compare the pattern of torque production among NM, E0 and E30 while performing of 8 RM seated knee extensions exercises.

The NM, ER and seated knee extensions were chosen for this investigation because knee extensors had the following features:

I. Quadriceps muscle was a larger and stronger muscle group (compared with elbow flexors in the first study) which could truly examine the capability ER in providing external force and eliciting adequate muscle activation in big muscle groups.

II. It was shown that both NM and ER were the VRT training devices which could have mechanical advantages of providing external force in accordance with force generating capability of the knee extensor muscles (Cabell and Zebas, 1999; Page and Ellenbecker, 2003).

III. ER has long been accepted as an affordable, portable and versatile exercise device compared with expensive and cumbersome NM. Therefore, in case of eliciting equal training responses, ER could be acknowledged as a cost-effective and easy setup exercise device compared with expensive and cumbersome NM.

1.3.3 Objectives of third study. The third part of our investigation was comprised of a counterbalance cross-sectional design where all subjects completed two modalities of exercise (ER and NM) with a three week "wash-out" period between experiments. Muscle performance tests including Maximum Voluntary Isometric Contraction (MVIC) and submaximal isometric contraction as well as acute physiological responses including EMG activity and hormonal responses were measured following 5 sets of a 10 RM knee extension training protocol. It is worth noting that a big muscle group like knee extensors could be a better choice for investigating the discrimination in the acute neuromuscular and hormonal responses following the two training protocols (ER and NM). The importance of the study is underlined by the fact that the relatively short term responses at the outset of a resistance training program may potentially provide insight to the longer term adaptations.

1.4 Hypothesis

The hypotheses of each study are stated in the following.

1.4.1 Hypotheses of the first study. For the first investigation, it was expected that reducing the initial length of the elastic material and using additional elastic bands in parallel to the current elastic unit would increase the provided tensile force in the elastic device, particularly at the beginning of the concentric and end of eccentric segments. On this basis, we hypothesized that:

I. By applying a combination of the above mentioned strategies in E30, significantly higher EMG and applied load would be achievable by E30 compared with E0, particularly at the beginning of the concentric and end of the eccentric segments.

II. By applying a combination of the above mentioned strategies in E30, equal magnitude of RMT production and EMG activity would be gained by E30 compared with DB.

1.4.2 Hypotheses of the second study. Similarly as the first study, it was expected that reducing the initial length and using additional elastic units would enhance the provided external force E30. On this basis, we hypothesized that:

I. Significantly higher EMG and applied load would be achievable by E30 compared with E0 during performing seated knee extension exercises, particularly at the beginning of the concentric and end of eccentric segments.

II. Equal torque production and EMG activity would be gained by E30 compared with NM.

1.4.3 Hypotheses of the third study. On the basis of results achieved in the second investigations (as it will have been comprehensively discussed in chapter V, equal overall muscle activity was observed between E30 and NM throughout performing 8 RM seated knee extension exercise) we hypothesized that:

I. Equal acute responses would be observed in MVIC and submaximal isometric contraction following training with ER compared with NM exercise.

II. Equal acute responses would be detected in electromyographic activity (frequency and amplitude of electromyogram signals) following training with ER compared with NM exercise.

III. Equal acute anabolic hormones responses would be achieved following training with ER compared with NM exercise.

1.5 Significance of Study

The present study was designed to address the question of "whether using a modified ER device can result in similar physiological responses (acute neuromuscular and anabolic hormonal responses) as the NM?" 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. More specifically, ascertaining the loading profile and magnitude of torque production across various segments of ROM, while performing ER and NM, may create a better understanding about force-angle relationship of these types of exercise. Measuring the EMG of prime movers also can clarify the rate of muscle activation while undertaking each mode of training. Finally, investigating the acute neuromuscular and anabolic hormonal responses following training protocols using the two types of exercise would offer valuable information about dose-response relationship and effect of each type of training. The data can be used to optimize training protocols in contribution of these training devices in late rehabilitational stages as well as the recreational and athletic settings.