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The effects of breathing techniques upon blood pressure during isometric exercise

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THE EFFECTS OF BREATHING TECHNIQUES UPON BLOOD PRESSURE DURING ISOMETRIC EXERCISE

by

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An Abstract

of a thesis submitted in partial fulfillment

of the requirements for the degree of

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Thesis Advisor: Dr. G. A. Sforzo

ABSTRACT

Thirty normotensive college-aged female subjects were studied to assess the effects of ventilatory training upon blood pressure. Subjects were randomly assigned to one of three training groups: (a) The VAL group was taught to perform a Valsalva maneuver during isometric efforts, (b) the NO-VAL group was taught to avoid performing the Valsalva maneuver, and (c) the CONT group was given no instructions. Amplified auscultation of two blood pressure measurements were made pre- and posttraining during 10 contractions of the quadriceps at 65° of knee flexion on a Cybex dynamometer. Breathing patterns were recorded using an impedance pneumograph and physiograph. The data were analyzed using a 2 x 2 x 3 (Time x Trial x Group) MANCOVA design, with resting blood pressure as the covariate. Inspection of a significant Time x Group ($p < .05$) interaction revealed the VAL group had significantly increased (162/124 vs. 179/136 mmHg), the NO-VAL group had significantly decreased (163/120 vs. 148/112 mmHg), and the CONT group had not significantly altered (157/117 vs. 153/117 mmHg) blood pressure response to static exercise following ventilatory training. These data illustrate training to avoid the Valsalva maneuver may

help mitigate the typical blood pressure rise during intense static contractions.

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A Thesis presented to the Faculty of
the Division of Health, Physical
Education, and Recreation
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Requirements for the Degree
Master of Science

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by
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Ithaca College
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Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Patrick O'Connor

submitted in partial fulfillment of the requirements for the degree of Master of Science in the Division of Health, Physical Education, and Recreation at Ithaca College has been approved.

Thesis Advisor:

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Dean of Graduate Studies:

Date: 12/4/89 '0

DEDICATION

This thesis is dedicated to William Ware for his friendship and encouragement throughout the years.

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Chapter 1

INTRODUCTION

According to the United States Public Health Service (U.S. Public Health Service, 1960), disability due to immobilization was one of the leading preventable health problems in 1960 and is still of concern to many health professionals today (Kottke, Stillwell, & Lehmann, 1982). Bed rest, confinement to a wheel chair, posttraumatic and postsurgical states, and acute infections are all causes for therapeutic immobilizations. The physiological effects of immobilization manifest themselves in almost every organ system in the body. Atrophy from disuse causes a decrease in bone density as well as muscle size (Mazess & Whedon, 1983). As a preventive measure, immobilized patients are advised to perform resistive exercise to retard some of these debilitating effects (Kottke et al., 1982). The exercise mode of choice for patients immobilized by casts is often isometric resistance. Studies have shown that isometric exercise performed within a cast against resistance provided by the cast may retard the rate of isometric strength loss (Rozier, Elder, & Brown, 1979).

Isotonic or isokinetic exercises are frequently implemented prior to therapeutic immobilizations. Isometric exercise is more widely used than isotonic or isokinetic exercise following therapeutic immobilization and when immobilization is unavoidable or inadvertent (e.g., the patient in the posttraumatic state immobilized without forewarning). Postsurgical states and many other therapeutic immobilizations may leave isometric exercise as the only exercise available for implementation.

However, many health professionals have discouraged patients from using isometric exercise because it may have an adverse effect on the patient's blood pressure (Asmussen, 1981; Holtman & Sjoholm, 1982; Perez-Gonzalez, 1981). Additionally, recent reports documented cases of brain stem injury (Tuxen, Sutton, MacDougall, & Sale, 1983) and subarachnoid hemorrhage (Hall-Jurkowski, Sutton, & Duke, 1983) following maximal weight-lifting efforts. Vascular complications are a major concern for the elderly person experiencing an acute increase in blood pressure. The elderly are immobilized most often, deteriorate the fastest, and require a longer recovery period than the general populace. To make isometric exercise safer by minimizing the increase in blood pressure would be beneficial to all immobilized individuals, particularly the elderly.

Factors determining the blood pressure responses to isometric exercise are generally thought to originate from central and peripheral control mechanisms (Mitchell, Schibye, Payne, & Saltin, 1981; Shepherd, Blomqvist, Lind, Mitchell, & Saltin, 1981). The peripheral response mechanism acts reflexively, sending afferent impulses from the working muscles to cardiovascular centers. The central theory suggests impulses originate from the brain and descend to cardiovascular centers. Although studies have isolated and better defined these control mechanisms, few have attempted to change the local, chemical, or mechanical factors responsible for the peripheral response to isometric exercise.

The exercise-induced increase in blood pressure may be largely due to the mechanical act of inadvertently performing a Valsalva maneuver during isometric effort (Greer, Dimick, & Burns, 1984). The present study was designed to investigate the effect of using learned breathing techniques during isometric exercise on the performance of the Valsalva maneuver and subsequently upon blood pressure.

Scope of the Problem

This study examined the relationship between breathing techniques and systemic blood pressure during isometric exercise. Thirty female Ithaca College students volunteered to serve as subjects. Subjects were randomly assigned to one of three groups. Subjects were provided with detailed explanations and demonstrations before testing and then performed a pretraining isometric exercise regime, three training sessions, and a posttraining isometric exercise regime. Blood pressure was recorded before, during, and after exercise. Testing took place in the Physical Therapy Clinic in Smiddy Hall at the Ithaca College campus. Testing times were consistent for each individual, and all subjects were tested between 3:00 and 10:00 p.m. The data were subjected to a 2 X 2 X 3 (Time by Trial by Group) multivariate analysis of covariance (MANCOVA) to examine any difference in systemic blood pressure that might have been prompted by the experimental condition.

Statement of the Problem

This study was designed to investigate if breathing techniques help individuals avoid performing a Valsalva maneuver and thereby significantly reduce blood pressure elevations commonly seen during maximum isometric contractions.

Null Hypothesis

The teaching of breathing techniques will not significantly eliminate the performance of the Valsalva maneuver or avoid increases in blood pressure during isometric exercise.

Assumptions

This investigation was conducted with the following assumptions:

1. All subjects performed maximally during each isometric exercise trial.

2. A valid measure of blood pressure was recorded during each isometric exercise trial.

3. The detection device allowed deviations in breathing techniques to be recognized.

Definition of Terms

In this investigation, these terms were defined as follows:

1. Dynamic or phasic exercise: Short-lasting muscle contractions interspersed with periods of relaxation.

2. Isokinetic exercise: A dynamic exercise performed at a constant, selected speed of motion. Resistance varies as determined by the muscle's ability

to create tension throughout a range of motion.

3. Isometric exercise: A term used interchangeably with the term static exercise throughout this paper, and accurately described as the contraction of a muscle at a fixed joint angle. The only movement that occurs is the initial shortening of muscle fibers; no observable joint movement occurs.

4. Isotonic exercise: A dynamic exercise performed throughout a range of motion at a variable speed using a fixed external resistance. Isotonic exercise includes both concentric (shortening) and eccentric (lengthening) contractions.

5. Maximal voluntary contraction (MVC): The maximum amount of force that can be generated volitionally by an individual using a given muscle group.

6. Valsalva manuever: A term used to describe an anatomical maneuver involving the closing of the glottis after a full inspiration and a simultaneous maximal contraction of the expiratory muscles.

Delimitations

The design of this investigation had the following delimitations:

1. Subjects were Ithaca College females 18-24

years of age.

2. All isometric contractions were performed with the right knee, and strength was assessed with the Cybex II isokinetic dynamometer.

3. Blood pressure measurements were obtained through auscultation using an amplified stethoscope and a mercury sphygmomanometer.

4. All testing took place between 3:00 and 10:00 p.m. in the Physical Therapy Clinic located in Smiddy Hall at Ithaca College.

5. Positive indication of the performance of a Valsalva maneuver was determined by using an impedance pneumograph and physiograph.

Limitations

The investigation applies the following limitations:

1. The results can only be generalized to the population sampled.

2. Results can only be generalized to isometric exercising between 75-100% MVC in the right quadriceps muscle group immobilized at 65° of knee flexion and using 10-s contraction periods.

3. Results may have been affected by the use of volunteer subjects without regard to their level of

physical training.

4. Results can only be generalized to breathing patterns determined by an impedance pneumograph and physiograph.

Chapter 2

REVIEW OF RELATED LITERATURE

This chapter has been organized according to the following topics: (a) resistive exercise and strength gain, (b) isometric exercise for the immobilized person, (c) cardiovascular control during isometrics, (d) pressure changes during resistive exercise, (e) the Valsalva maneuver, and (f) summary.

Resistive Exercise and Strength Gain

Specific guidelines for maximum isotonic strength gains were developed using the overload principle. This principle states that muscular strength cannot increase without exercise utilizing resistance greater than normally encountered during activities of daily living. DeLorme (1945) developed an isotonic method of progressive resistance exercise by finding an individual's 10-repetition maximum (RM) and having the subject perform sets at 50%, 75%, and 100% of the 10-RM, with weekly adjustments of the 10-RM as strength improved.

German researchers first demonstrated that a single daily isometric contraction performed maximally for 1 s or at 66% of maximum for 6 s allowed a weekly increase of approximately 12% in strength, depending on previous training levels (Hettinger & Muller, 1953). More recent research does not dispute the ability of isometric exercise to develop strength, but has found weekly increases are significantly lower (5%) than Hettinger and Muller originally reported (MacDougall, Elder, Sale, Moroz, & Sutton, 1980). However, MacDougall et al. trained subjects heavily for 5 to 6 months, significantly longer than Hettinger and Muller, and weekly strength gains become smaller as an individual's strength plateaus. Therefore, longer training periods lowered average weekly strength gains, accounting for the variation between the reports.

A review of the literature reveals many comparisons of static and phasic exercise modes. In earlier research, it was found that both isotonic and isometric exercises produced hypertrophy and increased strength of skeletal muscles, although some believed isotonic exercise probably produced the best psychological and physiological results (Rasch & Morehouse, 1957). Many subjects expressed a dislike for isometric exercise because it was frustrating to perform a maximal effort and "see almost nothing happen." Accordingly, subjects found this type of exercise to be boring.

Popularization of the DeLorme (1945) isotonic technique and the isometric strength findings of Hettinger and Muller (1953) stimulated further research. Clinical investigations by Rose and his associates (Rose, Radzyminski, & Beatty, 1957) found that isometric exercises are as effective at increasing strength as gains reported using traditional DeLorme exercises. In this experiment subjects held a maximally loaded quadriceps femoris in full extension for 5 s each day. Strength gains plateaued at approximately 8 weeks.

Liberson and Asa (1959) also compared the effectiveness of daily brief isometric exercise with the traditional DeLorme (1945) method. Individuals (N = 26) were divided into three groups, each exercising the hypothenar eminence. Group A performed isotonic exercise, Group B performed a single isometric maximum contraction, and Group C performed repeated isometric contractions. Results indicated greater increases in both strength and endurance in the isometric exercise groups, with repeated isometric contractions allowing the greatest gains.

More recent research found that torque values varied between an isometric contraction and an isotonic contraction for the knee extensors at different angles (Murray, Gardner, Mollinger, & Sepic, 1980). This may be explained by the inverse relationship between increasing velocity of a contraction and force production (Fenn & March, 1935; Wilkie, 1950). Discussion of this phenomenon is beyond the scope of this text, but it occurs as a result of mechanical properties of the muscle fiber (Murray et al., 1980). The amount of tension in a muscle may be determined by the number of cross-bridges formed between the thick and thin myofilaments during a contraction. Isometric exercises allow more time at any given joint angle, permitting a greater number of cross-bridges to form, thereby producing maximum tension. Due to the constant joint angle unique to isometric exercise, recruitment of more motor units occurs as the contraction is held and muscle fibers begin to fatigue. Isotonic contractions at increasing speeds do not allow adequate time for an optimal number of cross-bridges to form, therefore less tension can develop at any given joint angle.

Isometric and isotonic contractions were not constant at all three joint angles used in the experiment by Murray et al. (1980). This may be attributed to the fact that peak torque tends to occur earlier in the range of motion at higher velocities with isotonic exercise (Moffroid, Whipple, & Hofkosh, 1972).

Past investigators suggested that training improvements may not be significantly different between isotonic and isometric strength, if time, angle, and effort are taken into consideration (Rosentswieg & Hinson, 1972).

Regardless of comparative research between exercise types, both isometric and isotonic exercise are effective modes for increasing muscular strength and endurance. Proper implementation according to the specific demands and needs of the individual should then be the determining factor when choosing between these exercise modalities.

Isometric Exercise for the Immobilized Person

While isometric exercise is an effective strengthening method, the majority of a person's daily activity is done using isotonic contractions. Moreover, as previously indicated, isometrics tend to be boring, making isotonics the popular choice for improving strength in healthy populations. However, isometrics are most practical in therapeutic settings for immobilized individuals whose condition precludes the use of isotonic exercise to maintain strength. Isometrics enable the individual to maintain adequate strength until mobility is regained and isotonic exercise can be resumed.

Immobilization has various detrimental physiological effects, as first reported by Cuthbertson (1929). These were expanded upon (Dietrick, Whedon, & Shorr, 1948), and in the 1960s further research on this topic was stimulated by the exploration of space and the effects of weightlessness (Kottke et al., 1982). In space, the muscular system was found to be specifically affected by significant atrophy with an accompanying decrease in muscle strength, endurance, and coordination. Resistive exercise regimes decreased these negative effects, with isometrics most practical under zero gravity conditions. Further research suggested the use of isometric exercise as a preventive measure to decrease the disabling effects of immobilization on the muscular system (Rozier et al., 1979).

Rozier and colleagues (1979) utilized subjects immobilized by a cast to demonstrate the ability of isometric exercise to prevent significant negative muscular changes from immobilization. College students ($\underline{N}$ = 20) wore a long-leg cast on the left lower extremity for 9 days. The control group performed no exercise, while the experimental group performed five repetitions of 6-s maximum isometric contractions with

6 s of rest between repetitions. The control group demonstrated a significant decrease in quadriceps strength, as measured by the Cybex II isokinetic machine. The experimental group did not experience any decrease in muscular strength.

Patients immobilized in a cast or confined to bedrest are examples of individuals for whom isometric exercises are ideally suited. Liberson and Asa (1959) cited specific case histories in which bedridden patients with limited mobility utilized isometrics effectively to increase strength. Most patients had generalized weakness and were recovering from poliomyelitis. They exercised using the general principles first introduced by Hettinger and Muller (1953). However, it should be noted that isometric exercise programs should be specifically designed according to the condition causing immobilization for maximum strength gains to occur (Fardy, 1981).

Cardiovascular Control during Isometrics

Research comparing isotonic and isometric exercise as a valuable method for increasing strength has been paralleled by investigations concerned with acute rises in blood pressure during resistive exercises. Blood pressure control is multifactorial and is not determined by one factor, but by many interrelated systems. Briefly, two major controls (peripheral and central) are typically thought to be responsible for regulating the blood pressure rise observed during isometric exercise. Note that neither peripheral nor central control act independently, but are believed to work in concert.

The peripheral control theory states that afferent impulses from skeletal muscle chemoreceptors and mechanoreceptors act reflexively to stimulate cardiovascular centers located in the medulla (Mitchell et al., 1981). Reflex activity is thought to originate primarily from chemical metabolites in working muscles stimulating Type III and IV afferent fibers, and mechanoreceptors detecting the change of tension in working muscles follow similar afferent pathways. These afferent fibers ascend along the spinothalamic tract to cardiovascular centers located in the medulla (Shepherd et al., 1981). Vagal activity to the heart decreases as a result of this afferent input to the medulla, and sympathetic noradrenergic receptors are stimulated to increase both heart rate and contractility. Sympathetic tone is also increased, causing vasoconstriction of splanchnic, renal, and other intra-abdominal vessels. Increased pressure is detected by mechanoreceptors, called baroreceptors, located in the carotid sinus and aortic arch, but cutaneous vasodilation occurs in an attempt to maintain balanced automatic tone (Guyton, 1981). The baroreceptor feedback attempts to stabilize pressure, but does not completely prevent an increase in blood pressure during isometric exercise. This is a reflex peripheral-central control mechanism loop that can be reversed by decreased detection of chemical and mechanical signals originating in the working muscles.

The central command theory was formulated by Alam and Smirk (1937). Subjects exercised while blood was occluded with a pneumatic pressure cuff. When exercise was terminated, though occlusion continued, blood pressure fell quickly but remained above control levels. These results suggested that pressure increases may originate through conscious effort from higher centers. More recent studies confirmed Alam and Smirk's original hypothesis (Shepherd et al., 1981). Subjects had their forearm and intrinsic hand muscles temporarily paralyzed with succinylcholine chloride and attempted to exercise isometrically using a handgrip dynamometer. Blood pressure rose significantly higher than at rest when contractions were consciously attempted in response to higher command, although no muscular activity was observed due to paralysis (Freyschuss, 1970). Higher centers of the brain appear to directly stimulate cardiovascular centers in the medulla, increasing sympathetic tone while inhibiting vagal centers. Although neither the peripheral nor the central control mechanisms act independently, the question of which is the dominant control system is unanswered.

Mitchell et al. (1981) suggested that central command dominates when using larger muscle masses accompanied by a great central stimuli to many motor units. Petrofsky and associates (Petrofsky, Phillips, & Lind, 1981) reported that pressor responses to sustained isometric contractions were greater in anesthetized cats, activating fast glycolytic muscle fibers as opposed to slow oxidative fibers. Accordingly, it was hypothesized that peripheral control may be more dominant when glycolytic fibers are primarily recruited. Contraction of slow oxidative (soleus muscle) fibers resulted in no increase in blood pressure. Postural muscles are primarily composed of slow oxidative fibers, and much of their work is done isometrically. Blood pressure remains relatively constant during postural activity, supporting the hypothesis that peripheral control may dominate when glycolytic fibers are recruited.

Although advances have been made, the control mechanisms of blood pressure during resistive exercise are not fully understood. Various aspects (e.g., contraction durations, percentages of maximum volitional contraction [MVC], and muscle masses) of isotonic and isometric exercise blood pressure responses have been researched, however a need still exists for further investigation in this area.

Pressure Changes during Resistive Exercise

White and Moore (1925) found variations in the diastolic arterial pressure of different subjects during static exercise. Two subjects demonstrated a drastic increase in diastolic arterial pressure during static exercise, yet some demonstrated only a slight rise, some a slight fall, and others no significant change. It must be noted that subjects held their legs in extension against gravity for 10 min to attain these results. Clearly this manipulation was not in a therapeutic or functional context, nor was it in accordance with Hettinger and Muller's (1953) recommendations for optimally increasing isometric strength.

One experiment comparing the effect of static and dynamic work on blood pressure found that when static work was performed maximally, by squeezing a grip dynamometer for 1 min, both systolic and diastolic blood pressure increased significantly (Tuttle & Horvath, 1957). Dynamic work in the same experiment consisted of having subjects exercise for 1 min on a bicycle ergometer. Blood pressure responses to this dynamic exercise differed from isometric work in that systolic blood pressure increased significantly, but diastolic pressure remained the same or decreased slightly. This experiment compared static and dynamic work, but its researchers made no attempt to standardize work loads between the two types of exercise. Moreover, they compared the upper extremities with the larger muscle bulk used when exercising the lower extremities.

Holtman and Sjoholm (1982) studied the effects of static knee extension on blood pressure by having subjects hold contractions for 5 min. Drastic increases were reported in both systolic and diastolic blood pressures. Once again, a nonfunctional situation that rarely occurs in daily living or exercise training activities was used as the exercise stimulus, thereby rendering the results clinically uninterpretable. Health professionals familiar with such studies have avoided prescribing isometric exercise in therapeutic settings for fear of blood pressure elevation.

Published work by Sharkey (1966) is not in agreement with those described above (Holtman & Sjoholm; Tuttle & Horvath, 1957) in that he reported isotonic work demonstrated consistently higher systolic and diastolic blood pressures than static work. Sharkey attributed his findings to the type of dynamic resistive exercise used. Isotonic contractions consisted of leg extensions with continued support of the load. Therefore, peripheral vascular resistance may have increased more than typically recorded during bicycle or treadmill exercise. Isotonic weight lifting may involve more of a "static component" than bicycle or treadmill exercise because the continued support of the load causes more cross-bridges to form in working muscle. Bicycle or treadmill exercise involves greater velocities with lesser loads.

Recent researchers have also recorded large increases in systemic pressure during weight lifting (MacDougall, Tuxen, Sale, & Moroz, 1985). Five experienced body builders recorded a mean peak pressure of 320/250 mmHg during maximum double leg presses to fatigue. These researchers concluded that increased mechanical compression of blood vessels in the working muscles and the performance of the Valsalva maneuver were responsible for the blood pressure increases. Postural muscles contracting isometrically for stabilization may also increase peripheral resistance compounding the pressor response during maximal isotonic lifts.

Many of the earlier studies presented here have not been in accordance with Hettinger and Muller's (1953) basic principles of isometric exercise as a method of strength gain. Some studies use unrealistic lengths of contractions, different muscle groups, and different work loads to make comparisons between static and phasic exercise. Recent work has compared these types of exercise in a more scientifically acceptable fashion (Greer et al., 1984). Five subjects performed a 10-RM isometric and isotonic exercise regime at 75% and 100% of their MVC. This is consistent with the regime used therapeutically in many health care settings. Results indicated isometric exercise increased systolic and diastolic blood pressure significantly more than isotonic exercise.

Many studies have attempted to determine safe levels of isometric exercise by isolating specific factors that may influence blood pressure. Some have studied the effects of static exercise in relationship to muscle mass, concluding that pressure responses increased when a greater mass of skeletal muscle was involved. Researchers used three different isometric activities performed by 12 subjects to demonstrate increased pressures when using large muscle masses (Seals, Washburn, Hanson, Painter, & Nagle, 1983). A one-arm handgrip, a two-leg extension, and a "dead-lift" maneuver were performed for 3 min at 30% MVC. It was concluded that a direct relationship existed between size of the active muscle mass and the magnitude of increases seen in mean arterial blood pressure.

Similar results were reported by Buck, Amundsen, and Nielsen (1980) and Mitchell et al. (1981). Buck et al. measured the systolic blood pressure of 21 healthy male subjects at 20-s intervals until fatigue. Exercise consisted of a sustained isometric contraction of the index finger adductors and of handgrip muscles using 40% MVC. Regression lines indicated significant differences between the types of exercise, with systolic pressure greater during the handgrip. This supports the theory that a direct relationship might exist between the size of active muscle mass and blood pressure.

Peripheral vascular resistance is increased with larger muscle masses because of increased compression of veins and arteries. This fact may also contribute to increased pressures seen with larger muscle masses. Asmussen (1981) used this rationale to explain why, with decreasing percentages of MVC, less pressure was developed than at higher MVC percentage levels. He suggested that the critical value below which contractions can be maintained is between 10% and 25% MVC. Muscle fiber type was a factor that he attributed to the variability in these MVC values. Slow oxidative muscle fibers tended to tolerate greater percentages of MVC without causing as dramatic an increase in blood pressure as fast glycolytic fibers. He attributed this to the fact that, as previously discussed, peripheral control may be more dominant when glycolytic fibers are recruited.

Another important consideration when analyzing blood pressure responses to isometric exercise is the length of contraction time. Longer durations are met by increasing blood pressure levels, as has been noted throughout this review. Many studies utilized contractions of long duration, some as long as 10 min (Asmussen, 1981; Holtman & Sjoholm, 1982). Asmussen justified such long durations with the argument that rhythmic isometric exercise too closely resembles dynamic exercise because brief muscle contractions are interrupted by periods of relaxation. However, as previously mentioned, contractions of such long duration are rarely of any functional value.

The Valsalva Maneuver

Isometric exercise is often accomplished with some simultaneous stabilization of the abdominal and thoracic musculature. This stabilization is often accompanied by the performance of a Valsalva maneuver during the activity. Closing the glottis after full inspiration, while maximally contracting the expiratory muscles, can increase intrathoracic pressure by greater than 100 mmHg above atmospheric pressure (McArdle, Katch, & Katch, 1981). This increase in intrathoracic pressure forces blood from the heart into the arterial system, thereby causing an abrupt rise in systemic pressure.

In numerous studies, subjects have been instructed to avoid performing the Valsalva maneuver during testing, but in none of these have subjects actually been measured for compliance or trained in proper breathing techniques. Sharkey (1966) noted the performance of the Valsalva maneuver during contractions of 30-s duration at 40% MVC, but did not use specific instrumentation to detect or confirm his observations. Recent researchers have realized the significance of the Valsalva maneuver on cardiovascular parameters and have begun measuring pressures associated with it (MacDougall et al., 1985).

Summary

After the literature concerning isometric exercise has been reviewed, it becomes clear that isometrics is still a valid topic for research, because many questions remain unanswered. This review supports the need to produce more research on isometric exercise that is performed in the functional context of activities of daily living.

Complicating research is the multifactorial nature of blood pressure control. The many peripheral and central control mechanisms make it very difficult to attribute any one specific factor as antagonist to the adverse responses noted by earlier researchers. However, this should not discourage researchers from confronting this challenging problem. The Valsalva maneuver, as previously discussed, causes mechanical compression of blood vessels, thereby increasing vascular resistance and, subsequently, blood pressure. More stringent guidelines and methodologies should be followed to isolate specific factors to make research functionally useful.

Chapter 3

METHODS AND PROCEDURES

This chapter explains the procedures used to investigate the effects of breathing techniques on systemic blood pressure during isometric exercise in 27 college-aged females. The method of subject selection, testing procedures, and data analyses are outlined in the following sections.

Subject Selection

The subjects for this study were 30 female Ithaca College students from the health and physical education, physical therapy, and biology departments. Three subjects were dismissed from the study for lack of compliance with scheduled testing times, reducing the original subject pool to 27. The subjects were recruited by class announcement, and interested subjects were asked to fill out a general questionnaire (Appendix A). Significant cardiovascular or pulmonary problems would disqualify any candidate from participation. An acute or chronic knee problem or use of prescription drugs could also have excluded subjects. If candidates had no contraindications to participate, as determined by their answers to the questionnaire, they were eligible to take part in the study. All accepted subjects were of good general health and had completed a physical exam within the last 12 months.

Testing Procedures

Each subject attended an introductory meeting and was asked to read and sign an informed consent (Appendix B) describing the purpose, benefits, methods, potential side effects, and their role in the study. At this meeting subjects were introduced to equipment to be used during testing, and two resting blood pressure readings were taken with an electronic stethoscope (Bosch Electronic Stethoscope EST-40), auscultating at the left brachial artery. Initial readings were recorded to screen for hypertension and to determine baseline systemic blood pressure levels. Prior to dismissal from the introductory meeting, subjects were given an appointment card (Appendix C) reminding them of testing times and test day contraindications. Subjects were also verbally instructed about the testing contraindications listed below.

1. Subjects were instructed not to smoke at least 3 hr prior to testing. Smoking has been reported to cause immediate detrimental effects on cardiovascular function during exercise. These effects include tachycardia, increased pulse-pressure product, and

impaired oxygen delivery (Hirsch, Darryl, Wasserman, Robinson, & Hansen, 1985).

2. Intense exercise was discouraged prior to testing because researchers have suggested this decreases glycogen stores and may affect performance (Gollnick, 1974).

3. Subjects were asked to refrain from eating for a minimum of 3 hr prior to testing. This allows adequate absorption and digestion to occur before exercise testing (McArdle et al., 1981).

4. Subjects were instructed to avoid drinking liquids containing caffeine (e.g., coffee, tea, some sodas) at least 3 hr prior to testing. Caffeine is a central nervous system stimulant and has been reported to increase the respiration rate and mean arterial blood pressure (Robertson et al., 1978).

5. Subjects were also asked to refrain from drinking alcoholic beverages the day of testing. Large amounts of alcohol can decrease exercise performance (Blomqvist, Saltin, & Mitchell, 1970).

6. Additionally, subjects were asked to wear loose pants and a short-sleeve shirt to allow easy palpation of the anatomical knee axis and the brachial artery. After the instruction about contraindications, subjects

were dismissed from the introductory meeting if they had no questions regarding the study.

All subjects were exposed to the exercise regime prior to being randomly assigned to a training group. They were comfortably seated at the Cybex II isokinetic machine and stabilized at the ankle, thigh, and hips with velcro straps. A surface electrode was placed mid-axillary in the fifth or sixth intercostal space on each side of the subject. The electrodes were channelled to an impedance pneumograph and physiograph (E & M 4-Channel Desk Model Physiograph, Type DMP-4A) to measure chest excursion during exercise. Two resting systemic blood pressure readings were then recorded as previously described. Subjects were instructed to perform 10 submaximal isokinetic knee extensions followed by knee flexions to warm up the working muscle and attempt to prevent musculoskeletal injury during testing. These contractions were done at a speed setting of 80°/s.

Subjects were allowed to relax following the warm-up and given testing instructions. Each subject was instructed to perform 10 maximum isometric contractions with her right leg immobilized at 65° of knee flexion. Each contraction lasted 10 s, with a 5-s relaxation period between each two contractions. Systemic blood pressure was recorded during the 5th and 10th contractions and 30 s after the 10th contraction. The subject's arms remained folded across her lap during testing. During contractions, torque was recorded on the Cybex II Dual-channel Recorder, and peak torque (ft lb) was determined to be the highest torque level recorded during the 10 contractions. The procedures described above were used for pretraining testing, all training sessions, and the posttraining testing exercise bouts. Individuals were tested at the same time of day for each of their exercise bouts. All testing occurred between 3:00 and 10:00 p.m.

Subjects were randomly assigned to one of three groups after the pretraining testing. Groups were designed as the Valsalva group (VAL) (using a forced Valsalva maneuver during isometric contractions), the no-Valsalva group (NO-VAL) (using controlled breathing techniques during isometric contractions), and the control group (CONT) (not instructed to use any particular breathing technique). The VAL group was instructed to perform a forced Valsalva maneuver during isometric contractions.

The pretraining testing and the first training session were separated by 72 hr, to allow for adequate recovery of the working muscles. Pretraining peak torques were used to determine each subject's MVC. Subjects were instructed to perform maximally during all contractions and resist fatigue below the 75% MVC level. A torque dial located on the dynamometer was visible to subjects during exercise. All subjects received ongoing verbal coaching during training exercise bouts. Training procedures were identical to the pretraining test session, with the exception of the breathing instructions used according to group assignment. The three training sessions were each separated by 48 hr, and a period of 72 hr was allowed between the last training session and the posttraining testing. Subjects performed the isometric contractions during the posttraining testing, using the same format as described for pretraining testing and the training sessions. They also were asked to perform the assigned breathing techniques they practiced during the exercise training sessions assigned (for the VAL and NO-VAL groups).

Data Analyses

A 2 X 2 X 3 (Time by Trial by Group) multivariate analysis of covariance (MANCOVA) design was used to analyze blood pressure data resulting from the procedures described. Time reflects measures made during pretraining and posttraining testing, and the blood pressures measured during the 5th and 10th contractions represent Trial. Systolic blood pressure was determined to be the first audible pulse; diastolic pressure was determined to be the first significant change in volume of the pulse (4th Kortokoff sound). Group was divided into VAL, NO-VAL, and CONT groups. The VAL group was instructed to perform a forced Valsalva maneuver during isometric contractions. The NO-VAL group was instructed to take a full inspiration before each contraction and exhale during contractions. The CONT received no instructions regarding breathing techniques.

Pneumographic data were interpreted qualitatively to determine if subjects were complying with the learned breathing techniques. These data were also used to assess whether the Valsalva maneuver was performed during pretraining testing.

Resting blood pressures were recorded twice at the introductory meeting and twice prior to each exercise bout. The 10 readings that resulted were averaged after dropping the highest and lowest values from the original 12 readings and these mean scores (systolic and diastolic) were used as covariates in the SPSS MANOVA computer analysis. The following interactions were examined: the three-way interaction of exercise grouping with pre- and posttraining times and contraction trials (Time by Trial by Group), the two-way interactions of pre- and posttraining times with contraction trials (Time by Trial), exercise grouping with contraction trials (Group by Trial), and exercise grouping with pre- and posttraining times (Group by Time). Additionally, the main effects of Time, Trial, and exercise Group were analyzed. If significant three-way or two-way interactions were seen in the analysis, appropriate simple effects were investigated. The rejection criterion for the null hypothesis was a significance level of $p < .05$.

Chapter 4

RESULTS

The results obtained from systemic blood pressure readings recorded from subjects in the Valsalva group (VAL), the no-Valsalva group (NO-VAL), and the control group (CONT) during the performance of an isometric exercise regime are described in this chapter. All raw scores were recorded on individual score sheets (Appendix D). A summary of these raw scores is provided in Appendix E. Raw score means and standard deviations of systolic and diastolic blood pressure for Group, Time, and Trial are presented in Table 1. Resting systemic blood pressures were recorded 12 times during the experiment, then the 10 values that remained after dropping the highest and lowest values were averaged. These resting values (shown also in Appendix E) were then used as covariates in the statistical analysis. The reporting of data is divided into eight sections corresponding to the statistical tests performed: (a) three-way interaction, (b) two-way interactions, (c) main effects, (d) simple interaction effects for Time by Trial for individual groups, (e) simple main effects, (f) univariate interaction effects for individual groups, (g) univariate main effects for

Table 1

Systolic and Diastolic Blood Pressures

Group[a]	Time		Trial	
			5th	10th
VAL	Pre[b]	SP[c]	153.3 ± 8.7	170.0 ± 16.2
		DP[c]	117.3 ± 14.5	129.8 ± 11.0
	Post[b]	SP	173.1 ± 19.3	184.2 ± 16.8
		DP	132.7 ± 11.3	139.3 ± 10.4
NO-VAL	Pre	SP	160.9 ± 21.6	165.6 ± 11.4
		DP	117.3 ± 9.1	123.6 ± 12.2
	Post	SP	144.9 ± 14.6	152.0 ± 10.2
		DP	110.0 ± 11.9	114.4 ± 10.1
CONT	Pre	SP	155.4 ± 20.5	159.3 ± 17.5
		DP	114.2 ± 14.4	118.9 ± 13.2
	Post	SP	147.8 ± 18.0	158.9 ± 17.8
		DP	112.4 ± 10.5	121.1 ± 14.4

Note. Values are *M* ± *SD* from raw scores, in mmHg.
[a]*n* = 9 per group. [b]Pre refers to pretest scores

(table continues)

(before breathing training); post refers to posttest scores (after breathng training). [c]SP and DP are systolic and diastolic blood pressures.

individual groups, and (h) planned comparisons for the group score during posttraining testing.

Interaction Effects

Three-way Interaction

Systolic and diastolic blood pressure data were submitted to a three-way multivariate analysis of covariance (MANCOVA), with average resting systolic and diastolic pressures as the covariates. The MANCOVA results are provided in Table 2. No significant (p > .05) three-way interaction of systemic blood pressure response was found among exercise groups, pre- and posttraining times, and contraction trials. The nonsignificant interaction was followed by an analysis of the two-way interactions of Time by Trial, Group by Trial, and Group by Time.

Two-way Interactions

The results of the two-way interactions are noted in Table 2. The analysis of Time by Trial was not statistically significant, p > .05, indicating that the change in sytemic blood pressure measurements from 5th to 10th contraction trials was the same for pre- and posttraining times.

The Group by Trial interaction was not statistically significant, p > .05, showing that for

Table 2

MANCOVA Summary Table for Systemic Blood Pressure

Source	Hypothesis *df*	Error *df*	*F*[a]
Group	4	44	3.23*
Time	2	23	.85
Group X Time	4	48	6.47*
Trial	2	23	35.66*
Group X Trial	4	48	1.54
Time X Trial	2	23	.97
Group X Time X Trial	4	48	1.73

[a]Approximate *F* as calculated by SPSS MANCOVA.

*Significant at the $p < .05$ level.

VAL, NO-VAL, and CONT groups, the patterns of the changes in systemic blood pressure measurements for the 5th and 10th contraction trials were similar.

The Group by Time interaction was statistically significant, $p < .05$. That is, the exercise systemic blood pressure measurements for the VAL, NO-VAL, and CONT groups followed different patterns from pre- to posttraining time periods.

Main Effects

Because of nonsignificant two-way interactions of both Time by Trial and Group by Trial, the main effect of Trial could be interpreted directly from this analysis. Results indicated a statistically significant difference, $p < .05$, as seen in Table 2. By examining raw data in Appendix E and group means in Table 1, it can be seen that both systolic and diastolic blood pressures increased from the 5th to the 10th contraction across groups, with the exception of systolic blood pressure in the NO-VAL group.

Because the Group and Time variables were involved in a statistically significant interaction, Group and Time main effects as shown here were uninterpretable, as the direction of change in systemic blood pressure for groups across time is not known. However, inspection of specific time interactions in Table 3 and group means in Table 1 indicate the direction of change across time. Systemic pressure increased in the VAL group, decreased in the NO-VAL group, and did not change in the CONT group across time.

The Time by Trial interactions were also of particular interest, therefore the two-way interactions between Time and Trial were examined for each group individually.

Simple Interaction Effects for Time by Trial for Individual Groups

The results of the simple effects following the two-way interaction for Time by Trial for each group are noted in Table 3. The Time by Trial analysis for each group demonstrated no significant interaction, $p > .05$, indicating that the pattern of the systemic blood pressure change from pretraining to posttraining was the same for the 5th contraction trial as it was for the 10th contraction trial in the VAL group, the NO-VAL group, and the CONT group.

Simple Main Effects

Because no significant interaction of Time by Trial was found for the VAL, NO-VAL, and CONT groups, the main effects for both Time and Trial independent of one

Table 3

MANCOVA Summary Table of Time and Trial Simple Effects for Each Group

Group	Source	F^a
VAL		
	Time	8.13*
	Trial	20.20*
	Time X Trial	.91
NO-VAL		
	Time	61.88*
	Trial	19.56*
	Time X Trial	.65
CONT		
	Time	.49
	Trial	33.00*
	Time X Trial	4.39

Note. In each analysis, the treatment *df* = 2 and the error *df* = 7.

[a]Approximate *F* as calculated by SPSS MANOVA.

*Significant at the $p < .05$ level.

another were determined for each group.

The results of the simple main effects of Time for each group are noted in Table 3. There was a significant difference, $p < .05$, between the pretraining and posttraining exercising systemic blood pressure readings in the VAL group and the NO-VAL group, but not in the CONT group. Posttraining exercising blood pressure readings were greater than pretraining levels in the VAL group, but were less than pretraining levels in the NO-VAL group. The CONT group's exercising systemic blood pressure readings did not change significantly, $p > .05$, from pretraining to posttraining.

The results of the simple main effects of Trial for each group are noted in Table 3. Exercising systemic blood pressure readings increased significantly ($p < .05$) from the 5th to the 10th contraction in all groups.

Univariate Interaction Effects for Individual Groups

The simple main effects for all groups demonstrated statistically significant differences for both Time and Trial effects, with the exception of Time for the CONT group as described above. Because a significant multivariate difference was found, univariate analyses were performed for each group to determine whether systolic blood pressure, diastolic blood pressure, or both were responsible for the bivariate significant differences.

For the VAL and NO-VAL groups, the univariate analysis of the two-way interactions demonstrated no significant difference, $p > .05$, for either systolic or diastolic blood pressures (see Table 4). The univariate analysis indicated that for the CONT group there was a significant interaction effect of Time and Trial upon systolic blood pressure, but not diastolic.

Univariate Main Effects for Individual Groups

The results of univariate main effects for the three groups for systolic and diastolic blood pressure are indicated in Table 4. A significant difference was found, $p < .05$, from the pre- to posttraining time for both systolic and diastolic blood pressure for the VAL and the NO-VAL groups. Systolic and diastolic blood pressure readings were greater during posttraining for both groups. Neither systolic nor diastolic blood pressure was significantly different, $p > .05$, over time in the CONT group.

Table 4

ANCOVA Summary Table of Time and Trial Simple Effects for Each Group

Source			SS	MS	F
VAL[a]					
	Time	SP[b]	2601.00	2601.00	18.25*
		DP[b]	1393.78	1393.78	14.67*
	Trial	SP	1736.11	1736.11	46.16*
		DP	821.78	821.78	12.45*
	Time X Trial	SP	69.44	69.44	1.74
		DP	75.11	75.11	1.00
NO-VAL[a]					
	Time	SP	1965.44	1965.44	40.78*
		DP	608.44	608.44	20.15*
	Trial	SP	312.11	312.11	3.11
		DP	256.00	256.00	44.52*
	Time X Trial	SP	13.44	13.44	.62
		DP	7.11	7.11	.85

(table continues)

Source			SS	MS	F
CONT[a]					
	Time	SP	148.03	148.03	.89
		DP	.44	.44	.01
	Trial	SP	506.25	506.25	8.22*
		DP	400.00	400.00	27.12*
	Time X Trial	SP	117.36	117.36	8.87*
		DP	36.00	36.00	.72

Note. The *df* = 1 and error *df* = 8 for all groups.
[a]VAL refers to the Valsalva-trained group, NO-VAL is the group trained not to use a Valsalva maneuver, and CONT is the control group. [b]SP and DP are systolic and diastolic blood pressures.
*Significant at the $p < .05$ level.

The results of univariate main effects for each group between trials for systolic and diastolic blood pressure are indicated also in Table 4. A significant difference was found between the 5th and 10th contraction for both systolic and diastolic blood pressure for the VAL and CONT groups. Both systolic and diastolic pressures increased from the 5th to the 10th contraction during exercise. A significant difference, $p < .05$, was found between the 5th and 10th contraction in diastolic blood pressure for the NO-VAL group, for whom diastolic blood pressure increased from the 5th to the 10th contraction during exercise. No significant difference, $p > .05$, was found between the 5th and the 10th contraction for systolic blood pressure during exercise for the NO-VAL group.

Planned Comparisons of Posttraining Data

Planned comparisons of posttraining data were performed in order to assess whether training the NO-VAL group to avoid the performance of the Valsalva maneuver during exercise could reduce the pressor response compared to that seen in the CONT group. There were no significant Group and Trial interaction effects on exercising systemic blood pressure readings during posttraining. However, there was a significant difference between trials in exercising systemic blood pressure during the posttraining. Also, a significant difference was found among groups in exercising systemic blood pressure readings during posttraining. Univariate results indicated that both systolic and diastolic blood pressures were significantly different among groups, $p < .05$.

Comparison of the NO-VAL and CONT means revealed a significant difference in posttraining systolic and diastolic blood pressures. Review of the means and standard deviations in Table 5 revealed that the CONT group mean was larger than the NO-VAL group mean.

Pneumographic Data

Pneumographic data were qualitatively assessed and interpreted to determine breathing patterns used during the isometric contractions. Respective compliance to learned breathing techniques in the VAL and NO-VAL groups, as well as potential learned breathing techniques by the CONT group, could also be examined.

Pretraining breathing patterns were similar for all subjects (see Figure 1). Subjects typically inspired maximally prior to the initiation of a contraction, but demonstrated irregular patterns of inspiration and expiration throughout the contraction. An occasional

Table 5

Posttraining Blood Pressure Analyses

		Means		
	Group	Covariate	Dependent	Adjusted
SYSTOLIC[a]				
	VAL	112.67 (7.70)	178.89 (18.43)	177.75
	NO-VAL	114.67 (7.76)	148.44 (11.96)	144.99[c]
	CONT	108.00 (6.89)	152.89 (17.55)	157.48[c]
DIASTOLIC[b]				
	VAL	80.00 (3.97)	136.00 (10.75)	135.50
	NO-VAL	80.89 (7.79)	112.22 (10.91)	110.80[d]
	CONT	77.67 (8.60)	117.33 (11.52)	119.25[d]

Note. Values in parentheses represent the *SD* for *M* above, in mmHg.

[a]Significant difference among groups, $F(2,23) = 13.08$, $p < .05$. [b]Significant difference among groups, $F(2,23) = 19.78$, $p < .05$. [c]Significant

difference in systolic pressures between NO-VAL and CONT groups, $F(1,15) = 6.13$, $p < .05$. [d]Significant difference in diastolic pressures between NO-VAL and CONT groups, $F(1,15) = 6.24$, $p < .05$.

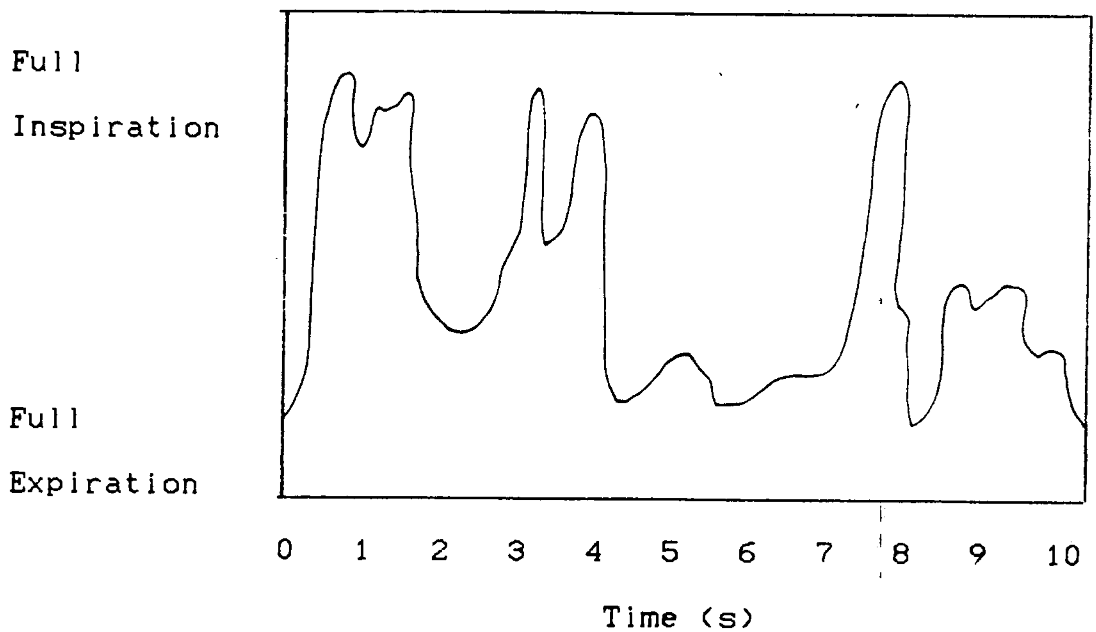
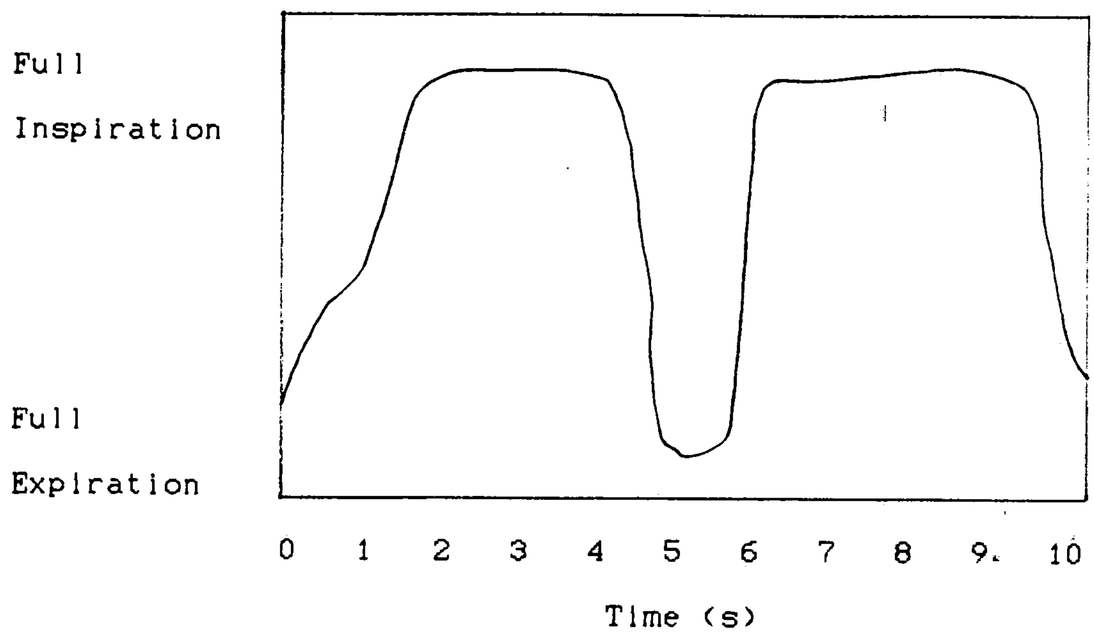


Figure 1. Typical breathing patterns for all subjects during pretraining.

Valsalva maneuver was noted, but more typically subjects performed partial Valsalva maneuvers during contractions. Typical partial Valsalva maneuvers can be seen between Seconds 3 and 4 in Figure 1.

Typical breathing patterns for the VAL group are illustrated in Figure 2. The VAL group could be seen taking a full anticipatory inspiration just prior to contractions or during the first 1-2 s of each contraction. The inspiration was held as long as possible, attempting to exhale against a closed glottis during contractions. Subjects who were unable to sustain a full inspiration during a single contraction were instructed to exhale completely and take another full inspiration. Typically, subjects performed one or two Valsalva maneuvers during each 10-s contraction period. A typical Valsalva maneuver can be seen between Seconds 1 and 5 in Figure 2.

The NO-VAL group typically demonstrated one or two sinusoidal curves during each of the 10-s contractions. Initial anticipatory inspiration was noted just prior to contractions or during the first 1-2 s of a contraction, as typically noted for all subjects in testing. However, the NO-VAL group continually exhaled during contractions, as graphically noted in Figure 3 between



<u>Figure 2</u>. Typical breathing patterns for the VAL group after training.

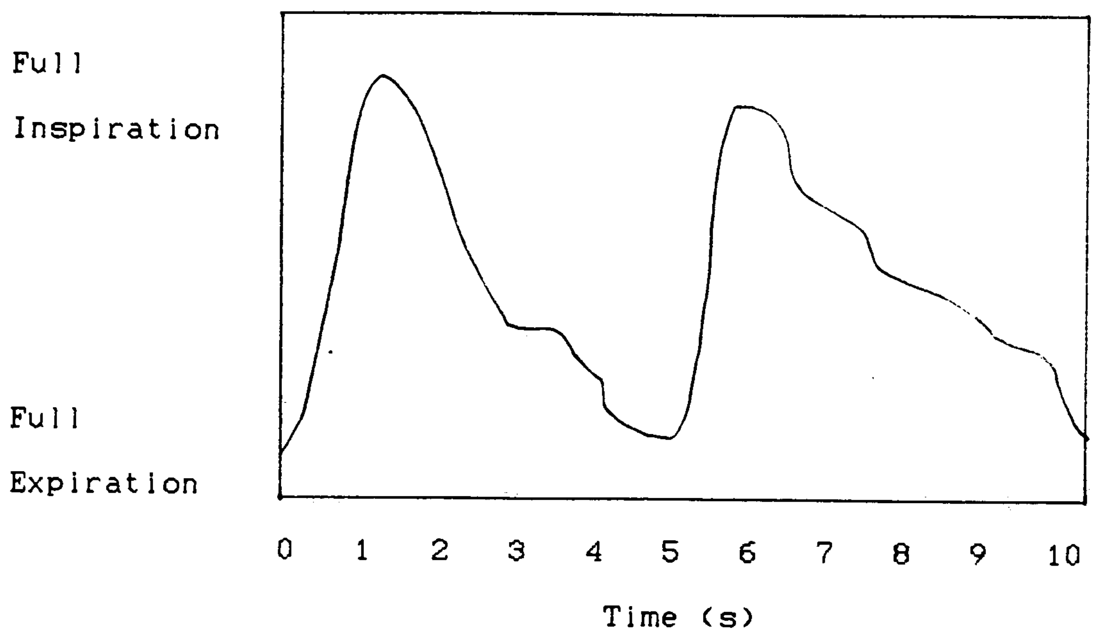


Figure 3. Typical breathing patterns for the NO-VAL group after training.

Seconds 1 and 5. When a new inspiration was needed, subjects inhaled rhythmically, again exhaling slowly for the remainder of the contraction.

The CONT group demonstrated breathing patterns similar to those recorded by all subjects during pretraining contractions (see Figure 4). Again, CONT subjects could be seen performing irregular breathing patterns including occasional Valsalva maneuvers or partial Valsalva maneuvers throughout each contraction.

Summary

MANCOVA results indicated no significant three-way interaction was found among Time, Trial, and Group. However, a two-way Group by Time interaction indicated significantly different ($p < .05$) blood pressure responses from pretraining to posttraining among the three groups. Univariate ANCOVA demonstrated the Time effect across the groups was the same for both systolic and diastolic pressures. Inspection of the means (see Table 1) shows both systolic and diastolic exercising pressures for the VAL and NO-VAL groups were greater and lesser, respectively, than values recorded during pretraining exercise. Moreover, planned comparisons revealed that at posttraining, systolic and diastolic pressures for the NO-VAL group were significantly less

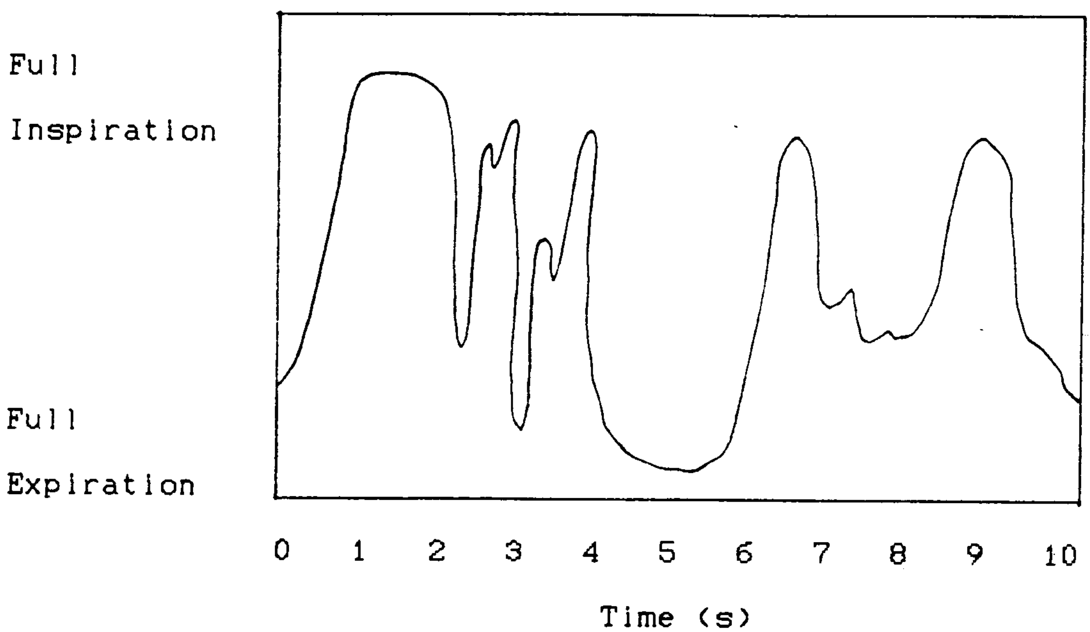


Figure 4. Typical breathing patterns for the CONT group after training.

than for the CONT group, further emphasizing the pressor-attenuating ability of breathing instruction (see Table 5).

Univariate ANCOVA of the main effect for Trial confirmed that both systolic and diastolic blood pressure rose significantly from the 5th to the 10th contraction for all groups, with the exception of systolic blood pressure in the NO-VAL group.

Pneumographic data were visually inspected and interpreted qualitatively. All subjects demonstrated irregular breathing patterns and occasional Valsalva maneuvers or partial Valsalva maneuvers during the pretraining exercise bout. During posttraining, the VAL group typically performed one or two Valsalva maneuvers in the time period required to perform a contraction and demonstrated breathing patterns with sustained periods of inspiration. The NO-VAL group demonstrated a sinusoidal curve representing rhythmic inspiration and expiration during the posttraining exercise bout, and the CONT group during posttraining continued to demonstrate breathing patterns similar to those in the pretraining exercise bout.

Chapter 5

DISCUSSION OF RESULTS

The purpose of this study was to investigate the effect of using learned breathing techniques during isometric exercise on the performance of the Valsalva maneuver, and subsequently upon blood pressure. Research has demonstrated that maximal isometric contractions, if held for as little as 2 s, produce extreme elevations in systemic blood pressure (Mitchell & Wildenthal, 1974). Additionally, performance of the Valsalva maneuver during contractions can contribute to this effect by increasing heart rate and peripheral resistance, although stroke volume is decreased because of impaired venous return (Bezucha, Lenser, Hanson, & Nagle, 1982). Few cases of permanent injury with isometrics are reported, however, the potential for serious injury does exist for those individuals suffering from cardiovascular diseases (Lamb, 1984; Tuxen et al., 1983).

Recent research demonstrated that the Valsalva maneuver alone can increase systemic blood pressure significantly and that this increase can be directly attributed to an associated increase in intrathoracic pressure (MacDougall et al., 1985). Increases in both intra-abdominal and intrathoracic pressures have been associated with the Valsalva maneuver during various lifting activities (Harman, Frykman, Clagett, & Kraemer, 1988). In the present study, the ability of one group to increase systemic pressure to greater levels, after being instructed to perform the Valsalva maneuver during exercise, exemplifies the potency of a forced Valsalva upon pressor responses and supports previous reports.

All groups recorded a significant increase ($p < .05$) in systemic blood pressure from the 5th to the 10th contraction (Trial) during the isometric exercise regime. This increase may be attributed to the fact that as subjects perform more repetitions, their muscles fatigue and they begin to recruit more motor units, including those accessory muscles associated with the Valsalva maneuver (MacDougall et al., 1985). The straining efforts and increased recruitment of accessory muscles may account for the systemic pressure elevations seen, particularly in the VAL and CONT group during the posttraining exercise bout. Involvement of accessory muscles may have increased intrathoracic pressure, thereby driving up peripheral resistance leading to the greater pressures observed. Intense isometric MVCs produce both immediate and profound systolic and diastolic responses, moderate tachycardia, and enhanced contractility, resulting in a moderate increase in cardiac output without an increase in stroke volume (Stopford, 1988). The increased pressor responses seen during the Valsalva maneuver appear to be directly influenced by the contraction of abdominal, thoracic, and respiratory muscles that increase intrathoracic pressure accordingly (MacDougall et al., 1985).

The ability of the NO-VAL group to avoid a significant increase in systolic blood pressure from the 5th to the 10th contraction may be attributed in part to avoidance of the Valsalva maneuver (MacDougall et al., 1985). Learning rhythmic breathing techniques leads to avoidance of the Valsalva maneuver and consequently attenuates an increase in intrathoracic pressure and the contraction of accessory muscles, thereby checking the blood pressure rise. Any further increase in pressor response other than those immediate changes that occur with forced static contractions may be averted.

Visual interpretation of the pneumograph data indicated that all subjects performed irregular Valsalva or partial Valsalva maneuvers during pretraining contractions. Moreover, prior to ventilatory training the three groups had very similar pressor responses to static work. As discussed above, systemic blood pressure rose significantly from the pretraining to the posttraining exercise bout for the VAL group. Conversely, the results indicated that systolic and diastolic pressures decreased in those trained to avoid the Valsalva maneuver (i.e., the NO-VAL group).

Straining maneuvers associated with the Valsalva may account for about 20 mmHg of the rise in mean arterial pressure (MAP) during isometric exercise (Williams & Lind, 1987). The present findings showed that a consciously performed Valsalva maneuver during exercise resulted in a 13 mmHg rise in MAP [diastolic + .33 X (pulse pressure)], and learned avoidance of the Valsalva maneuver prevented a 10 mmHg increase in MAP for NO-VAL. Therefore, in support of the work of Williams and Lind, it was concluded that straining during isometric efforts can account for a 20-25 mmHg rise in MAP. The rise associated with the Valsalva maneuver could be considered independent of other central reflex changes of cardiovascular centers and may be attributed to the mechanical effect of increased pressure on the abdominal and thoracic vasculature. Accordingly, it is suggested that learning proper breathing techniques may reduce elevations in systemic blood pressure associated with the isometric contractions by eliminating performance of a Valsalva maneuver. This is supported by posttraining systolic and diastolic pressures measured in the NO-VAL group that are significantly lower than in the CONT group. The mechanism underlying attenuation of the pressor response is likely related to mitigating the rise in intrathoracic and intra-abdominal pressures caused by stabilization of the abdominal and thoracic musculature during a straining maneuver. Additionally, reflex sympathetic activity that normally follows the Valsalva would also be avoided (Deering & Harron, 1987; Eckberg & Wallin, 1987).

It is possible the decreased pressures seen in the NO-VAL group reflect decreased effort during the exercise. It is known that performance of the Valsalva maneuver allows increased stabilization of postural and proximal muscle groups, thereby enhancing the ability of the prime mover to generate torque. It is also known that a greater active muscle mass elicits greater pressor responses (Mitchell et al., 1981). However, the work of Mitchell et al. was done by varying muscle mass involvement at 40% MVC. Freyschuss (1970) demonstrated that no relationship exists between cardiovascular response during isometric contractions and the degree of effort above 70% MVC. Furthermore, Asmussen (1981) has confirmed that leg extension greater than 30% MVC will elicit maximal occulusion of blood flow and nearly maximize circulatory response. All contractions (i.e., leg extensions) in this study were performed at greater than 75% MVC. Therefore, it is unlikely that the influence of effort upon circulatory response could be held accountable for pressure differences observed between groups.

Pneumographic data revealed that some type of Valsalva maneuver was utilized by the CONT group during both pretraining and posttraining exercise bouts. Individuals seemingly perform a Valsalva maneuver unconsciously when confronted with near maximum efforts. The CONT group displayed no significant change in systemic blood pressure from pretraining to posttraining. This demonstrates failure by the CONT group to spontaneously learn an advantageous breathing pattern over three exercise sessions and emphasizes the need to provide clear breathing instructions if attenuation of the pressor response to static efforts is desired.

Summary

The purpose of this study was to assess whether ventilatory training could significantly mitigate the blood pressure rise commonly believed to be associated with isometric contractions. All groups demonstrated an increased systemic pressor response from the 5th to 10th isometric contraction (Trial) during exercise bouts.

Systemic blood pressure increased significantly for the VAL group from the pretraining to postraining exercise bout. The performance of a forced Valsalva maneuver appears to enhance the pressor response associated with isometric contractions.

The CONT group demonstrated no change in pressor response from the pretraining to posttraining exercise bout, apparently failing to spontaneously learn breathing techniques that would alter their pressor response across time. The NO-VAL group utilized rythmical breathing and was able to mitigate the pressor response that was seen in both the VAL and CONT groups.

Systemic pressure decreased from the pretraining to posttraining isometric exercise bout. Most importantly, a significant difference ($p < .05$) in systolic and diastolic blood pressure was found when comparing the posttraining NO-VAL and CONT group data. Observation of group means revealed greater systolic (157.68 vs. 143.66) and diastolic (119.07 vs. 110.49) blood pressure readings in the CONT group. The posttraining group differences support the conclusion that instruction in breathing techniques to avoid the performance of the Valsalva maneuver lowers blood pressure during isometric contractions and may help mitigate the adverse pressor response associated with isometric contractions.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents an overview of the entire experiment. The chapter is divided into three sections: (a) summary, (b) conclusions, and (c) recommendations.

Summary

The purpose of this study was to assess whether ventilatory training could significantly mitigate the blood pressure rise commonly believed to be associated with isometric contractions.

To obtain the results, 30 normotensive college-aged subjects attended an introductory meeting during which an informed consent form and resting blood pressure values were obtained. Prior to ventilatory training, testing of systemic blood pressure response to maximal isometric efforts was identical for all subjects. Each subject was immobilized at 65° of knee flexion on a Cybex dynamometer. Two blood pressure measurements were obtained at rest and again during 10 isometric contractions of the quadriceps (one during the 5th and one during the 10th contraction). Each maximal contraction was held for 10 s and separated from the next by a 5-s recovery. Breathing patterns were recorded using an impedance pneumograph and physiograph, while blood pressure (BP) was measured by amplified auscultation. Following pretraining testing, subjects were randomly divided into three groups. The first treatment group (VAL) was taught to perform a forced Valsalva maneuver during isometric contraction of the right quadriceps. The second treatment group (NO-VAL) was taught to avoid performance of the Valsalva during isometric contractions. The control (CONT) group was given no directions for breathing during testing. During three training sessions, subjects performed their assigned breathing techniques. Posttraining was conducted in a fashion identical to pretraining data collection 72 hr after the final training session. Results were subjected to a 2 X 2 X 3 (Time X Trial X Group) MANCOVA. The average of 10 resting blood pressures, after dropping the high and low values, was used as the covariate in the analysis of both systolic and diastolic pressure.

Results revealed no significant three-way interaction among Time, Trial, and Group. However, a significant two-way (Group X Trial) interaction was detected. Univariate analyses for both systolic and diastolic blood pressure were performed for all groups, and both systolic and diastolic BPs across time were significant ($p < .05$) for the VAL and NO-VAL groups; BP was not significantly changed across time in the CONT group. One-way ANCOVA revealed posttraining systolic and diastolic blood pressure were significantly ($p < .05$) different among the groups. Further, a planned comparison demonstrated posttraining systolic and diastolic blood pressures were significantly ($p < .05$) different between the NO-VAL and the CONT groups. Examination of group means indicated the CONT group recorded higher systolic and diastolic blood pressure readings than the NO-VAL group after the ventilatory training.

Conclusions

1. Blood pressure decreased significantly as a result of learning to avoid the Valsalva maneuver (i.e., ventilatory training) for the NO-VAL group. Therefore, training to avoid performance of the Valsalva maneuver appears to mitigate the blood pressure response associated with isometric exercise.

2. A significant increase in blood pressure was recorded from the 5th to the 10th contraction trial, with the exception of systolic blood pressure in the NO-VAL group. A direct relationship appears to exist between blood pressure and the number of static

contractions performed.

3. Blood pressure increased significantly from pretraining to posttraining exercise bout in the VAL group. It appears that the performance of a forced Valsalva maneuver enhances the blood pressure response associated with isometric exercise.

4. Blood pressure did not significantly change from the pretraining to posttraining exercise bout for the CONT group. No spontaneous adaptations to reduce the blood pressure response to isometric exercise occur with physical training alone.

Recommendations

The following recommendations are being made for further research on this topic:

1. This study required subjects to perform contractions ranging from 75%-100% MVC. Exercise testing at a specific percentage of MVC could be used to determine pressor responses at varying levels of MVC. This could help establish guidelines for isometric exercise below percentages of MVC that produce adverse pressor responses.

2. The performance of the Valsalva maneuver was measured qualitatively using an impedence pneumograph and physiograph in this study. Interthoracic pressures

recorded by indwelling catheterization or buccal mouth pressures could help determine to what degree interthoracic pressures contribute to the pressor response in relation to other perhipheral factors.

3. Arterial blood pressure was recorded by amplified auscultation of the left brachial artery. Indwelling catheterization of the brachial artery or arteries of the working muscle could also help determine to what degree peripheral factors contribute to the increased pressor response seen with isometric efforts.

4. Testing various age groups and subjects with significant cardiovascular histories might enhance general understanding of the pressor response to static work in these populations.

5. Subjects in this study performed isometric contractions of the right quadriceps. Further research is needed using smaller muscle masses or postural muscles that contract statically for extended periods during activities of daily living.

Appendix A

GENERAL QUESTIONNAIRE

(1) Name ______________________________

(2) Age __________

(3) Sex __________

(4) Campus address ______________________

(5) Campus phone ______________________

(6) Home address ______________________

(7) Do you have a history of cardiovascular problems?

Yes No (Circle one)

Elaborate if "yes": ______________________

(8) Do you have a history of cardiopulmonary problems?

Yes No (Circle one) Elaborate if "yes":

____

(9) Are you a smoker? Yes No (Circle one)

Quantity: _____ packs.

(10) Are you presently on prescription or over the counter drugs? Yes No (Circle one)

Type: __________

Dose: __________

(11) Do you have any acute or chronic problems with your knees? Yes No (circle one)

Right Left (circle one)

(12) Are you of good general health?

Yes No (Circle one)

(13) When was your last physical exam? _______________

(14) Would you be willing to participate in an exercise physiology study?

Yes No (circle one)

Appendix B

INFORMED CONSENT FORM

1. a) Purpose of the study. To investigate the area of isometric (static) exercise and its effect on blood pressure.

   b) Benefits. To enhance the understanding of blood pressure responses to isometric exercise typically used in the clinical setting and possibly increase the use of isometrics in certain populations.

2. Methods. Subjects will be asked to attend an introductory meeting. During the introductory meeting subjects will be randomly assigned to one of three groups and all questions will be answered. A total of five exercise sessions will be required of each subject for training and data collection. Exercise sessions will consist of ten 10-s maximum static contractions separated by 5-s rest periods. The static contactions will consist of extending the right knee while it is immobilized at 65°. Blood pressure and chest excursion will be monitored during all exercise bouts. The formal exercise bouts will each take approximately 15-30 min to complete.

The entire project will span approximately 2 weeks. Individual sessions will occur on alternating days with a minimum of 48 hours separating each two sessions.

3. Will this hurt? Some muscle soreness may develop as with any novel exercise. This soreness rarely lasts more than 3-4 days and should not be more than a minor discomfort. A warm-up will be perfomed to minimize the likelihood of musculotendinous injury. Slight increases in blood pressure may occur during exercise, but will not be greater than levels seen during normal exercise or heavy lifting and are not expected to pose a danger.

4. Need more information? Additional information can be obtained by calling Patrick O'Connor (273-9130) or Dr. G. Sforzo (274-3359) and by attending the introductory meeting (TBA). All questions are welcomed and will be answered.

5. Withdrawal from the study. Participation is strictly voluntary, and you are free to withdraw consent or discontinue this study at any time. There is no consequence or penalty associated with your decision not to take part or

discontinue participation.

6. Will the data be maintained in confidence? All data will be confidential. All subjects will be assigned a number, and all data will be discussed according to the subject numbers to protect the identity of the subject. A brief summary of general findings will be given to subjects upon completion and interpretation of the study.

7. I have read the above and I understand its content and I agree to participate in the study. Neither my physician (Dr.) nor I know of any reason why I should not take part in this experimental study. I acknowledge that I am 18 years of age or older.

_________________________ ____________

Signature, Date

Appendix C

APPOINTMENT CARD

Name: ______________________

Scheduled Time: ____________

You are scheduled to exercise on the following days:

Friday, April 18th

Monday, April 21st

Wednesday, April 23rd

Friday, April 25th

Monday, April 28th

Please do not eat, smoke cigarettes, drink beverages containing caffeine (e.g., coffee, tea, some sodas), or exercise heavily at least 3 hours prior to exercise sessions. Also, please bring a short sleeve shirt and sweat pants. Changing rooms are available. Note that all exercise sessions will be performed at the same time of day.

Thank you,

Patrick O'Connor

Appendix D

SCORE SHEET

Name:	________	Local Address:	________
Group:	________	Local Phone:	________
Time:	________	Peak Torque:	________

Introductory Meeting:	Resting b.p.	______	______
Pre:	Resting b.p.	______	______
	b.p. 5th contraction. . .	______	
	b.p. 10th contraction . .	______	
	b.p. 30 s post exercise .	______	
Phase 1:	Resting b.p.	______	______
	b.p. 5th contraction. . .	______	
	b.p. 10th contraction . .	______	
	b.p. 30 s post exercise .	______	
Phase 2:	Resting b.p.	______	______
	b.p. 5th contraction. . .	______	
	b.p. 10th contraction . .	______	
	b.p. 30 s post exercise .	______	
Phase 3:	Resting b.p.	______	______
	b.p. 5th contraction. . .	______	
	b.p. 10th contraction . .	______	
	b.p. 30 s post exercise .	______	
Post:	Resting b.p.	______	______
	b.p. 5th contraction. . .	______	

b.p. 10th contraction . . ______

b.p. 30 s post exercise . ______

Comments: ____

Appendix E

RAW DATA

Raw Blood Pressure Scores for the Valsalva Group

ID#	RESTING		PRETEST				POSTTEST			
			5th		10th		5th		10th	
	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.
1	127	85	160	90	190	140	210	144	214	150
2	105	74	158	140	172	142	168	140	182	144
3	107	82	162	120	174	124	186	138	192	144
4	114	80	160	128	174	132	166	132	180	142
5	109	78	150	110	190	140	192	144	204	148
6	107	76	140	120	144	122	166	128	176	134
7	122	81	150	108	154	114	156	114	164	126
8	116	86	160	128	178	138	166	138	182	146
9	107	78	140	112	154	116	148	116	164	120

Note. All scores recorded in mmHg. Resting scores are the average of 10 pretraining BP scores dropping the highest and lowest values. 5th and 10th represent trial.

(table continues)

Raw Blood Pressure Scores for the No-Valsalva Group

ID#	RESTING		PRETEST				POSTTEST			
			5th		10th		5th		10th	
	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.
1	110	80	160	110	162	110	140	108	144	108
2	114	84	148	126	158	136	144	116	152	122
3	122	80	162	110	168	118	154	106	150	110
4	123	83	174	118	180	128	154	118	166	124
5	105	79	160	130	164	140	152	118	158	120
6	127	99	210	130	186	138	170	128	168	130
7	111	75	140	108	150	108	122	86	138	98
8	113	72	138	110	166	116	128	106	148	110
9	106	76	156	114	156	118	140	104	144	108

Note. All scores recorded in mmHg. Resting scores are the average of 10 pretraining BP scores dropping the highest and lowest values. 5th and 10th represent trial.

(table continues)

Raw Blood Pressure Scores for the Control Group

ID#	RESTING		PRETEST				POSTTEST			
			5th		10th		5th		10th	
	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.	Sys.	Dia.
1	112	83	200	140	200	136	164	124	176	136
2	116	75	168	110	160	128	174	112	172	110
3	104	79	150	120	160	122	142	122	160	128
4	112	84	164	124	150	124	156	110	160	140
5	109	81	148	120	158	124	156	116	174	130
6	97	66	132	90	140	90	124	92	136	98
7	117	91	155	114	164	122	144	116	168	122
8	101	64	134	100	142	110	118	100	124	104
9	104	76	148	110	160	114	152	120	160	122

Note. All scores recorded in mmHg. Resting scores are the average of 10 pretraining BP scores dropping the highest and lowest values. 5th and 10th represent trial.

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