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The primary purpose of this study was to determine the differential effects, in young fit males, of weight training and aerobic training on pulmonary, cardiorespiratory, and strength factors regarded as critical to resistance to gravitational forces experienced in military aircraft. Thirty male college physical education majors served as subjects for the study. Twenty subjects were assigned to either a weight training group or an aerobic training group, and trained three times each week for 10 weeks. Five weight lifters and five distance runners, all of national class, were each tested once for pulmonary function. Differences in measured parameters between national class weight lifters and distance runners were statistically insignificant, with the exception of greater maximal expiratory pressure (PE_{max}) for the weight lifters ($p < .05$). There were no significant differences between effectiveness of the training programs in pulmonary function, dynamic muscular strength, and aerobic capacity. No significant differences in pre- and post-

training means for pulmonary function and aerobic function were observed within either training group. No significant differences in pre-and post-training means for dynamic strength were observed as outcomes of the weight training program. A significant difference in pre- and post-training means for dynamic strength was observed in the aerobic training group ($p < .05$). Ten weeks of weight or aerobic training does not produce, in young fit males, significant changes in the parameters of pulmonary function and aerobic capacity thought to be important in resistance to gravitational forces. The aerobic training, which included running in rough, mountainous terrain, significantly improved leg muscle strength. Both experimental groups significantly increased performance time on the bicycle ergometer ($p < .05$). Longitudinal weight training may produce a significant increase in PE_{max}).

Differential Effects of Strength Training and Endurance Training on Parameters Related to Resistance to Gravitational Forces

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Differential Effects of Strength Training and Endurance Training on Parameters Related to Resistance to Gravitational Forces

CHAPTER I

INTRODUCTION

The introduction of high performance fighter aircraft has lead to mishap, often fatal in nature. An early fighter aircraft tragedy involving a U.S. Air Force F-16 occurred in 1983. Although aircraft malfunction at first was suspected, the actual cause for this and subsequent tragic mishaps was manifested in the failure of the pilots to resist acceleration forces (Gillingham & Fosdick, 1988).

The first perception of unconsciousness due to acceleration forces in an aircraft was reported during World War II (Burton, 1988). Until the late 1970s, only high performance aircraft were believed to create problems with loss of consciousness. However, an anonymous survey revealed that many less powerful aircraft, including trainer jets, were inclined to induce loss of consciousness, suggesting that loss of consciousness might have been responsible for unexplained accidents for some time (Pluta, 1984). Since then the danger of failure to resist acceleration forces has been recognized by the aviation community. Today, the term for this phenomenon is gravity-induced loss of consciousness (G-LOC).

Continuous exposure to head-to-foot linear acceleration prevents the maintenance of normal arterial blood pressure, and disrupts adequate circulation of blood to all organs, even to the brain (Christy, 1971). Because consciousness is dependent upon oxygen being available to the brain, and vision is dependent upon oxygen being available to the retina, reduced head-level blood pressure precipitates loss of consciousness.

G-LOC differs from "blackout" or "grayout" in terms of depth of awareness of reality (Burton, 1988). "Blackout" or "grey-out" is related to the eyes which have a static inflation pressure, thus requiring higher blood pressure. Therefore, the eye is more sensitive to oxygen deficit than the brain. Loss of vision from this source is immediately restored upon renewed oxygen delivery to the retina, whereas G-LOC remains for variable periods of time regardless of restored blood supply to the brain (Burton & Whinnery, 1985). Consequently, various degrees of loss of vision may be useful to detect gravity tolerance limits, although loss of consciousness occurs with little warning (U.S. Air Force [USAF], 1986).

Since the first report on G-LOC, many studies have focused on the blackout phenomenon and on lower G-levels associated with the relaxed state; i.e., without anti-G-LOC straining maneuver (Parkhurst, Leverett, & Shubrooks, 1972;

Rook & Dawson, 1938; Rossen, Kabat, & Anderson, 1943; Shubrooks, 1972; Stewart, 1945; Stoll, 1956; Wood, Lambert, & Code, 1947; Yanguell, 1932). Before high performance aircraft were developed, aircrew members resisted low level gravitational forces (+Gz) without straining. However, as more advanced aircraft were developed, G-LOC research was directed toward measuring and improving human tolerance to sustained high gravity with rapid onset rate. These studies have brought into focus the fact that G-LOC is a very common occurrence among military aircrew members and that more measures must be taken to prevent resulting financial and personnel loss.

Withstanding gravitational forces is mainly dependent upon the individual's ability to maintain proper ocular and cerebral pressure, which is known as +G-tolerance. At present, improvement of equipment, the straining maneuver, and physical training are considered as the most effective means of resisting gravitational forces (USAF, 1986). Physical training improves strength, stamina, and the body's compensatory mechanisms (Åstrand & Rodahl, 1977). The anti-G straining maneuver increases blood flow to the brain through a voluntary isometric contraction of the body's entire musculature, engaging somatopressor reflexes and mechanical compression of the vascular tree and an increase of pressure within the chest by exhalation against a partially or fully closed glottis. A reflex vasoconstriction in the vascular bed other than those of the exercising muscle causes an immediate increase in blood pressure (Bezucha, Lenser, Hanson, & Nagle, 1982; Nutter & Wickliffe, 1981). The mechanical compression of the vessel wall causes elevation of blood pressure which is proportional to the size of the muscle (Seals, Washburn, Hanson, Painter, & Nagle, 1983; MacDougall, Tuxen, Sale, Moroz, & Sutton, 1985). As observed in a centrifuge, weight training, or other forms of resistance training, produces a significant improvement in human G-tolerance (Tesch, Hjort, & Balldin, 1983; Balldin, 1985; Epperson, Burton, & Bernauer, 1985). The pertinence of weight training is that this form of exercise is similar to the straining maneuver used by aircraft crew members to resist the effects of gravitational forces (USAF, 1986).

Excessive aerobic conditioning, such as seen in trained endurance athletes, is known to be detrimental to G-tolerance due to decreased orthostatic tolerance (Parnell & Whinnery, 1987; Raven & Smith, 1984; Goldwater, De Lada, Polese, Keil, & Luetscher, 1980). The level of aerobic conditioning was shown to be an important factor related to reduction of G-tolerance. Cardiac dysrhythmia and decreased response of the carotid sinus baroreceptors may result from a high level of aerobic conditioning (Whinnery, 1982; Whinnery, Laughlin, & Hickman, 1979; Whinnery, Laughlin, & Uhi, 1980). However, Convertino et al. (1984) and Smith and Raven (1986) showed that a significant increase in $\dot{V}O_2$ max induced by a short term endurance training did not change the blood control system. Aerobic training is also important to improve circulatory efficiency and stamina and thus to maintain G-tolerance (Cooper & Leverett, 1966; Bulbulian, 1986). Regardless of the type, physical training appears to have little influence on relaxed G-tolerance, and instead improves the efficacy of the straining maneuver necessary to resist high gravitational forces (USAF, 1986).

Mechanical methods such as the anti-gravitational pressure suit, anti-gravitational valve, assisted positive pressure breathing, and seat configurations leading to semi-prone or supine positions are also used by military aircrew members to improve G-tolerance. However, the most effective means to improve G-tolerance might be the anti-G straining maneuver, which consists of repeated quick inhalations followed by vigorous straining and forceful exhalations (Wood & Hallenbeck, 1945). Two types of anti-G straining maneuvers, L-1 and M-1, are used by high performance military aircraft pilots. The M-1 straining maneuver uses a tensing of abdominal and leg muscles with a forced exhalation against a partially closed glottis. On the other hand, the L-1 maneuver employs muscle tensing with a Valsalva maneuver against a totally closed glottis (Gillingham, 1988). Although there exists little difference between the two types, except for the duration of breath holding, the L-1 maneuver is widely recommended because it is more comfortable and convenient (Burton, Leverett, & Michaelson, 1974; Gillingham, 1988).

Repeated quick inhalations and exhalations performed during an anti-G staining maneuver emphasizes the importance of respiratory muscle function and pulmonary function. Improvement of respiratory muscle function and pulmonary function is assumed to facilitate the anti-G straining maneuver in terms of effectiveness because the respiratory muscles can be susceptible to fatigue as can any other muscle (Roussos & Macklem, 1982; Bye, Esau, Walley, Macklem, & Pardy, 1984; Loke, Mahler, & Virgulto 1982). Therefore, the training of respiratory muscle is believed as important as other steps taken to improve G-tolerance.

Whether pulmonary function improves and respiratory muscle is trainable have long been controversial. However, it is presently well understood that respiratory muscle strength and endurance can be improved if a specific training program limited to the respiratory muscle is applied properly (Keens et al., 1977).

Swimming is known to affect respiratory muscle condition (Clanton, Dixon, Drake, & Gadek, 1987), although running can influence respiratory muscle strength and endurance as well (Robinson & Kjeldgaard, 1982; Kaufmann, Swenson, Ferel, & Lucas, 1974). Moreover, static exercise, such as resistance strength training, has been demonstrated as a means to increase strength of respiratory muscle (Merrick & Axen, 1981).

Statement of the Problem

Over the years many have focused on the influence of physical fitness and related parameters on G-tolerance. The importance of military aircrew physical conditioning has also been investigated in detail. Most studies have shown that intense aerobic training may have adverse effects on high-G tolerance (Klein, Wagman, & Kuklinski, 1977), and that weight or resistance training may have some positive effects (Balldin, 1985).

In addition, the broad physiologic differences between the effects of resistance training and aerobic training are well understood in the aviation community. The usual supposition is that both forms of training could be used to develop G-tolerance and physical fitness of fighter aircraft crew members, when performed with adequate intensity and duration (Burton, 1986).

Exposure to high accelerative force is associated with extreme physiological stress on the body. Exposure to sustained and rapid onset G-forces places demands on muscle, cardiovascular, and pulmonary function. However, not much attention has been paid to differential alterations induced by the two physical training modes relative to the parameters related to resistance to gravitational force.

Purpose of the Study

The primary purpose of this study was to determine the differential effects in young, relatively fit males on parameters related to resistance to gravitational forces of 10-week training regimens representing strenuous weight and aerobic training. The secondary purpose was to compare selective pulmonary function variables in highly trained weight lifters and endurance runners in order to examine the possibility of long term training effect on pulmonary function.

Hypotheses

The null hypotheses tested in this study were as follows:

Hypothesis 1: There is no significant difference in development of pulmonary function as measured by Forced Vital Capacity, Forced Expiratory Volume in one second, Maximal Voluntary Ventilation, Peak Expiratory Flow, and Maximal Expiratory Pressure between the resistance training group and the aerobic training group.

Hypothesis 2: There is no significant difference in pre- and post-training mean scores for pulmonary function within the two training groups.

Hypothesis 3: There is no significant difference in development of cardiorespiratory function as measured by peak $\dot{V}O_2$ between the resistance training group and aerobic training group.

Hypothesis 4: There is no significant difference in pre- and post-training mean scores for cardiorespiratory function within the two groups.

Hypothesis 5: There is no significant difference in strength development between the resistance training and aerobic training groups.

Hypothesis 6: There is no difference in pre- and post-training mean score for strength within the two training groups.

Hypothesis 7: There is no difference in pulmonary function of long term weight lifters as opposed to long term distance runners.

Delimitations

The study was delimited as follows:

1. The subjects in each experimental group consisted of 10 male physical education students from the College of Physical Education and Sports, Kyung Hee University at Suwon campus, Korea.
2. The training subjects exercised three days per week for ten weeks.
3. Each workout was limited to two hours.

4. The college male elite weight lifters and endurance runners were tested for pulmonary function only.

Limitations

The limitations of this study were as follows:

1. Complete control of physical activity outside of training was not possible.
2. The motivation of subjects to perform to maximum capacity during testing and training could not be controlled.
3. The post-training tests for both cardiorespiratory function and strength development were necessarily administered more than two weeks after the last training session, which may have decreased the detection of potential training effects.
4. Lack of complete randomness exists since subjects were volunteers.

Definition of Terms

Body Temperature and Pressure Saturated (BTPS): Gas volume at body temperature and ambient pressure (PB), saturated with water vapor (Stedman, 1982).

Cybex II Dynamometer: An electromechanical instrument which provide measurement of static and dynamic strength, muscular endurance, and power. At a particular angular velocity, the internal motor resists acceleration caused by applied torque.

Forced Vital Capacity (FVC): The maximal amount of air that can be exhaled from the lungs by forced effort after a maximal inspiration (Bartels, Dejours, Kellog, & Mead, 1973).

Forced Expiratory Volume in one second ($FEV_{1.0}$): The maximal amount of air that can be forcefully exhaled in one second after maximal inspiration. The $FEV_{1.0}$ serves as an indirect assessment of the flow resistive properties of the airways (Kory, Collahan, Boren, & Syner, 1961).

G: The ratio of gravitational or accelerative force divided by the force of the Earth's gravity.

Gravity Induced Loss of Consciousness (G-LOC): A state of altered perception wherein (one's) awareness of reality is absent as a result of sudden, critical reduction of cerebral blood circulation caused by increased G-force (Burton, 1988).

+Gz-tolerance: Ability to maintain adequate blood pressure and oxygen supply to the brain and retina under headward linear gravitational stress (USAF, 1986).

Kilopond-Meter (Kpm): The amount of work performed when raising a mass of one kilogram against the force of gravity (Åstrand & Rodahl, 1977).

Maximal Expiratory Pressure (PE_{max}): The pressure at the mouth generated during maximum expiratory effort against a closed valve. PE_{max} is a reflection of the strength of the respiratory muscle (Clausen, 1982).

Maximal Oxygen Consumption ($\dot{V}O_2$ max): The highest oxygen uptake a subject can attain during physical work while breathing air at sea level. This is often expressed as absolute value (l/min) in relation to relative value ($ml \bullet kg \bullet min^{-1}$), which allows comparison of maximal oxygen uptake between individuals of different body weight.

Maximal Voluntary Ventilation (MVV): The maximal volume of air that can be exhaled per minute with maximal effort of quick and deep breathing (Kory et al., 1961). The MVV is measured during a 12-second period of maximal inspiratory and expiratory effort at approximately one breath per second. With FVC and $FEV_{1.0}$, MVV provides an assessment of the dynamic functional capacity of the ventilatory apparatus (Cotes, 1968).

One Repetition Maximum (1-RM): The greatest load a muscle is able to contract against for one repetition (Lamb, 1984).

Oxygen Consumption ($\dot{V}O_2$): The amount of oxygen absorbed through the lungs and transported by the blood to bodily organs and tissues.

Peak Expiratory Flow (PEF): Maximum flow rate of expiration which is maintained at least .01 second (Wright & McKerrow, 1959).

Peak Oxygen Uptake (peak $\dot{V}O_2$): The highest attained oxygen consumption value during maximal exercise (Brook & Fahey, 1984).

Peak Ventilation (peak $\dot{V}E$): The amount of air expired ($\dot{V}E$) in one minute (Fox & Mathews, 1981).

Relatively Fit: In this study, subjects were physically active physical education majors and thus were physically fit to a greater degree than average people their age. This is reflected in mean initial peak $\dot{V}O_2$ for the training groups.

Repetition: The number of times a dynamic contraction is repeated in a specific exercise set (Lamb, 1984).

Set: A series of repetitions without a rest for a specific exercise (O'Shea, Simmons, & O'Connor, 1989).

Station: An area where a specific exercise is performed.

Strength: The ability of a muscle or a muscle group to produce force during a maximum exertion (Fox & Mathews, 1981).

Target Heart Rate: The heart rate an individual must attain and maintain to derive physiological benefit from exercise (McArdle et al., 1986).

CHAPTER II

REVIEW OF LITERATURE

The phenomenon of G-LOC is not new. Although it has been of scientific interest only since the beginning of this century, voluminous amounts of time and money have been spent to illuminate the essence of gravitational stress.

The literature reviewed in this chapter was surveyed to provide broad existing information on respiration, physiological alterations by physical training, and the effects of physical training on G-tolerance.

Gravitational Physiology

A major concern of gravitational physiology is the physiological consequences that could be expected by changes in body position and motion. Of the various physiological consequences, impedance of cardiovascular and pulmonary function are most prominent, and of vital interest because those two systems support internal respiration and metabolism at a cellular level. Transitory changes in these systems could drastically impair body function or result in loss of life.

Cardiovascular Response to Gravitational Stress

The heart and blood vessels respond to the controlling influence of several levels of the central and peripheral nervous systems (Brown, 1979). Gravitational stress is caused by headward linear acceleration and concomitant tailward gravitoinertial forces (Christy, 1971). Due to the 30 cm hydrostatic column between the heart and the brain, venous return is reduced. Consequently, the cardiac output decreases and head-level blood pressure drops proportionate to G-load. When G-load reaches a level at which the weight of the column of blood nearly equals the pressure at heart level, cerebral perfusion is severely compromised and unconsciousness ensues.

The outward migration of fluid at the precapillary level is also influenced by the increase of G-force in which supporting tissue pressure is reduced (Christy, 1971). As weight of the circulating blood is increased, the intravascular pressure exceeds the osmotic pressure of the plasma protein at the venous end of the capillary, which results in an inadequate return of fluid to the vascular system (Greenleaf, Convertino, & Mangseth, 1979).

Upon the occurrence of G-stress various compensatory mechanisms work to increase gravitational tolerance. When stress is reduced at the baroreceptors, peripheral vessels in skeletal muscle are constricted. Other stretch receptors respond to change in blood volume and pressure throughout the body and serve to decrease blood flow to the lower portions of the body and raise blood pressure to maintain cerebral blood flow (Gauer, 1961). The heart works harder by increasing heart rate and thus pumping more blood throughout the system. As the G-stress decreases, an abrupt drop of heart rate occurs (Gauer, 1961) because stretch reflexes are still mobilized.

Over the years many researchers (Smith & Raven, 1986; Convertino, Montgomery, & Greenleaf, 1986; Raven, Rohm-Young, & Blomqvist, 1984; Lee, Lindeman, Yiengst, & Shock, 1966) have attempted to study cardiovascular response to orthostatic conditions, using Lower Body Negative Pressure (LBNP), tilt table, and immersion of the body in water, in an effort to examine the control of blood pressure in individuals undergoing exposure to gravitational stress. Reports from these investigations have indicated that aerobic training may alter the cardiovascular mechanism and impair blood pressure control mechanisms (Mangseth & Bernauer, 1980; Stegemann et al., 1974).

Endurance training is known to increase parasympathetic (vagal) activity (Scheuer & Tipton, 1977) and decrease sympathetic response to exercise stress (Raven, Connors, & Evonuk, 1970; Hartley et al., 1972). Such changes in vascular control may be caused by an increased compliance of the leg veins, an inability to produce vasoconstriction, tachcardia and, eventually, by an altered baroreceptor sensitivity (Raven et al., 1984). However, Convertino et al. (1984) suggested a possible genetic factor in blood pressure control, assessing cardiovascular responses to orthostasis in 8 men aged 18 to 29 before and after an 8-day cycle ergometer exercise training regimen for 2 hours per day at 65 percent $\dot{V}O_2$ max. Each subject performed 60° head-up tilt before and after exercise. Blood pressure and blood composition were determined each minute before, during, and after tilt. Following exercise training, $\dot{V}O_2$ max, plasma volume, and mean tilt duration time increased, while mean while mean tilt HR and rate pressure product decreased. These data suggest that a short duration of exercise training enhances cardiovascular adjustment during tilt. Convertino, Sather, Goldwater, and Alford (1986) measured $\dot{V}O_2$ max and graded lower body negative pressure to tolerance (LBNP) in 18 males aged 21 to 51 in an attempt to test the hypothesis that orthostatic tolerance may be inversely related to aerobic fitness ($\dot{V}O_2$ max). No relationship between aerobic fitness variables and peak LBNP was found.

Pulmonary Response to Gravitational Stress

It is generally known that blood distribution in the body is altered by the need of various organs under varying conditions of physical exertion or environmental change. The lung is an organ vulnerable to environmental changes. Therefore, the physiologic effect of exposure to +Gz acceleration on the lung has been examined in detail by many researchers. Gravitational stress may produce shunting of blood in parts of the lungs, which leads to insufficient oxygenation of the arterialized blood (Barr, 1962). Consequently, this impairs ability to tolerate acceleration.

In a study by Barr (1963), a human subject breathing air was examined to determine the effects of exposure to a force of five G caused by headward acceleration. The average arterial oxygen saturation was found to be decreased by 8.8 percent. The alveolar-arterial O_2 difference also increased fourfold.

Banchero, Cronin, Rutishauser, Tsakiris, and Wood (1967) investigated the effects of oxygen inhalation on arterial oxygen saturation during exposures to transverse acceleration. At the highest levels of acceleration arterial blood oxygen saturation decreased and lesser changes were observed in the oxygen saturation of mixed venous blood. Pulmonary arterial-venous shunting increased progressively with the level of acceleration. Arterial desaturation was not prevented by the inhalation of a high oxygen breathing medium. Blood oxygen changes were thought to be related to severe disturbance of ventilation-perfusion ($\dot{V}/\dot{Q}$) ratios within the lungs.

In an attempt to study the effect of breathing 100 percent oxygen on pulmonary gas exchange during headward acceleration, Barr, Brismar, and Rosenhamer (1969) examined eight subjects breathing 100 percent oxygen and wearing anti-G suits. Mean inspiratory minute volume (VI) increased seven liters, accompanying a small acidotic change in arterial pH. Average end-tidal PCO_2 decreased by seven mmHg. The arterial oxygen saturation (SaO_2) decreased and was thought to be the result of a reduced oxygen content of blood coming from alveoli with very low V/Q ratios.

Michaelson (1972) observed changes of end-tidal CO_2 tension, tidal volume (VT), respiratory rate (f), and heart rate of nine male subjects wearing anti-G suits and breathing either air or 100 percent O_2 by exposing them to continuously increasing +Gz conditions. His observation on the effects of 100 percent oxygen breathing was similar to the findings reported by Barr et al. (1969).

Leverett, Burton, Crossley, Michaelson, and Shubrooks (1973) attempted to determine pulmonary gas exchange and blood oxygenation in a man who was exposed to high sustained +Gz. The arterial O_2 tension (PaO_2) values obtained were quite similar to those of Michaelson (1972) in regard to +Gz effect. The arterial CO_2 tension was not affected by high sustained +Gz. The study concluded that arterial saturation may continue to decrease in relation to G-level or duration at high sustained +Gz.

Respiratory Muscle Training and Muscle Function

The human respiratory system provides for internal and external respiration, both of which are critical to maintain normal functioning of the system. The respiratory muscles are components of external respiration and are susceptible to fatigue (Campbell, Agostoni, & Davis, 1970). The function of respiratory muscles is to overcome pulmonary tissue, chest wall, and airway resistance. Airway resistance is associated with the magnitude of the interaction between the flowing gas molecules during inspiration, the length of the airway, and the diameter of the airway radius (West, 1984).

The chest wall is comprised of the diaphragm and the rib cage. The abdomen and rib cage are affected by forces developed by respiratory muscles, the diaphragm, the external and internal intercostals, and the accessory muscles. The diaphragm and external intercostal muscles are accepted as the primary muscles employed during breathing (Campbell et al., 1970).

Respiratory muscle fatigue can be defined as the inability of the muscles to generate a required pressure for adequate alveolar ventilation. It is believed that inadequate motor output from the central nervous system (CNS) and failure of the peripheral nervous system may be important factors in muscle fatigue (Roussos & Macklem, 1982).

Respiratory muscle fatigue is, in fact, caused by failure of the energy supply to meet the energy demand of those muscles. The determining factors for the energy demand of the respiratory muscle are the work of breathing, strength of the respiratory muscles, and their efficiency. The imbalance of the energy system could be treated by clinical procedures if the causes are pathologic, such as hypoxemia, edema, or bronchospasm. Training the respiratory muscles represents a possibility for the improvement of respiratory muscle performance and, thus, for the prevention of respiratory muscle fatigue.

Leith and Bradley (1976) evaluated five-week differential muscle training modes, focusing on normal subjects. The study utilized control, strength training, and endurance training groups. The strength training group performed a maximum static inspiratory and expiratory maneuver at 20 percent interval over the vital capacity (VC) volume range for 30 minutes per day, five days each week, while the endurance training group performed normocapnic hyperpnea to exhaustion. Normorcapnic hyperpnea was a deeper breathing than that experienced during normal activity. The results of this study showed increased respiratory muscle strength and endurance for both training groups.

Keens et al. (1977) demonstrated similar results to those of Leith and Bradley (1976). The study used an endurance training group and a control group. Training subjects performed sustained normocapnic hypercpnea for 15 minutes per day, five days each week. The endurance training group had improved respiratory muscle endurance after the training.

In 1980, Haas and Haas investigated the effect of strength training on inspiratory muscle as evidenced by changes in various pulmonary function tests. The $\dot{V}O_2$ max was also assessed. The training program consisted of an attempt to maintain 85 percent of maximal inspiratory pressure (PI_{max}) until fatigue. Outcomes proved the effectiveness of such training on pulmonary function, but failed to alter the $\dot{V}O_2$ max.

In 1981, Merrick and Axen evaluated inspiratory capacity, peak inspiratory flow rate and maximal pressures generated by the inspiratory muscles under the static conditions in 20 healthy young adolescents before and after a six-week program of diaphragmatic breathing exercises. The subjects performed maximal voluntary diaphragmatic contraction with a heavy weight placed on the anterior abdominal wall to resist diaphragmatic descent. The study failed to prove the effectiveness of isotonic exercise on function of various respiratory muscles.

In a study by Morgan (1981), the effects of five weeks of respiratory muscle endurance training on cardiorespiratory function was investigated. During the training period the subjects were instructed to ventilate at 85 percent of their 15-second maximum voluntary ventilation (MVV_{15}) four times each day. The quantity was increased by five percent on the next day. There was an increase in MVV_{15}, although no significant change was observed in their $\dot{V}O_2$ max.

In 1983, Chen and Martin evaluated the effects of four weeks of ventilatory muscle training on ventilatory function and work performance for nine healthy subjects. Inspiratory muscle loading was used for the ventilatory muscle training. The experimental group demonstrated significant improvement in ventilatory muscle endurance as well as work performance.

Physical Training and Pulmonary Function

Athletes and physically active persons usually have greater static lung volume than sedentary persons (Kaufmann et al., 1974). Older endurance trained athletes also show significantly superior values than older sedentary individuals in pulmonary function when interpreted as relative to body size (Hagberg, Yerg, & Seal, 1988; Gutin, Zohman, & Young, 1981). It would seem that physical training could, therefore, be a primary means for improvement of pulmonary function. However, the effects of training on pulmonary function are still somewhat controversial (Newman & Moser, 1979; Davis, Frank, Whipp, & Wasserman, 1979; Newman, Smalley, & Thomson, 1961; Grimby & Saltin, 1966).

Vaccaro and Clarke (1978) reported a nonsignificant improvement in selected pulmonary function variables in a group of previously untrained 9- to 11-year old children after seven months of swim training. Zauner and Benson (1981) observed an increase in FVC of children during each year of a three-year study to examine the effects of prolonged intense swim training. As an outcome of training, young swimmers showed progressive increases in FVC, $\dot{V}O_2$ max, and PWC which were independent of growth. Their research suggested a training adaptation, although the specific mechanism could not be delineated.

McKay, Braund, Chalmers, and Williams (1983) measured pulmonary function for 10 male and 15 female swimmers aged 13 to 20 from the Scottish national and youth squads, 1981-1982. The results suggested that regardless of sex, pulmonary function values for the subjects were greater than provided by prediction tables and nomograms (Kambruoff & Brodie, 1971; Camprag, 1977).

Twelve weeks of swim training was applied to 16 competitive female swimmers (age 19 ±1 years) (Clanton et al., 1987). Eight performed inspiratory muscle training in addition to swim training. The remaining eight comprised the control group and performed only swim training. Both groups showed equal increases in VC, total lung capacity (TLC), and functional residual capacity (FRC), with no effect on residual volume (RV), suggesting that swim training improves inspiratory muscle strength and endurance. Findings implied some changes might be a function of an elevation in respiratory muscle capacity to compress the chest wall and lungs.

Swimmers and athletes trained in the hypoxic state have been found to have significantly superior pulmonary function when compared to other athletes (Andrew, Becklake, Guleria, & Bates, 1972; Crosbie, Reed, & Clark, 1979; Eriksson, Engström, Karlberg, Saltin, & Thorin, 1978). This may indicate that swim training develops inspiratory muscle function. However, Keens et al. (1977) demonstrated that forms of exercise other than swimming might have greater effect upon respiratory muscle. Koch (1980) observed pulmonary function in 12- to 16-year old boys with high physical activity, but failed to demonstrate a relationship between pulmonary function and activity level.

The effects of running on ventilatory muscle function were studied in a group of 11 previously sedentary, healthy adults during a 20-week training program (Robinson & Kjeldgaard, 1982). Twelve healthy volunteers were used as a control group. At the end of the training period, the experimental group demonstrated a significant increase in PE_{max}, MVV and maximum sustainable ventilatory capacity for 15 minutes (MSVC), whereas there was no significant change in the control group. This result indicated that running improved ventilatory muscle strength.

Yerg, Seals, Hagberg, and Holloszy (1985) investigated the effects of endurance training on ventilatory function of older individuals aged 58 to 80 years. The training was continued for 12 months, and selected pulmonary function variables were improved, suggesting a more efficient level of ventilation in older sedentary people as an outcome of training.

Cordain, Glisan, Latin, Tucker, and Stager (1987) determined the effects of long term exercise on respiratory muscle function and pulmonary volume in a group of male runners aged 16 to 58 years. In addition, they examined for relationships among variables. The results showed significantly lower PE_{max} and greater RV than predicted values for normal individuals. However, FVC was not different from values reported for normal non-smoking individuals.

Differential Training Regimens and +Gz Tolerance

An optimal level of physical fitness is a very important factor for aircrew members in terms of reduced fatigue, enhanced work performance, improved cognitive functioning, and reduced coronary risk (Wilmore, 1977; Cooper, 1982). It is also well understood that continuous and abrupt exposure to high-G is physically demanding and requires specific physical conditioning. It is, however, still controversial regarding which type of physical training and what level of physical conditioning are required for high G-tolerance.

A positive relationship between cardiac dysrhythmia and +Gz acceleration was reported in early studies (Burton et al., 1974; Bjurstedt, Rosenhamer, & Tyden, 1976). Shubrooks (1972) also reported "high G-bradycardia" and sinoatrial block in subjects exposed to high +Gz and stated that increased vasovagal activity, such as might be developed through intense aerobic training, leading to syncope, may be a factor. Slowing down of the sinus pacemaker response was also thought as a factor. A report by the U.S. Air Force School of Aerospace Medicine suggested that an excessive increase in vagal tone developed by endurance training is related to prolonged time of incapacitation after +Gz-LOC (Whinnery, 1982). Cooper and Leverett (1966) failed to prove any relationship between aerobic power and G-tolerance when no straining maneuvers were involved. Stegemann et al. (1974) demonstrated that endurance training decreases the effectiveness of blood pressure control, suggesting that intense aerobic training may not be the appropriate means to prepare for a high-G environment.

Parnell & Whinnery (1987) determined the effect of long term aerobic conditioning on +G tolerance in 27 long term aerobically conditioned subjects. The subjects were tested for gradual and rapid onset G. The results revealed that there was no relationship between aerobic condition and +G tolerance, but that an increased susceptibility to motion sickness was associated with long-term aerobic training. A certain amount of motion sickness is commonly reported by fighter pilots and other military aircrew members. Banta, Ridley, McHugh, Grissett, and Guedry (1987) evaluated susceptibility to motion sickness in 29 males who had high, moderate, and low levels of aerobic fitness.

Based on the results obtained, it was concluded that men with high aerobic fitness may have an increased susceptability to motion sickness.

Other studies, in comparison, indicated that strength building resistance training is likely to increase G-tolerance because the anti-G straining maneuver requires repeated active muscle tensing. Spence, Parnell, and Burton (1981) conducted a strength training program emphasizing only abdominal muscle groups designed to increase tolerance to simulated aerial combat maneuvering (SACM). Balldin, Myhre, Tesch, Wilhelmsen, and Andersen (1985) also conducted the same type of strength training program, examining the effects of 11 weeks of abdominal muscle training on intra abdominal pressure (IAP), G-tolerance and muscle strength and endurance for 10 fighter pilots. The G-tolerance was measured in a human centrifuge as a SACM simulation. Both studies failed to demonstrate the effectiveness of abdominal muscle strength training for improving gravitational resistance. Abdominal muscle conditioning alone was not an effective means for improving SACM tolerance, nor was it for reducing the frequency of acceleration exposures necessary to maintain a high G-tolerance.

Epperson, Burton, and Bernauer (1982) attempted to determine the effect of differential physical conditioning regimens on SACM. No change was observed in tolerance to SACM after 12 weeks of running training, whereas the weight training group increased tolerance to SACM. The role of muscle strength in SACM G-tolerance was assessed in seven young men by Epperson et al. (1985). The subjects performed a 12-week program of whole body weight training, demonstrating a 99 percent increase in abdominal strength and a 26.2 percent increase in biceps strength. The SACM tolerance time was also increased 53 percent after training.

Tesch et al. (1983) showed that 11 weeks of weight training increased SACM tolerance time by 39 percent. Again, SACM tolerance time was measured in a human centrifuge. Strength gain was also observed in knee extensor muscle, although aerobic performance and various muscle histochemical analyses were unchanged.

Tesch and Balldin (1984) investigated the relationship between sustained G-tolerance and muscle fiber distribution in 28 fighter pilots and 10 non-pilots. The results revealed that there was no correlation of fiber type composition or capillary supply with increased G-tolerance. It was concluded that muscle fiber type distribution and associated metabolic characteristics do not affect sustained G-tolerance to any significant extent.

As previously stated, ability to resist +Gz acceleration is dependent on maintenance of head level arterial pressure and cerebral blood flow (Blomqvist & Stone, 1983). Since there is a hydrostatic effect on the heart to head blood column during +Gz acceleration, arterial pressure at heart level should be elevated to resist +Gz force in high

+Gz environments (Gauer, 1961). At present, the most effective means of improving aircrew +Gz tolerance is the anti-G straining maneuver (M-1/L-1) (USAF, 1986).

As earlier discussed, the anti-G straining maneuver consists of two parts: a quick inhalation followed by a forceful straining type of exhalation and tensing of large muscles of the arms, legs, and abdomen. Tensing the muscles squeezes blood pooled in the large veins in the lower extremities back into the chest. The anti-G straining maneuver raises arterial blood pressure as a consequence of forcibly raising intrathoracic pressure. However, prolonged exhalation impedes returning of venous blood and prolonged inhalation drops pressure in the chest, and thus causes a drop in blood pressure (Guo, Zhang, Jing, & Zhang, 1988).

In 1972, Lohrbauer, Wiley, Shubrooks, and McCally evaluated the effect of sustained muscular contraction on tolerance to +Gz acceleration and compared it to that of anti-G garments. Eight subjects were tested for acceleration on the human centrifuge. The results showed that sustained muscular contraction combined with anti-G garments during exposure to +Gz acceleration increases +Gz tolerance.

Shubrooks and Leverett (1973) studied the systemic arterial pressure (Psa) response to the Valsalva maneuver and its effects on acceleration tolerance in 10 healthy men during exposure to +Gz acceleration. The subjects were tested for +Gz tolerance using the human centrifuge. The results illustrated that the increased intrathoracic pressure produced by the Valsalva maneuver or M-1, elevates Psa and +Gz tolerance, although a previous study by Wood and Lambert (1952) reported a considerable reduction in +Gz tolerance for subjects who performed a Valsalva maneuver in the relaxed state.

A number of studies (Burns, 1975; Burton et al., 1974; Leverett et al., 1973) measured intrathoracic pressure and arterial pressure during a vigorous anti-G straining maneuver. The results revealed that intrathoracic pressures of 100 mmHg can be generated during high G-stress, suggesting the straining maneuver can raise G-tolerance by as much as four-G. Wood, Lambert, and Code (1981) determined that the anti-G straining maneuver produces high degrees of protection from high +Gz acceleration force if the pilot is protected by an inflated anti-G suit.

In a recent study by Gillingham and Fosdick (1988), United States Air Force aircrew members underwent high G-training with emphasis on demonstration of an effective anti-G straining maneuver and discussion of the G-time tolerance curve. Aircrew were exposed to high-G training on a human centrifuge and tested for +Gz tolerance after the training. This study concluded that high-G training is an appropriate method for preventing losses of aircraft due to G-LOC.

Guo et al. (1988) designed a new anti-G straining maneuver, the Q-G Maneuver, consisting of volitional muscle mobilization, stepwise tensing of leg and abdominal muscles, and maintenance of a shallow thoracic respiration throughout. Twenty-four pilots were tested on the ground and three pilots were tested on a centrifuge. All were monitored for heart level blood pressure and peripheral vision. The results showed that the maneuver was effective and might be usefully employed during high load.

Summary

Based on the review of related literature, physical training has been shown to affect certain physical fitness components considered as critical to +Gz tolerance both favorably and unfavorably, depending on the style, intensity, and duration of training. Strength, aerobic capacity, and pulmonary capacity are considered very important factors to anti-G straining maneuvers since continuous straining maneuvers demand high levels of isometric strength and respiratory endurance.

Of the many organs in the body, the heart and lungs are the most important and vulnerable parts in the body in terms of sustaining +Gz forces. Upon the occurrence of G-stress, the heart works harder to pump more blood and thus maintains blood pressure at the head level. Insufficient oxygenation of the arterialized blood is also caused by shunting of blood in parts of the lungs. Pulmonary function, considered as crucial to straining maneuver, is believed to respond to exercise training by increasing the strength and endurance of the respiratory muscles. Improved respiratory muscle endurance and strength would permit the respiratory maneuver to be performed more easily and efficiently. Cardiovascular function also responds to exercise training, and to an even greater extent to endurance type exercise. However, it is known that an excessively high level of aerobic fitness possessed by aircrew members is detrimental to +Gz tolerance because of the relative loss of vascular control caused by reduction of baroreceptor sensitivity.

CHAPTER III

MATERIALS AND METHODS

The present study was performed at the Kyung Hee University Hospital, Kyung Hee University, and the Korea Sport Science Institute in Seoul, Korea during the fall semester of the 1989 academic year. The purpose of the research was to determine if differential physical training regimens, represented by strength training and aerobic training, influenced parameters related to resistance to gravitational forces in young, fit male college students, and if any differences of effectiveness exist between the two training regimens. The secondary purpose was to compare the selective pulmonary function variables of national class weight lifters and endurance runners who had been highly trained for a prolonged period. This chapter describes the selection of subjects, training regimen, equipment, and testing procedures.

Subjects

Thirty male student volunteers from Kyung Hee University participated as subjects in the research project. Twenty of them were fit young students who were enrolled in the Department of Physical Education and participated in 10 weeks of physical training. Young, relatively physically fit males were purposely selected since they possess characteristics typical of military aircrew members. These 20 subjects were randomly divided into two groups: group I (strength training) and group II (aerobic training). The remaining 10 subjects were top class weight lifters and middle and long distance runners who were also enrolled in the Department of Physical Education. In this latter group, pulmonary function was tested only once to determine mean differences between the two types of athletes. Details of the study were explained in writing to each subject prior to the signing of the Informed Consent Statement (Appendix A). The Institutional Review Board for Protection of Human Subjects at Oregon State University approved the research plan and the Informed Consent Statement. A summary of the physical characteristics of the subjects is shown in Tables 3.1 and 3.2.

Table 3.1. Physical Characteristics of Experimental Subjects.

	Mean	SD	Range
Age (yrs)	20.85	2.49	19-27
Height (cm)	172.45	4.67	165-180
Weight (kg)	66.30	5.37	59-74

Table 3.2. Physical Characteristics of National Athletes.

	Mean	SD	Range
Age (yrs)	20.20	1.31	18-21
Height (cm)	174.60	2.31	170-177
Weight (kg)	68.00	9.70	56-81

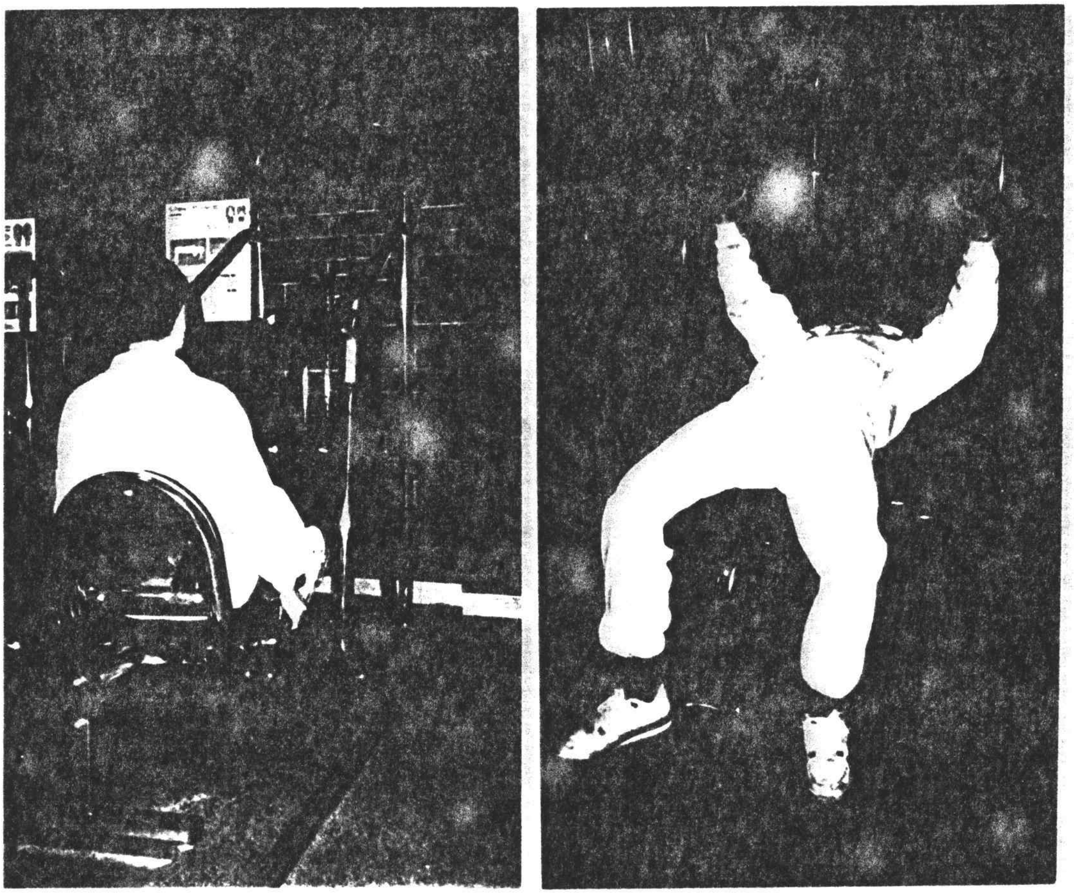
Training Procedures

Weight Training Program

Weight training was performed at the Kyung Hee University weight training room. The equipment used included a Universal Gym (Universal Gym Products, Irvine, CA 92714), dumbells, and barbells. Before the subjects entered the training period, a pre-conditioning session was administered for one week. During the pre-conditioning period the subjects were oriented concerning the research project. They were familiarized with the training instruments, training and testing procedures, as well as with correct exercise technique. The one repetition maximum (1-RM) weight was also measured using a Universal Gym for each of the lifting exercises during this period. The 1-RM was used as baseline for the establishment of the workout program during the training period. All physiological testing was administered after the pre-conditioning period.

After the completion of the pre-conditioning period and initial testing, the 10-week training period began. Subjects trained three times each week (Monday, Wednesday, and Friday) for 10 weeks. The weight training program consisted of two circuits, one for strength emphasis workouts and the other for endurance emphasis workouts. Monday and Wednesday workouts employed strength emphasis and Friday workouts employed endurance emphasis. Before the subjects began to exercise on the Universal Gym, they warmed up using dumbell and barbells.

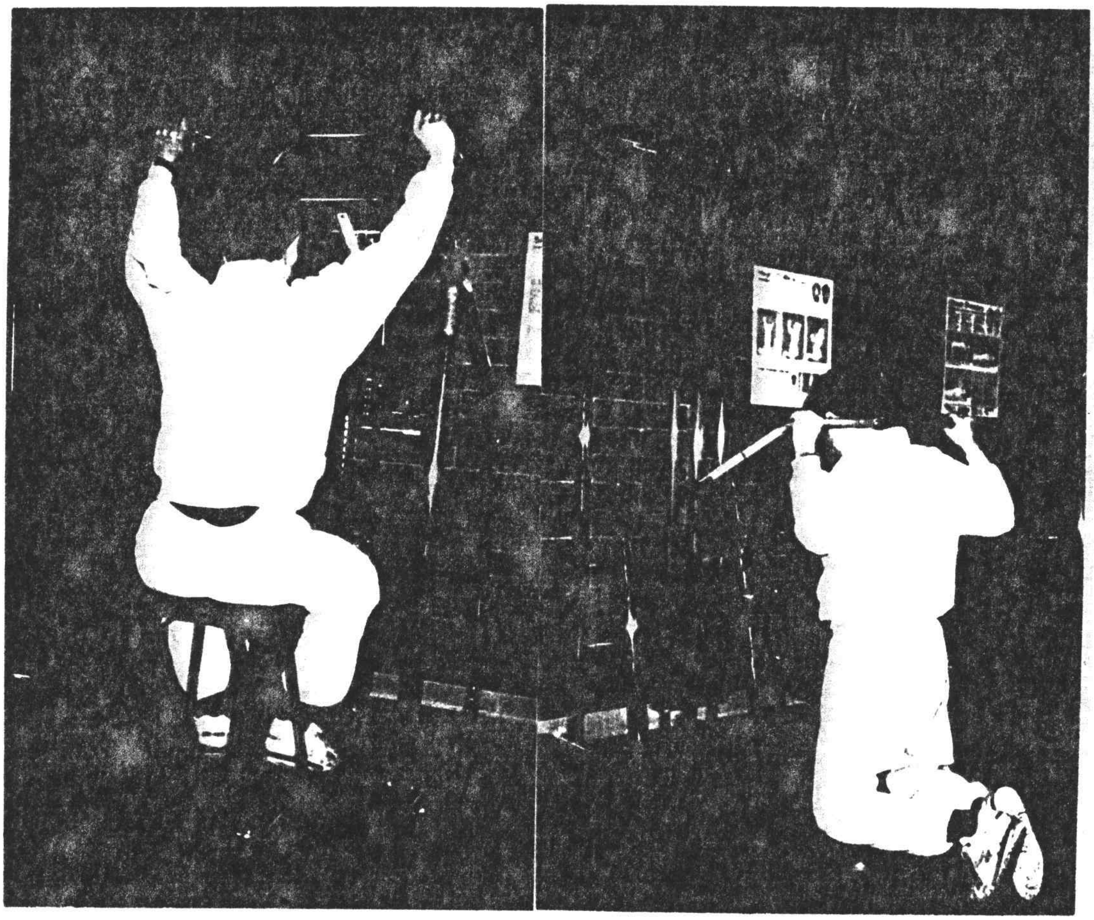
The strength and endurance emphasis workout consisted of 12 exercises which were performed first with larger muscle group activity and then with smaller muscle group activity (Appendix B). Exercises performed by subjects are shown in Figures 3.1--3.5. In the strength emphasis workout the subjects completed heavy resistance loads with fewer repetitions, whereas in endurance workouts the subjects completed lighter resistance loads with a number of repetitions. Repetitions were performed within three to five seconds, and an equal amount of time was given between each period of a given exercise. A two-minute rest period was allowed between each set. Respiratory straining was done against a partially closed glottis during the contraction. Subjects exhaled on extension.



Leg Press

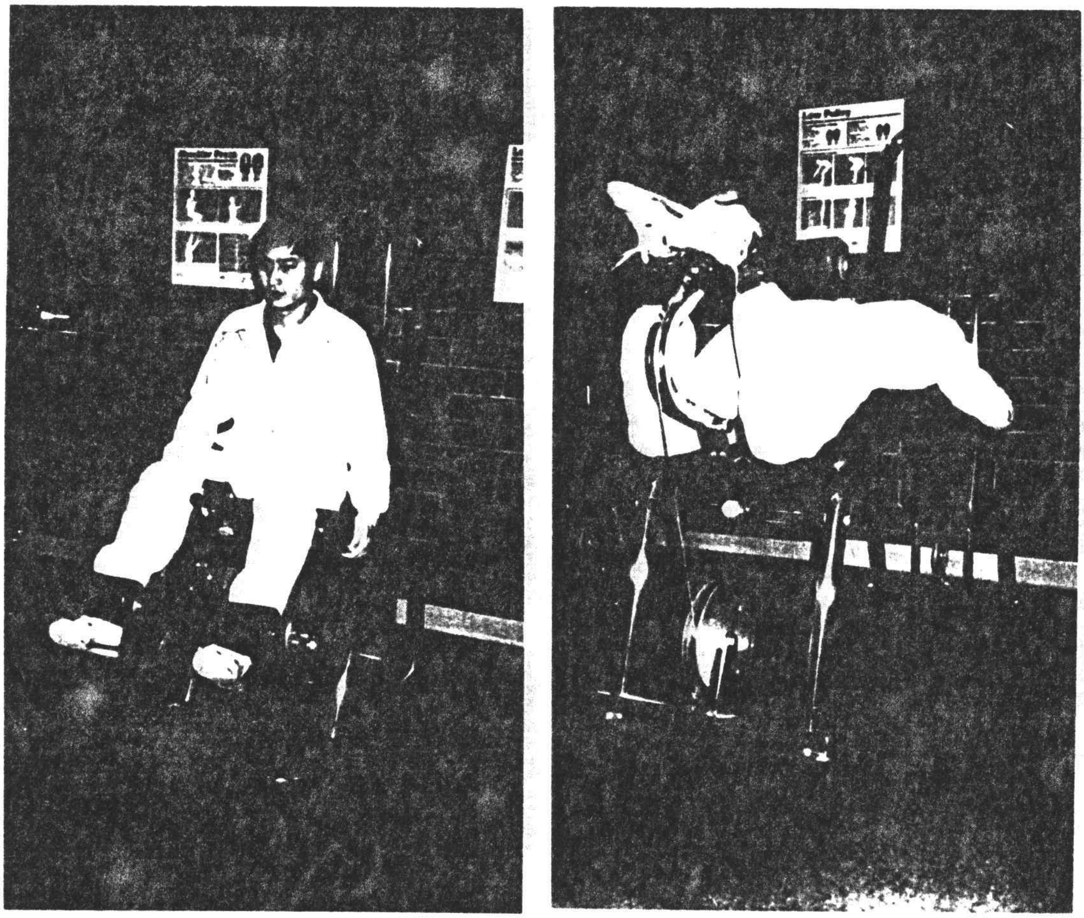
Bench Press

Figure 3.1. Weight Training (A).



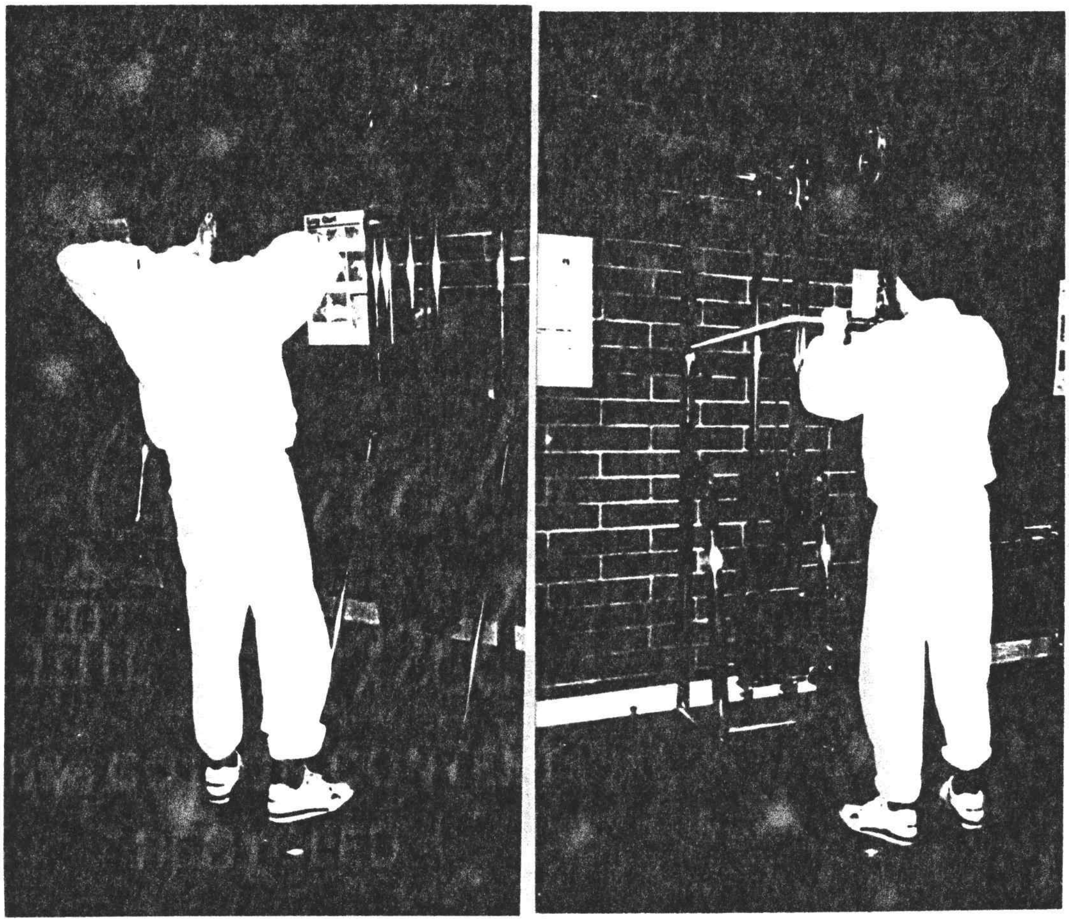
Military Press Lat Pull

Figure 3.2. Weight Training (B).



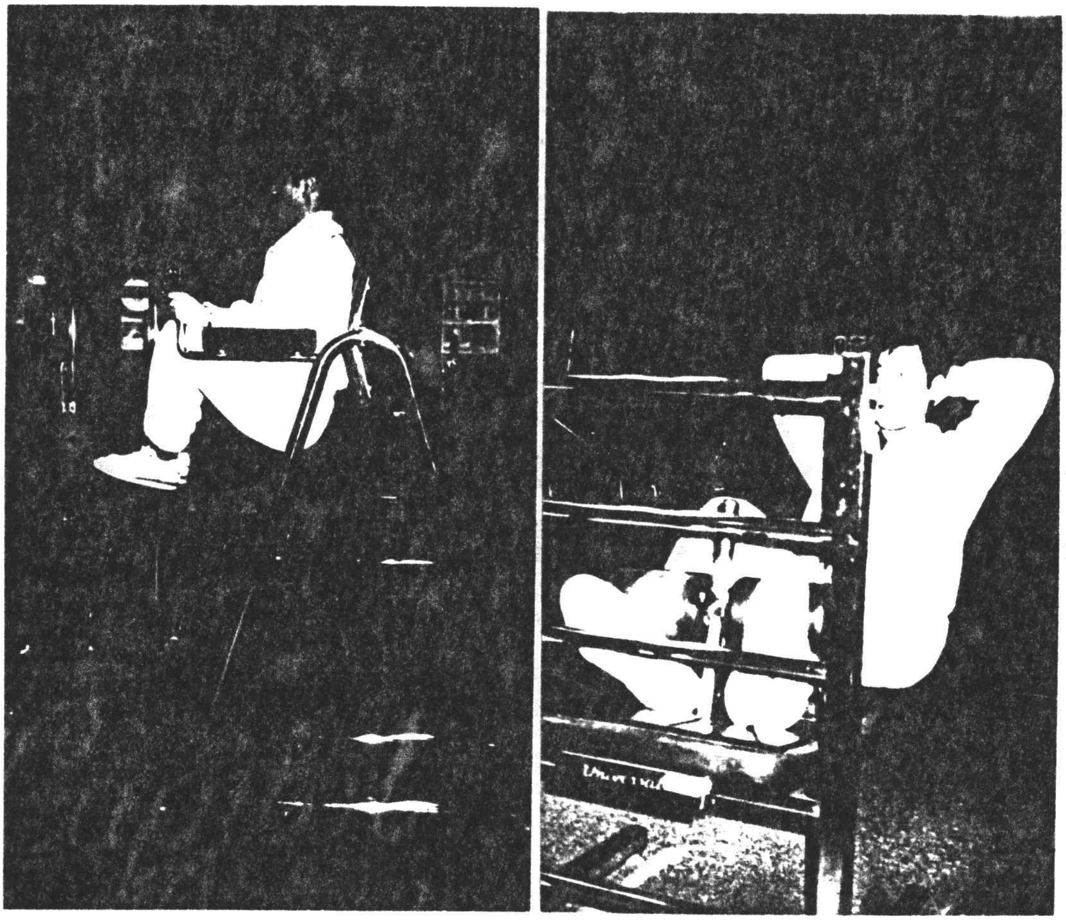
Leg Extension Leg Curl

Figure 3.3. Weight Training (C).



Upright Row Triceps Extension

Figure 3.4. Weight Training (D).



Leg Raise Sit-Up

Figure 3.5. Weight Training (E).

The weight training program was divided into three phases, consisting of two three- and one four-week periods (Table 3.3). During the first phase the weight training group used 70 percent of their 1-RM, with five repetitions for four sets for the strength emphasis workouts. For the endurance emphasis workouts, 50 percent of their 1-RM was used with 10 repetition for three sets. During the second phase subjects trained with 75 percent of 1-RM, combined with four repetitions for three sets for the strength emphasis workouts, whereas they executed 15 repetitions with three sets at 50 percent of 1-RM for the endurance emphasis workouts.

Table 3.3. Weight Training Program Schedule.

Phase (week)	Workout Poundage		Repetitions		Sets	
	a	b	a	b	a	b
Phase I (1-3)	70%	50%	5	10	4	3
Phase II (4-6)	75%	50%	4	15	3	3
Phase III (7-10)	80%	50%	3	15-20	2	3

a = Strength emphasis circuit
b = Endurance emphasis circuit

During the third phase subjects trained at 80 percent of 1-RM with three repetitions for two sets for the strength emphasis workouts, whereas they trained at 50 percent of 1-RM with 15 to 20 repetitions for three sets for the endurance emphasis workouts. However, the workload remained constant if the subjects were uncomfortable with the load. When the subjects felt comfortable, they moved to the next phase. This regimen continued for the entire training period. The training always began and ended with a short period of stretching. This involved all muscle groups that were used during the strength and endurance development sessions.

Aerobic Training Program

The aerobic training (jogging and running) was performed at Kyung Hee University. The purpose of aerobic training was to improve the function of the cardiorespiratory system through its continuous stimulation over the extended period of training.

All subjects were required to participate in a pre-conditioning aerobic session before the aerobic training started. During this period the subjects were instructed about running speed, running technique, and heart rate target zone. After the pre-conditioning session and initial testing, 10 weeks of aerobic training began. The training program included outdoor workouts involving cross-country or track running alternated with walking to maintain heart rate within a target range. The subjects ran three times per week (Monday, Wednesday, and Friday).

Target heart rate was determined by adding the percent of the difference between predicted maximum heart rate and resting heart rate to the resting heart rate. Predicted maximum heart rate was determined by subtracting age from 220 (USAF, 1986). For example:

Age: 20,
resting heart rate: 65,
maximum heart rate: 220 - 20 = 200,
difference: 200 - 65 = 135,
60 - 80% of 135 = 81 - 108, and
target heart rate = 146 - 173.

The aerobic training program was divided into four phases (Table 3.4.). Subjects ran at an intensity of 100 heart beats per minute for 20 minutes during the first phase. During the second phase the subjects ran at an intensity of 60 percent of the target heart rate for 30 minutes. During the third phase the subjects ran with an intensity of 70 percent of the target heart rate for 40 minutes. During the forth phase the subjects ran at an intensity of 70 percent of the target heart rate for 50 minutes.

Table 3.4. Ten-Week Aerobic Training Program.

Phase (week)	Duration (min)	Intensity
I (1)	20	100 beats HR/min
II (2-3)	30	60% predicted HR
III (4-6)	40	70% predicted HR
IV (7-10)	50	70% predicted HR

Subjects completely unaccustomed to aerobic conditioning began the program by initially running short distances at a slow pace. The speed and distance of running were increased as the desirable level of conditioning was attained. As alternatives to running, indoor soccer and basketball were provided in instances of bad weather.

Pulmonary Function Testing

The pulmonary function testing was performed at Kyung Hee University Hospital. The following pulmonary function parameters were selected for the test: FVC, $FEV_{1.0}$, MVV, PEF, and PE_{max}.

All pulmonary function parameters except PE_{max} were measured using the Gould 1000 Pulmonary Function Testing System (Sensormedics, Yorba Linda, CA). The subjects were seated, and a nose clip applied. They were then instructed to take a maximum inspiration and to exhale as fully and quickly as possible. The subjects made three attempts with short periods of intervening rest and for each subject the greatest of these maximal volumes, converted to BTPS, was recorded as FVC.

For MVV the subject was seated, and a nose clip was applied. The subject was instructed to breathe as fast and deeply as possible for 12 seconds. Opportunity was given to practice this maneuver. After practice and a short rest, the subject then repeated the MVV procedures three times. The greatest of these volumes was converted to BTPS and recorded as the MVV.

The PEF was estimated from the maximal expiratory flow curve obtained for FVC which was produced within the first 15 percent of the volume expired from maximum inspiration and sustained for 10 milliseconds.

The PE_{max} was measured using the Boerhinger Respiratory Pressure System (Mannheim Diagnostics, Indianapolis, IN). The measurement was made with seated subjects using a rubber scuba diving type mouthpiece, and wearing nose clips. The subject were instructed to position themselves without strain and with an erect spinal attitude. Subjects breathed room air through the mouthpiece several times. After the breathing pattern was stable and at the end of an inspiration, the subjects were instructed to exhale as forcibly as possible against the valve. During exhalation the subjects were asked to hold the mouthpiece and support their cheeks with both hands. They were told to avoid using the muscles of the face to generate the pressure. The test was repeated until the measurements obtained were considered maximal and reproducible within 10 percent.

Muscular Strength Testing

The muscular strength test for all subjects was performed using a Cybex II dynamometer (Cybex, A Division of Lumex, Inc., Rankonkoma, NY, 11779) at the Korea Sports

Science Institute Exercise Prescription Laboratory. The Cybex II dynamometer with dual channel recorder measured torque in foot pounds (ft•lb) and angular velocity in degrees per second (deg/sec). These units were transformed to Newton meters (N•m) and radians per second (rad/sec), respectively.

After the pre-conditioning period, all subjects were tested for muscular strength. The post-test was administered to the subjects to determine any changes in muscular strength (Figure 3.6.). Right knee extensor strength, as indicated by measurements of peak torque, was measured with a speed controlled dynamometer. The subjects were firmly fixed in the sitting position in an exertion chair. The right leg was stabilized with a strap at mid thigh. The ankle was secured to the lever arm using a tibial pad. The subjects were allowed to complete extension and flexion for warm-up with the speed set at 180 degrees per second. Then, the subjects performed three efforts at full range of motion as hard and fast as possible at angular velocities of 300 and 60 deg/sec. The maximal peak torque was defined as the highest value attained from three single attempts with 30 to 40 seconds of recovery between attempts.

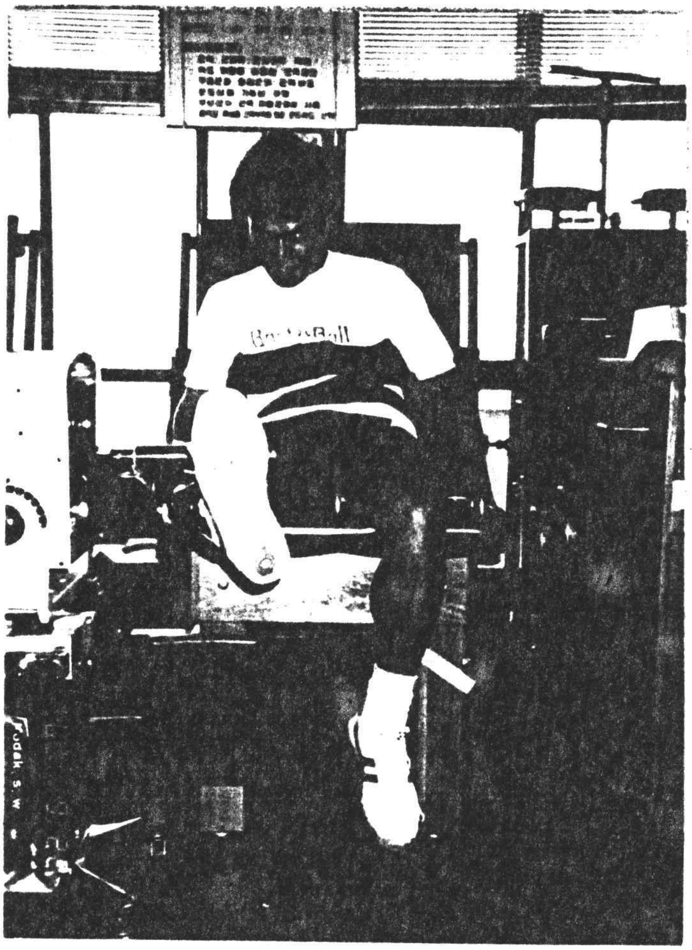


Figure 3.6. Muscular Strength Testing.

Aerobic Capacity Testing

These tests were performed at the Korea Sports Science Institute Sports Physiology Laboratory in Seoul, Korea. After the pre-conditioning period, both groups participated in aerobic capacity testing. This test was administered again after the experimental period. Maximal effort was elicited by Monark bicycle ergometry (Figure 3.7).

Before subjects began to exercise, they took five minutes of seated rest and were measured for resting blood pressure. After a five-minute rest, subjects began to exercise at 600 kpm at 50 rpm. The workload was increased 150 kpm every three minutes until the subject become completely exhausted. Testing was also terminated when subjects were unable to maintain 50 rpm for 10 seconds.

Metabolic determinations were made every 30 seconds via open circuit spirometry. The expired air samples were assessed for O_2 and CO_2 concentration by a Jaeger Oxyscreen Gas Analyzer (Erich Jaeger Company, Leibnizstr-7, FRG). The gas analyzer was calibrated against gases of known concentration before and after the test. All the cardiorespiratory function variables, including oxygen consumption, were automatically analyzed via an automated computer system (Rayfield Electronics, Chicago, Il). The subjects' heart rates were monitored using a Physio-Control Lifepack 7 (Physio-Control Corp.) in order to measure heart rate

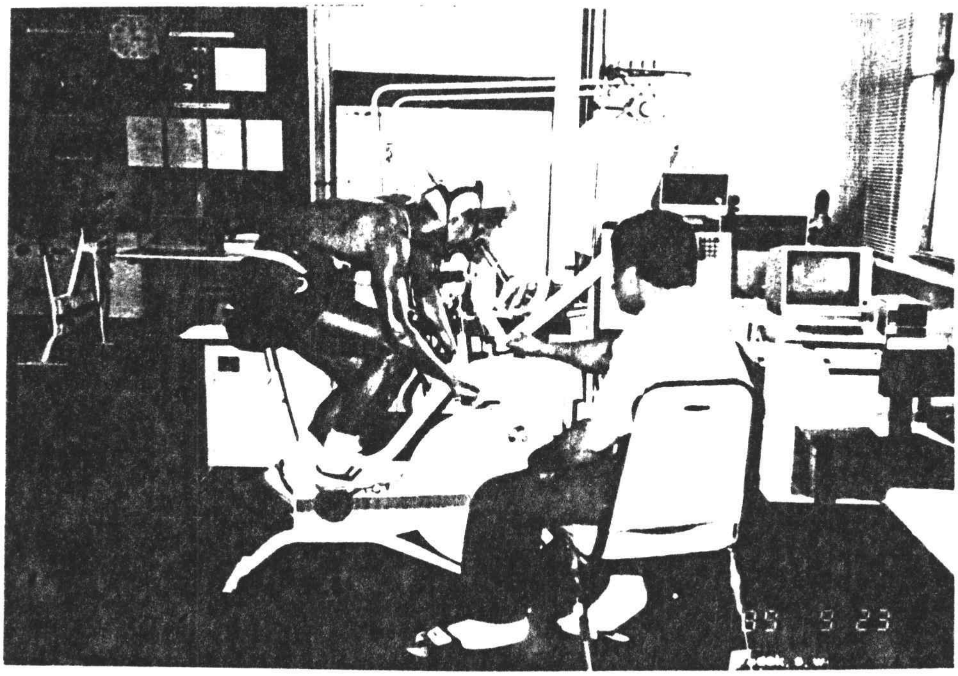


Figure 3.7. Aerobic Capacity Testing.

responses during the test. Blood pressure was continuously monitored indirectly by auscultation of the brachial artery using an automated digital sphygmonameter at the first 30 seconds of every minute during the test. Performance time on the bicycle ergometer was measured using the stopwatch. After the termination of exercise, subjects were seated and blood pressure was continuously monitored until it returned to normal.

Experimental Design

The independent variables were weight training and aerobic training. The dependent variables were peak $\dot{V}O_2$, peak $\dot{V}E$, BTPS, performance time, pulmonary function (FVC, $FEV_{1.0}$, PEF, MVV, PE_{max}), and dynamic strength. The .05 level of probability was selected as indicative of statistical significance.

Statistical Analysis

Following data collection, statistical analyses were performed using the SAS statistical package (Freund, Littell, & Spector, 1986) for the IBM computer (International Business Machines Corp.) on all variables, and on the physical and physiological characteristics of the subjects. The methods for the statistical analysis of physical characteristics included determination of the means, standard deviations, and extreme values of the variables.

The repeated measures analysis of variance (ANOVA) were applied to determine significance of difference in changes due to training between the aerobic and weight training groups. The Student paired t-test was applied to determine if any change existed between pre- and post-test means within each group as a result of physical training. The independent t-test was applied to determine if mean differences in pulmonary function variables existed between weight lifters and distance runners. The statistical analyses were done at the Korea Sports Science Institute computer laboratory.

CHAPTER IV

RESULTS AND DISCUSSION

The purposes of this study were to investigate the differential effects of 10 weeks of weight training and aerobic training on physical fitness components related to gravitational tolerance and to examine for effects of longitudinal weight and aerobic training on pulmonary function. The data obtained were statistically treated by repeated measures analysis of variance (ANOVA) to determine if differences due to training in means of measured parameters existed between the weight training group and the aerobic training group . The Student paired t-test was used to determine if any difference existed in pre- and post-training mean scores for each dependent variable within each group. An independent t-test was computed on pulmonary function variables between weight lifters and long distance runners to determine the differential effects of longitudinal resistance and aerobic training. The raw data for these variables are provided in Appendices C, D, E, and F. The results of this study are presented under the subheadings: 1) pulmonary function variables; 2) dynamic leg extension strength; and 3) aerobic capacity.

Results

Pulmonary Function Variables

Forced Vital Capacity (FVC)

Statistical analysis was conducted to determine if there were significant differences in FVC between the two training groups after training. Two subjects in the weight training group failed to take the pulmonary function post-training test and therefore their pre-test scores were discarded.

The summary table of the ANOVA for FVC (Table 4.1) shows an insignificant F-ratio for the training groups by trials (F = 2.23), which means that there were no significant differences between the two experimental groups. Therefore, the null hypothesis was accepted. The results of paired t-tests shown in Table 4.2 also demonstrate lack of significant FVC differences within each group. Neither of the experimental groups showed a significant change in FVC after the training. Comparison of means for FVC pre- and post -training is shown in Figure 4.1. Table 4.2, through use of the independent t-test, indicates no differences between the weight lifters and distance runners in FVC. Comparison of means for FVC of weight lifters and distance runners is shown in Figure 4.2.

Table 4.1. ANOVA Summary for Pulmonary Function (FVC, in liters).

Source of variation	dF	SS	MS	F	p
Between groups	1	0.37	0.37	0.26	0.62
Within groups	16	23.65	1.47		
Between trials	2	0.03	0.01	1.32	0.28
Groups by trials	2	0.06	0.03	2.23	0.12
Within trials	32	0.44	0.01		

$p < 0.05$

Table 4.2. Pulmonary Function (FVC) Variables, t-tests.

FVC	**X**	**SD**	**X**	**SD**
FVC t-test before & after 10 weeks training				
	Weight Training		Aerobic Training	
Pre-training	5.40	.84	5.27	.59
Post-training	5.53	.87	5.27	.60
t	0.30		-0.01	
p	0.76		0.99	
FVC t-test, weight lifters vs. distance runners				
	Weight Lifters		Distance Runners	
	5.72	.56	5.05	.76
t	1.42			

$p < 0.05$

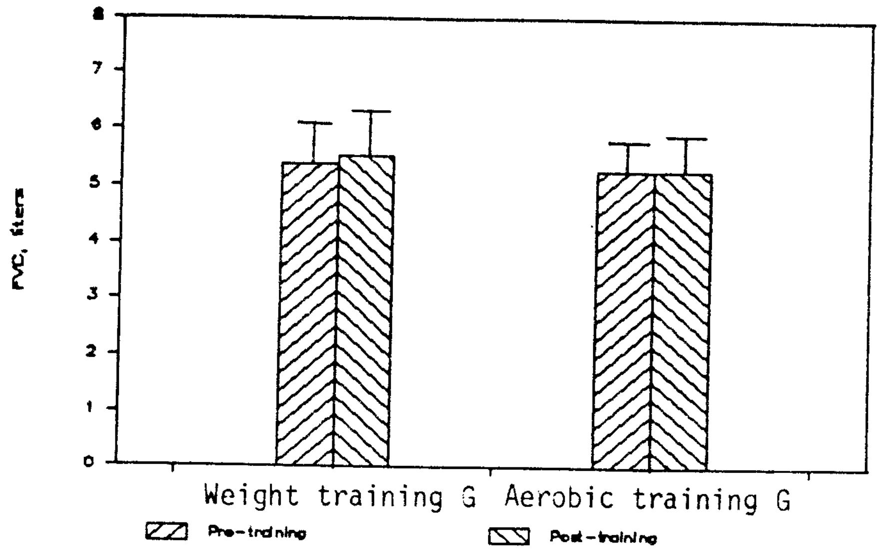


Figure 4.1. Mean FVC Pre- and Post-Training Scores.

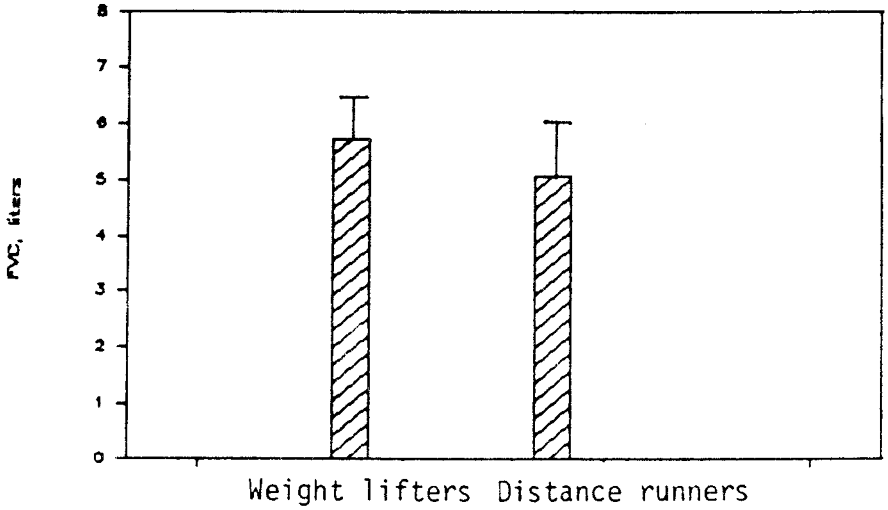


Figure 4.2. Mean FVC, Weight Lifters vs. Distance Runners.

Forced Expiratory Volume in One Second ($FEV_{1.0}$)

The repeated measures ANOVA results are shown in Table 4.3. The F-ratio for the groups by trials ($F = 0.92$) was not statistically significant. There were no significant differences between the training groups. Therefore, the null hypothesis was accepted. The results of paired t-tests shown in Table 4.4 indicated no change within either group. The graph in Figure 4.3. compares the $FEV_{1.0}$ pre- and post-training means of each group. Comparison of mean $FEV_{1.0}$ in the two groups of athletes with prolonged training also revealed no differences at the .05 level (Table 4.4). The graph in Figure 4.4 compares the $FEV_{1.0}$ means of two groups of athletes.

Table 4.3. ANOVA Summary for Forced Expiratory Volume in One-Second ($FEV_{1.0}$ in liters).

Source of variation	dF	SS	MS	F	p
Between groups	1	0.005	.005	.01	.93
Within groups	16	2.160	.760		
Between trials	2	0.003	.001	.10	.90
Groups by trials	2	0.020	.010	.92	.40
Within trials	32	0.440	.010		

* $p < 0.05$

Table 4.4. Forced Expiratory Volume (FEV$_{1.0}$) Variables, t-tests.

FEV$_{1.0}$	**X**	**SD**	**X**	**SD**
FEV$_{1.0}$ t-test before & after 10 weeks training				
	Weight Training		Aerobic Training	
Pre-training	4.47	.61	4.50	.49
Post-training	4.54	.47	4.46	.50
t	0.25		-0.19	
p	0.80		0.84	
FEV$_{1.0}$ t-test, weight lifters vs. distance runners				
	Weight Lifters		Distance Runners	
	4.83	.55	4.41	.63
t	0.93			
$p < 0.05$				

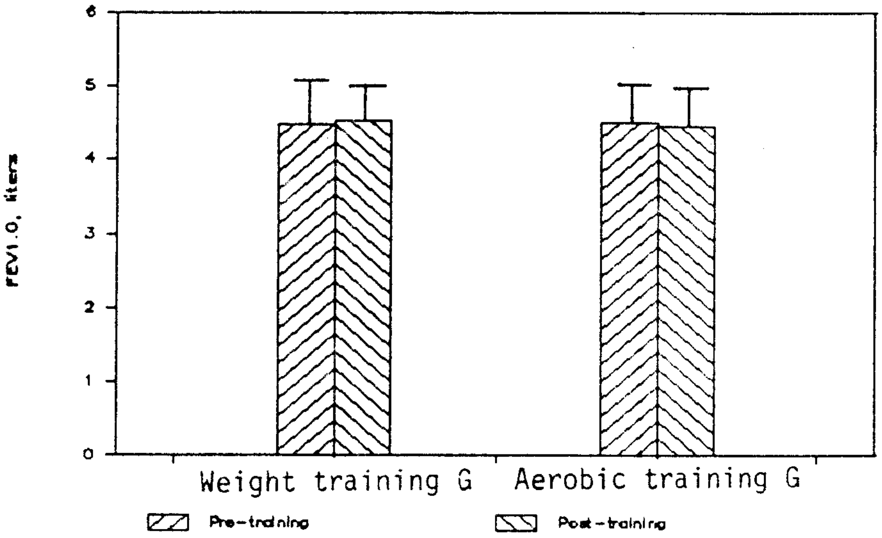


Figure 4.3. Mean FEV$_{1.0}$ Pre- and Post-Training Scores.

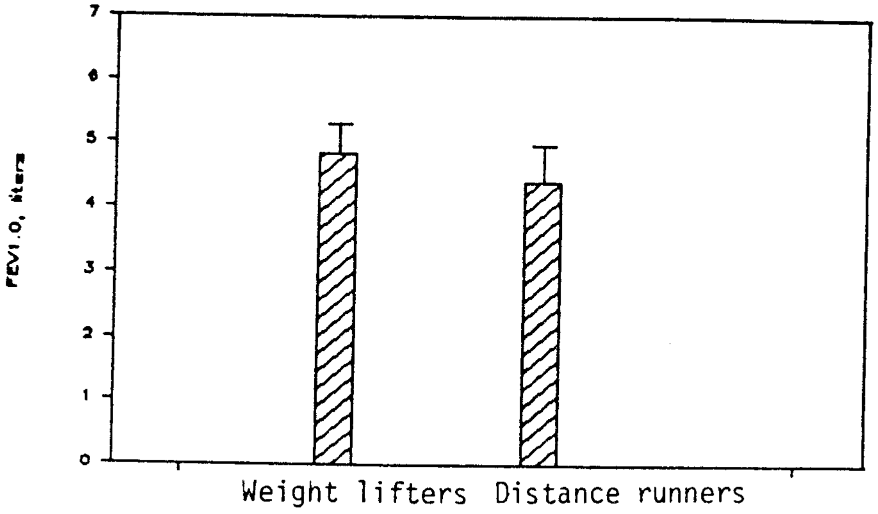


Figure 4.4. Mean $FEV_{1.0}$, Weight Lifters vs. Distance Runners.

<u>Peak Expiratory Flow</u> (PEF)

The repeated measures ANOVA results are shown in Table 4.5. The F-ratio (F = .35) for differences between the training groups was not statistically significant. Consequently, the null hypothesis was accepted. There were no significant differences between the weight training group and the aerobic training group for PEF. Paired t-tests within groups (Table 4.6) showed nonsignificant changes. Neither of the computed t-values was statistically significant at the .05 level. The graph in Figure 4.5 compares the PEF pre- and post-training means for each group. The comparison between the two groups of athletes with prolonged training comparison between the two groups of athletes with prolonged training also revealed no mean differences at the .05 level (Table 4.6). The graph in Figure 4.6 compares the PEF means of two groups of athletes.

Table 4.5. ANOVA Summary for Peak Expiratory Flow (PEF, in l/s).

Source of variation	dF	SS	MS	F	p
Between groups	1	0.93	0.93	.18	.67
Within groups	16	82.62	5.16		
Between trials	2	0.15	0.07	.34	.71
Groups by trials	2	0.15	0.07	.35	.70
Within trials	32	7.16	0.22		

* $p < 0.05$

Table 4.6. Peak Expiratory Flow (PEF) Variables, t-tests.

PEF	X	SD	X	SD
PEF t-test before & after 10 weeks training				
	Weight Training		Aerobic Training	
Pre-training	10.49	1.45	10.90	1.13
Post-training	10.74	1.77	10.89	1.12
t	0.31		-0.01	
p	0.75		0.98	
PEF t-test, weight lifters vs. distance runners				
	Weight Lifters		Distance Runners	
	11.67	1.04	11.4	1.69
t	0.01			

$p < 0.05$

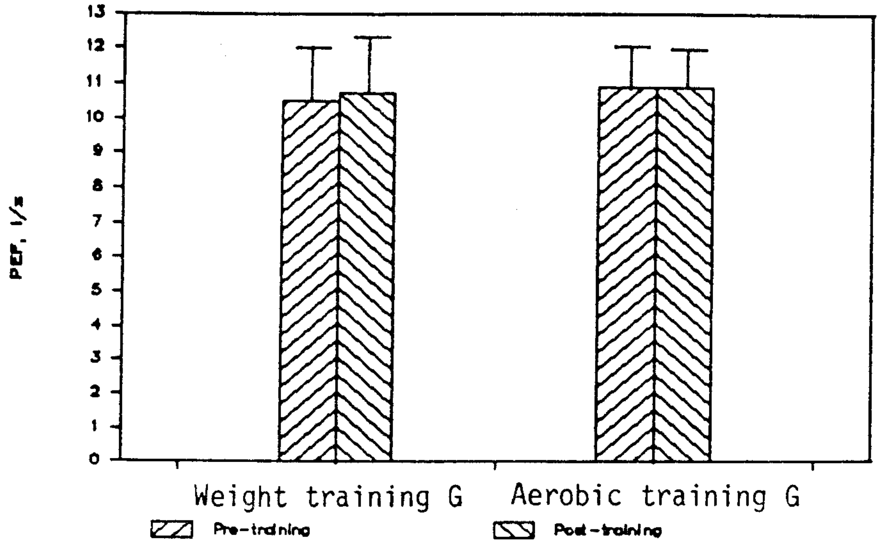


Figure 4.5. Mean PEF Pre- and Post-Training Scores.

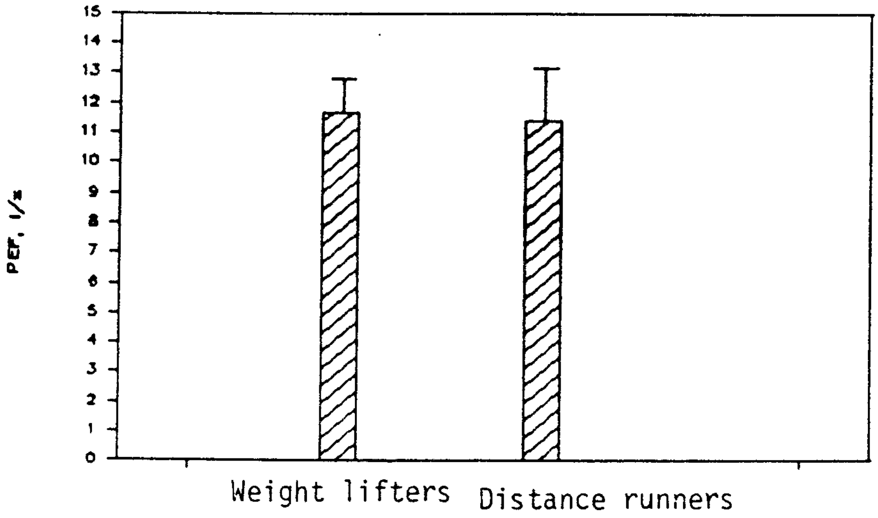


Figure 4.6. Mean PEF, Weight Lifters vs. Distance Runners.

Maximal Voluntary Ventilation (MVV)

The summary table of the ANOVA for MVV appears as Table 4.7. There were no significant differences between the two training group (F = 2.86), although the p value indicated marginal significance. Therefore, the null hypothesis was accepted. The results of a paired t-test showed that there were no significant differences in the pre- and post-training mean scores within either group (Table 4.8). Both groups showed nonsignificant increases in MVV. There was a significant main effect among trials, which seems to be due to changes evidenced by the weight training group. The p value for the weight training group was 0.052, indicating marginal significance. Comparison of mean MVV pre- and post-training is shown in Figure 4.7. Table 4.8 indicates no differences between the weight lifters and distance runners through the use of the independent t-test. The graph in Figure 4.8 compares the MVV means of two groups of athletes.

Table 4.7. ANOVA Summary for Maximal Voluntary Ventilation (MVV, in l/min).

Source of variation	dF	SS	MS	F	p
Between groups	1	152.62	152.62	0.08	.78
Within groups	16	32233.30	2014.58		
Between trials	2	2836.05	1418.02	15.56	.0001
Groups by trials	2	515.90	257.95	2.83	.07
Within trials	32	2916.95	91.15		

$p < 0.05$

Table 4.8. Maximum Voluntary Ventilation (MVV) Variables, t-tests.

MVV	X	SD	X	SD
MVV t-test before & after 10 weeks training				
	Weight Training		Aerobic Training	
Pre-training	152.62	20.23	164.80	33.34
Post-training	176.75	25.13	176.00	26.85
t	2.11		0.82	
p	0.052		0.41	
MVV t-test, weight lifters vs. distance runners				
	Weight Lifters		Distance Runners	
	171.60	23.33	192.6	27.77
t	1.05			
$p < 0.05$				

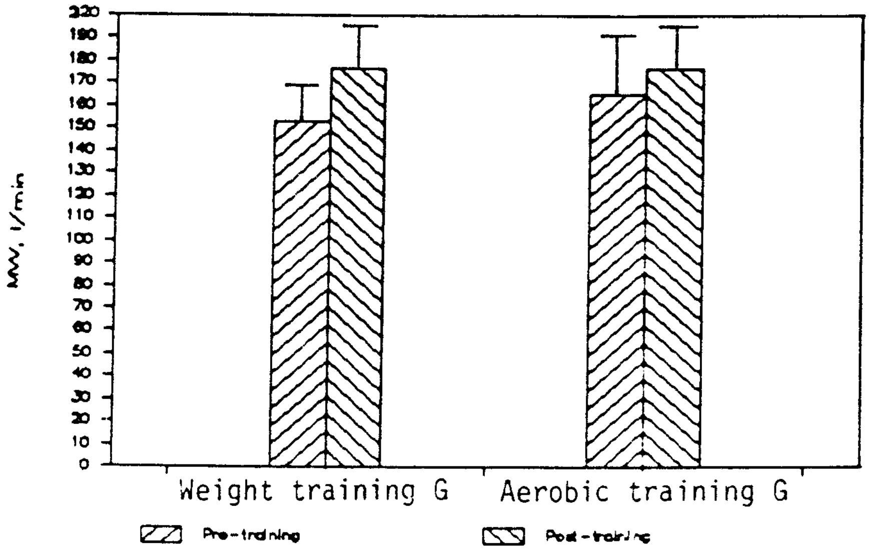


Figure 4.7. Mean MVV Pre- and Post-Training Scores.

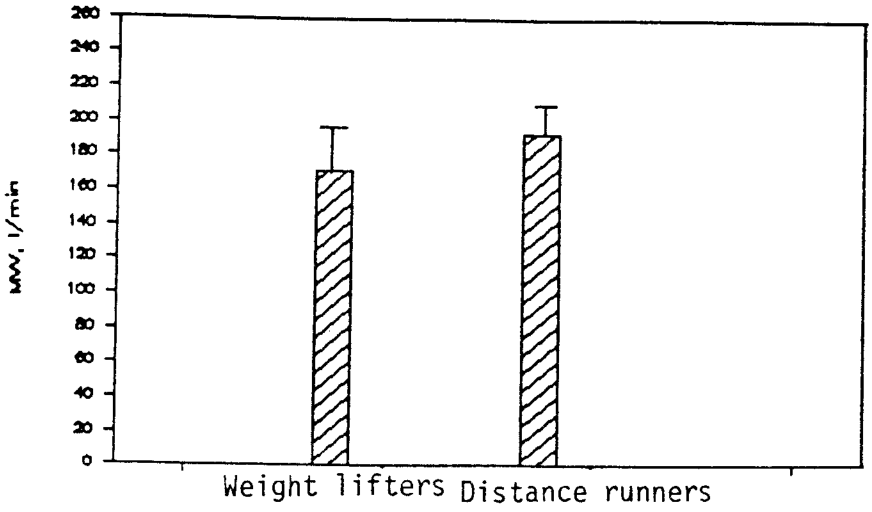


Figure 4.8. Mean MVV, Weight Lifters vs. Distance Runners.

Maximal Expiratory Pressure (PE_{max})

The results of repeated measures ANOVA are shown in Table 4.9. The F-ratio for the groups by trials was not statistically significant (F = .26). There were no significant differences observed as results of differential training. Therefore, the null hypothesis was accepted. Paired t-tests showed that there was no significant difference in pre- and post-training means within each group (Table 4.10). Comparison of means for PE_{max} pre- and post-training is shown in Figure 4.9. Comparison between the two different groups of athletes with long-term training revealed significant differences at the .05 level (Table 4.10). The weight lifters recorded a higher PE_{max} (184 mmHg) than did the distance runners (134 mmHg). The graph in Figure 4.10 compares the PE_{max} means of two groups of athletes.

Table 4.9. ANOVA Summary for Maximal Expiratory Pressure (PE_{max}, in mmHg).

Source of variation	dF	SS	MS	F	p
Between groups	1	72.59	72.59	.06	.81
Within groups	16	20336.66	1271.04		
Between trials	2	53.88	26.94	.07	.93
Groups by trials	2	194.62	97.31	.26	.77
Within trials	32	12068.33	377.13		

$p < 0.05$

Table 4.10. Maximal Expiratory Pressure (PE_{max}) Variables, t-tests.

FVC	**X**	**SD**	**X**	**SD**
PE_{max} t-test before & after 10 weeks training				
	Weight Training		Aerobic Training	
Pre-training	155.00	39.64	158.00	29.36
Post-training	156.25	19.95	152.00	21.49
t	0.07		-0.52	
p	0.93		0.60	
PE_{max} t-test, weight lifters vs. distance runners				
	Weight Lifters		Distance Runners	
	184.00	19.49	134.0	32.02
t	3.34^*			

$^*p < 0.05$

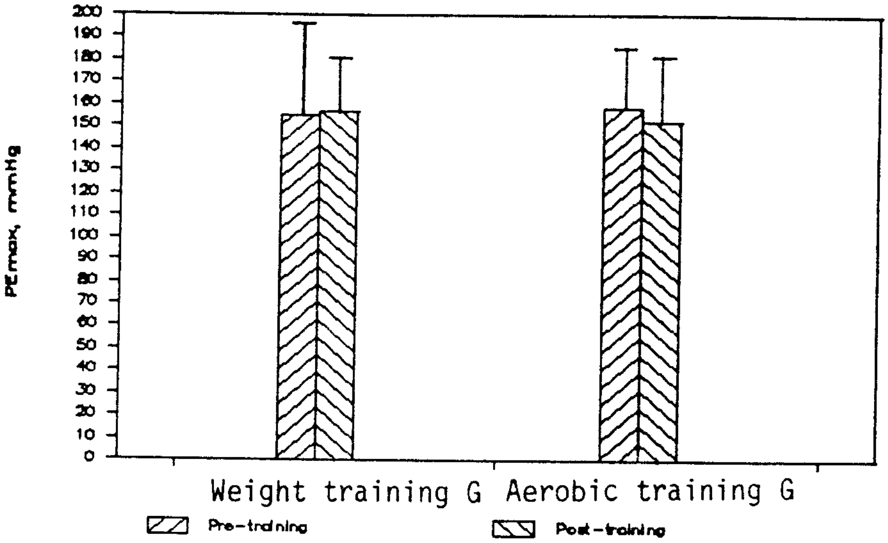


Figure 4.9. Mean PE_{max} Pre- and Post-Training Scores.

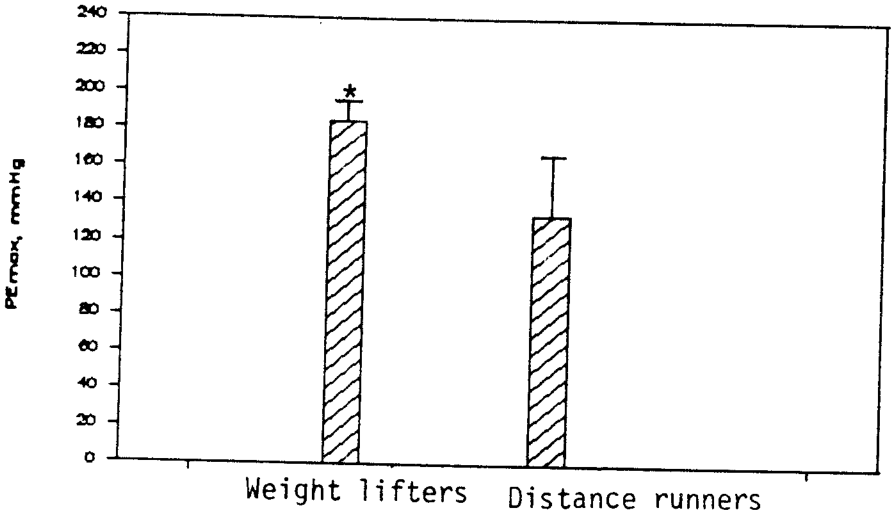


Figure 4.10. Mean PE_{max}, Weight Lifters vs. Distance Runners.

Dynamic Muscular Strength

Muscular strength was assessed by right knee extensor strength at angular velocities of 300° and 60° per second (respectively, fast and slow contraction speeds). One subject in each experimental group failed to take the muscular strength post-training test and these pre-test scores were discarded.

Muscular strength during fast dynamic contraction for the weight training group and aerobic training group increased 7.08 and 15.25 N•m, respectively. The F-ratio for fast dynamic contraction, shown in Table 4.11, demonstrated that there was no significant difference between outcomes of the two training programs ($F = 1.87$). Differences could not be attributed to training mode. Therefore, the null hypothesis was accepted. The differences between pre- and post-training means were compared using a paired t-test for each group. The computed t-values are shown in Table 4.12, and were 1.06 and 2.24, respectively, for the weight training group and aerobic training group. The aerobic training group showed a significant post-training mean difference in fast dynamic contraction. Comparison of means for fast dynamic contraction pre- and post-training is shown in Figure 4.11.

Table 4.11. ANOVA Summary for Dynamic Muscular Strength at 300° Angular Speed (N•m).

Source of variation	dF	SS	MS	F	p
Between groups	1	875.17	875.17	2.70	.120
Within groups	16	5190.39	324.39		
Between trials	1	1132.09	1132.09	13.73	.001*
Groups by trials	1	154.25	154.25	1.87	.19
Within trials	16	1319.74	82.48		

* $p < 0.05$

Table 4.12. Dynamic Muscular Strength Before and After 10-Weeks of Differential Training, t-tests, Fast Contractions.

	Weight Training		Aerobic Training	
	X	**SD**	**X**	**SD**
Pre-training	75.42	15.17	81.14	9.37
Post-training	82.50	12.86	96.39	18.1
t	1.06		2.24	
p	0.30		0.03*	

* $p < 0.05$

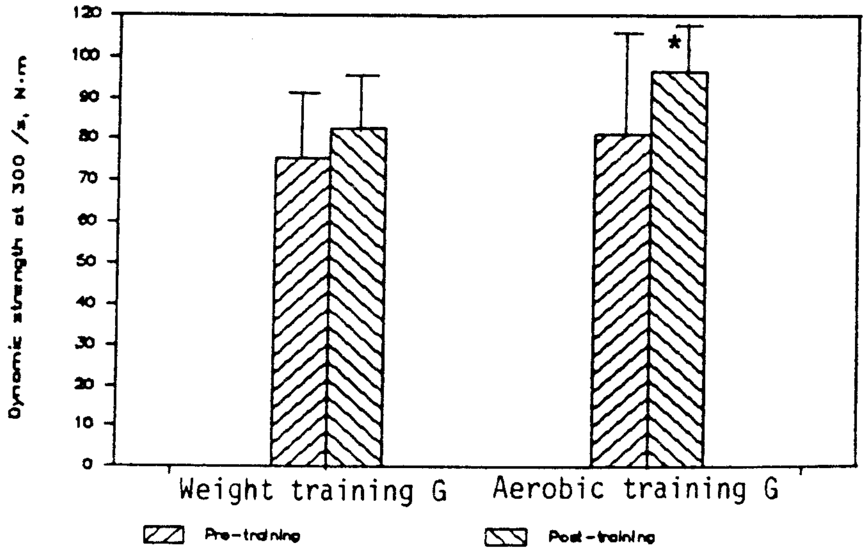


Figure 4.11. Mean Fast Dynamic Contraction
Pre- and Post-Training Scores.

Muscular strength during slow contraction for the weight training group and aerobic training group increased 19.49 and 18.02 N•m, respectively. The ANOVA for slow dynamic contraction (Table 4.13) suggests that there were no significant differences between the two training groups (F = .19). Observed difference between the outcomes of the training programs could not be attributed to training. Therefore, the null hypothesis was accepted. Both groups demonstrated nearly the same increase in slow dynamic muscular strength. Student paired t-tests in Table 4.14 showed no significant differences between the pre- and post-training means. Comparison of means for slow dynamic contraction pre- and post-test is shown in Figure 4.12.

Table 4.13. ANOVA Summary for Dynamic Muscular Strength at 60° Angular Speed (N•m).

Source of variation	dF	SS	MS	F	p
Between groups	1	2809.00	2809.00	1.55	.23
Within groups	16	29084.36	1817.77		
Between trials	1	5299.84	5299.84	58.39	.0001*
Groups by trials	1	213.25	213.25	2.35	.14
Within trials	16	1452.15	90.75		

* $p < 0.05$

Table 4.14. Dynamic Muscular Strengths Before and After 10-Weeks of Differential Training, t-tests, Slow Contractions.

	Weight Training		Aerobic Training	
	X	**SD**	**X**	**SD**
Pre-training	164.34	35.6	177.20	19.44
Post-training	183.82	37.6	195.22	33.46
t	1.12		1.39	
p	0.27		0.18	

$p < 0.05$

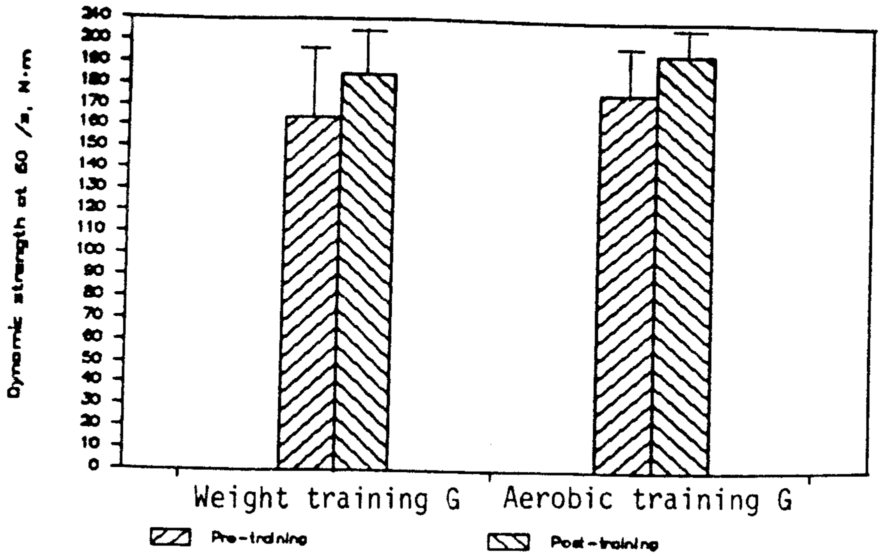


Figure 4.12. Mean Slow Dynamic Contractions Pre- and Post-Training Scores.

Aerobic Capacity

Aerobic capacity, as expressed by peak $\dot{V}O_2$, was measured twice, at the beginning and end of training, to examine for changes caused by the differential training program. Peak $\dot{V}E$ was simultaneously measured. One subject in each experimental group failed to take the post-training aerobic capacity test and pre-test scores were discarded. The ANOVA for peak $\dot{V}O_2$ expressed as l/min is summarized in Table 4.15. The F-ratio (F = .47) of groups by trials revealed that differences between the two groups could not be attributed to the type of training. Therefore, the null hypothesis was accepted. Differences between the pre- and post-training means were tested for significance using a paired t-test. The computed t-values and mean scores are shown in Table 4.16. Neither of the training groups evidenced significant changes in peak $\dot{V}O_2$ after training. Comparison of means for peak $\dot{V}O_2$ (l/min) pre- and post-test is shown in Figure 4.13.

Table 4.15. ANOVA Summary for Aerobic Capacity, No. 1 (Peak $\dot{V}O_2$, l/min).

Source of variation	dF	SS	MS	F	p
Between groups	1	0.20	.20	.45	.51
Within groups	16	7.24	.45		
Between trials	1	0.03	.03	.41	.52
Groups by trials	1	0.04	.04	.47	.50
Within trials	16	1.52	.09		

$p < 0.05$

Table 4.16. Peak $\dot{V}O_2$ Before and After 10-Weeks of Differential Training, No. 1, t-tests (l/min).

	Weight Training		Aerobic Training	
	X	**SD**	**X**	**SD**
Pre-training	3.47	.41	3.69	.68
Post-training	3.47	.47	3.55	.47
t	0.02		-0.48	
p	0.98		0.63	

$p < 0.05$

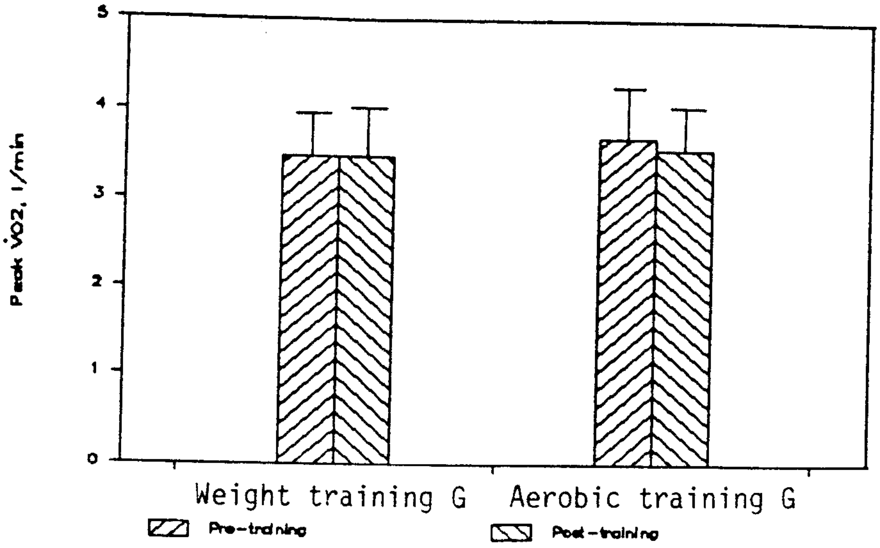


Figure 4.13. Mean Peak $\dot{V}O_2$ (l/min) Pre- and Post-Training Scores.

Results of the ANOVA for peak $\dot{V}O_2$ expressed in ml•kg•min^{-1} are presented in Table 4.17. The F-ratio (F = .12) was not significant at the .05 level, revealing that there were no significant differences between the two experimental groups. Therefore, the null hypothesis was accepted. The computed t-values in Table 4.18 also showed that there was no difference between the pre- and post-training mean scores within each training group. Both groups recorded nonsignificant decreases in peak VO_2 following training. The graph in Figure 4.14 compares the peak $\dot{V}O_2$ (ml•kg•min^{-1}) pre- and post-test mean scores for each group.

Table 4.17. ANOVA Summary for Aerobic Capacity, No. 2 (Peak $\dot{V}O_2$, ml•kg•min^{-1}).

Source of variation	dF	SS	MS	F	p
Between groups	1	11.22	11.22	.17	.68
Within groups	16	1048.32	65.52		
Between trials	1	13.52	13.52	.60	.44
Groups by trials	1	2.61	2.61	.12	.73
Within trials	16	359.42	22.46		

$p < 0.05$

Table 4.18. Peak $\dot{V}O_2$ Before and After 10-Weeks of Differential Training, No. 2, t-tests (ml•kg•min^{-1}).

	Weight Training		Aerobic Training	
	X	**SD**	**X**	**SD**
Pre-training	52.75	5.85	54.41	8.04
Post-training	52.06	7.60	52.73	4.34
t	-0.21		-0.55	
p	0.83		0.58	

$p < 0.05$

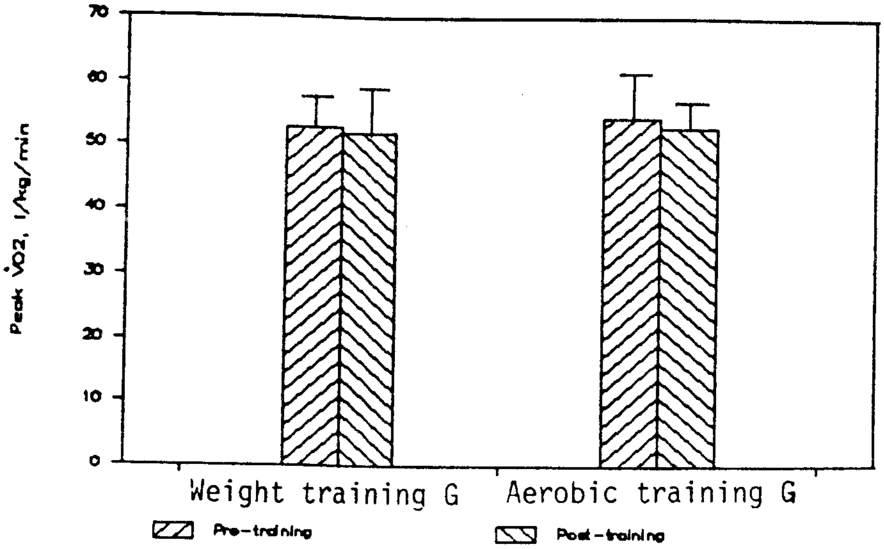


Figure 4.14. Mean Peak $\dot{V}O_2$ (ml•kg•min^{-1}) Pre- and Post-Training Scores.

Results of repeated measures ANOVA for peak $\dot{V}E$, BTPS, are shown in Table 4.19. There were no significant differences between the weight training and the aerobic training groups. The t-test (Table 4.20) showed that both groups recorded nonsignificant increases in peak $\dot{V}E$ after training. Comparison of mean scores for peak $\dot{V}E$, BTPS, pre- and post-training, are shown in Figure 4.15.

Table 4.19. ANOVA Summary for Peak $\dot{V}E$ (BTPS, 1/min).

Source of variation	dF	SS	MS	F	p
Between groups	1	21.31	21.31	0.04	.85
Within groups	16	9721.28	607.58		
Between trials	1	361.63	361.63	1.62	.22
Groups by trials	1	174.68	174.68	0.78	.38
Within trials	16	3569.71	223.10		

$p < 0.05$

Table 4.20. Peak $\dot{V}E$ Before and After 10-Weeks of Differential Training, t-tests.

	Weight Training		Aerobic Training	
	X	**SD**	**X**	**SD**
Pre-training	120.70	10.85	125.53	28.14
Post-training	131.51	25.35	128.57	13.94
t	1.17		0.29	
p	0.25		0.77	

$p < 0.05$

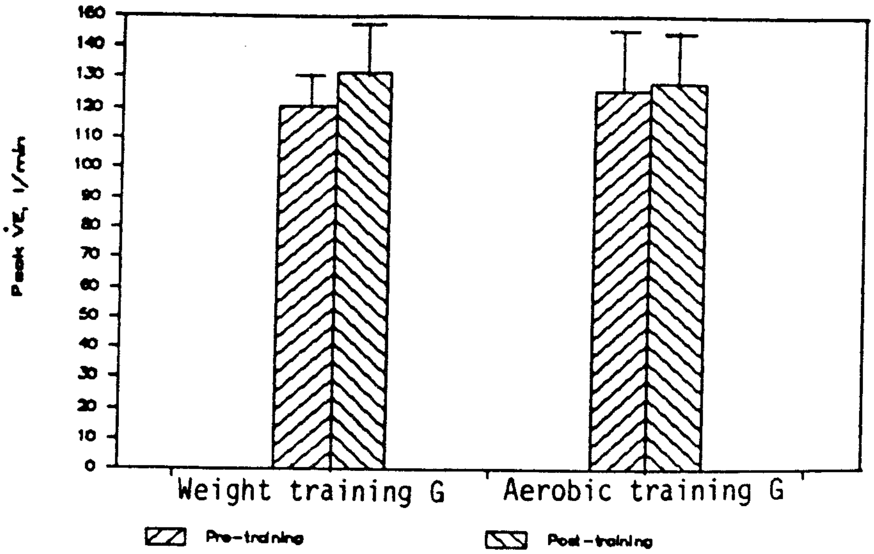


Figure 4.15. Mean Peak $\dot{V}E$ Pre- and Post-Training Scores.

Results of repeated measures ANOVA for performance time are shown in Table 4.21. There were no significant differences between the weight training group and the aerobic training groups. Both experimental groups demonstrated nearly the same increase in performance time. Independent t-tests (Table 4.22) revealed that both groups significantly increased performance time on the bicycle ergometer after training. The computed t-values for the weight training group and the aerobic training group were 5.27 and 3.24, respectively. The comparison of means for performance time pre- and post-test is shown in figure 4.16.

Table 4.21. ANOVA Summary for Performance Time (in seconds).

Source of variation	dF	SS	MS	F	p
Between groups	1	10574.69	10574.69	0.23	.63
Within groups	16	727729.77	45483.11		
Between trials	1	825373.14	825373.14	137.93	.001*
Groups by trials	1	2384.69	2384.69	0.39	.53
Within trials	16	95743.55	5983.97		

* $p < 0.05$

Table 4.22. Performance Time Before and After 10-Weeks of Differential Training, t-tests.

	Weight Training		Aerobic Training	
	X	SD	X	SD
Pre-training	725.00	130.0	775.00	214.0
Post-training	1046.00	125.0	1063.00	154.0
t	5.27*		3.24*	

* $p < 0.05$

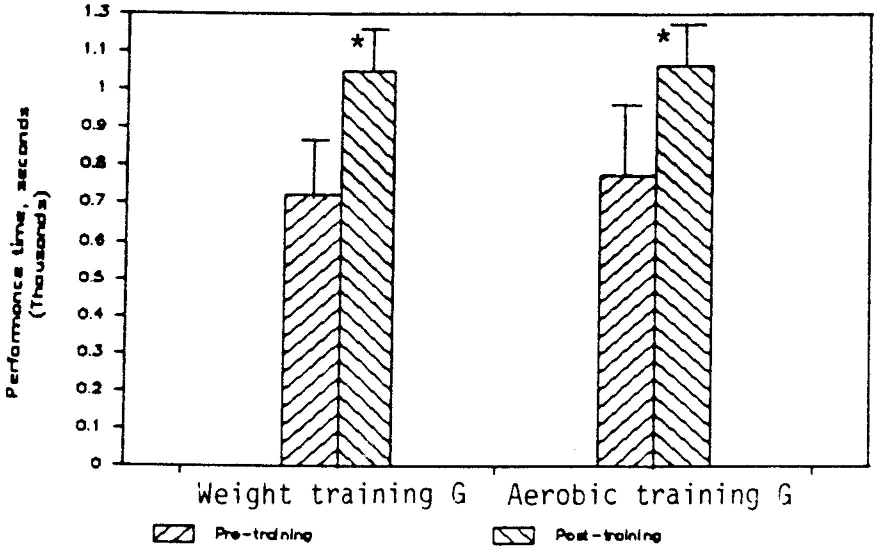


Figure 4.16. Mean Performance Time Pre- and Post-Training Scores.

Discussion

The present study was designed to determine if either resistance or aerobic physical conditioning could influence physical fitness components regarded as important factors in gravitational force tolerance. The +Gz force tolerance was not measured in this study. The main objective was to determine if either resistance or aerobic training could enhance the potential of young, fit men to resist the physical stress caused by high +Gz forces. The discussion of the results is presented under the following subheadings: 1) pulmonary function, 2) strength development, and 3) aerobic capacity.

Pulmonary Function

A number of previous studies have demonstrated that physical training can result in improved respiratory function, depending on the mode of training (Robinson & Kjeldgaard, 1982; McKay et al., 1983; Yerg et al., 1985). However, based on the data obtained in this study it was found that neither training group demonstrated statistically significant changes in pulmonary function and respiratory muscle function tests after training, although F-ratio and t-value for MVV indicated marginal significance. Therefore, it can be said that there was no difference in the effectiveness of resistance as opposed to aerobic training in terms of developing FVC, $FEV_{1.0}$, PEF, MVV, and PE_{max} in young, relatively fit men.

The aerobic group in this study did not show significant change in pulmonary function variables after training. Some of the subjects tested actually demonstrated insignificant decreases in pulmonary function variables following training. Such decreases and insignificant mean changes generally are difficult to explain, but certain possibilities exist. Since pre- and post-training pulmonary function tests were not necessarily conducted at exactly the same time of day, this uncontrolled variable may have affected pulmonary function measurements. Tests were also administered on the same day for all. Some subjects may have suffered minor respiratory congestion during pulmonary function tests. Some subjects were smokers and failure of training to affect pulmonary function might be explained by the adverse effects of smoking. The training duration of 10 weeks may not have been sufficiently long for eliciting training effects in the group of young, fit men. The results of this study are similar to previous studies which reported that (1) mild exercise training of short duration may not improve pulmonary function in young individuals (Davis et al., 1979) and that (2) endurance training may influence some other factors of pulmonary components, such as pulmonary diffusing capacity, pulmonary blood volume, and membrane permeability, instead of static and dynamic lung volume (Palatsi, Niemelä, & Takkunen, 1980).

Strength training in this study did not cause significant change in tests of pulmonary and respiratory function, although insignificant increases were observed in most post-training mean scores. This is not surprising since a number of others (Kim, 1986; Simpson, 1982; Merrick & Axen, 1981) have reported that resistance training typically does not affect these parameters. One of the most important parameters measured in this study was PE_{max}, which is frequently used to evaluate respiratory muscle strength (Chen & Kuo, 1989; Black & Hyatt, 1969; Rubinstein et al., 1988; Clausen, 1982; Leech, Ghezzo, Stevens, & Becklate, 1983). The strong expiratory movement during the anti-G straining maneuver is accompanied by a full or partial Valsalva maneuver. It was anticipated that strong respiratory movements during weight training might induce proficiency with the Valsalva maneuver and/or develop respiratory musculature of the neck and chest important to the performance of anti-G straining maneuvers. Clanton et al. (1987) reported that increase in respiratory muscle force might occur from conditioning of the respiratory muscles of the neck and chest wall, which are more important in expanding the chest at large volumes, although Jacobs (1987) did not see any significant change after 12 weeks of circuit weight training. Tesch (1984) reported that maximal expiratory pressure may be related to the strength of larger skeletal muscles.

Anticipated respiratory muscle adaptations did not occur in the subjects in this study, which suggests either that PE_{max} is not associated with muscular strength training or that a strength training program suitable for already fit subjects was not applied. However, when comparing the data of differently trained elite athletes, weight lifters demonstrated statistically significant greater PE_{max} than did the distance runners. The PE_{max} values ($\bar{X}$ = 184) of national class weight lifters were higher than those of the national class distance runners ($\bar{X}$ = 134). The PE_{max} values of the distance runners were lower than those of either experimental group, which supports the findings of Cordain et al. (1987) and Pyorala, Heinonen, and Karvonen (1968), both of which reported that long term endurance training might decrease PE_{max}. Pyorala et al. pointed out that lower and deep rhythms of breathing might reduce airway resistance resulting in lower PE_{max}. Therefore, based on the information available, it might be possible that PE_{max} could be improved by longitudinal resistance training. That is, PE_{max} would increase if the relationship between overall strength and the ability to generate expiratory pressure is cause and effect. On the other hand, the present study offers no firm supporting evidence for this phenomenon since it was impossible to acquire pre-training data on the national class weight lifters and distance runners.

Dynamic Strength Development

The physical stress caused by high acceleration force affects the leg, trunk, and arm muscles, which are recruited to perform respiratory and other muscular maneuvers. The abdominal and thigh muscles are very active when straining maneuvers are performed in the human centrifuge (Tesch, 1984). Contractions of these muscles helps to prevent the pooling of blood in the abdominal region and lower extremities (Gillingham, 1988), and aids in central venous return. Chest muscles contract to produce a forceful expiration against a closed or partially closed glottis (Epperson et al., 1985). It is obvious that this kind of muscular capability might be developed by training against high resistance. If military aircrew members were trained to improve muscle strength with repeated intense contractions, they might maintain vision with a lower percentage of maximal voluntary contraction and sustain the contraction longer with a more rapid recovery. Studies (Tesch et al., 1983; Epperson, Burton, & Bernauer, 1977) have shown that increased strength helps aircrew members perform anti-G straining maneuvers effectively, thereby increasing +Gz tolerance.

Typically, improved strength is accompanied by muscle hypertrophy, which in turn is believed to be the result of enlarged muscle fiber diameter (Gonyea, 1980; Ho et al., 1980). It is generally accepted that most types of resistance training programs can induce strength development. However, the results of the present study failed to show a statistically insignificant increment in post-training strength for the weight training group. The weight training group showed a nonsignificant increase in quadriceps extension dynamic strength, 9.3 percent increase in fast dynamic contraction, and an 11.8 percent increase in slow dynamic contraction. Although strength increase is limited at fast contraction velocities (Petersen, Miller, & Wenger, 1984), strength improvement was evident at both velocities in the present study. Recent studies (Jacobs, Bell, Pope, & Lee, 1987; Tesch et al., 1983) have observed increases in both slow and fast contraction following resistance training. The insignificant change in this study may be due to the fact that the training program was not solely concentrated on strength acquisition. The program for the weight training group was divided into two circuits: strength emphasis and endurance emphasis. The relatively mild initial intensity of the workouts might also have affected the results of this study.

It is of interest that the aerobic training group improved both fast and slow dynamic muscular strength to a greater extent did the weight training group: by 18.7 and 10.1 percent, respectively, for fast and slow dynamic contractions. The increase in fast dynamic muscular strength was statistically significant. These results are difficult to explain. Although the subjects were randomly assigned, the pre-training strength values of the aerobic training group were insignificantly higher than those of the weight training group for both contraction speeds. This may suggest that subjects in the aerobic training group were naturally endowed for strength acquisition. The varied motivational factors within each group during testing and training could be an additional explanation. Also, the aerobic training group ran in a mountainous terrain area, which might have had a strength developing influence on leg musculature. Finally, better neuromuscular adaptation could be a cause. Increased maximum force production may be brought about by improved innervation and additional recruitment of high threshold motor units. Perhaps members of the aerobic training group had greater inherent adaptability in this regard than did members of the resistance training group.

Aerobic Capacity

Physical training for high performance aircraft crew members is similar in many respects to training for athletic performance which requires specific aerobic and anaerobic conditioning programs. During air combat maneuvers, pilots experience high G-forces for short periods of time. They also face fatigue caused by the stress of this sort of flying. Physical training programs for military aircrew members should be designed to increase the effectiveness of the anti-G straining maneuver as well as the stamina required in the flight environment. Probably a certain amount of endurance training should be applied to induce optimum fitness and health, and for maintaining +Gz tolerance. However, earlier studies (Banta et al., 1987; Parnell & Whinnery, 1987) have reported adverse effects on +Gz tolerance of long term aerobic training by aircrew members. Severe endurance training causes decreased effectiveness of the blood pressure control system by reducing the sensitivity of the high pressure baroreceptors (Stegemann et al., 1974). Aerobic training also enhances cardiovascular vagal tone (Whinnery, 1982). Excessive vagal stimulation transmitted to the gastrointestinal tract and heart may cause motion sickness as well as cardiac dysrhythmia. This may reduce the +Gz tolerance of aircrew members. However, a study by Convertino et al. (1984) showed a short term endurance training regimen which induced a significant increase in $\dot{V}O_2$ max, and did not change the responsiveness of the blood control system. Therefore, carefully designed programs of aerobic exercise may be helpful to +Gz tolerance.

This study showed no significant difference in peak $\dot{V}O_2$ expressed either as liters per minute or as milliliters per kilogram per minute within or between the weight training group and aerobic training group. The study also indicated that there were no significant differences in mean peak $\dot{V}E$ within and between the two training groups.

A possible explanation for the failure of training to increase $\dot{V}E$ and peak $\dot{V}O_2$ in this study may be that subjects in both groups already possessed a high level of cardiorespiratory function and muscular strength at the time of the initial test. When the pre-test mean peak $\dot{V}O_2$ attained working on a bicycle ergometer was compared with that from previous studies attained running on a treadmill (Jacobs et al., 1987; Tesch et al., 1983; Epperson et al., 1982), it was clearly high. Bicycling on the ergometer produces a lower O_2 uptake in comparison to running on the treadmill (Mckay & Banister, 1976; Åstrand & Rodahl, 1977). It also may be reasonable to mention that 10 weeks of physical conditioning may not be long enough in duration for adequate stimulation of the cardiorespiratory system, especially in those with initially high levels of aerobic function. It is interesting to note that peak exercise time on the bicycle ergometer was significantly improved for both groups after training. This result in the face of no change in aerobic power, may reflect an improvement in the function of anaerobic pathways in these subjects. Another possibility is that subjects simply anticipated that they would perform better after training and thus provided a superior effort at the post-training assessment.

CHAPTER V

CONCLUSION

Summary

The purpose of the present study was to determine the differential effects in young fit, males of weight training and aerobic training on parameters regarded as critical to gravitational resistance. A secondary purpose was to compare weight lifters and distance runners with respect to the same pulmonary and respiratory factors. The study was conducted at Kyung Hee University, Kyung Hee University hospital, and the Korea Sports Science Institute in Seoul, Korea during the fall semester of the 1989 academic year. Weight training was performed in the Kyung Hee University weight room, and aerobic training in open terrain and on the Kyung Hee University track and field ground. The subjects for the study include 30 male college undergraduate student. Twenty experimental subjects were young, fit physical education majors with a mean age of 20.8 years; a mean height of 172.4 cm; and a mean weight of 66.3 kg. They were randomly assigned into two experimental groups: the weight training group and the aerobic training group. The remaining 10 subjects were five national class weight lifters and five national class distance runners with a mean age of 20.2 years; a mean height of 174.6 cm; and a mean weight of 68 kg. They were tested only once for pulmonary function.

Prior to the start of the experimental period, all subjects to be trained were tested for pulmonary function, muscular strength, and aerobic power. Pulmonary function testing was done using a Gould 1000 System (Sensomedics, Yorba Linda, CA) and a Boerhinger System (Mennhein Diagnostics, Indianapolis, IN) in the Kyung Hee University hospital. Strength tests and aerobic capacity tests were administered in the Korea Sports Science Institute using a Cybex II dynamometer (Cybex, A Division of Lumex, Inc., Rankonkoma, NY 11779) for the former, and a Monark bicycle ergometer in conjunction with a Jaeger Oxyscreen automatic gas analyzer (Erich Jaeger Company, Leibnizstr-7, FGR) for the latter. After the pre-test, the experimental groups engaged in strength training and aerobic training which consisted of two hours for each session, three sessions per week for a period of 10 weeks. The subjects were retested after the 10 weeks of training. Two subjects in the weight training group failed to take the pulmonary function post-test and one subject in each experimental group failed to take the strength and aerobic post tests. Their pre-test scores were therefore discarded.

For the statistical analyses, repeated measures ANOVA were used to assess the significance of difference in changes due to training between the two training groups.

Student paired t-tests were used to assess the significance of mean test scores within each group. An independent t-test was used to determine the difference between weight lifters and distance runners for all measured parameters. The .05 level of significance was used as the critical level for rejection of the null hypotheses in the present study.

Based on the results there were no significant differences in the effectiveness of the training programs in pulmonary function, strength development, and aerobic capacity. Differences in measured parameters between weight lifters and distance runners were statistically insignificant, except for PE_{max} which was greater for the weight lifters. There was no significant difference in the pre- and post-training means for pulmonary function within the weight training group and within the aerobic training group. There were no significant differences in the pre- and post-training means for dynamic strength expressed in fast contraction speed within the weight training group. There was a significant difference in the pre- and post-training means for dynamic strength expressed in fast contraction speed within the aerobic training group. There was no significant difference in the pre- and post-training means for dynamic strength expressed in slow contraction speed within the weight training group and within the aerobic training group. There were no significant differences in the pre- and post-training means for aerobic capacity within the weight training group and within the aerobic training group.

Conclusions

In view of the findings of this study, the following conclusions were warranted:

1. The 10 weeks of weight training and aerobic training employed in this study failed to produce significant changes in the parameters of pulmonary function thought to be important in resistance to gravitational forces in young, fit males.

2. The 10 weeks of weight training employed in this study failed to produce significant changes in dynamic muscular strength in young, fit males.

3. In this study, the aerobic training, which included running in rough, mountainous terrain, significantly improved leg muscle strength.

4. Neither the 10 weeks of weight training nor aerobic training produced a significant change in aerobic capacity in the young, fit males.

5. Longitudinal weight training may produce a significant increase in PE_{max}.

6. Ten weeks of weight training and aerobic training employed in this study produced significant changes in performance time on the bicycle ergometer in young, fit males.

Recommendations

The following recommendations are based on the results of this study and earlier studies:

1. A study should be undertaken with young males representative of a more diverse range of fitness levels, but still similar to that observed in military aircrew members.

2. Future studies with objectives similar to those of the present study should utilize training programs of greater frequency, duration, and intensity, especially if establishing effective training methods for military aircrews is an issue.

3. In the future, evaluation of changes in G-tolerance as assessed in the human centrifuge should be an aspect of physical training studies.

4. A study should be undertaken to determine if a combination of endurance and resistance training might minimize the unfavorable effects of endurance training alone.

5. A study should be initiated to establish at what peak VO_2 and/or after what duration of intense aerobic training is the ability to resist G-forces adversely affected.

6. Based on outcomes of the present study and facts established in the review of literature, until research findings dictate otherwise, it is recommended that military aircrew members train with resistance exercises three times

per week and with aerobic exercises three times per week. Aerobic workouts should be no longer than 30 minute in duration and should be performed at a target heart rate range. Such programs are provided as described in a report from the U.S. Air Force School of Aerospace Medicine and the Naval Aerospace Medical Research Laboratory (1988).

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APPENDICES

Appendix A

Informed Consent Release

In consideration of the benefits to be derived and the data to be generated, the undersigned, a student of Kyung Hee University, agrees to participate in the research project, "Differential Effect of Weight Training and Aerobic Training on the Parameters Related to Resistance to Gravitational Forces," under the direction of Dr. C. W. Zauner, Professor of Exercise and Sports Science, Oregon State University, Oregon, U.S.A.

The undersigned states that he has read an outline of a proposed study, including the possible risks and benefits, and is participating voluntarily and consents to following testing and training program outlined. The undersigned also agrees to the use of the data generated as the above agencies may desire.

At any time during the study, if circumstances should arise and the undersigned cannot complete the study, he is free to discontinue. The student, however, understands that payments as agreed can be provided only if the study is completed in full.

Participant

Date

Appendix B

Weight Training Program (Universal Gym)

Strength Emphasis

1. Leg press
2. Bench press
3. Lat pull
4. Military press
5. Arm curl
6. Sit-up
7. Leg raise

Endurance Emphasis

1. Leg extension
2. Leg curl
3. Lat pull
4. Military press
5. Upright row
6. Shoulder shrug
7. Arm curl
8. Triceps extension
9. Sit-up
10. Leg raise
11. Bench press
12. Neck series

Appendix C

Raw Data for the Weight Training Group

	FVC (liters)			FEV$_{1.0}$-(liters)			PEF (l/s)		
	a	b	c	a	b	c	a	b	c
1	5.39	5.58	5.65	4.45	4.57	4.62	8.76	9.12	9.30
2	5.04	5.10	5.15	3.92	4.14	4.04	9.56	9.36	9.33
3	5.15	5.11	5.28	4.04	3.97	4.30	11.17	10.51	11.6
4	5.82	5.87	5.91	4.74	4.71	4.65	10.46	9.64	9.64
5	4.67	4.97	4.95	4.03	4.31	4.35	9.53	9.86	9.48
6	4.54	4.41	4.61	4.00	3.85	4.01	11.76	12.95	13.28
7	5.40	5.33	5.27	4.86	4.91	4.92	13.14	13.25	13.43
8	7.23	7.11	7.46	5.72	5.52	5.44	9.56	10.20	9.91

	MVV (l/min)			PE$_{max}$ (mmHg)		
	a	b	c	a	b	c
1	143	163	183	130	130	130
2	153	178	171	90	150	170
3	118	126	151	140	150	130
4	141	158	146	190	200	180
5	145	147	160	130	160	140
6	175	172	184	200	150	170
7	178	209	221	200	170	160
8	168	174	198	160	160	170

a = pre-test
b = mid-test
c = post-test

Raw Data for the Weight Lifters

	FVC	FEV$_{1.0}$	PEF	MVV	PE$_{max}$
1	5.81	5.19	10.62	202	190
2	4.93	3.85	11.41	141	150
3	5.73	5.08	12.02	160	200
4	6.41	5.01	13.31	185	190
5	5.83	5.05	11.02	170	190

Appendix D

Raw Data for the Weight Training Group

	Leg Strength				Peak $\dot{V}O_2$			
	300 (N•m)		60 (N•m)		(l/min)		(ml•kg•min^{-1})	
	a	b	a	b	a	b	a	b
1	62.33	74.52	135.5	150.4	2.75	3.20	43.4	51.4
2	48.78	65.04	121.9	147.6	3.32	3.73	54.3	60.0
3	75.88	94.85	170.7	195.1	3.45	2.71	56.1	41.2
4	70.46	82.65	154.4	155.8	4.11	4.27	64.7	67.3
5	85.36	86.72	150.4	170.7	3.62	3.29	51.2	45.8
6	89.43	69.10	162.6	185.6	3.56	3.73	50.0	50.3
7	100.27	107.05	243.9	264.2	4.00	3.74	54.5	50.9
8	70.46	81.30	149.0	168.0	3.15	3.01	52.0	49.8
9	75.88	81.30	191.0	216.8	3.31	3.63	48.6	51.9

	Peak $\dot{V}E$ (l/min)		Performance Time (seconds)	
	a	b	a	b
1	121.4	143.3	543	885
2	106.9	138.8	672	1200
3	102.8	75.6	720	930
4	117.2	155.0	807	1110
5	125.0	115.2	760	955
6	122.8	151.8	607	1110
7	135.6	123.6	911	1090
8	120.7	126.1	608	910
9	133.9	153.6	900	1210

a = pre-test
b = post-test

Appendix E

Raw Data for the Aerobic Training Group

	FVC (liters)			FEV$_{1.0}$ (liters)			PEF (l/s)		
	a	b	c	a	b	c	a	b	c
1	5.70	5.80	5.92	4.93	4.80	5.04	10.08	10.31	10.74
2	4.64	4.72	4.45	4.08	4.28	3.93	10.90	11.10	12.45
3	5.96	5.66	5.82	5.22	4.91	4.99	13.43	13.07	12.90
4	5.02	4.97	4.86	3.96	3.86	3.73	9.68	9.61	9.70
5	5.43	5.49	5.59	4.19	4.10	4.21	11.72	10.69	11.45
6	4.38	4.59	4.61	4.09	4.06	4.28	10.49	11.14	10.40
7	5.94	6.16	5.73	4.71	4.52	4.31	11.17	11.87	11.01
8	4.96	5.17	5.20	4.14	4.37	4.37	9.49	8.94	9.42
9	4.79	4.77	4.55	4.47	4.53	4.47	11.24	11.31	9.97
10	5.92	5.93	5.98	5.30	5.30	5.32	10.86	10.39	10.95

	MVV (l/min)			PE$_{max}$ (mmHg)		
	a	b	c	a	b	c
1	169	154	176	150	150	130
2	179	173	185	110	140	160
3	217	208	216	200	200	170
4	118	123	127	140	140	140
5	141	135	167	140	120	120
6	127	142	166	160	160	180
7	184	177	186	150	150	160
8	132	148	150	210	150	150
9	183	195	173	170	160	180
10	198	191	214	150	160	130

a = pre-test
b = mid-test
c = post-test

Raw Data for the Distance Runners

	FVC	FEV$_{1.0}$	PEF	MVV	PE$_{max}$
1	3.85	3.40	10.03	166	140
2	4.97	4.52	10.26	168	120
3	5.96	5.17	13.18	229	110
4	5.31	4.51	13.33	213	170
5	5.17	4.46	10.20	187	130

Appendix F

Raw Data for the Aerobic Training Group

	Leg Strength				Peak $\dot{V}O_2$			
	300 (N•m)		60 (N•m)		(l/min)		(ml•kg•min^{-1})	
	a	b	a	b	a	b	a	b
1	79.94	85.36	154.40	186.9	2.47	2.64	39.5	42.9
2	75.88	78.59	150.40	176.1	4.61	3.63	62.4	51.1
3	81.30	94.85	168.00	216.8	3.45	3.29	52.5	50.1
4	92.14	124.66	203.20	243.9	3.73	4.00	48.5	52.0
5	78.59	92.14	181.57	181.5	3.89	3.57	60.8	55.0
6	85.37	105.69	181.57	235.7	4.54	3.90	64.9	55.5
7	69.10	66.39	162.60	172.0	3.25	3.09	58.1	54.6
8	97.56	109.75	200.54	224.2	3.20	3.77	49.1	57.8
9	70.46	111.11	192.41	219.5	4.12	4.14	53.9	54 8

	Peak $\dot{V}E$		Performance Time (seconds)	
	a	b	a	b
1	108.2	118.2	340	730
2	152.8	132.1	915	1150
3	97.5	107.0	680	1020
4	98.6	136.8	793	1202
5	144.1	143.7	904	1095
6	175.5	149.2	830	1035
7	123.4	133.9	598	960
8	109.6	116.9	840	1115
9	130.1	119.4	1083	1255

a = pre-test
b = post-test