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Low-intensity exercise, vascular occlusion, and muscular adaptations

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LOW-INTENSITY EXERCISE, VASCULAR OCCLUSION,
AND MUSCULAR ADAPTATIONS

by

Masaru Teramoto

Bachelor of Science
Utah State University
2003

A thesis submitted in partial fulfillment
of the requirements for the

**Master of Science Degree in Exercise Physiology
Department of Kinesiology
School of Health and Human Sciences**

**Graduate College
University of Nevada, Las Vegas
May 2006**

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ABSTRACT

Low-Intensity Exercise, Vascular Occlusion, and Muscular Adaptations

by

Masaru Teramoto

Lawrence A. Golding, Ph.D., Examination Committee Chair
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University of Nevada, Las Vegas

The study investigated the effects of low-intensity exercise on muscular fitness when combined with vascular occlusion. Male ($n = 8$) and female ($n = 11$) college students performed two sets of a 5-min step exercise using a 12-inch bench 3 times/week for a total of 5 weeks. During the step exercise, blood flow to one leg was partially restricted (vascular occlusion) with a blood pressure cuff placed around the thigh, while the other leg was not occluded. Parameters of muscular fitness were not affected by vascular occlusion. Muscular strength and endurance of both occluded and non-occluded legs were increased after the training in both men and women, regardless of blood flow ($p < .05$). Vascular occlusion had no additional effects in promoting muscular strength and endurance gains of the legs, when incorporated into a 5-week step exercise program.

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CHAPTER 1

INTRODUCTION

A new area of research is resistance training with vascular occlusion. Studies indicate that low-intensity resistance training [50% of one repetition maximum (1 RM)] can substantially increase muscle size and strength when combined with restricted blood flow (vascular occlusion) to the working muscles (Takarada et al., 2000b). Muscle size and strength gains caused by low-intensity resistance training with vascular occlusion were even comparable to the gains caused by high-intensity resistance training (80% of 1 RM) (Takarada et al., 2000b).

It is well-accepted that moderate to high-intensity resistance training promotes muscle size and strength gains; whereas, low-intensity resistance training promotes muscular endurance gain (American College of Sports Medicine, 2000; Fleck & Kraemer, 1988; Kraemer et al., 2002). Intensity or load of resistance training is generally quantified as a repetition maximum (RM), for example, 1 RM and 5 RM (maximum weight that can be lifted only one time and five times), or percentage of 1 RM, for example, 50% of 1 RM (Fleck & Kraemer, 1988; Stone, Chandler, Conley, Kramer, & Stone, 1996; Tan, 1999). Several studies have demonstrated that low-intensity resistance training, such as 30-40 RM and 15-35% of 1 RM, is still effective in increasing muscular strength for previously untrained individuals (Moss, Refsnes, Abildgaard, Nicolaysen, & Jensen, 1997; Stone & Coulter, 1994). However, it is generally agreed that resistance of at least 60% of 1 RM

for untrained individuals and 80% of 1 RM for trained individuals are necessary to maximize strength gain (Kraemer et al., 2002; Rhea, Alvar, Burkett, & Ball, 2003).

Although other studies have recently supported the effects of low-intensity resistance training or low-intensity exercise with vascular occlusion on muscle size and strength gains (Abe, Kearns, & Sato, in press; Takarada, Sato, & Ishii, 2002; Takarada, Tsuruta, & Ishii, 2004), exact mechanisms underlying these training adaptations are not fully understood. In addition, there is not enough research to indicate what mode of exercise and how much of occlusive stimulus are effective in optimizing the training effects.

Purpose of the Study

The purpose of this study was to investigate the effects of low-intensity exercise on muscular strength, endurance, and lean and fat mass of the leg when combined with vascular occlusion.

Research Hypothesis

A 5-week step exercise combined with vascular occlusion affects muscular strength, endurance, and lean and fat mass of the leg differently than the step exercise without vascular occlusion.

Need for the Study

High-intensity resistance training may be difficult for unfit individuals, older people, and rehabilitating patients. If research demonstrates that low-intensity resistance training or other low-intensity exercises with vascular occlusion can promote muscle size and

strength gains, it will benefit those who cannot perform high-intensity resistance training. Rehabilitation personnel, such as physical therapists and athletic trainers, will be able to design and prescribe much safer and still effective resistance training programs for their patients and athletes. If daily physical activities, such as walking and stepping, combined with vascular occlusion are known to be effective in improving muscular fitness, it will expand the training's availability.

Definitions

1. Vascular occlusion: Partial restriction of blood flow
2. Independent variable: Test (pre & post), Blood flow (occlusion& no occlusion)
3. Dependent variable: Muscular strength (1 RM strength), muscular endurance (50% of 1 RM as resistance), and lean and fat mass of each leg

Assumptions

1. The validity and reliability of the results relied on the subjects. It was assumed that all instructions were given to the subjects, and that they followed the instructions during the experiments.
2. The subjects were healthy college males and females. They were not engaged in regular, heavy resistance training programs at the time of the study.

Limitations

1. The results of the study cannot be inferred to the groups of people other than healthy college populations.

2. Vascular occlusion was achieved by a standard manual thigh blood pressure cuff at a set pressure. In contrast, Abe et al. (in press), Takarada et al. (2002), and Takarada et al. (2000b) used a specially designed elastic belt (M.P.S.-700, VINE Medical Instruments Inc. Tokyo, Japan) that electrically monitored the occlusion pressure and therefore could maintain a constant pressure during the exercise. Unlike the elastic belt, occlusion pressure used in this study was constantly changing during a step exercise.

CHAPTER 2

REVIEW OF THE LITERATURE

Contents

- I. Muscular Fitness
- II. Resistance Training
- III. Neural Adaptations to Resistance Training
- IV. Muscular Adaptations to Resistance Training
- V. Cross Education
- VI. Muscle Atrophy with Aging
- VII. Resistance Training with Vascular Occlusion
- VIII. Summary

Muscular Fitness

Muscular fitness is an essential part of daily living. Muscles are required to work when performing any physical task. Maintaining a desirable level of muscular fitness helps to prevent health-related problems, such as osteoporosis, type II diabetes, and risk of injuries and disabilities (American College of Sports Medicine, 2000). It also improves performance of daily activities and enhances quality of life (Payne, Gledhill, Katzmarzyk, Jamnik, & Ferguson, 2000). If muscular fitness is monitored on a regular basis, it can be the goal for rehabilitating patients who are trying to return to their pre-injury fitness

levels (Golding, 2000). Muscular fitness is mainly divided into two components: muscular strength and muscular endurance (American College of Sports Medicine, 2000).

Muscular strength refers to the maximal force that can be generated by the muscles. To assess muscular strength, the 1 RM testing is the common field test that determines the maximum amount of weight or resistance that can be lifted only one time (Graves, Pollock, & Bryant, 1998). Muscular strength is based on the function of: 1) the number of muscle fibers activated (Sale, 1987) and 2) the size of muscle fibers [muscle cross-sectional area (CSA)] (Masuda, Kikuhara, Takahashi, & Yamanaka, 2003; Maughan, Watson, & Weir, 1983). It indicates that the more the muscle fibers are activated or the larger the muscle or muscle group is, the greater the force is generated (Masuda et al., 2003; Maughan et al., 1983; Sale 1987). Neural factors, such as pattern and magnitude of motor unit activation, are associated with muscular strength (Sale, 1988). A motor unit consists of the motor neuron and specific muscle fibers innervated by the motor neuron. Sale (1988) indicates that full activation of motor units and better coordination of the muscles to the specific movement are key elements for strength gain. According to Sale (1988) and Behm (1995), electromyography (EMG) is the most common technique to measure muscle activity and changes of motor unit activation during muscle contraction. Increased integrated EMG muscle activity reflects increased motor unit activation, which results in increased force production (Sale, 1988). Muscular strength is best improved by lifting heavier resistance (near to maximum) with fewer repetitions (Moss, Refsnes, Abildgaard, Nicolaysen, & Jensen, 1997).

Muscular endurance is the ability to maintain a given level of force output. Muscular endurance is determined by fitness testing that includes lifting lighter weights with more

repetitions (Golding, 2000). According to Bemben (1998), assessing muscular strength is generally a focal point for fitness testing and research. However, since exerting maximal force is seldom required, muscular endurance, rather than muscular strength, may be more of a predictor of ability to perform daily physical activities (Bemben, 1998). Muscular endurance is quantified as the number of repetitions completed using a given resistance. There appears to be a negative linear or exponential relationship between the number of repetitions and percentage of 1 RM resistance (Mayhew, Ball, Arnold, & Bowen, 1992). Several studies have demonstrated that 1 RM muscular strength of some types of exercise (e.g., bench press) can be predicted from relative muscular endurance (number of repetitions) determined using submaximal resistance (Brzycki, 1993; Mayhew et al., 1992). In general, muscular endurance is best improved by lifting lighter resistance (50% of 1 RM) with more repetitions (≥ 20 repetitions) (Deschenes & Kraemer, 2002). However, traditional resistance training designed for muscle size and strength gains has been also shown to increase muscular endurance (Huczel & Clarke, 1992; Stone & Coulter, 1994).

Resistance Training

Resistance training is a form of exercise using heavy resistance and also referred to as strength training or weight training (Fleck & Kraemer, 1988). According to American College of Sports Medicine (2000), resistance training should be incorporated into adult exercise and rehabilitation programs to improve muscular fitness.

Resistance training is categorized based on muscle contraction. In isotonic (also called dynamic) resistance training, the length of the muscles changes and movement of

the object occurs during muscle contraction. Push-ups and dumbbell curls are the examples of isotonic resistance training. Isotonic resistance training is further divided into concentric and eccentric phases. Concentric phase or muscle contraction occurs when the muscles shorten while exerting force. For example, when dumbbells are raised or curled, it is concentric muscle contraction. Eccentric phase or muscle contraction occurs when the muscles lengthen while exerting force. When dumbbells are lowered after curled up, it is eccentric muscle contraction. In isometric (also called static) resistance training, the length of the muscles remains unchanged while exerting force against an immovable object. Finally, isokinetic resistance training is designed to allow maximal force exertion throughout the range of motion (ROM) at a given velocity. Isokinetic device maintains constant velocity throughout the ROM. Therefore, resistance is controlled during exercise; resistance is decreased at the weak points in the ROM, and resistance is increased at the strong points in the ROM. In theory, maximal force is exerted at all points in the ROM during isokinetic resistance training.

Several considerations should be taken into account when designing resistance training programs. According to Tan (1999), training intensity and volume are two of the most essential considerations for resistance training programs.

Training intensity is, simply stated, “load or resistance used” in exercise (Tan, 1999). It is usually expressed as a repetition maximum (RM) or a percentage of 1 RM, such as 50% of 1 RM (Fleck & Kraemer, 1988; Stone, Chandler, Conley, Kramer, & Stone, 1996). For example, 1 RM and 5 RM are the greatest resistance that can be lifted only one time and five times. Campos et al. (2002) indicates that high-intensity and low-repetition resistance training is superior to promoting strength gain; whereas, low-

intensity and high-repetition resistance training achieves greater muscular endurance gain. Stone and Coulter (1994), on the other hand, demonstrated that low-intensity (30-40 RM) resistance training still increased bench press and squat strength for previously untrained individuals after 9 weeks of training.

Training volume refers to “the total work performed within a specified time” (Tan, 1999). It is typically determined by: 1) total repetitions = sets $\times$ repetitions (Baker, & Wilson, 1994) or 2) volume load = sets $\times$ repetitions $\times$ resistance (Kraemer et al., 2002). Training volume is as equally important as training intensity for strength gain (Tan, 1999), and may be more important during the early stage of training (Kramer et al., 1997). According to Kramer et al. (1997), after 14 weeks of a single set (1 set to failure; 8-12 repetitions) or multiple sets (≥ 3 sets; not to failure; 10 repetitions), the multiple sets of training achieved 50 % greater gain in muscular strength of 1 RM squat than the single set of training. Superiority of multiple sets over a single set has also been demonstrated by Paulsen, Myklestad, and Raastad (2003).

The American College of Sports Medicine position stand recommends the following training protocols to optimize muscle size, strength, and endurance gains (Kraemer, et al., 2002).

- To increase muscular strength:

For novice individuals, 60-70% of 1 RM should be used for 8-12 repetitions with either single or multiple sets, 2-3 times per week. For advanced individuals, 80-100% of 1 RM should be used for 8-12 repetitions with either single or multiple sets, 4-6 times per week.

- To increase muscle size (muscle hypertrophy):

For novice individuals, 70-85% of 1 RM should be used for 8-12 repetitions with 1-3 sets per exercise. For advanced individuals, 70-100% of 1 RM should be used for 1-12 repetitions with 3-6 sets per exercise. Training frequency should be similar to the strength training.

- To increase local muscular endurance:

For novice individuals, light resistance (10-15 repetitions) with moderate to high volume should be used. For advanced individuals, light resistance (≥ 10 -25 repetitions) should be used with multiple sets per exercise. Training frequency should be similar to the strength and hypertrophy trainings.

Neural Adaptations to Resistance Training

It has been suggested that neural adaptations, such as changes in pattern and magnitude of motor unit activation and rate of force production, plays a major role in strength gain, especially during the early stage of resistance training (Moritani & DeVries, 1979; Sale, 1988). Motor unit activation is based on the size principle, indicating that motor units with low threshold are activated first and motor units with high threshold are activated next, according to force requirement (Sale, 1987). Motor units with low or slow twitch forces (ST or type I) have low threshold and therefore activated first, resulting in a weak force production (Edstrom & Grimby, 1986; Sale, 1987). Motor units with high or fast twitch forces (FT or type II) have high threshold and therefore activated next, resulting in a strong force production (Edstrom & Grimby, 1986; Sale, 1987). Behm (1995) suggests that high-threshold motor units should be activated by high-intensity resistance exercise to optimize neural adaptations to training.

Hakkinen, Pakarinen, and Kallinen (1992) found that, after 3 weeks of combined moderate and high-intensity resistance training, strength gains of the knee extensor muscles were mainly caused by neural adaptations. They found that EMG muscle activity was increased by 15.8% compared to 4.6% increase in muscle cross-sectional area after the training (Hakkinen et al., 1992). The results of their study showed that neural adaptations contributed to strength gain more than muscle hypertrophy (Hakkinen et al., 1992). Narici, Roi, Landoni, Minetti, and Cerretelli (1989) found that 60% of strength gain was caused by increased muscle activity; whereas, 40% of strength gain was caused by muscle hypertrophy after 60 days of isokinetic knee extension resistance training [6 sets of 10 maximal voluntary contraction (MVC)]. Neils, Udermann, Brice, Winchester, and McGuigan (2005) conducted the study including 8 weeks of either 80% of 1 RM traditional resistance training or 50% of 1 RM superslow resistance training for upper and lower bodies. There were no changes in body composition of the subjects, even though muscular strength of bench press and squat were increased by 6.8 and 3.6% for the traditional resistance training and 8.6 and 9.1% for the superslow resistance training, respectively (Neils et al., 2005). Other studies have also demonstrated that resistance training causes neural adaptations found by increased EMG muscle activity (Hakkinen, Alen, & Komi, 1985; Hakkinen & Komi, 1986). Exact mechanisms of strength gain caused by neural adaptations are yet to be understood. It is hypothesized that resistance training may allow additional activation of motor units, increase the firing frequency of motor units, increase reflex potentiation, and/or increase synchronization of motor unit impulses (Behm, 1995; Sale, 1988).

Muscular Adaptations to Resistance Training

Increase in muscle size (muscle hypertrophy) is considered to be a major factor for strength gain as resistance training is progressed (Sale, 1988; Shoepe, Stelzer, Garner, & Widrick, 2003). As stated previously, muscular strength is positively correlated with muscle CSA (Masuda et al., 2003; Maughan et al., 1983). Several studies have demonstrated that muscle hypertrophy occur through an increase in the size of muscle fibers (Campos et al., 2002; Shoepe et al., 2003).

Both ST and FT muscle fibers can increase in size after resistance training; however, some studies suggest that FT muscle fibers can achieve greater muscle hypertrophy than ST muscle fibers (Campos et al., 2002; Staron et al., 1990). According to Staron et al. (1990), after 20 weeks of high-intensity (6-8 RM) resistance training, there were increases in size of muscle fibers in the vastus lateralis muscles with type I by 15%, IIA by 45%, and IIAB + IIB by 57%, respectively. Campos et al. (2002) demonstrated that, after 8 weeks of high-intensity (3-5 RM) or moderate-intensity (9-11 RM) resistance training using leg press and knee extension exercises, a muscle CSA of each major muscle fiber type increased by 12.5% for type I, 19.5% for type IIA, and 26% for type IIB, respectively. Kraemer et al. (1998) indicate that ST muscle fibers increase in size by slowing down protein break-down; whereas, FT muscle fibers increase in size by enhancing protein synthesis.

Several studies have demonstrated that men and women experience similar strength gains and muscle hypertrophy when relative changes before and after training are compared (Abe, DeHoyos, Pollock, & Garzarella, 2000; Cureton, Collins, Hill, & McElhannon Jr., 1988). According to Abe et al. (2000), after 12 weeks of moderate-

intensity (8-12 RM) resistance training, mean relative increases in 1 RM knee extension and chest press strength were both 19% for men, and 19% and 27% for women, respectively. In addition, relative increases in muscle thickness of upper and lower body measured by ultrasound were 12-21% and 7-9% for men, and 10-31% and 7-8% for women, respectively (Abe et al., 2000). Cureton et al. (1988) demonstrated that, after 16 weeks of high-intensity (70-90% of MVC) resistance training using elbow and knee extension and flexion exercises, relative changes in strength and muscle CSA were similar between men and women; whereas, absolute changes were greater in men than in women.

It has been reported that muscle fiber type conversion occurs after long-term resistance training (Kraemer et al., 1995; Staron et al., 1990). Human skeletal muscle fiber is classified based on the pH sensitivity of myosin adenosine triphosphatase (mATPase) (Staron, 1997). There are seven muscle fiber types identified: types I, IC, IIC, IIAC, IIA, IIAB, and IIB (Staron, 1997; Staron, & Johnson, 1993). Type IIB muscle fibers have highest force development capabilities, while type I muscle fibers have lowest force development capabilities (Bottinelli, Canepari, Reggiani, & Stienen, 1994). There considered to be three myosin heavy chain (MHC) isoforms in the human skeletal muscles: MHCI, MHCIIa and MHCIIb (Staron, 1997). Three major fiber types of human skeletal muscles are type I, type IIA, and type IIB (Staron, 1997; Staron, & Johnson, 1993). Type I muscle fiber has MHCI, type IIA has MHC IIa, and type IIB has MHCIIb (Staron, 1997; Staron, & Johnson, 1993). As to other muscle fiber types, Type IIAB muscle fiber has both MHCIIa and MHCIIb, and type IC, IIC, and IIAC muscle fibers have both MHCI and MHCIIa (Staron, 1997; Staron, & Johnson, 1993). Several studies

have demonstrated that resistance training convert MHCIIb to MHCIIa, corresponding to a conversion from type IIB to type IIA muscle fibers (Kraemer et al., 1995; Staron et al., 1990). According to Staron et al. (1990), after 20 weeks of high-intensity (6-8 RM) resistance training completed by untrained women, type IIB muscle fibers decreased from 16.2% to 2.7%; whereas, type IIA muscle fibers increased from 32.5% to 39.3%. In the study by Kraemer et al. (1995), after 12 weeks of high-intensity (5-10 RM) resistance training completed by physically active men, there was a shift in percentage from type IIB to type IIA muscle fibers with type IIB decreased from 19.1% to 1.9% and type IIA increased from 23.3% to 40.5%. This fiber conversion (type IIB to type IIA) was also observed in other studies (Jurimae, Abernethy, Blake, & McEniery, 1996; Staron et al., 1994).

Cross Education

Cross education, also known as cross exercise, cross training, or cross transfer, refers to increase in strength of untrained contralateral limb after one limb is trained (Munn, Herbert, & Gandevia, 2004; Zhou, 2000). Several studies have investigated cross education; however, the results are inconsistent, and exact mechanisms, though likely involving in nervous systems, have yet to be identified (Zhou, 2000).

Munn et al. (2004) analyzed 13 past cross education studies using a meta-analysis. They estimated that an average of 7.8% strength gain in the untrained contralateral limb that was 35.1% of strength gain that occurred in the trained limb (Munn et al., 2004). According to Farthing and Chilibeck (2003), cross education occurred when training includes fast, eccentric muscle contraction, indicating that cross education may depend

on contraction type and velocity. Farthing, Chilibeck, and Binsted (2005) recently found that training dominant hand-grip strength caused an increase in non-dominant untrained hand-grip strength; whereas, cross education from the non-dominant to the dominant hand did not occur. In the study by Shima et al. (2002), MVC and integrated EMG muscle activity of the untrained plantar flexor muscles were increased after 6 weeks of unilateral heel raise training (70-75% of 1 RM). Furthermore, cross education effect was not lost after 6 weeks of detraining (Shima et al., 2002).

Muscle Atrophy with Aging

It is well documented that muscular fitness decreases with aging, leading to reduction in muscle size and loss of motor units and strength, called muscle atrophy (Bemben, 1998). Frontera et al. (2000) reported that the subjects (in 60-70s) lost muscular strength of knee extensor and flexor muscles by 23.7-29.8% with the overall loss of 2.0% per year for extensors and 2.5% per year for flexors over a 12-year period. They also found that muscle CSA decreased by 12.5% at total thigh tissues, by 14.7% at all thigh muscles, by 16.1% at knee extensor muscles, and by 14.9% at knee flexor muscles (Frontera et al., 2000). According to Hughes et al. (2001), the subjects (initial age of 45-78 yr) lost isokinetic strength of knee extensor and flexor muscles by 14% and 16%, respectively after 10 years.

Loss of Muscular strength with aging may be associated with changes in the size and number of muscle fibers. Lexell (1995) indicates that muscle atrophy with aging is caused by the loss of the number and size of muscle fibers, especially type II muscle fibers. In the study by Jakobsson, Borg, and Edstrom (1990), there was no difference of

type I muscle fiber CSA between young (23-37 yr) and elderly (66-77 yr) people; whereas, type IIA muscle fiber CSA in elderly people was 30% smaller than CSA in young people. According to Stalberg and Fawcett (1982), denervation of type II motor units results in the reinnervation of the remaining fibers by type I motor neurons. As a consequence of reinnervation, an increase in the number of type I muscle fibers and an increase in the type I to type II muscle fiber ratio is observed along with type I muscle fiber grouping (Stalberg & Fawcett, 1982).

Strength loss and muscular atrophy may increase the risks of falls and physical impairment in older people. Gehlsen and Whaley (1990) found that men and women with a history of falls had 41.7% and 27.1% lower total muscular strength of hip extensor, knee extensor, and ankle plantar flexor muscles than men and women with no history of falls. According to Wolfson, Judge, Whipple, and King (1995), isokinetic knee and ankle strength were measured in older people (in 80s) with and without a history of falls. People with a history of falls showed much lower strength of each testing measurement, as particularly noted that strength of ankle dorsiflexor muscles was only 9.5% of strength recorded in people with no history of falls (Wolfson et al., 1995).

Several studies indicate that resistance training helps to prevent strength loss and muscle atrophy with aging and improve functional performance (Fiatarone et al., 1990; Golding, 2001; Kalapotharakos, Michalopoulos, Tokmakidis, Godolias, & Gourgoulis, 2005; Taaffe, Duret, Wheeler, & Marcus, 1999). Fiatarone et al. (1990) reported that after 8 weeks of high-intensity (80% of 1 RM) resistance training, muscular strength of the knee extensor muscles in elderly subjects (86-96 yr) was increased by 174 %. A total midthigh muscle area was also increased by 9.0 %, and gait speed was improved by 48%

after the training (Fiatarone et al., 1990). According to Kalapotharakos et al. (2005), sedentary older adults (60-74 yr) completed a 12-week high-intensity (80% of 1 RM) or moderate-intensity (60% of 1 RM) resistance training. A combined 1 RM of knee extensor and flexor muscles increased from 43.09 to 76.75 kg and from 40.16 to 57.95 kg after the high-intensity and moderate-intensity resistance trainings, respectively (Kalapotharakos et al., 2005). Walking velocity, stair-climbing time, and chair-rising time were also improved by 30%, 13.5%, and 28.7%, respectively, after the high-intensity resistance training and 32.8%, 13.2%, and 30.7%, respectively, after the moderate-intensity resistance training (Kalapotharakos et al., 2005). Taaffe, Duret, Wheeler, and Marcus (1999) demonstrated that even once per week of high-intensity (80% of 1 RM) resistance training lasting 24 weeks improved 1 RM muscular strength, timed chair rise, and 6-meter backward tandem walk in older people (65-79 yr). Golding (2001) in a preliminary report of a 30-year exercise study showed that men who exercised regularly did not lose muscular strength as measured by sit-ups, bench press, and arm curls. He concluded that strength loss with age was more a function of disuse than the passing of years (aging) (Golding, 2001).

Resistance Training with Vascular Occlusion

Several studies have investigated the effects of low-intensity resistance training combined with vascular occlusion on muscle size and strength. At first, Shinohara, Kouzaki, Yoshihisa, and Fukunaga (1998) and Takarada et al. (2000b) demonstrated that substantial muscle size and strength gains occurred after low-intensity resistance training with vascular occlusion. Since then, more studies have been conducted to examine the

training effects (Abe, Kearns, & Sato, in press; Burgomaster et al., 2003; Moore et al., 2004; Takarada, Sato, & Ishii, 2002; Takarada, Tsuruta, & Ishii, 2004).

In the study by Shinohara et al. (1998), untrained young males completed 4 weeks (12 sessions) of low-intensity (40% of MVC) isometric knee extension exercise with or without vascular occlusion (> 250 mmHg). The training with vascular occlusion increased MVC of knee extension by 26%, as well as maximal rate of torque development; whereas, the training without vascular occlusion did not affect either of the two measurements (Shinohara et al., 1998). In the study by Takarada et al. (2000b), postmenopausal women completed 16 weeks (32 sessions) of low-intensity (50% of 1 RM) isotonic elbow flexion exercise with vascular occlusion (110 mmHg), exercise without vascular occlusion, or high-intensity (80% of 1 RM) exercise without vascular occlusion. There were greater increases in muscle CSA and isokinetic strength of elbow flexor muscles after the low-intensity training with vascular occlusion than after the low-intensity training without vascular occlusion (Takarada et al., 2000b). In addition, the low-intensity training with vascular occlusion produced the same level of muscle size and strength gains as high-intensity training without vascular occlusion (Takarada et al., 2000b).

Takarada et al. (2002) used previously trained male rugby players as the subjects who completed 8 weeks (16 sessions) of low-intensity (50% of 1 RM) isotonic knee extension exercise with or without vascular occlusion (200 mmHg). There were increases in isokinetic torque, muscle CSA, and dynamic endurance of the knee extensor muscles after the training with vascular occlusion (Takarada et al., 2002). In contrast, no significant changes were found in any of the measurements after the training without

vascular occlusion (Takarada et al., 2002). Takarada et al. (2004) used much lower training intensity (10-20% of 1 RM) combined with vascular occlusion (218 mmHg), without vascular occlusion, or vascular occlusion without exercise. After 8 weeks (16 sessions) of isotonic knee extension exercise, isotonic and isometric strength, as well as muscle CSA, of the knee extensor muscles were increased after the training with vascular occlusion; whereas, there were no significant changes for any measurement after the training without vascular occlusion or vascular occlusion without training.

There are some studies that found no or limited effects of resistance training with vascular occlusion on strength gain. Burgomaster et al. (2003) conducted the study including 8 weeks (16 sessions) of low-intensity (50% of 1 RM) isotonic elbow flexion exercise with or without vascular occlusion (100 mmHg). Even though the resistance training resulted in increased isokinetic strength of the elbow flexor muscles, there was no difference of strength gains between training with and without vascular occlusion (Burgomaster et al., 2003). Moore et al. (2004) conducted the study including 8 weeks of low-intensity (50% of 1 RM) isotonic elbow flexion exercise with or without vascular occlusion (100 mmHg). They found that maximal voluntary dynamic 1 RM strength of the elbow flexor muscles was increased in both occluded and non-occluded arms; whereas, isometric MVC was increased only after the training with vascular occlusion (Moore et al., 2004).

Abe et al. (in press) found that a daily physical activity, such as walking, was effective in increasing muscle size and strength when combined with vascular occlusion. Their subjects performed 3 weeks (36 sessions) of treadmill walking with either both legs occluded (160-230 mmHg) or not occluded. After the training, there were increases in

muscle CSA of the thigh muscles, leg press and leg curl 1 RM strength, and isometric MVC of knee extension in the occlusion group; whereas, no significant changes were found in the non-occlusion group (Abe et al., in press).

One hypothesis to explain the effects of training with vascular occlusion is proposed through EMG studies. Takarada et al. (2000a, 2000b) found that muscle activity measured by EMG was greater during resistance exercise with vascular occlusion than during exercise without vascular occlusion. They found greater plasma lactate concentration after the exercise with vascular occlusion than after the exercise without vascular occlusion (Takarada et al., 2000a, 2000b). The relationship between elevated plasma lactate concentration and increased EMG muscle activity was also observed by past studies (Moritani, Sherman, Shibata, Matsumoto, & Shinohara, 1992; Sundberg, 1994). Therefore, Takarada et al. (2000a, 2000b) speculated that: 1) vascular occlusion elevated plasma lactate concentration, 2) elevated plasma lactate inhibited muscle contraction during the exercise, 3) additional motor units were activated to maintain the same force production as shown by increased EMG muscle activity, and 4) this additional motor unit activation contributed to muscle size and strength gains. The theory that accumulated plasma lactate increases motor units activation has yet to be understood. It is known that accumulation of metabolic by-products, such as hydrogen ion from lactic acid, stimulates group III and IV afferent neurons and activates metaboreceptors within the active skeletal muscles (Houssiere et al., 2005; McClain, Hardy, & Sinoway, 1994). This activation of metaboreceptors increases sympathetic nerve activity to the skeletal muscles, known as metaboreflex (Houssiere et al., 2005). Accumulated plasma lactate and hydrogen ions caused by vascular occlusion may increase activation of

metaboreceptors, increase sympathetic nerve activity to the skeletal muscles, and increase motor unit activation.

Another hypothesis is concerning human growth hormone. Takarada et al. (2000a) found that, 15 minutes after low-intensity (20% of 1 RM) isotonic knee extension exercise with vascular occlusion (214 mmHg), there was an increase in plasma growth hormone found in the blood sample obtained from the arm; whereas, no such change was observed after exercise without vascular occlusion. Increased plasma growth hormone after resistance exercise with vascular occlusion was also observed by other studies (Abe et al., in press; Takarada et al., 2004). Past studies found that serum growth hormone secretion was increased immediately after high-intensity (5-10 RM) resistance exercise with multiple sets (Kraemer et al., 1991; Kraemer et al., 1990; Mulligan et al., 1996). Growth hormone is known to increase glucose and amino acid uptake and promotes protein synthesis for muscle hypertrophy. (De Palo, Gatti, Lancerin, Cappellin, & Spinella, 2001). Some animal and human studies have shown that growth hormone promotes muscle hypertrophy and prevents muscle atrophy (Grindeland et al., 1994; Linderman, Gosselink, Booth, Mukku, & Grindeland, 1994; Vittone et al., 1997); whereas, other studies have shown no such effects (Taaffe et al, 1994; Yarasheski et al., 1992; Yarasheski, Zachwieja, Campbell, & Bier, 1995). Research on human growth hormone and its effects on muscular adaptations are not conclusive; however, it is hypothesized that even 10-20% of 1 RM resistance exercise, when combined with vascular occlusion, produces adequate stimuli to promote growth hormone secretion, which contributes to muscle size and strength gains.

Summary

The decline of muscular fitness causes health-related problems. Resistance training is the most common approach for improving muscular fitness. Adaptations caused by resistance training, including neural and muscular adaptations, are complex phenomena. New findings of muscular adaptations have been reported when resistance training is performed, along with restricted blood flow to the working muscles.

The present study investigated the effects of low-intensity exercise on muscular fitness when combined with vascular occlusion. The study was conducted because few studies have used daily physical activities, such as walking and stepping, as exercise regimens combined with vascular occlusion. Step exercise was chosen because it requires no expensive equipment, has a low risk of injury, and is easy to perform. If research demonstrated that daily physical activities with vascular occlusion were effective in promoting muscle size, strength, and endurance gains, this training would be available to more people. Older people and rehabilitating patients would be able to improve muscular fitness more safely.

CHAPTER 3

METHODS

Subjects

Male (n = 8) and female (n = 11) college students participated in the study. Overall physical characteristics of the subjects are described in Table 1. They were not engaged in a regular, heavy resistance training programs at the time of the study. Prior to the beginning of the study, all subjects signed and agreed to an informed consent form approved by the University of Nevada, Las Vegas (UNLV) Biomedical Institutional Review Board (Appendix A). The subjects also completed the Physical Activity Readiness Questionnaire – PAR-Q (Appendix A) and Additional Questionnaire for Participants – AQP (Appendix A). Those who answered yes to any question on either of the two questionnaires were eliminated from the study.

Subject	Gender	Age	Ht. (cm)	Wt. (kg)	Resting Blood Pressure at Thigh		
					Systolic	Diastolic	Midpoint
1	M	33	163.0	77.1	126	82	104
2	M	20	171.5	84.8	120	80	100
3	M	23	177.3	79.1	120	80	100
4	M	22	180.0	74.2	130	60	95
5	M	25	178.5	83.7	130	50	90
6	M	25	181.0	69.5	110	70	90
7	M	25	189.5	99.0	122	75	99
8	M	18	177.5	66.5	110	56	83
Mean		23.9	177.3	79.2	121.0	69.1	95.1
SD		4.5	7.6	10.2	7.9	12.3	6.9

Subject	Gender	Age	Ht. (cm)	Wt. (kg)	Resting Blood Pressure at Thigh		
					Systolic	Diastolic	Midpoint
1	F	25	168.5	74.1	115	58	87
2	F	19	158.5	59.6	130	80	105
3	F	34	160.0	59.0	118	60	89
4	F	24	167.5	70.3	114	70	92
5	F	28	163.0	66.5	110	60	85
6	F	19	168.0	63.1	122	80	101
7	F	23	159.0	51.3	120	75	98
8	F	30	164.5	58.7	116	70	93
9	F	23	169.5	62.4	122	70	96
10	F	23	157.0	53.7	130	80	105
11	F	30	174.5	59.9	124	80	102
Mean		25.3	164.5	61.7	120.1	71.2	95.6
SD		4.7	5.5	6.7	6.4	8.7	7.1

Subject	Gender	Age	Ht. (cm)	Wt. (kg)	Resting Blood Pressure at Thigh		
					Systolic	Diastolic	Midpoint
Mean		24.7	169.9	69.1	120.5	70.3	95.4
SD		4.6	9.0	12.0	6.8	10.1	6.9

Table 1: Physical characteristics of the subjects in: 1) males, 2) females, and 3) both genders.

General Procedures

Subjects completed a 5-week training program, a pre-test before the training program, and a post-test after the training program. A one-day orientation session was given to the subjects before the experiments. During the orientation session, blood pressure (BP) was taken at the thigh for each subject. While a subject was lying prone on the padded table, a standard manual thigh BP cuff (20.5-cm width; 76.0-cm length) was placed around the left thigh slightly above the subject's knee. A stethoscope was placed on the popliteal fossa with the upper portion of the stethoscope diaphragm covered with the bottom of the cuff. Then, the cuff was inflated to 200 mmHg, and gradually released. The first sound heard through the stethoscope was identified as systolic BP. After subsequent sounds disappeared, it was identified as diastolic BP. Both systolic and diastolic BP were recorded, and a midpoint between the two BP was determined for each subject (Table 1).

After the BP measurement, the subjects had a trial session to perform step exercise with vascular occlusion, so that they could be familiar with an exercise protocol. The BP cuff was placed around one thigh of a subject, which served as an occluded leg; whereas, the other leg served as a non-occluded leg. The occluded and non-occluded legs were counterbalanced between a dominant and a non-dominant leg among the subjects. Then, the cuff was inflated to a midpoint between systolic and diastolic BP for each subject to partially restrict blood flow to the muscles distal to the cuff. While one leg was under a vascular occlusion condition, the subjects performed stepping using a 12-inch bench (Figure 1). After a few minutes of stepping, the cuff was deflated and removed from the subject's leg.

Figure 1: Step exercise with vascular occlusion.

Instructions for testing protocols to measure muscular fitness were given during the orientation session. Trial sessions for muscular strength and endurance tests were also held to familiarize the subjects with testing protocols and to find the baseline muscular strength and endurance for each subject.

Training Protocol

Subjects completed three training sessions per week for a total of 5 weeks (15 sessions). An training session consisted of two sets of 100 steps combined with vascular occlusion. An exercise protocol, including the use of a BP cuff for vascular occlusion, was the same as the orientation session. The mean occlusion pressure used among the subjects was $[95.4 \pm 6.9 \text{ mmHg (mean} \pm \text{SD)}]$. The stepping rate was maintained at 20 steps/min with a metronome set at 80 beats/min, which resulted in four beats/step (up, up,

down, down). Therefore, completing 100 steps lasted 5 minutes. A lead leg was changed every 10 steps to counterbalance the training intensity between the legs. During a 100-step exercise, the BP cuff was kept inflated, and immediately after completing 100 steps, the cuff was deflated. The cuff was inflated again prior to the second set of 100 steps. A 5-minute rest was provided between the sets. After each training session, the subjects rated any discomfort during exercise using the Borg CR10 Scale (Borg, 1988) (see Appendix A).

Measurements of Muscular Fitness

Subjects completed a three-day testing session before and after the 5-week training period (pre- and post-test). On the first day, lean and fat mass for each leg was measured with the dual-energy x-ray absorptiometry (DEXA; GE Lunar Corporation, Washington, D.C.) (Figure 2).

Figure 2: Dual-energy x-ray absorptiometry (DEXA).

On the second day, muscular strength (1 RM) for each leg was determined using unilateral leg press with the incline leg press machine (Figure 3). First of all, a subject placed his or her legs on the weighted plate, while sitting on the machine. Then, the subject slightly pushed the weighted plate with both legs and released the support systems attached by the side of the machine with the arms. Next, the subject released one leg (non-tested leg) from the weighted plate. The subject lowered and then pushed the weighted plate back to the starting position at a full range of motion. After completion of exercise, the support systems were replaced. After a warm-up of 5-10 repetitions at about 30-50% of his or her body mass as resistance, a subject began one repetition trial, starting with body mass as the first resistance. If the lift was succeeded, resistance was increased; whereas, if the lift was failed, resistance was decreased. The one repetition trial was continued until 1 RM was determined. If 1 RM was not determined within five trials, another testing session was given to the subjects.

Figure 3: Measurements of muscular strength and endurance.

On the third day, muscular endurance (50% of 1 RM endurance) for each leg was determined. A subject performed leg press at a set resistance until he or she could no longer continue, and the number of repetitions completed until failure was recorded. The exercise protocol was the same as the 1 RM strength test. Resistance was 50% of 1 RM strength that was determined in the pre-test, and was also used in the post-test.

Statistical Analysis

Mean 1 RM strength, 50% of 1 RM endurance, lean and fat mass for each leg were analyzed using a 2 (test) x 2 (blood flow) analysis of variance (ANOVA) with repeated measures on both factors.

CHAPTER 4

RESULTS AND DISCUSSION

Vascular occlusion did not affect any of the muscular fitness measurements in men or women ($p > .05$). Muscular strength and endurance were increased after the 5-week step exercise with or without vascular occlusion in both men and women ($p < .05$). Lean and fat mass of the leg was not changed after the 5-week step exercise with or without vascular occlusion in either of the genders ($p > .05$).

Muscular Strength

1 RM strength (kg) of both occluded and non-occluded legs was measured before and after the 5-week training period, using isotonic unilateral leg press with the leg press machine. After the 5-week step exercise program, 1 RM strength in men was significantly increased from 82.6 to 98.1 kg for the occluded leg and from 85.6 to 93.0 kg for the non-occluded leg, respectively (see Figure 4-A). In women, 1 RM strength was significantly increased from 42.8 to 54.1 kg for the occluded leg and 41.3 to 48.6 kg for the non-occluded leg, respectively. The results are shown in Figure 4-B. The interaction was not significant between test (pre and post) and blood flow (occlusion and no occlusion) in either men ($F_{1,7} = 5.511, p = .0513$) or women ($F_{1,10} = 3.956, p = .0748$). However, there was a trend that strength gain of the occluded leg was greater than that of the non-occluded leg in both genders.

There was a significant increase in 1 RM strength before and after the 5-week step exercise in both men (main effect for test: $F_{1,7} = 8.845$, $p = .0207$) and women (main effect for test: $F_{1,10} = 19.728$, $p = .0013$). There was no significant difference in 1 RM strength between the occluded and non-occluded legs in either men (main effect for blood flow: $F_{1,7} = .226$, $p = .6490$) or women (main effect for blood flow: $F_{1,10} = 4.382$, $p = .0628$). The 5-week step exercise program was effective in promoting muscular strength gain; however, vascular occlusion had no additional effect on promoting muscular strength gain.

Figure 4-A: Difference of muscular strength in men before and after the 5-week step exercise with or without vascular occlusion. * Significant difference ($p < .05$).

Figure 4-B: Difference of muscular strength in women before and after the 5-week step exercise with or without vascular occlusion. * Significant difference ($p < .05$).

Muscular Endurance

50% of pre-test 1 RM endurance (repetitions) of both occluded and non-occluded legs was measured before and after the 5-week training period, using the same exercise protocol as the strength test. 50% of 1 RM strength (kg) determined at the pre-test was used as resistance during both pre- and post-test. After the 5-week step exercise program, 50% of pre-test 1 RM endurance in men was increased from 19 to 26 repetitions for the occluded leg and from 20 to 27 repetitions for the non-occluded leg, respectively (see Figure 5-A). In women, 50% of pre-test 1 RM endurance was increased from 14 to 28 repetitions for the occluded leg and 14 to 23 repetitions for the non-occluded leg, respectively. The differences can be seen in Figure 5-B. The interaction was not significant between test (pre & post) and blood flow (occlusion & no occlusion) in either men ($F_{1,7} = .107$, $p = .7536$) or women ($F_{1,10} = 4.764$, $p = .0540$). However, although not

statistically significant, there was a trend that endurance gain in the occluded leg was greater than that in the non-occluded leg in women.

There was a significant increase in 50% of 1 RM endurance before and after the 5-week step exercise in both men (main effect for test: $F_{1,7} = 8.103$, $p = .0248$) and women (main effect for test: $F_{1,10} = 19.779$, $p = .0012$). There was no significant difference in 50% of 1 RM endurance between the occluded and non-occluded legs in either men (main effect for blood flow: $F_{1,7} = .467$, $p = .5165$) or women (main effect for blood flow: $F_{1,10} = 2.626$, $p = .1362$). Although the 5-week step exercise program was effective in promoting muscular endurance gain, the vascular occlusion had no effect on promoting muscular endurance gain.

Figure 5-A: Difference of muscular endurance in men before and after the 5-week step exercise with or without vascular occlusion. * Significant difference ($p < .05$).

Figure 5-B: Difference of muscular endurance in women before and after the 5-week step exercise with or without vascular occlusion. * Significant difference ($p < .05$).

Lean and Fat Mass

Lean and fat mass of both occluded and non-occluded legs were measured using the dual-energy X-ray absorptiometry (DEXA) before and after the 5-week training period.

There were no significant changes in lean mass before and after the 5-week step exercise program, or between occluded and non-occluded legs in either men or women. These changes can be seen in Figure 6-A and 6-B. The interaction was not significant between test (pre & post) and blood flow (occlusion & no occlusion) in either men ($F_{1,7} = .217$, $p = .6553$) or women ($F_{1,10} = .194$, $p = .6686$). Either of the main effects were not significant in men (test: $F_{1,7} = 2.904$, $p = .1321$; blood flow: $F_{1,7} = 1.725$, $p = .2304$) or women (test: $F_{1,10} = 1.251$, $p = .2895$; blood flow: $F_{1,10} = .663$, $p = .4345$). The results indicates that the 5-week step exercise with or without vascular occlusion did not affect lean mass of the leg.

Figure 6-A: Difference of lean mass in men before and after the 5-week step exercise with or without vascular occlusion. No significant difference ($p > .05$) between pre- and post-test with or without vascular occlusion.

Figure 6-B: Difference of lean mass in women before and after the 5-week step exercise with or without vascular occlusion. No significant difference ($p > .05$) between pre- and post-test with or without vascular occlusion.

Likewise, Figure 6-C and 6-D show that there was no significant change in fat mass before and after the 5-week step exercise program, or between occluded and non-occluded legs in either men or women. The interaction was not significant between test (pre & post) and blood flow (occlusion & no occlusion) in either men ($F_{1,7} = .004$, $p = .9521$) or women ($F_{1,10} = .098$, $p = .7610$). Either of the main effects were not significant in men (test: $F_{1,7} = .267$, $p = .6214$; blood flow: $F_{1,7} = 2.086$, $p = .1919$) or women (test: $F_{1,10} = .154$, $p = .7030$; blood flow: $F_{1,10} = .717$, $p = .4170$). The results indicates that the 5-week step exercise with or without vascular occlusion did not affect fat mass of the leg.

Figure 6-C: Difference of fat mass in men before and after the 5-week step exercise with or without vascular occlusion. No significant difference ($p > .05$) between pre- and post-test with or without vascular occlusion.

Figure 6-D: Difference of fat mass in women before and after the 5-week step exercise with or without vascular occlusion. No significant difference ($p > .05$) between pre- and post-test with or without vascular occlusion.

Pain Scale

Discomfort during the exercise was rated using the Borg CR10 Scale (Borg, 1988) (see Appendix A). Mean pain scales of the male subjects for each training week were 2.1 (1st week), 1.8 (2nd week), 1.6 (3rd week), 1.4 (4th week), and 1.0 (5th week), respectively. For the female subjects, they were 2.4 (1st week), 1.9 (2nd week), 1.7 (3rd week), 1.5 (4th week), and 1.2 (5th week), respectively. These results suggest that the subjects became accustomed to the step exercise with vascular occlusion throughout the 5 week training period. No subjects could not complete 5 minutes of stepping because of discomfort or pain.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The present study showed that a 5-week step exercise combined with vascular occlusion did not affect muscular strength, endurance, and lean and fat mass of the leg differently than step exercise without vascular occlusion. After 5 weeks of training, muscular strength and endurance were increased for both occluded and non-occluded legs in men and women. Lean and fat mass of both legs did not change before and after the training.

Past studies have demonstrated that vascular occlusion promotes greater gains in muscle size, strength, and endurance when incorporated into low-intensity resistance training (Shinohara, Kouzaki, Yoshihisa, & Fukunaga, 1998; Takarada, Sato, & Ishii, 2002; Takarada et al., 2000b; Takarada, Tsuruta, & Ishii, 2004). Abe, Kearns, and Sato (in press) showed that treadmill walking achieved increases in muscle size and strength when combined with vascular occlusion; whereas, such increases did not occur after treadmill walking without vascular occlusion. Currently, it is not clear why there are differences of the results between the present and the past studies. However, the effects of vascular occlusion on muscular adaptations may be dependent on factors, such as the methods for restricting blood flow, level of occlusion pressure, and training protocols.

The present study used a standard manual blood pressure (BP) cuff to partially restrict blood flow to the working muscles. During the step exercise, occlusion pressure was changing throughout the exercise. In contrast, Abe et al. (in press), Takarada et al. (2002), and Takarada et al. (2000b) used a specially designed elastic belt (M.P.S.-700, VINE Medical Instruments Inc. Tokyo, Japan) that electrically monitored the occlusion pressure and therefore could maintain a constant pressure during the exercise. There are other studies that did not use such elastic belt to achieve vascular occlusion. According to Burgomaster et al. (2003), 8 weeks of low-intensity (50% of 1 RM) isotonic elbow flexion exercise produced a similar increase in isokinetic strength of the elbow flexor muscles between the occluded and the non-occluded arm, indicating no effects of vascular occlusion. Moore et al. (2004) found that vascular occlusion induced a greater increase in isometric maximal voluntary contraction (MVC) of the elbow flexor muscles after 8 weeks of low-intensity (50% of 1 RM) isotonic elbow flexion exercise. However, there was no additional effect of vascular occlusion on increasing maximal voluntary dynamic strength (Moore et al., 2004). It is speculated that the lack of oxygen in the muscles caused by vascular occlusion elevates plasma lactate concentration during the exercise, which activates additional motor units to maintain the same force production and therefore promotes greater muscle size and strength gains (Takarada et al., 2000a, 2000b). It may be crucial that a certain occlusion pressure be maintained during the exercise, so that plasma lactate is accumulated. Applying a constant occlusion pressure, rather than a variable occlusion pressure, to the working muscles may be an essential part of the training to maximize the training effects of vascular occlusion.

The differences of a level of occlusion pressure may be the reason for the inconsistent results among the studies. In the present study, a midpoint between systolic and diastolic BP for each subject was used as occlusion pressure. A mean occlusion pressure was 95 mmHg. However, occlusion pressure at the end of the exercise was mostly below the original set pressure. There was a possibility that the BP cuff placed around a subject's thigh slipped, while he or she was stepping, which could result in a decreased occlusion pressure. Most of the past studies that found the benefits of vascular occlusion used much higher occlusion pressure, such as around 200 mmHg (Abe et al., in press; Shinohara et al., 1998; Takarada et al., 2002; Takarada et al., 2004). Burgomaster et al. (2003) used an occlusion pressure of 100 mmHg and didn't find the difference of strength gains between the occluded and the non-occluded arm after 8 weeks of low-intensity (50% of 1 RM) isotonic elbow flexion exercise. Moore et al. (2004) found that vascular occlusion at a pressure of 100 mmHg induced a greater increase in isometric strength but had no effect on dynamic strength gain after 8 weeks of low-intensity (50% of 1 RM) isotonic elbow flexion exercise. On the other hand, Takarada et al. (2000b) demonstrated that occlusion pressure of 110 mmHg promoted greater muscle size and strength gains when incorporated into 16 weeks of low-intensity (50% of 1 RM) isotonic elbow flexion exercise. From these inconsistent results, it is not clear whether there is a certain occlusion pressure that maximizes the effects of vascular occlusion on training adaptations.

It is important to compare exercise regimens and training intensity among the studies. Most of the studies combined resistance training (isometric, isotonic, or isokinetic) with vascular occlusion (Shinohara et al., 1998; Takarada et al., 2002; Takarada et al., 2000b;

Takarada, et al., 2004); whereas, only a handful of research used daily physical activities, such as walking, as an exercise regimen (Abe, et al., 2005). According to Abe et al. (in press), after 3 weeks (36 sessions) of treadmill walking (50 m/min) with both legs either occluded (160-230 mmHg) or not occluded, there were increases in muscle size, isotonic strength, and isometric MVC of the knee extensor muscles in the occlusion group. However, no significant changes in any of the measurements were found in the non-occlusion group (Abe, et al., 2005). A mean oxygen uptake (VO_2) in the occlusion group was 708 ml/min (Abe et al., in press). By their estimation, it is equal to the metabolic cost of 10-20% of 1 RM resistance exercise (Abe et al., in press). In the present study, VO_2 during the step exercise was not measured. However, from the metabolic equations by American College of Sports Medicine (2000), an estimated VO_2 of stepping using a 12-inch bench with a stepping rate of 20 steps/min is 22.1 ml/kg/min. Since a mean body mass of the subjects in the present study was 79.2 kg, a mean absolute VO_2 was 1,750 ml/min, which is a greater energy expenditure than that measured in the study by Abe et al. (in press). In fact, 5 weeks of step exercise promoted muscular strength and endurance gains regardless of applying vascular occlusion or not. From the metabolic cost standpoint and the results of the present study, the step exercise used in the present study produced adequate training stimuli to induce adaptations to the training.

Neural adaptations to the training may explain the lack of significant changes in lean and fat mass of the legs observed in the present study. It has been indicated that major strength gain during the first 3-5 weeks of resistance training is mainly caused by neural adaptations, such as changes in pattern and magnitude of motor unit activation, without a significant increase in muscle size (Hakkinen, Pakarinen, & Kallinen, 1992; Moritani,

DeVries, 1979; Sale, 1988). Another study demonstrated that body composition was not changed after 8 weeks of traditional high-intensity (80% of 1 RM) or superslow (50% of 1 RM) resistance training (Neils, Udermann, Brice, Winchester, & McGuigan, 2005). Therefore, it is speculated that increased strength after the 5-week step exercise with or without vascular occlusion was caused by neural adaptations, which resulted in no significant changes in lean and fat mass of the legs.

Conclusions

The addition of vascular occlusion to a 5-week step exercise program did not result in greater muscular strength and endurance gains. However, low-intensity exercise, such as two sets of a 5-min step exercise three times per week for 5 weeks, was found to be an effective training protocol to increase muscular strength and endurance for previously untrained individuals. The 5-week step exercise did not affect lean and fat mass of the legs regardless of applying vascular occlusion or not.

Recommendations

1. The present study used a standard manual BP cuff that resulted in a variable occlusion pressure during the exercise. Future research should include the use of equipment that can maintain a constant occlusion pressure during the exercise. The differences of training adaptations between a variable and a constant occlusion pressure should be investigated.
2. The present study used a midpoint between systolic and diastolic BP for each subject as an occlusion pressure. A mean occlusion pressure used in the present study was 95

mmHg. Future research should examine the training adaptations caused by different levels of occlusion pressure.

3. The training period used in the present study was 5 weeks. Future research should include a step exercise program for a longer training period to determine muscular adaptations to the training.
4. Future research should investigate the relationship between plasma lactate concentration and training adaptations. It is hypothesized that elevated plasma lactate concentration caused by vascular occlusion is a major cause of muscle size and strength gains. It should be examined whether low-intensity exercise, such as step exercise, combined with vascular occlusion can elevate plasma lactate concentration during the exercise.
5. Future research should include potential side effects of restricting blood flow during exercise, which has yet to be studied and understood.

APPENDIX A

INFORMED CONSENT

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE – PAR-Q

ADDITIONAL QUESTIONNAIRE FOR PARTICIPANTS – AQP

BORG CR10 SCALE

INFORMED CONSENT

Department of Kinesiology

TITLE OF STUDY: Step Exercise with Vascular Occlusion: Effects on Muscular Fitness

INVESTIGATOR(S): Lawrence A. Golding, Ph.D. / Masaru Teramoto, B.S.

CONTACT PHONE NUMBER: (702) 895-3766 / (702) 895-2069

Purpose of the Study

You are invited to participate in a research study. The purpose of this study is to investigate the effects of low-intensity exercise on muscular fitness when blood flow of working muscles is moderately restricted.

Participants

You are being asked to participate in the study because you:

1. are a healthy adult.
2. have no injury at the lower body for the past 6 months, or no difficulty in flexing and extending a hip, knee, or ankle joint.

You will not be allowed to participate in this study if you are pregnant. The reason for this is that bone mineral density is determined using the DEXA scanner, a diagnostic X-ray device.

The UNLV Radiation Safety Office has developed the UNLV Reproductive Health Program to ensure that people occupationally exposed to radiation at UNLV are aware of the risks associated with their exposure. In addition, the principles of radiation protection require that ALL doses (this includes medical examinations) be kept As Low As Reasonable Achievable (ALARA).

This is of particular concern in a study such as this because a developing fetus is especially sensitive to radiation exposure in the first trimester of pregnancy.

The dose that a subject receives from the evaluation of bone mineral density is approximately three (3) millirem. Three millirem is less than 1% of the dose that we receive annually as a result of living in Las Vegas and is 0.6% of the limit for exposure of declared pregnant radiation workers.

The investigators recognize that the risks of participation in this study are very low, but they do not wish to expose a fetus to any unnecessary radiation.

For any female, there is a possibility that you are pregnant but do not know that you are. If it is found that you are pregnant after the study, you should know that the potential for damage of the exposed fetus is extremely low.

Concern for damage to an exposed fetus is typically expressed at a dose level of greater than 5000 millirem. The International Commission on Radiological Protection recommends that a one time fetal dose should not exceed 10000 to 20000 millirem.

Procedures

If you volunteer to participate in this study, you will be asked to do the following:

You will be asked to report to the UNLV Exercise Physiology Laboratory for an orientation session. During the orientation session, you will be asked to answer all of the questions in the Physical Activity Readiness Questionnaire – PAR-Q and Additional Questionnaire for Participants – AQP. If you have answered “YES” to one or more questions in either PAR-Q or AQP, you will not be asked to participate in the study. Also, your blood pressure will be measured at the thigh. If systolic blood pressure is 140 mmHg or more and diastolic blood pressure is 90 mmHg or more, you will not be asked to participate in the study.

After passing screening, you will be assigned to either 1) Group I or 2) Group II. If you are in Group I, a standard blood pressure cuff will be strapped around one of your upper legs (thigh) and inflated to the midpoint between your systolic and diastolic blood pressure. This will *moderately* restrict blood flow of the thigh. Then, you will perform stepping up and down for about a minute using a 12-inch box during moderate blood flow restriction. If you are in Group II, you will perform stepping without the blood pressure cuff. This will enable you to get accustomed to exercise that you will be doing during a training session. You will also be instructed how to perform leg press with a single leg using a seated leg press machine.

After the orientation session, you will be asked to attend a three-day testing session. On the first day, you will be asked to report to the UNLV Bigelow Health Sciences Building (BHS). Fat and lean body mass for each leg will be measured using the DEXA scan. The non-invasive DEXA scan will take approximately 20 minutes. On the second and third day, you will be asked to report to the UNLV Exercise Physiology Laboratory. On the second day, thigh girth and muscular strength for each leg will be measured. The strength test will determine a maximal weight that you can successfully leg press only one time with a single leg using the seated leg press machine. On the third day, muscular endurance for each leg will be measured using the seated leg press machine. The endurance test will measure how many times you can successfully leg press 50% of the weight determined during the strength test with a single leg.

After the testing session, you will be asked to report to the UNLV Exercise Physiology Laboratory 3 days a week for a total of 6 consecutive weeks to attend a training session. During the training session, you will again perform the same step exercise just like you did during the orientation session. This time, however, you will follow a metronome rhythm or beat while stepping, such as “up” (1 beat), “up” (1 beat), “down” (1 beat), “down” (1 beat). 1 complete cycle (up, up, down, down = 4 beats) will be counted as 1 step. You will be asked to complete two sets of 100 steps with a 5 to 10 minute rest between the sets. Completing 100 steps will last about 5 minutes. If you are in Group I, the blood pressure cuff will be also strapped around the thigh and inflated throughout an exercise set. Immediately after you finish each exercise set (100 steps), the cuff will be deflated and will not be inflated again until the beginning of the next 100 steps

After the 6-week training period, you will be again asked to attend the three-day testing session. Fat and lean body mass (by the DEXA scan), thigh girth, muscular strength and endurance will be measured again.

Benefits of Participation

There *may not* be direct benefits to you as a participant in this study. However, we hope to learn how step exercise training will affect muscular fitness when blood flow of working muscles is moderately restricted.

Risks of Participation

There are risks involved in all research studies. This study may include only minimal risks. Muscle and joint injuries are possible in any resistance exercise. You may have muscle soreness due to performing step exercise or taking the strength and endurance tests. To help minimize risks, you will be encouraged to warm-up by slowly stepping up and down a 12-inch box for a few minutes before each training session. You will be also encouraged to warm-up by leg pressing 5 to 10 times using a leg press machine without weight before the strength test. Uncomfortable sensation (mild pain, mild numbness, etc.) or lack of sensation in the leg during step exercise may occur due to restriction of blood flow. To help minimize risks, we will check your skin color change and swelling of leg, ankle, or foot during and after exercise to make sure your blood flow is not completely restricted. The DEXA scans will provide a small amount of exposure to radiation. Each scan provides approximately the same amount of radiation you receive from living in Nevada for less than 8 days. The risk associated with this exposure is minimal.

Cost /Compensation

There *will not* be financial cost to you to participate in this study. The study will take 60 minutes during a one-day orientation session, 60 minutes during a pre-test session for 3 days, 60 minutes during a training session 3 days a week for a total of 6 consecutive weeks, and 60 minutes during a post-test session for 3 days of your time. You *will not* be compensated for your time. *The University of Nevada, Las Vegas may not provide compensation or free medical care for an unanticipated injury sustained as a result of participating in this research study.*

Contact Information

If you have any questions or concerns about the study, you may contact Dr. Lawrence Golding at **702-895-3766** or Masa Teramoto at **702-895-2069**. For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact **the UNLV Office for the Protection of Research Subjects at 702-895-2794.**

Voluntary Participation

Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with the university. You are encouraged to ask questions about this study at the beginning or any time during the research study.

Confidentiality

All information gathered in this study will be kept completely confidential. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked facility at UNLV for at least 3 years after completion of the study. After the storage time the information gathered will be shredded and destructed.

Participant Consent:

I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

Signature of Participant

Date

Participant Name (Please Print)

Participant Note: Please do not sign this document if the Approval Stamp is missing or is expired.

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7. Do you know of <u>any other reason</u> why you should not do physical activity?

If
you
answered

YES to one or more questions

Talk with your doctor by phone or in person **BEFORE** you start becoming much more physically active or **BEFORE** you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PARENT
or GUARDIAN (for participants under the age of majority) _____

WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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You Can Do It - Working 24 hrs a day outside from your truck

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• K-ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee.	• F-ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee.
• G-ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee.	• C-ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee.
• P-ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee.	• T-ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee ee.
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Benefits of regular walking: Health risks of inactivity

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Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 <http://www.hc-sc.gc.ca/hpp/bp/p2guide/pdf/guideEng.pdf>

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FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below).

The Physical Activity Readiness Questionnaire (PAR-Q) — to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The Physicist At Activity Reviews: Medical Examination for Pregnancy (PAPmed-X for Pregnancy) -- to be used by doctors with pregnant patients who wish to become more active.

References:

Arrais, G.A., Wigle, D.T., Mao, Y (1992). Risk Assessment of Physical Activity and Physical Fitness in the Canada Health Survey Follow-Up Study. *J. Clin. Epidemiol.* 45:4 419-428.

Hotz, B., Hult, L.A. (1994) Active Living and Pregnancy. In: A. Quinney, L. Gavett, T. Hall (eds.) *Toward Active Living: Proceedings of the International Conference on Physical Activity, Fitness and Health Campaign*, IL: Human Kinetics.

PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

Thomas, S., Reading, J., Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Can. J. Sport Sci.* 17:4 338-345.

For more information, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West

Ottawa, ON K2P 0J2

Tel. 1-877-651-3755 • FAX (613) 234-3565

Online: www.tscap.co

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gladhill (2002).

Disponible en français sous le titre «Questionnaire sur l'aptitude à l'activité physique - Q-APP (révisé 2002)».

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ADDITIONAL QUESTIONNAIRE FOR PARTICIPANTS – AQP

Department of Kinesiology

TITLE OF STUDY: Step Exercise with Vascular Occlusion:

Effects on Muscular Fitness

INVESTIGATOR(S): Lawrence A. Golding, Ph.D. / Masaru Teramoto, B.S.

CONTACT PHONE NUMBER: (702) 895-3766 / (702) 895-2069

This questionnaire is necessary for us to determine whether you will be asked to participate in testing and training sessions in the study or not.

Please read each question carefully and answer it by checking YES or NO.

YES NO

☐	☐	1. Have you had injury at the lower body for the past 6 months?
☐	☐	2. Do you have problem or difficulty in stepping up and down using a 12-inch bench? If you are not sure, please try stepping using a 12-inch bench equipped in the UNLV Exercise Physiology Laboratory and then answer the question.
☐	☐	3. Has your doctor ever said that you have a circulatory disease?
☐	☐	4. Is your systolic blood pressure (_____ mmHg taken by Masaru Teramoto) 140 mmHg or higher?
☐	☐	5. Is your diastolic blood pressure (_____ mmHg taken by Masaru Teramoto) 90 mmHg or higher?
☐	☐	6. Have you taken DEXA scans or X-ray for the past 3 months?

Signature of Participant

Date

Participant Name (Please Print)

Witness

Borg CR10 Scale (Borg, 1998)

0	Nothing at all	“No P”
0.3		
0.5	Extremely weak	Just noticeable
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	“Max P”
11		
↗		
•	Absolute maximum	Highest possible

APPENDIX B

RAW DATA

Muscular Strength

Subject	Gender	1 RM Strength (kg)			
		Non-Occluded Leg		Occluded Leg	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	M	86	104	86	118
2	M	113	136	113	136
3	M	64	73	59	82
4	M	73	82	77	91
5	M	132	136	122	145
6	M	45	50	45	54
7	M	86	68	64	64
8	M	86	95	95	95
Mean		85.6	93.0	82.6	98.1
SD		27.20	31.21	26.70	32.64

Subject	Gender	1 RM Strength (kg)			
		Non-Occluded Leg		Occluded Leg	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	F	50	54	50	64
2	F	32	50	36	45
3	F	32	41	36	59
4	F	73	77	73	82
5	F	50	45	50	50
6	F	45	64	50	77
7	F	27	41	18	32
8	F	27	32	36	41
9	F	36	41	41	45
10	F	41	45	36	50
11	F	41	45	45	50
Mean		41.3	48.6	42.8	54.1
SD		13.34	12.50	13.70	15.17

Muscular Endurance

Subject	Gender	50% of Pre-Test 1 RM Endurance (Repetitions)			
		Non-Occluded Leg		Occluded Leg	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	M	20	35	18	39
2	M	39	40	35	39
3	M	22	28	19	32
4	M	20	22	23	21
5	M	20	22	20	26
6	M	16	18	16	20
7	M	14	15	8	10
8	M	12	32	16	23
Mean		20	27	19	26
SD		8.3	8.7	7.7	10.0

Subject	Gender	50% of Pre-Test 1 RM Endurance (Repetitions)			
		Non-Occluded Leg		Occluded Leg	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	F	6	20	4	21
2	F	20	25	18	28
3	F	7	21	8	51
4	F	12	17	13	15
5	F	20	22	19	26
6	F	31	51	30	64
7	F	7	15	6	20
8	F	13	17	10	16
9	F	10	16	8	17
10	F	15	22	17	24
11	F	16	27	18	29
Mean		14	23	14	28
SD		7.4	10.0	7.6	15.5

Lean Mass

Subject	Gender	Lean Mass (g)			
		Non-Occluded Leg		Occluded Leg	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	M	9,173	9,707	9,510	10,050
2	M	10,208	10,368	10,045	10,112
3	M	8,291	8,227	8,171	8,103
4	M	10,893	11,055	10,328	10,719
5	M	11,460	11,359	10,657	10,705
6	M	8,517	8,287	8,710	8,397
7	M	11,030	11,572	10,805	11,258
8	M	9,791	10,080	9,799	10,128
Mean		9,920	10,082	9,753	9,934
SD		1,185.0	1,291.9	925.2	1,118.8

Subject	Gender	Lean Mass (g)			
		Non-Occluded Leg		Occluded Leg	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	F	8,054	8,015	7,677	8,074
2	F	7,282	7,623	6,708	7,092
3	F	6,354	6,394	6,436	6,377
4	F	8,002	8,190	8,162	8,428
5	F	8,282	7,905	8,324	8,075
6	F	6,854	6,795	7,088	6,984
7	F	5,712	6,027	6,056	5,903
8	F	6,832	7,300	6,990	7,166
9	F	7,039	7,348	7,443	7,539
10	F	5,874	5,896	5,988	5,853
11	F	7,490	7,243	7,770	7,743
Mean		7,070	7,158	7,149	7,203
SD		861.3	789.0	802.0	876.4

Fat Mass

Subject	Gender	Fat Mass (g)			
		Non-Occluded Leg		Occluded Leg	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	M	2,474	2,665	2,564	2,756
2	M	3,455	3,235	3,396	3,157
3	M	5,127	4,038	5,051	3,975
4	M	1,816	2,098	1,723	2,033
5	M	2,177	2,127	2,028	2,008
6	M	2,142	2,128	2,197	2,161
7	M	4,383	4,589	4,289	4,465
8	M	1,796	1,849	1,800	1,856
Mean		2,921	2,841	2,881	2,801
SD		1,261.3	1,016.2	1,239.9	985.4

Subject	Gender	Fat Mass (g)			
		Non-Occluded Leg		Occluded Leg	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	F	4,611	4,457	4,398	4,490
2	F	2,735	2,786	2,519	2,599
3	F	2,824	2,848	2,861	2,840
4	F	3,143	2,924	3,205	3,009
5	F	3,267	3,138	3,275	3,205
6	F	3,290	3,711	3,396	3,814
7	F	2,780	2,995	2,949	2,935
8	F	1,872	2,093	1,914	2,055
9	F	3,632	3,392	3,851	3,479
10	F	2,755	2,846	2,807	2,820
11	F	2,386	2,421	2,466	2,582
Mean		3,027	3,056	3,058	3,075
SD		708.6	634.3	683.4	662.0

Pain Scale (Men)

Subject	Gender	Week 1	Week 2	Week 3	Week 4	Week 5
1	M	1	2	2	2	1
		3	3	2	2	1
		3	2	2	2	1
2	M	3	3	3	3	2
		3	3	3	2	2
		3	3	3	3	1
3	M	4	2	2	3	1
		2	2	3	2	1
		3	2	2	2	1
4	M	3	3	3	3	3
		2	3	3	2	2
		2	3	3	3	2
5	M	3	1	2	0.5	1
		1	2	0.5	1	0.5
		2	1	1	0	0
6	M	5	2	1	1	1
		2	2	1	1	0.5
		2	1	1	1	1
7	M	0.5	0.5	0.5	0	0
		0.5	1	0	0	0
		1	0	0	0	0
8	M	0	1	0.5	0	0.5
		0.5	1	0.5	0	0.5
		1	0.5	0.5	0.5	0.5
Mean		2.1	1.8	1.6	1.4	1.0
SD		1.24	0.95	1.09	1.13	0.76

Pain Scale (Women)

Subject	Gender	Week 1	Week 2	Week 3	Week 4	Week 5
1	F	3	1	2	0.5	1
		2	3	3	1	1
		1	2	0.5	0.5	0
2	F	3	2	1	0.5	0.5
		3	2	0.5	1	0.5
		3	2	1	1	0.5
3	F	3	1	2	1	0.5
		1	0.5	3	0.5	2
		4	0.5	1	0.5	0.5
4	F	0.5	0.5	0.5	0	0
		0.5	0.5	0	0	0
		1	0.5	0.5	0.5	0
5	F	3	2	2	1	1
		3	2	2	1	1
		2	2	1	1	1
6	F	5	1	0.5	2	0.5
		1	2	3	2	1
		2	2	3	3	0.5
7	F	2	2	2	2	1
		1	3	2	2	1
		0.5	2	2	2	2
8	F	2	3	3	2	1
		3	2	2	3	2
		4	2	1	3	1
9	F	2	1	0.5	1	1
		3	2	0.5	0.5	1
		2	1	1	1	1
10	F	3	2	2	3	3
		3	3	3	2	3
		3	3	3	2	2
11	F	3	3	2	3	3
		3	3	2	4	3
		4	3	3	3	2
Mean		2.4	1.9	1.7	1.5	1.2
SD		1.14	0.86	0.97	1.05	0.90

APPENDIX C

SUMMARY OF STATISTICS

Differences in Muscular Strength (2 x 2 Repeated ANOVA)

Men

Descriptive Statistics

	Mean	Std. Deviation	N
Pre-No	85.6250	27.19736	8
Pre-Occ	82.6250	26.69905	8
Post-No	93.0000	31.20897	8
Post-Occ	98.1250	32.64282	8

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
test	Sphericity Assumed	1046.531	1	1046.531	8.845	.0207
Error(test)	Sphericity Assumed	828.219	7	118.317		
bf	Sphericity Assumed	9.031	1	9.031	.226	.6490
Error(bf)	Sphericity Assumed	279.719	7	39.960		
test * bf	Sphericity Assumed	132.031	1	132.031	5.511	.0513
Error(test*bf)	Sphericity Assumed	167.719	7	23.960		

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

test	Mean	Std. Error
1	84.125	9.378
2	95.563	11.239

Estimates

Measure: MEASURE_1

bf	Mean	Std. Error
1	89.313	10.126
2	90.375	10.336

Differences in Muscular Strength (2 x 2 Repeated ANOVA)

Women

Descriptive Statistics

	Mean	Std. Deviation	N
Pre-No	41.2727	13.34235	11
Pre-Occ	42.8182	13.69539	11
Post-No	48.6364	12.50018	11
Post-Occ	54.0909	15.16875	11

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
test	Sphericity Assumed	955.114	1	955.114	19.728	.0013
Error(test)	Sphericity Assumed	484.136	10	48.414		
bf	Sphericity Assumed	134.750	1	134.750	4.382	.0628
Error(bf)	Sphericity Assumed	307.500	10	30.750		
test * bf	Sphericity Assumed	42.023	1	42.023	3.956	.0748
Error(test*bf)	Sphericity Assumed	106.227	10	10.623		

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

test	Mean	Std. Error
1	42.045	4.004
2	51.364	4.033

Estimates

Measure: MEASURE_1

bf	Mean	Std. Error
1	44.955	3.748
2	48.455	4.177

Differences in Muscular Endurance (2 x 2 Repeated ANOVA)

Men

Descriptive Statistics

	Mean	Std. Deviation	N
Pre-No	20.3750	8.27971	8
Pre-Occ	19.3750	7.67068	8
Post-No	26.5000	8.71780	8
Post-Occ	26.2500	9.99643	8

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
test	Sphericity Assumed	338.000	1	338.000	8.103	.0248
Error(test)	Sphericity Assumed	292.000	7	41.714		
bf	Sphericity Assumed	3.125	1	3.125	.467	.5165
Error(bf)	Sphericity Assumed	46.875	7	6.696		
test * bf	Sphericity Assumed	1.125	1	1.125	.107	.7536
Error(test*bf)	Sphericity Assumed	73.875	7	10.554		

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

test	Mean	Std. Error
1	19.875	2.756
2	26.375	3.207

Estimates

Measure: MEASURE_1

bf	Mean	Std. Error
1	23.438	2.713
2	22.813	2.886

Differences in Muscular Endurance (2 x 2 Repeated ANOVA)

Women

Descriptive Statistics

	Mean	Std. Deviation	N
Pre-No	14.2727	7.40393	11
Pre-Occ	13.7273	7.57748	11
Post-No	23.0000	10.01998	11
Post-Occ	28.2727	15.46668	11

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
test	Sphericity Assumed	1489.455	1	1489.455	19.779	.0012
Error(test)	Sphericity Assumed	753.045	10	75.305		
bf	Sphericity Assumed	61.455	1	61.455	2.626	.1362
Error(bf)	Sphericity Assumed	234.045	10	23.405		
test * bf	Sphericity Assumed	93.091	1	93.091	4.764	.0540
Error(test*bf)	Sphericity Assumed	195.409	10	19.541		

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

test	Mean	Std. Error
1	14.000	2.243
2	25.636	3.682

Estimates

Measure: MEASURE_1

bf	Mean	Std. Error
1	18.636	2.527
2	21.000	3.137

Differences in Lean Mass (2 x 2 Repeated ANOVA)

Men

Descriptive Statistics

	Mean	Std. Deviation	N
Pre-No	9920.3750	1185.02995	8
Pre-Occ	9753.1250	925.16770	8
Post-No	10081.88	1291.89965	8
Post-Occ	9934.0000	1118.75875	8

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
test	Sphericity Assumed	234441.281	1	234441.281	2.904	.1321
Error(test)	Sphericity Assumed	565019.969	7	80717.138		
bf	Sphericity Assumed	198607.531	1	198607.531	1.725	.2304
Error(bf)	Sphericity Assumed	805795.719	7	115113.674		
test * bf	Sphericity Assumed	750.781	1	750.781	.217	.6553
Error(test*bf)	Sphericity Assumed	24187.469	7	3455.353		

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

test	Mean	Std. Error
1	9836.750	369.969
2	10007.938	423.693

Estimates

Measure: MEASURE_1

bf	Mean	Std. Error
1	10001.125	435.344
2	9843.563	359.192

Differences in Lean Mass (2 x 2 Repeated ANOVA)

Women

Descriptive Statistics

	Mean	Std. Deviation	N
Pre-No	7070.4545	861.31659	11
Pre-Occ	7149.2727	802.00226	11
Post-No	7157.8182	788.95283	11
Post-Occ	7203.0909	876.38878	11

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
test	Sphericity Assumed	54813.841	1	54813.841	1.251	.2895
Error(test)	Sphericity Assumed	438076.409	10	43807.641		
bf	Sphericity Assumed	42346.023	1	42346.023	.663	.4345
Error(bf)	Sphericity Assumed	638927.227	10	63892.723		
test * bf	Sphericity Assumed	3094.568	1	3094.568	.194	.6686
Error(test*bf)	Sphericity Assumed	159141.682	10	15914.168		

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

test	Mean	Std. Error
1	7109.864	246.850
2	7180.455	248.193

Estimates

Measure: MEASURE_1

bf	Mean	Std. Error
1	7114.136	245.850
2	7176.182	251.009

Differences in Fat Mass (2 x 2 Repeated ANOVA)

Men

Descriptive Statistics

	Mean	Std. Deviation	N
Pre-No	2921.2500	1261.28458	8
Pre-Occ	2881.0000	1239.93479	8
Post-No	2841.1250	1016.21165	8
Post-Occ	2801.3750	985.40999	8

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
test	Sphericity Assumed	51040.125	1	51040.125	.267	.6214
Error(test)	Sphericity Assumed	1339025.875	7	191289.411		
bf	Sphericity Assumed	12800.000	1	12800.000	2.086	.1919
Error(bf)	Sphericity Assumed	42957.000	7	6136.714		
test * bf	Sphericity Assumed	.500	1	.500	.004	.9521
Error(test*bf)	Sphericity Assumed	901.500	7	128.786		

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

test	Mean	Std. Error
1	2901.125	441.935
2	2821.250	353.626

Estimates

Measure: MEASURE_1

bf	Mean	Std. Error
1	2881.188	397.438
2	2841.188	388.367

Differences in Fat Mass (2 x 2 Repeated ANOVA)

Women

Descriptive Statistics

	Mean	Std. Deviation	N
Pre-No	3026.8182	708.63796	11
Pre-Occ	3058.2727	683.43267	11
Post-No	3055.5455	634.30645	11
Post-Occ	3075.2727	662.01905	11

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
test	Sphericity Assumed	5750.205	1	5750.205	.154	.7030
Error(test)	Sphericity Assumed	373341.545	10	37334.155		
bf	Sphericity Assumed	7203.841	1	7203.841	.717	.4170
Error(bf)	Sphericity Assumed	100509.909	10	10050.991		
test * bf	Sphericity Assumed	378.205	1	378.205	.098	.7610
Error(test*bf)	Sphericity Assumed	38699.545	10	3869.955		

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

test	Mean	Std. Error
1	3042.545	208.893
2	3065.409	194.929

Estimates

Measure: MEASURE_1

bf	Mean	Std. Error
1	3041.182	200.388
2	3066.773	200.594

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