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Ninety-six Salem fire fighters were used as subjects in this investigation which evaluated the efficacy of the Salem, Oregon Fire Department physical fitness program. Pre and post measures separated by three months of physical fitness conditioning were obtained from each fire fighter. The physical fitness measures were physical working capacity, maximal oxygen uptake, percent body fat, trunk flexion, grip strength, and one-minute situps. Fire fighter scores were age grouped and analyzed using a two-tailed paired observations t-test and a one-way analysis of variance. Values obtained in the t-test indicated that the age groups 20-29, 30-39, and 50 and over demonstrated significant ($p<.05$) improvement in all measures except grip strength. The 40-49 age group demonstrated significant ($p<.05$) improvement only in maximal oxygen uptake relative to body weight, percent body fat, and one-minute situps. Between groups analysis of variance demonstrated that age did not effect the observed amount of change from pre to post score in any measure. The results indicate that the physical fitness program is efficacious in producing an improved fire fighter physical fitness level and that all ages of fire fighters may benefit equally.

Initial Physical Fitness Evaluation of Salem Fire Department Personnel

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CHAPTER I

INTRODUCTION

Fire fighter physical fitness is a major issue in fire departments throughout the United States. Job related fire fighter injury, morbidity and mortality statistics are on the rise. Statistics indicate that fire fighting is the most dangerous occupation in the United States. Many fire departments are turning to development and maintenance of physical fitness in the individual fire fighter to remedy or alleviate some of the health hazards of the fire service. Research has indicated that the more physically fit an individual is the less susceptible to injury are that individual's muscles, joints and connective tissues.

Fire fighting is also associated with a high stress level. Physical fitness better enables the individual to withstand the stresses associated with the performance of duty.

Purpose of the Study

On February 1, 1978 the Salem (Oregon) Fire Department initiated a mandatory physical fitness program for all uniformed fire department personnel. The physical fitness program was monitored on a quarterly basis by the testing procedures and services of the Salem YMCA. The purpose of this thesis was to evaluate the efficacy of the physical fitness program in producing desirable changes in the selected fitness parameters.

Significance of the Study

The value of any physical fitness program must lie in its results. If the individual participating in the program is sufficiently physically fit, as determined by physical fitness test scores, then the program must be of sufficient intensity to maintain this fitness level. However, if physical fitness is not at a high level then the program must be graded in intensity for proper fitness development. The significance of this study lies in the comparison of pre fitness program test scores and the subsequent first quarter scores. If positive significant changes from the pre test to the first quarter test are demonstrated it may be assumed that the physical fitness program is of sufficient intensity and proper design. The assumption will also be true if scores which were high to begin with show no deterioration. If, however, low scores show no improvement indications become apparent of a need for restructuring the program. An assumption was made that the natural tendency for a decrease in fitness scores occurring with increasing age will not display a noticeable effect over a three-month interval of time. Additional assumptions required by this study included the accuracy of the fire fighters' self-reported body weights and the physiological state in which the fire fighters reported for testing. Body weight measures were needed to determine oxygen consumption per kilogram of body weight. The required physiological state of the fire fighter included a post absorptive state, abstinence from the use of tobacco for two hours and freedom from strenuous physical exertion on the day of and prior to the hour of testing. Questioning of the subjects by the test administrators is the only assurance that these conditions were met.

Methodology and Delimitations

The testing procedure involved a determination of values for physical working capacity, maximal oxygen uptake, percent body fat, trunk flexion, dominant hand grip strength and one minute timed situps. The obtained values for each test were used in establishing a physical fitness profile for the individual fire fighter. The measures of trunk flexion, hand grip strength and one minute timed situps were direct measurements. Measures of physical working capacity, maximal oxygen uptake and percent body fat were obtained indirectly.

Limitations

In interpreting the results from the indirect and generalized measures the researcher realizes that the measures were, at best, only closely related to measures that could be attained directly and, at worst, only relative. The use of such measures is possible and acceptable since the individual and group are being self compared on pre and post tests. No interpopulation comparisons were made. Relative change was the important statistic not absolute difference between populations.

Hypotheses

The hypotheses advanced were that the age group mean values in each physical fitness parameter measured would change as a result of the physical fitness program. To test these hypotheses the null hypothesis was assumed for each measure in each age group. $\overline{X}_1$ was set equal to the age group mean value for a given physical fitness parameter in the pre test and $\overline{X}_2$ set equal to the post test score. The null hypothesis for each measure was:

$$H_o: \overline{X}_1 = \overline{X}_2$$

In effect, then, this null hypothesis was used for each of the seven parameters measured in the four age groups: totalling 28 tests of the null hypothesis.

A paired observation two-tailed t-test was the statistical test used to determine acceptance or rejection of the null hypothesis. If the null hypothesis was rejected then the physical fitness program must have produced the change in mean score values from pre to post.

Additionally, a Groups x Trials ANOVA procedure was utilized to determine the effect of subjects' ages on amount of change from pre score to post score. The null hypothesis for the four age groups (G_1, G_2, G_3, G_4) was

$$H_o: \; G_1 = G_2 = G_3 = G_4$$

for each of the seven physical fitness test items.

Summary

During the course of fighting a fire a fire fighter is often called upon to exert himself maximally or near maximally over prolonged periods of time. In addition, the fire fighter is subjected to heat stress and intense air pollution. The ability for the individual fire fighter and groups of fire fighters to withstand such stressors and still function effectively and safely is directly related to the level of physical fitness of those involved. An improvement in mean physical fitness score values would indicate an improvement in physical fitness relative to the parameter involved and for the age group under consideration.

CHAPTER II

REVIEW OF RELATED LITERATURE

The training effect of graded physical activity upon the physiological processes of the human body is a highly researched and documented area of investigation. However, the importance of physical training to job performance in the fire service is an area of research only recently investigated and by only relatively few fire departments and concerned researchers. The purpose of this review of literature is to elucidate the need for programs to reduce the health hazards of fire fighting and to demonstrate how the research literature supports the concept of physical fitness as an ameliorating agent against such hazards.

In this study, physical fitness is referenced to job performance and is thus defined as the ability of the fire fighter to efficiently, effectively, and safely meet the physical demands of the occupation while maintaining an energy reserve for emergency situations. This definition implies a necessary level of muscular strength, joint flexibility, muscular endurance and cardiovascular endurance needed by a fire fighter to perform his assigned tasks.

Health Hazards of the Fire Service

The International Association of Fire Fighters publishes an annual report of injury, morbidity, and mortality statistics associated with fire fighting in the previous year. These statistics indicate that fire fighting is the most dangerous occupation in the United States. The relationship of these statistics to the involvement of fire departments in physical fitness programs becomes readily apparent when scrutinized in terms of cause and in terms of the possible remedying effects of exercise programs.

Heart Rate Factors in Fire Fighting

Heart rate appears to be an important parameter in fire fighting. Barnard, medical consultant to the Los Angeles Fire Department, has conducted research studies utilizing active fire fighters. Barnard (4,32) tested a 26 year old fire fighter on a maximal capacity treadmill test. The subject's heart rate peaked at 190 beats per minute (bpm). This same subject was monitored by telemetry while actually fighting a fire. During the course of the fire this fire fighter's heart rate reached a plateau of 195 bpm. In addition, this subject maintained a heart rate of 160 bpm for over 60 consecutive minutes. During three hours of fighting two consecutive fires a 27 year old fire fighter maintained a heart rate of 160 bpm for over two of the three hours.

The maximum heart rate that an individual may achieve is age related. As age increases the maximum heart rate decreases. For the 26 year old fire fighter the maximal heart rate attainable was approximately the 195 bpm he achieved while fighting the fire. This fire fighter was taxed to his limit. A 41 year old with a maximum heart rate of 180 bpm was monitored by Barnard while fire fighting. This individual achieved and sustained a heart rate of at least 145 bpm for 65 minutes.

Barnard attributes these high heart rates not only to the physical work involved but also to heat stress, the nature of the protective gear being worn, the emotional stress involved, and the fire fighter's forced breathing of noxious fumes such as carbon monoxide (5).

The significance of a high heart rate lies with its effect on cardiac output. Cardiac output is the amount of blood the left ventricle pumps in to peripheral circulation per minute. Two factors determine cardiac output. One factor is stroke volume or the quantity of blood pumped out by the left ventricle with each contraction. The second factor is the heart rate or how many times per minute the heart muscle contracts. During exercise, in the normal heart, the heart rate and stroke volume will both increase thus increasing cardiac output and increasing the oxygen supply to the exercising tissues. However, once the heart rate becomes too rapid the time interval between heart beats becomes too short for effective venous filling of the heart and cardiac output actually begins to decrease from its maximum value due to a decreased stroke volume (59, 87). In physically fit fire fighters a given work load can be performed at lower heart rates thus keeping cardiac output at a level closer to the optimum. This ability to work at a closer to optimum cardiac output level is due to an increased stroke volume accompanying the decreased heart rate. The maximum effective heart rate for optimum cardiac output is approximately two and one-half times the resting heart rate (87).

Other than physical exertion, high heart rates can be induced by emotional states. Barnard (7) monitored fire fighters for a continuous 24 hour period. A complete log of all activities was kept during this period. Within 15-30 seconds of the fire alarm sounding the fire fighter showed a mean heart rate increase of 47 bpm. The range of heart rate increase extended from 12 bpm to 117 bpm. One minute after the fire fighters boarded the truck and were enroute to the fire heart rates still showed a mean increase of 30 bpm. Barnard suggests that these high heart rates are due to excessive sympathetic nervous system activity resulting in dischage of high levels of catecholamines. If this be the cause then the fire fighters are subjected to an elevated risk of developing premature heart disease (36, 62, 88).

Heart disease is definitely a problem with fire service personnel.

Summaries of national surveys conducted in past years by the International Association of Fire Fighters and reported in the literature review the problem of heart disease (2, 5, 6, 33). In 1976 there were 107 reported fire fighter in-line-of-duty deaths. Forty-three of these deaths were due to heart attack. In 1975 forty-seven of the 102 deaths were attributed to heart attack. Heart disease outranks such other causes of death as burns, asphyxiation and mechanical injury.

Heart disease is even more pervasive than the above statistics indicate. In 1975 there were 721 fire fighters forced to leave their departments and seek other employment or retire because of occupational diseases. More than 62% of this number, 453 individual cases, were due to heart disease. In 1976 the statistics were similar. Heart disease was the cause of 431 out of 673 cases of retirement or job change.

Lemon and Hermiston (55) studied 20 fire fighters between the ages of 23 and 43. These twenty fire fighters performed the most strenuous tasks considered to be a duty of fire fighting. The researcher found that the men must work between 60 to 80% of their maximal oxygen uptake while performing these tasks. At this rate of work, the authors concluded, fire fighting should not contribute significantly to the development of heart disease. It should be noted, and the authors do note, that the fire fighters did not perform the tasks in simulated fire conditions, thus, the stress of emotional involvement, heat and air pollution were not affecting task performance.

Barnard compared the level of coronary heart disease (CHD) risk factors between matched populations of active fire fighters and sedentary insurance underwriters (6). Although the fire fighters averaged lower risk factors they had a higher incidence of ischemic stress tests. Barnard suggests that since fire fighters are a medically selected population with a low CHD risk factor profile heart disease could possibly be job related.

The ability to work more effectively and more efficiently as a result of an increase in maximum oxygen consumption is an important facet of injury protection for fire fighters. By engaging in aerobic training of the type resulting in increased oxygen uptake the fire fighter is possibly helping to protect himself from heart disease. Although research is not conclusive there appears to be a positive relationship between physical fitness and decreased heart disease (10, 22, 38, 46, 47, 89, 99, 109). The fact that exercise is being used to rehabilitate patients after heart attack (25, 48, 56, 74, 94) lends credence to the possible role of exercise in prevention.

Fire Fighter Injuries

As stated earlier job related deaths and injuries make fire fighting the most dangerous occupation in the United States. The national surveys conducted by the International Association of Fire Fighters also tell the tale of high injury rates. The 1975 survey included 71% of all fire fighters serving in governmental units in the United States. Of the fire fighters surveyed there were 51,313 on the job injuries of which 38,296 occurred at the scene of a fire. Eight hundred and thirty five fire fighters received injuries serious enough to seek early retirement. In the five years ending in 1976 fire fighter injuries per 100 workers ranged from 43 to just under 48. The leading type of injury in 1976 was a sprain or strain. Sprains and strains accounted for 32.65% of all injuries and exceeded by almost double the next leading type of injury (2).

The Salem Fire Department employs approximately 150 fire fighters. Twenty-eight injuries were reported for the 1976-77 fiscal year (61). The most prevalent injury was in the sprain-strain category. Of the eight injuries so categorized six afflicted the back. Fire Department injuries for the four fiscal years 1973/74 through 1976/77 cost the city of Salem an average of $24,224. Fiscal 1975/76 had 164 man days lost due to injury. In 1976/77 the figure rose to 191 man days lost.[1]

The Salem Fire Department also has a problem with heart disease. The Salem Retirement Board considers fire fighter heart problems to be job related. Thus, early retirements due to heart disease are a possible added expense to the city and have been in the past.

The literature suggests that physical fitness might indeed supply the answer, at least in part, to the question of how to curb the spiralling statistics associated with the health hazards of fire fighting. Barnard (4) states that before 1971 injury rates in the Los Angeles Fire Department increased for five consecutive years. Following the initiation of a fire fighter physical fitness program Los Angeles realized a decrease in injury rates.

How physical fitness affects the body thus effecting the body's ability to work safely and efficiently is well documented in the research literature. It should be noted, however, that physical training is "specific to the overload used." Specificity applies not only to the effect desired, whether it be strength, endurance, flexibility or some other parameter, but also the muscle group or joint exercised. To produce a desired effect training must be appropriate. Astrand states:

> Physical training entails exposing the organism to a training load or work stress of sufficient intensity, duration, and frequency to produce a noticeable or measureable training effect....(3, p. 393)

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1. Report prepared for Salem Fire Chief John Degnim, by Field Safety Representative, Ron Hutchinson. Report dated September 30, 1977.

The Salem Fire Department physical fitness program is designed to produce a training effect in the areas of muscular strength, muscular endurance, flexibility, body composition and cardiovascular endurance (maximum oxygen uptake).

Demonstrated Need for Physical Fitness Programs

Due to strenuous physical demands in fire fighting a high level of physical fitness is expected of fire fighters. This supposition of physical fitness has not been demonstrated in fact. Lemon and Hermiston (54) studied 45 fire fighters between the ages of 23 and 49. Maximum oxygen uptake, arm and leg strength, grip strength and percent body fat were measured. From the values obtained for the fire fighters the researchers concluded the data were only within the normal range for the sedentary North American male population. It was noted that these fire fighters were not engaged in a physical fitness program. Barnard (5, 6) compared treadmill performance between Los Angeles city fire fighters and a matched group of insurance underwriters, policemen and airline pilots. Ischemic cardiac response to the treadmill test was observed in 5-6% of the policemen and airline pilots and 8% of the insurance salesmen. However, fire fighters were ischemic responders at a 10% rate. Although the higher level of ischemic response shown by the fire fighters does not necessarily indict their level of physical fitness, the possibility of such a contributing cause must certainly be considered along with job stresses not associated with other occupations.

White and Hunt (104) measured physical fitness parameters of San Diego fire fighters before and after a 16 week fitness program. The pre test scores indicated a low level of physical fitness. In a study of 100 fire fighters, Davis et al. (24), demonstrated a physical fitness range for fire fighters from excellent to poor with the physical fitness level generally decreasing with increasing age.

The Salem Fire Department has very minimal qualifications for entry into its fire service. Prior to the newly initiated physical fitness program the Department had no provision for developing or maintaining high physical fitness levels among the city's fire fighters. The City of Salem handbook of rules for the fire and police departments specifies only a minimum height and weight (weight commensurate to height as determined by a medical examiner at the time of the fire fighter's physical examination). The physical examination by a medical doctor is required before appointment to the fire service and biannually throughout employment.[2]

Physical Requirements of Fire Fighting

The components of physical fitness, as related to fire fighting, involves the fire fighter's ability to exert strength, the ability for the muscles to do work repeatedly and continuously, the ability of the cardiovascular system to provide sufficient oxygen for the muscular work being performed, the capacity to utilize the least amount of oxygen in the most effective way, and the ability for the skeletal joints to move throughout their full range of motion. In effect, muscular strength, muscular endurance, cardiovascular endurance, percent body fat, and joint flexibility are all important components of fire fighter physical fitness.

Muscular Strength

Muscular strength requirements of fire fighting are quite variable depending on specific situations. The fire fighter may be wearing close

2. City of Salem, Oregon, Civil Service Rules for Fire Department and Police Department (Revised July 1, 1976).

to 70 pounds of protective equipment (32). Add to this the weight of accessory equipment such as a 35 pound exhaust fan, manipulation of ladder sections or 65-70 pound hose sections and the fire fighter now bears quite an external burden. In emergency situations the fire fighter may also be faced with the task of carrying a fire victim out of a burning building, perhaps down a ladder, or removing burning objects from a structure. The greater the muscular strength of the fire fighter the more capable he will be of performing these duties at safe submaximal levels.

Muscular strength in fire fighters is important for several reasons. Muscular strength is important for joint stability (3). Kraus (52) adds that strong and resilient muscles are important for injury prevention through a shielding action of the joints. In addition, strong and resilient back, abdominal and hip flexor muscles are important for care of the back. Strength, therefore, is an important aspect of injury prevention. With an increase in strength loads of a constant weight such as ladders, fire hose sections, and protective clothing become less of a burden as they require a smaller percentage of maximum strength to manipulate and use. Increased strength may reduce heavy work to moderate and moderate work to light thus achieving a reduced relative work load for the fire fighter. Increased strength will also increase the reserve for emergency situations that the fire fighter might encounter.

Grip strength is the measure being used to evaluate the Salem fire fighters' strength level. The literature is conflicting in its reports on the ability of grip strength to predict general strength levels. According to deVries (27) although the relationships of strength among various body parts are not perfect they are highly generalizable. Tornval (101) reported a correlation of 0.69 ($p < .01$) between hand grip and general strength (as determined by measurements of 22 muscle groups). Astrand (3) reports two studies that reported that the correlation between muscles of different body parts is rather low (0.4 or less). It was concluded that general muscle strength should not be predicted from single measures such as hand grip strength but from a well selected battery of tests. DeVries agrees that more than one test should be used even though hand grip was significantly related to general strength. Barrick (8) and Rasch et al. (85) agree that grip strength is independent of general strength and should not be used to predict general strength. Bernauer and Bonanno (11) reported that grip strength failed to differentiate between physically fit and unfit groups. However, Davis et al. (24), in their study on fire fighter physical fitness relative to field performance, conclude that of several important physical fitness components muscular strength as demonstrated by grip strength was of significant value. Tornval (101) concludes that for practical reasons muscle groups, such as the finger flexors used in the handgrip strength test, which are readily accessible and reproducible, should be chosen for estimating general muscular strength.

The strength requirements of fire fighters involve both dynamic and isometric contractions. Handgrip strength is an isometric measure. A high correlation (r = .80) between dynamic and isometric strength make handgrip strength an acceptable measure (3, 27). A reliability figure of 0.91 has been reported for the handgrip test (53).

The relationship between muscular strength and muscular endurance varies with the type of loading. If the load is relative, one requiring a certain percentage of the maximum strength, the relationship is very slight. If the load is absolute, the relationship is very high (17, 96). Since fire fighters are dealing with absolute loads such as equipment weight, strength level is important in the ability to endure prolonged work with the weight involved.

Muscular Endurance

Muscular endurance becomes increasingly important as the length of the actual fire fighting time increases. The average fire in Salem has been reported to require 30 to 45 minutes of fire fighting activity.[3]

Muscular endurance is dependent on blood flow through exercising muscle. Blood flow supplies oxygen to the working site and removes waste products. As long as oxygen is supplied, at the rate needed for work, exercise can proceed under aerobic conditions. As conditions become anaerobic, at high intensities, the ability to work is diminished and limited by the availability of anaerobic energy supplies. Aerobic work can proceed for periods of time in excess of one hour but pure anaerobic work is limited to seconds and minutes. Seldom, however, is a fire fighter's work purely aerobic or purely anaerobic. If the fire fighter has developed good muscular endurance, higher levels of work may be performed under predominately aerobic conditions.

Muscular endurance was tested in Salem fire fighters by the performance of maximum repetitions of situps in one minute. Bernauer and Bonanao (11), in their study on development of physical profiles for specific jobs, indicate situps distinguish between the physically fit and unfit. The use of abdominal muscle endurance for general muscular endurance follows the same line of reasoning as in using grip strength as a measure for general muscular strength (72, 73). A reliability of 0.94 for the situp as a test of muscular endurance has been reported (53).

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3. Personal interview with Dennis Voight, Administrative Assistant to the Fire Chief, Salem Fire Department, Salem, Oregon.

The value of abdominal endurance as measured by situps goes beyond its relationship to general muscular endurance. Morris et al. (70) have shown that when loading the trunk (as in lifting and carrying) the abdominal and other trunk muscles, by contracting, serve to reduce the load on the spine. Morris calculates the lumbrosacral disk pressure can be reduced 30% by contracting trunk muscles. A reflex mechanism causes the trunk muscles to contract which, in turn, fixes the rib cage and compresses the abdominal cavity. The effect of fixing the rib cage and compressing the abdominal cavity is to increase intercavitary pressure which aids in spinal support.

Percent Body Fat

An added component directly related to physical fitness and task performance is the percent fat of the fire fighter's body. As the percentage of body fat increases so too does the amount of oxygen needed per unit of lean body mass during work. The metabolic cost of lifting one's own body is directly proportional to gross body weight (68). Since an increase in fat content of the human body most usually signals an increase in gross body weight the metabolic cost of work increases with fat content.

Adequately oxygenating the blood supplying the extra fat tissue becomes a problem when fat content increases, especially if the oxygen transporting system is unconditioned. Exercise tolerance is reduced as fat content increases.

Gross obesity marked by a heavy chest wall affects the ability to ventilate the lungs. This decreased ventilation again reduces the ability to transport oxygen because of the reduced oxygen exchange between the air in the lungs and the blood in the pulmonary capillaries. In addition, the blood pressure of an overweight or obese person tends to be higher causing the heart to work harder and suffer the adverse stress of doing pressure work requiring increased oxygen. Heart disease is more prevalent in the obese, especially the hypertensive obese (76).

A careful monitoring of the body's percentage of fat is thus important as one index of physical fitness. Percent body fat is far more valuable as a tool of evaluation in this regard than is a person's weight. Weight alone gives no indication of body composition. For fire fighters Davis et al. (24), reported that body composition is an important characteristic when analyzing the physical performance capabilities of fire fighters.

Rather than use body weight as a measure of physical fitness it is more appropriate to analyze the components of body weight, and in particular determine the percentage of body fat. Each individual's body will vary in proportion of water, fat, muscle, bone, and connective tissue (49). If weight alone is scrutinized and compared to height/weight tables such as those published by the Metropolitan Life Insurance Company of New York, gross misjudgments may be made. For example, a large muscular athlete would be considered overweight by such tables and overweight implies fat. In reality such a person could have a low fat percentage but the table would indicate obesity (76). Weight charts are designed from data collected from insured populations and such data is considered normal, not necessarily desirable. The desirable weights for specific heights and average builds of male subjects are actually 15-20 pounds below table weights (57).

Although the terms "overweight" and "fat" are not synonymous, this paper, when using the term "overweight", is referring to a condition in which the fat content of the male body is above the 16-20% considered normal.

Obesity is a common term used in reference to body fat; but it is a term without precise definition. Obesity is variously used to describe deviations in weight, attributed to excess fat, with a minimum figure 10-20% above desirable weight (12, 76). As the percentage of body fat increases above the desirable level (16%) towards and into the obesity range physical health may be adversely affected.

The medical problems of obesity are well documented. Life expectancy has been shown to decrease as obesity increases (57, 66). Lew (57), in a summary of the Society of Actuaries Build and Blood Pressure Study (1959), reports that individuals accepted for life insurance coverage which were 10% or more above desirable weight had a one-third higher mortality rate. Individuals 20% or more above desirable weight had a one-half again higher mortality rate. Lew believes the above statistics actually underestimate the risks of obesity as a result of the care insurance companies use in accepting markedly overweight persons for life insurance coverage.

Reduction in longevity associated with obesity is generally due to the effects of obesity on other body systems. Obesity is a predisposing factor in heart disease, kidney disease, hypertension, respiratory infections, lethargy resulting from inefficient carbon dioxide removal from the blood, diabetes mellitus, and digestive disturbances (12, 21, 34, 57, 76). In short, obesity may affect every bodily function. Lew reports the increased mortality of overweight persons is due primarily to heart and circulatory disease (two-fifths higher occurrence than standard risks), cerebral hemorrhage and vascular disorders of the central nervous system (one-half higher), and nephritis (three-fourths higher). If the overweight person also has hypertension the mortality risk is three to four times higher than standard risks.

Body composition, as the individual grows older, usually shifts towards a higher fat percentage if body weight remains stable or increases (14, 49, 76). However, regular exercise has been shown to result in reductions of body fat and increases in lean body mass (12, 14, 15, 21, 34, 49, 79, 82). In effect, exercise can retard or reverse the aging process effect on body composition.

Actual statistics indicate men who reduced their body fat level to normal values have practically the same mortality risk as at standard (57). Brozek and Keys (49) studied two populations of older men matched for height and age. One population was physically active throughout their adult lives. The second population had always led sedentary lives. Although the active group was heavier than the inactive group the heavier group had a lower percent body fat rating. The active group showed little of the disease atrophy characteristic of aging.

In a study of 100 fire fighters by Davis et al. (24), body composition was reported to be an important aspect of efficiency while performing various fire fighting tasks. Ability to perform increased as percent body fat decreased. Miller and Blyth (68), in their study on body fat content, conclude that the metabolic cost of lifting the body is directly proportional to gross body weight and as the percent body fat increases the oxygen requirement per unit of lean body mass increases. Implications for fire fighters working at the scene of a fire become obvious in terms of ladder and stair climbing—especially in the presence of restricted oxygen supply. In short, the more body fat the fire fighter carries the more difficult his fire fighting tasks will be.

The sedentary individual has a tendency to increase the percent body fat. Fire fighters are considered engaged in a very active occupation, thus, possibly not showing a tendency to increase in body fat. Lemon and Hermiston (54) demonstrated that this is not necessarily the case. In their study of 45 fire fighters they showed a three percent difference in body fat between younger fire fighters and older fire fighters. The age difference between the groups was 26 years. As this was not a longitudinal study it cannot definitely be stated that this difference can be attributed to aging, but the implication remains.

Determination of body composition may be performed directly using laboratory methods or indirectly using field measures (10). The most common laboratory methods are the techniques of hydrostatic weighing (44, 95) and radiographic analysis (71,91). Although these direct methods are more exact than field methods they require expensive equipment, involve complex and time consuming procedures, and are themselves subject to error (34). As Behnke and Wilmore state:

> ...because of the belief that assessments of body composition are valuable and of interest and importance for the general population, methods have been proposed which are applicable to field testing (10, p. 38).

Although the validity and reliability of these measures vary Behnke and Wilmore believe they are meaningful for mass screening. As Keys and Brozek indicate, the major contribution of body composition is the metabolic significance of the results and not of body weight or size comparisons.

> For many research purposes as well as practical applications absolute accuracy is not essential and it is not essential or even important to know the total amount of fat in the body. It is enough to know...the difference in the same person at different planes of nutrition. For these questions it is fortunate that high reliability may be achieved if suitable precautions are taken (49, p. 250).

Field methods involve anthropometric measurements. Examples of such measurements are skinfolds, body part diameters and thicknesses, lengths, and circumferences. A multitude of prediction equations utilizing such measures are available from the literature (35, 77, 78, 95, 105, 110). The field method used in this study is one developed by Zuti and Golding (35) for active adult males.

In indirect evaluation of body composition it is important to use a field method developed for the specific population under measurement. Research has shown that field methods developed for one population are seldom transferrable to other populations (58, 84). Salem fire fighters, as active adult males engaged in a physical fitness program, are a suitable population for Zuti and Golding's method.

Behnke and Wilmore report the reliability of anthropometric measures to be quite high if trained anthropometrists perform the measurements. In reviewing "a study of 133 males...the reliability coefficients for two trials on 44 measurement sites ranged from r=.92 to r=.99" (10). The YMCA staff taking the anthropometric measures for this study are not only highly trained but also very experienced in the use of the Zuti and Golding protocol.

Joint Flexibility

Just as endurance and strength are specific to muscle or muscle groups so, also, is flexibility specific to individual joints. Flexibility is limited by the soft tissues surrounding the involved joint. These soft tissues are the muscles and their covering fascia, the connective tissue (tendons and ligaments), and the skin (45). All of the soft tissues are responsive to static stretching exercises designed to make them less restrictive (27).

The importance of flexibility is in its role as an injury preventative (22, 52, 64, 103). Good flexibility demonstrates the absence of adhesions and muscular limitations to smooth efficient movement thus allowing the body to move smoothly through a full range of motion (50).

Trunk flexion is the flexibility measure used in this study to generalize overall body flexibility (72, 73). As in the grip strength and situp tests the generalization to overall body flexibility may not necessarily be appropriate. However, the trunk flexion test serves an important function as a specific measure of hip, back and hamstring flexibility. Impaired flexibility in these areas may lead to lower back pain or injury of the back (50, 52, 72). In human motion trunk flexion is the movement of greatest importance (53). Fire fighter injury statistics in the sprain-strain category show a predominance of back problems (2). Flexibility of the trunk may help to reduce back problems and lower the injury statistics in that category.

Cardiovascular Endurance

An important physical fitness measure is the condition of the fire fighter's cardiovascular system. The greater the fire fighter's maximal oxygen uptake the greater the intensity of work he may perform aerobically. A greater capacity to work aerobically implies a lessened burden on the heart and a reduced rate at which the heart must work to supply the oxygen to the exercising tissues. A high aerobic capacity allows a given level of submaximal work to be performed for a longer period of time than if the individual's aerobic capacity was lower.

The ability of the oxygen transport system to supply the working tissues with the needed oxygen directly effects the amount of work that may be performed and, in turn, this ability is affected by body fat. The measures in the fire fighter physical fitness test battery which estimate the body's ability to transport and deliver oxygen are called physical working capacity (PWC) and maximum oxygen uptake.

DeVries defines physical working capacity as the maximum level of work capable of being performed by an individual. The method of determining physical working capacity is by measuring the maximal oxygen consumption. Direct measurement of maximal oxygen consumption requires sophisticated gas collection and analysis equipment as well as requiring the subject to exert himself maximally. From a practical point of view such direct measurement is not feasible for large groups because of cost, time consumption, complexity, and equipment requirements. Also, certain potential health problems are inherent in maximal testing of an individual.

Problems such as ventricular fibrillation or myocardial infarction, although improbable in healthy subjects, are possible in adult populations (99). Statistics suggest the improbability of untoward incidents occurring during testing. Rochmis and Blackburn (86) surveyed 170,000 exercise stress tests. Mortality rate for those tests was one in ten thousand. A total of thirteen fatalities occurred; six fatalities were on submaximal tests and involved cardiac patients. Ellestad et al. (31), report that of 4020 cardiac patients monitored on a maximal capacity protocol there were no incidents of serious consequence. The safety factors related to using submaximal tests with all varieties of populations has also been reported (29, 31, 90, 100).

Indirect measurement of maximal oxygen uptake is based on a linear relationship between heart rate during submaximal work and oxygen uptake (3, 67). Oxygen uptake is related to cardiac output. Wang states:

> Since cardiac output is linearly related to the minute oxygen consumption, at least at submaximal levels of exercise, changes in pulse rate provide a useful estimate of changes in oxygen uptake (102, p. 27).

By recording heart rate at different submaximal workloads and plotting the heart rate reading against workload and oxygen uptake it is possible to extrapolate linearly to an age predicted maximum heart rate. By this extrapolation to maximum heart rate the maximum oxygen uptake and PWC are determined simply by dropping a line to intersect the abscissa on which the two are plotted.

Maximum heart rate varies inversely with age thus the necessity of using age predicted heart rate (3, 27). Sources of error in estimating maximum oxygen uptake are attributable to deviations in heart rate. Although Sime et al. (93), found through test-retest measures that heart rate at rest and during exercise is a stable measure of healthy middle-aged men and therefore suitable for longitudinal evaluations of groups and individuals it must be realized that the standard deviation of heart rate within an age group is ±10 bpm (3). This heart rate difference will underestimate or overestimate the maximal oxygen uptake of individual subjects but groups will not be affected due to the averaging process of group measures. In groups such as the Salem fire fighters accuracy of prediction is ±5 percent, whereas with individuals it is ±10 percent (26). It has been stated absolute accuracy of such measure is not an important criteria for evaluating the physical fitness program. Relative change will indicate efficacy and thus indirect measures are suitable for this research.

The YMCA estimation of maximal oxygen uptake is based on the Astrand-Rhyming nomogram (73). The nomogram was derived from direct maximum measures of oxygen uptake (3). The correlation between direct measurements and nomogram estimations is significant, r=.74 ($p < .01$) (29). For older men the test-retest reliability with a one-week intervention was r=.84, also significant (28).

The importance of maximal oxygen uptake cannot be overestimated when considering the effect a high level of uptake will have on the performance of fire fighters. Working muscle tissue has the potential for a blood flow increase eighteen times blood flow at rest; the heart may show an increase four times the resting flow rate. Increase in blood flow increases the potential for oxygen exchange by a factor of three (16). The muscle tissue must be trained to be able to take advantage of the increased potential for oxygen delivery. Biochemical adaptations as a result of aerobic training of the muscles are largely responsible for the increased extraction of oxygen from the blood (39, 43, 59, 87). This arterio-venous oxygen difference is a salient feature of endurance training. In effect, since more oxygen is extracted from the blood in the trained state, the heart will not have to beat as quickly to supply enough blood for oxygen exchange in working tissue. Thus, the increased ability to utilize oxygen explains the reduction in heart rate at sub-maximal work levels when comparing the trained to the untrained state.

Karvonen (48) states that in work performance the functional ability of the heart becomes the limiting factor. Referring to the arteriovenous oxygen gradient Karvonen indicates that part of the adaptation to exercise is the ability of the muscles to function aerobically at lower tensions of oxygen in the blood and the ability to withstand the production of anaerobic metabolites such as lactic acid. Implications for fire fighters are straight forward. The increased ability to function aerobically at high rates of work means a longer possible work period and at higher intensities. Thus, the fire fighter may be able to function more efficiently and at safer work loads while ostensibly performing more easily the same work performed before the physical fitness program.

Other Potential Contributions of the Physical Fitness Program

Potential contributions of physical fitness goes beyond those parameters measured by the YMCA testing procedures. Stress, heat tolerance, blood pressure, and blood lipids are also affected by physical training.

Blood Pressure Reduction

Blood pressure measurements were not included in this study because of difficulty in obtaining readings not affected by anticipatory response. Since blood pressure level is job related in its relation to the physical fitness program the YMCA staff found it impossible to obtain readings unaffected by sympathetic nervous response.

Rushmer (87) generalizes the possible problems of high blood pressure as the following: shorter life expectancy, headache, vertigo, stroke. left ventricular hypertrophy, and congestive heart failure. Reduction in blood pressure is therefore important to alleviate the potential for development of such problems.

Physical training of the type employed in the fire fighter physical fitness program has been shown to lower resting and exercise blood pressure levels (both diastolic and systolic readings) (26, 75, 106). It has also been shown that greater blood pressure reductions occurred in borderline hypertensive men than in normotensive (13, 20).

CHD Risk Factors

Heart disease has continually been mentioned as a problem in the fire service. Certain risk factors are associated with coronary heart disease. The risk factors most commonly mentioned are increased blood lipids (cholesterol and triglycerides), hypertension, smoking, obesity, and physical inactivity (21, 66, 103). All of the risk factors except blood lipids and smoking were previously mentioned.

Smoking is a problem the individual fire fighter must consider. The risk of cancer aside, smoking also lowers the oxygen consumption level by tying up hemoglobin with carbon monoxide (3). Hemoglobin transports the oxygen within the blood to the cellular sites. If the hemoglobin binding sites are binding carbon monoxide the ability to transport oxygen is reduced.

Exercise may lower blood lipid levels in some individuals (1, 41, 60, 63). In addition, the level of blood lipids in physically fit subjects has been observed to be lower than the levels in the unfit or less fit (22, 60).

Heat Tolerance

Fire fighters are subjected to environmental temperatures ranging from 200-500°F when fire fighting. Besides the pure discomfort associated with the heat the induced hyperthermia is a limitation to performance (61). As the body's core temperature increases much of the blood flow normally supplying working tissues is diverted to cutaneous flow in an effort to dissipate the internal heat to the external environment. Pirnoy et al. (80), have observed a decrease in maximal oxygen consumption during work in hot environments. They explain this decrease due to diverted blood flow. This decrease in maximal oxygen consumption has been verified by other researchers (23, 51).

Ability to withstand work in the heat and physical fitness is closely related. The higher the initial level of physical fitness the higher will be the maximal oxygen uptake. Since work in the heat reduces the attained level of maximal oxygen uptake it stands to reason the percentage difference subtracted from a higher initial level will result in a higher level available for such work. Equally important, physical fitness has a preacclimatizing effect. Training increases the body's ability to adapt to work in the heat (40, 81, 107). Strydom and Williams (97) demonstrated that increases in heart rate and rectal temperature upon exposure to heat stress were reduced by conditioning. However, this conditioning effect was good for only two hours before a reversion to pre-training levels took place. Most fires involve less than two hours of work. Whether or not the results of such studies which dealt with temperatures at 110°F or less can be applied to the extremely hot temperatures found at the scene of a fire needs to be resolved.

Emotional Stress

Finally, mention should be made of stress levels and their relationship to fire fighting. Barnard (6) has indicated that one of the factors precipitating high heart rates in fire fighting is emotional stress. Emotional stress is indicated by heart rate recordings immediately after the fire alarm sounds, during the truck ride to the fire, and during prolonged periods of actual fire fighting. Rushmer (87) indicates that high heart rates, unaccompanied by mechanisms such as physical work which increases venous return to the heart and augments stroke volume, are not effective in increasing cardiac output. In essence, the engine is racing but the transmission is in neutral. The heart is pumping rapidly thus requiring greater blood flow through the coronary arteries to supply itself with the necessary oxygen for such work. Since stroke volume is not increasing due to lacking venous return the oxygen requirement is not being met, this can possibly result in coronary insufficiency precipitating coronary distress.

Emotional stress is also associated with an increase in the blood cholesterol level (37). The relationship of stress to coronary heart disease and coronary insufficiency has been documented (7, 36, 62, 88). Physical exercise helps to control the stress response, and helps to alleviate the adverse stress responses that do occur, by prestressing the body which allows adaptive controlling mechanisms to develop (21, 52, 88).

Summary

Physical fitness is not a panacea for all the problems and health hazards of the fire service. However, some of the beneficial aspects of physical fitness have been pointed out and the potential of a program designed to enhance physical fitness may not be denied. Whether or not the physical fitness program is effective in enhancing the parameters described herein will be surfaced by the testing procedures of the Salem YMCA.

CHAPTER III

METHODS AND PROCEDURES

The data used in the preparation of this thesis was collected in Salem, Oregon by the personnel of the Salem YMCA between the dates of February 1, 1978 and May 31, 1978. The collected data represents the initial physical fitness test of the Salem fire fighters and tests after the first quarter of the fitness program. The first semester scores follow three months of participation in a physical fitness program designed for the Salem Fire Fighters. The physical fitness program is modeled after a similar program utilized by the Los Angeles Fire Department. The adaptation and administration of this physical fitness program was in conjunction with the Salem YMCA. Evaluation of the test scores for indications of the physical fitness program's efficacy is the purpose of this investigation.

Subjects

The Oregon State University Board for the Protection of Human Subjects (Appendix A) granted approval for this investigation.

All uniformed Salem Fire Department personnel were required to actively participate in the Department's physical fitness program and be evaluated by the testing procedures of the Salem YMCA. The number of uniformed personnel exceeds a population of 150 fire fighters. Data for 96 male fire fighters between the ages of 20 and 59 were complete enough for inclusion in the data analysis.

Physical Fitness Test Procedures and Equipment

Criteria utilized by the YMCA for acceptance of a fire fighter into the testing program includes medical clearance. In most cases the fire fighter's most previous required biannual physical examination served as the acceptable criterion. If, however, the most previous physical examination was more than one year past, the test administrators requested another examination be taken immediate to testing. The request became a requirement if the YMCA staff believed there to be any concern whatsoever in the safety of testing certain individuals.

The fire fighters were requested not to smoke or eat for at least two hours prior to their scheduled testing time. In addition, they were requested to abstain from physical exertion, if possible, on the day of and prior to testing.

The parameters measured by the YMCA physical fitness test battery are muscular strength, joint flexibility, muscular endurance, body composition, and cardiovascular endurance. The test chosen for each parameter was a standard YMCA test. The administration of each test follows the guidelines found in the YMCA instructors guide (73).

Grip Strength

Grip strength, the test used for strength determination, used an Harpenden Hand Grip Dynamometer (Figure 1). The grip size of the dynamometer was adjusted for individual comfort and hand size. Proper fitting of grip size, in accordance with the International Committee for the Standardization of Physical Fitness Tests (ICSPFT) (53), involved the subject placing the second joint of each finger under the handle with the palm, at the base of the thumb, gripping the opposite side. The subject holds the dynamometer in his dominant hand, raised, with the elbow bent, to head level (Figure 2), but not touching the body. With a vigorous concentrated effort the subject squeezed the dynamometer grip with maximal force while extending the arm down, without touching the body (Figure 3). If the arm touched the body the trial was invalidated. Three trials were allowed with the best score recorded.

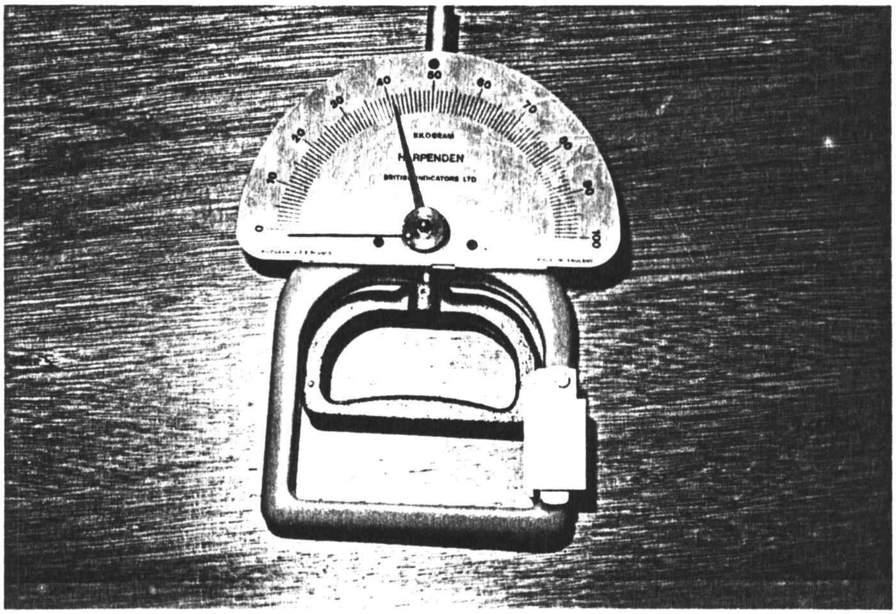

Figure 1. Harpenden handgrip dynamometer used for measuring grip strength.

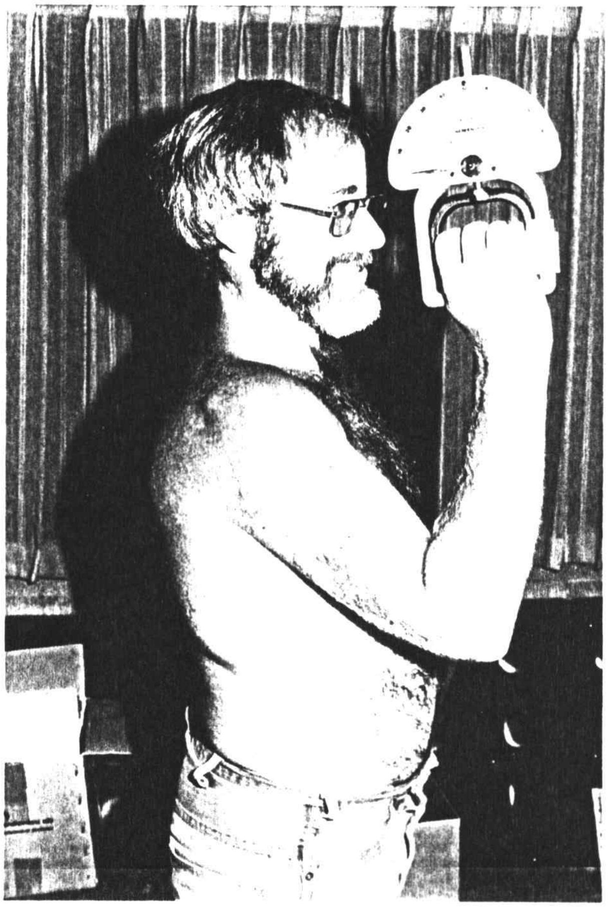

Figure 2. Starting position for grip strength test.

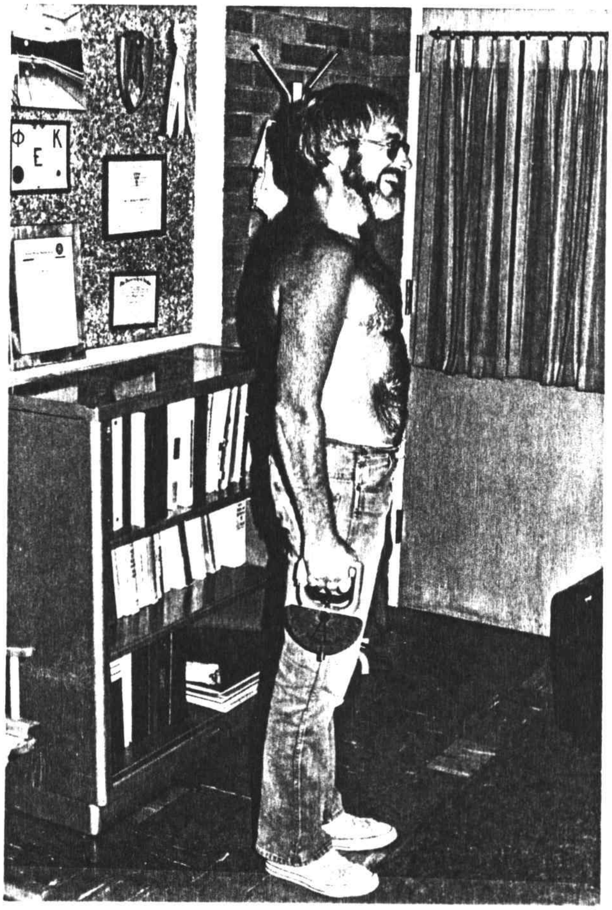

Figure 3. Finishing position for grip strength test.

Grip strength was recorded in kilogram units read from the dynamometer dial. The score was mechanically recorded on the dial as a result of the tension produced during the grip. Between each trial the dial was reset to the zero point.

Joint Flexibility

Trunk flexion was the flexibility measure used. Prior to this test the subject was encouraged to warm up and perform some preliminary stretches. The subject was instructed to refrain from bouncing movements while stretching.

Test protocol required the subject to sit on the floor, or mat, with his legs extended and his heels touching the near edge and perpendicular to a tape line. The 15 inch mark of the yardstick rested on the near edge of the taped heel line (Figure 4). The zero mark of the yardstick was toward the subject's crotch. On his own volition the subject stretched forward and reached with his fingertips as far down the yardstick as he possibly could while keeping his knees locked. The test administrator braced the subject's heels to prevent movement (Figure 5). To insure against any form of bouncing type movement the subject was required to hold the stretch for two seconds. Three trials were allowed with the best score being recorded. The score, in inches, is the farthest distance touched on the yardstick by the subject's fingertips.

As indicated, the "best"score in three trials was used for grip strength and trunk flexion. The use of "best"score rather than "mean" score conforms to ICSPFT guidelines. Research on the reliability of such scores also indicates that for maximal testing purposes the "best" score is more appropriate than the "mean" score (9, 42).

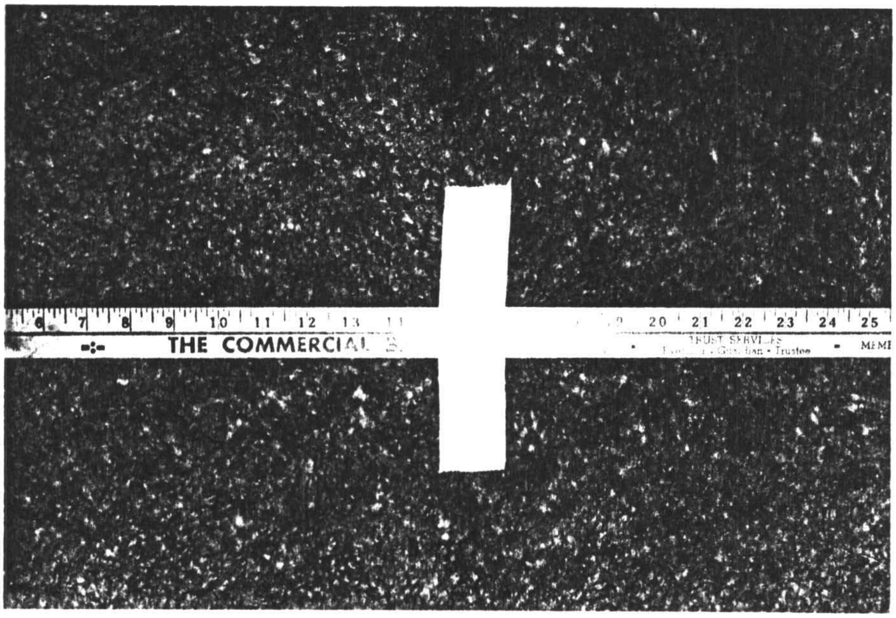

Figure 4. Yardstick and tape line for trunk flexion test.

Figure 5. Trunk flexion test.

Muscular Endurance

The maximum number of situps that might be performed in a one-minute period of time was used as the measure for muscular endurance. The subject began in a back lying position with heels drawn up to within 18 inches of his buttocks (Figure 6). Drawing the heels up reduces the influence of the iliopsoas muscle group and insures a more specific measure of abdominal endurance. The subject's hands were held with fingers interlocked behind the head. A partner held the feet down, at the ankles, and counted the repetitions performed (Figure 7). The test administrator signaled the subject to begin and kept time for one minute.

Proper performance of the situp required the subject to move from a back-lying position to a sitting position and touch the right elbow to the left knee then return to the back-lying position touching the hands to the mat. The next repetition the left elbow touched the right knee. This sequence of movements is performed as rapidly as possible for the one-minute time period.

The partner, while holding down the subject's feet, counted the number of repetitions out loud for the subject to hear. If the subject incorrectly performed a situp the number of the most previous correct situp was repeated to indicate the incorrect situp was non-counting. Incorrect situps were failure to touch elbow to opposite knee or failure to return fully to the back lying position.

At the conclusion of performance the number of correctly performed situps was recorded. Due to local muscular fatigue at the end of the trial only one trial was given. The subject was allowed to stop and rest during performance of the test, if required.

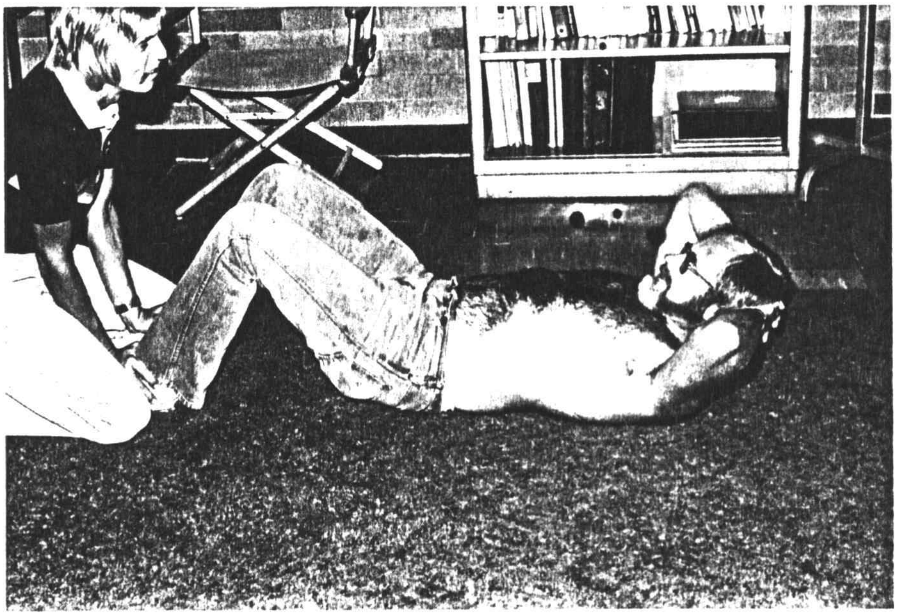

Figure 6. Starting position for situp test.

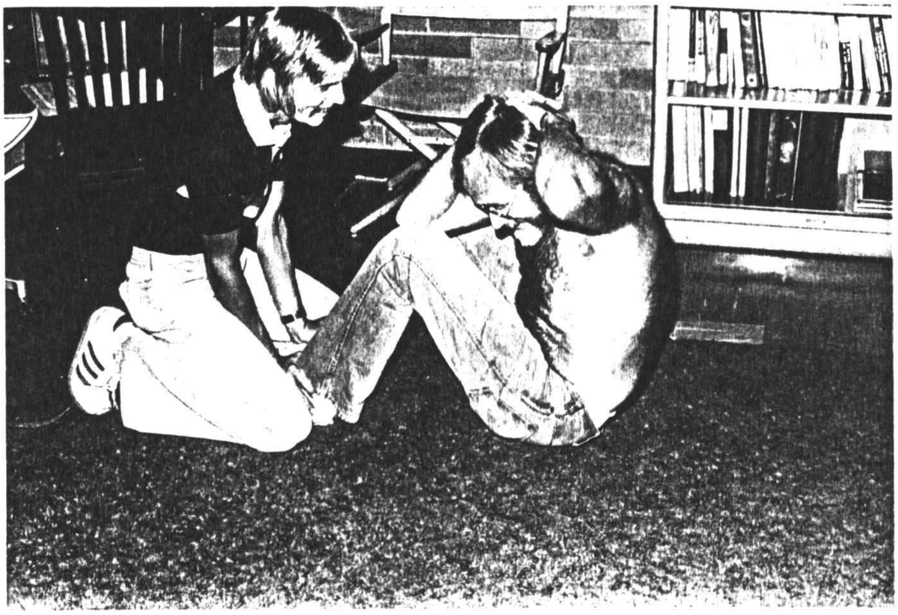

Figure 7. "Up" position for situp test.

Percent Body Fat

Body composition was determined using the procedure of Zuti and Golding (107). This procedure was developed for active adult males, thus, its selection by the YMCA, for the physical fitness test battery. Three individual anthropometric measures are included in Zuti and Golding's procedure for estimation of percent body fat.

The first measure, waist girth, involved measurement of waist circumference through a horizontal plane at the iliac crest level (Figure 8). The subject must be standing in a relaxed position with arms hanging at the side. Care must be taken to insure the subject does not draw the abdomen in. A non-expanding tape marked in centimeters was used (Figure 9). The tape used in this study was especially distributed for taking measures of this variety. The subject's waist girth was recorded in centimeters.

Pectoral skinfold was the second measure. A Lange skinfold caliper, conf rming to international specification for such instruments, was used for this measure (Figure 9). The examiner obtained a skinfold one-third of the distance from the axillary fold to the nipple along a line parallel to the pectoral tendon line (Figure 10). The width of the skinfold was recorded in millimeters. This measure was taken on the left side of the body.

The third measure was right wrist diameter measured in centimeters. A Craftsman #40182 caliper was used to measure the "greatest distance between the styloid processes at the distal ends of the radius and ulna" (73, p. 44) (Figure 11).

For all three of the anthropometric measures a confirming measure was taken. If the two measures did not agree a third measure, or as many

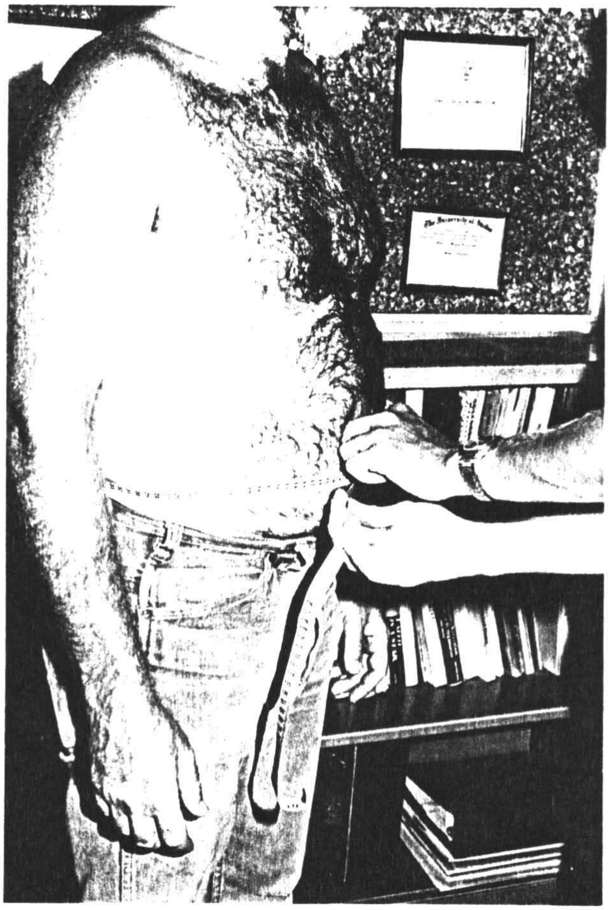

Figure 8. Waist girth measurement.

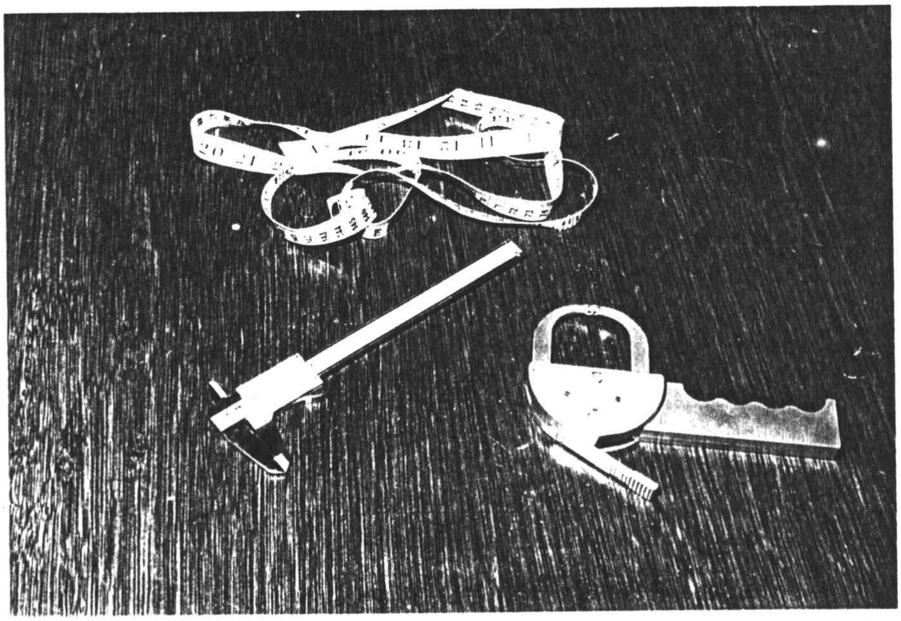

Figure 9. Tape measure, wrist caliper and skinfold caliper used in determining body fat.

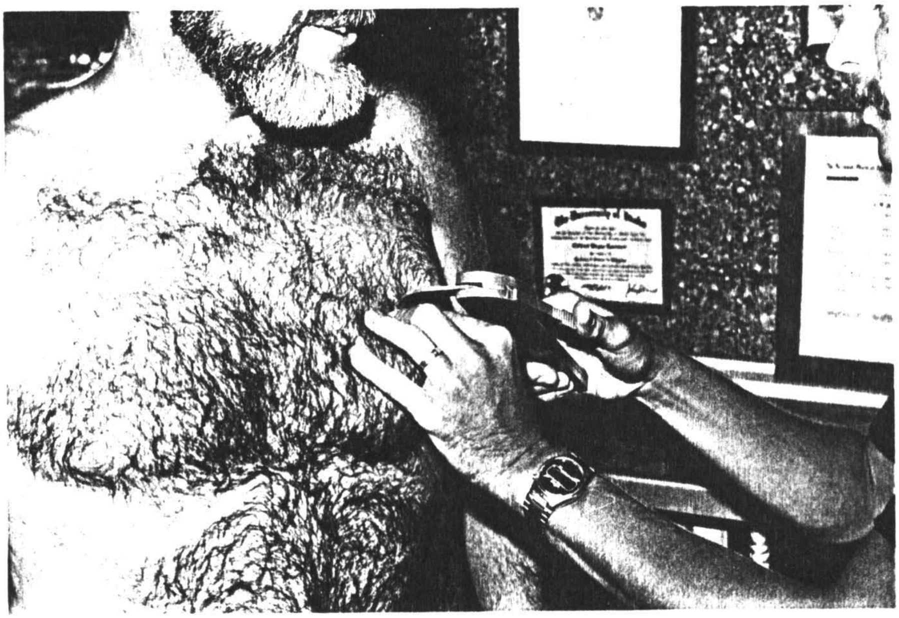

Figure 10. Pectoral skinfold measurement.

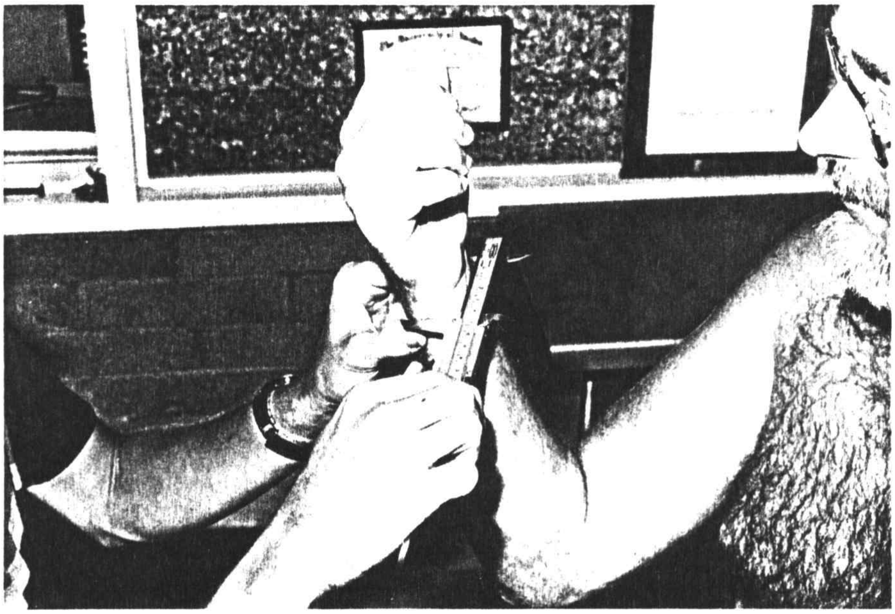

Figure 11. Wrist diameter measurement.

measures as was required for a consistent score, was taken. This procedure for score confirmation is in accord with Behnke and Wilmore (10).

Percent fat was then determined by placing the recorded values for the anthropometric measures into the following regression equation:

$$\% \text{ fat} = 8.7075 + 0.489 \text{ (waist)} + 0.449 \text{ (pectoral)} - 6.359 \text{ (wrist)}$$

By plotting percent fat against actual body weight (Appendix B), the fire fighter's desirable weight may be determined as a motivational technique for weight control.

Cardiovascular Endurance

The YMCA bicycle test protocol was used to determine the estimated maximal oxygen uptake and maximum workload. The subject sat upon the bicycle ergometer; adjustment of seat height required that on the downstroke, with the ball of the foot on the pedal, the leg should come nearly straight (Figure 12). When pedalling commenced the test administrator checked to insure that the subject was not required to wobble his hips to complete the downstroke.

The Salem YMCA uses two different brands of bicycle ergometer, the Monark and the Tunturi. The brand used by the subject on the pretest was also used on the posttest. Each bicycle was equipped with a speedometer. For one minute the subject pedaled with no resistance at a rate of 50 rpm. A metronome (Figure 13) was used to establish the cadence in which the right foot should be finishing the downstroke at each tick. During the initial minute the subject adjusted his cadence and used the adjustment time as a warmup. By pacing with the metronome the subject was able to locate the speed on the speedometer associated with the 50 rpm cadence. Once the correct speed had been located the subject was instructed to maintain this speed rather than concentrate on the metronome. The test

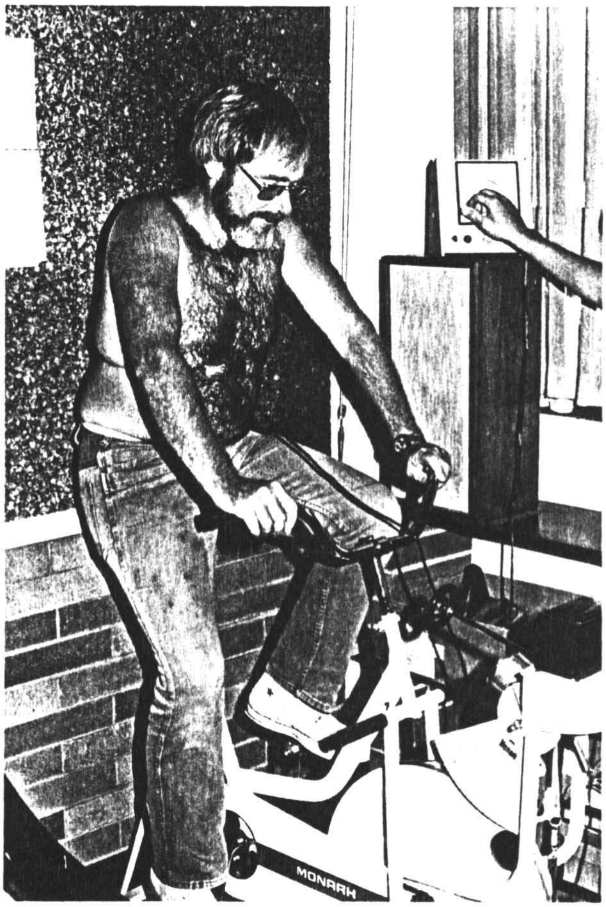

Figure 12. Proper leg extension on downstroke in bicycle ergometer test.

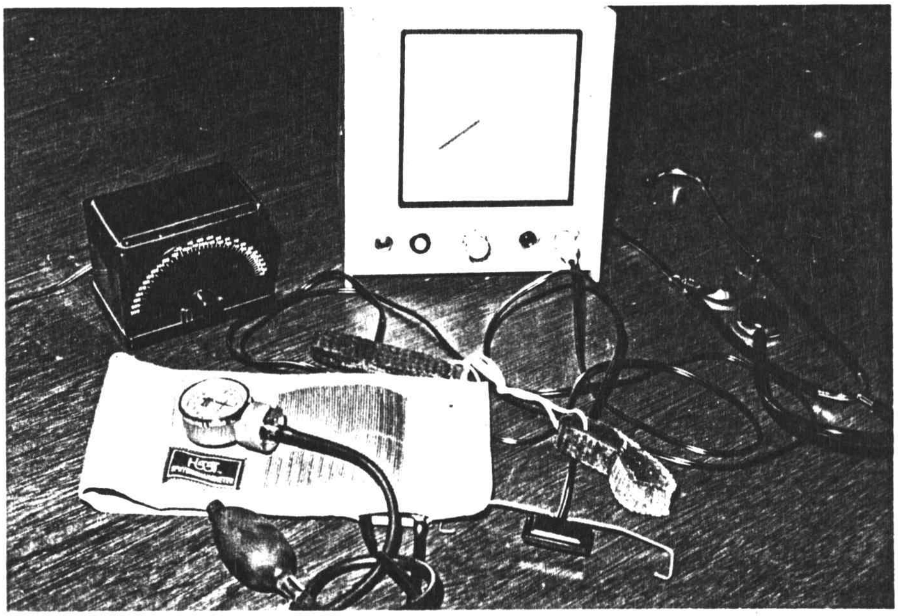

Figure 13. Cardiometern, metronome, stethoscope and blood pressure cuff and gauge used in testing cardiovascular endurance.

administrator periodically checked to see that the subject was pedalling in cadence with the metronome.

During the entire ergometer test the subject's heart rate was monitored electronically by a Cardionics AB "Cardiometern" (Figure 13). Observations of blood pressure were made every minute to insure the safety of test continuance (Figure 14). Blood pressure was determined by auscultation using a standard cuff and pressure dial (Figure 13).

At the end of the first minute the test administrator sets the first workload by adjusting the mechanical brake to induce a load of 300 kilogrammeters per minute (kgm/min). The subject pedaled at this load for three minutes. Heart rate was recorded during the latter part of the second minute and again at the latter part of the third minute. If these two heart rate readings differed by more than five beats the administrator assumed that a steady state had not been reached by the subject for that workload. The workload was extended for one minute or however long it took for a steady state to occur. If an extension of the workload was required the heart rate was recorded every 30 seconds until a steady state occurred.

Once a steady state had been attained a second (higher) workload was imposed. The same procedures as for the first workload were followed. A third workload followed a steady state for the second work load. The workload increment for the second and third workloads was determined by the steady state heart rate ending the previous work load. Three possible workloads were available for each the second and third increments. A guide to the setting of workloads was followed (Appendix C).

At the conclusion of the third workload the subject continued pedalling at gradually reduced workloads as a cool down.

Figure 14. Blood pressure measurement during bicycle ergometer testing.

Each workload was continuous with the preceding load. The new load was applied while the subject was pedalling at the previous load. With each new load the test administrator ascertained the pedalling frequency was held at 50 rpm.

The steady state heart rate in the second and third workloads was used to estimate maximum oxygen uptake. The first workload heart rate was not used as it was generally too low to be of any value.

A graph (Appendix D) was used to plot the heart rate (ordinate) versus the workload (abscissa). A straight line was drawn through the two heart rate plots and extended to a horizontal line associated with the estimated maximum heart rate. The estimated maximum heart rate is determined by subtracting the subject's age, in years, from 220. At the intersection of the line connecting the heart rate plots with the line for maximum heart rate a third line was dropped directly to the abscissa. The intersection of the third line with the abscissa indicated the estimated maximum workload and the associated maximum oxygen uptake. The maximal oxygen uptake was divided by the subject's body weight, in kilograms, to obtain an expression of oxygen uptake relative to body weight.

Maximal workload was recorded in terms of kgm/min with oxygen uptake as ml/kg·min (milliliters per kilogram·minute).

All six of the preceding physical fitness indices were recorded on the subject's score sheet (Appendix E). These score sheets, pre and post, were used for the data analysis.

Physical Fitness Program

Following the initial physical fitness screening each fire fighter was shown his personal profile chart (Appendix F). The implications of the profile chart were explained to the fire fighter by the YMCA personnel. As a result of the initial screening the fire fighter was assigned to a training group compatible in intensity to his current level of fitness.

A slide presentation was given to the fire fighters by the YMCA staff regarding proper techniques of exercising and engaging in the mandatory exercise sessions. An orientation to exercise and a demonstration session accompanied the slide presentation.

Each fire fighter was educated as to the importance of exercising within the limits set by the YMCA staff in terms of heart rate. The fire fighters were instructed to exercise at 80% of their predicted maximum heart rate based on their age.

The fire fighters were required to engage in the physical fitness program for one hour each shift worked. Since the fire fighters work shifts of 24 hours followed by 48 hours off the frequence of exercise was, minimally, once every three days. Exercise on off days was optional.

The mandatory exercise sessions were at 4:00 p.m. during the shift worked unless interrupted by a fire call. In the event of a fire call the session was scheduled whenever possible. The fire house captain was responsible for the group and the exercise sessions. The YMCA staff, prior to program implementation, spent time with the captains in teaching them how to properly conduct the exercise sessions.

The mandatory group sessions incorporated exercises designed to increase joint flexibility, muscular endurance, and muscular strength. In addition, following the group session the fire fighters were to engage in aerobic exercise of their own choosing such as pedalling a bicycle ergometer, jogging, or bench stepping. The aerobic phase of the exercise session was performed individually. Throughout the session the fire fighters monitored their pulse so as not to exceed the 80% age predicted maximum.

The exercise program was designed on three levels of fitness. Based on the initial maximum workload test score the fire fighter was placed in one of the three levels. Level one represented a score of "poor", level two represented "fair", and level three was for those fire fighters scoring "average" or better. This program gradation insured that the individual fire fighter would not exceed his exercise tolerance yet the program would produce a training effect.

The exercise sessions were conducted by a group leader. All fire fighters performed the same exercise at the same time. However, the number of repetitions the exercise was performed within the given time varied according to the fitness level. The graded program followed by the fire fighters is presented in Appendix G. As the weeks progressed new exercises were added.

Statistical Treatment

A paired observations two tailed t-test was used to test the null hypothesis

$$H_o: \bar{X}_1 = \bar{X}_2$$

where $\bar{X}_1$ equals the age group mean value for a given physical fitness parameter and $\bar{X}_2$ equals the post measure for the same parameter. The .05

level of confidence was chosen for the level of acceptance or rejection of the null hypothesis. The twenty eight null hypotheses tested (seven in each age group) were:

Age Group					
20-29	30-39	40-49	50+		
1	8	15	22	$H_o : \overline{X}_1 = \overline{X}_2$	maximum workload (PWC)
2	9	16	23	$H_o : \overline{X}_1 = \overline{X}_2$	for maximal oxygen uptake
3	10	17	24	$H_o : \overline{X}_1 = \overline{X}_2$	for maximal oxygen uptake relative to body weight
4	11	18	25	$H_o : \overline{X}_1 = \overline{X}_2$	for percent fat
5	12	19	26	$H_o : \overline{X}_1 = \overline{X}_2$	for trunk flexion
6	13	20	27	$H_o : \overline{X}_1 = \overline{X}_2$	for grip strength
7	14	21	28	$H_o : \overline{X}_1 = \overline{X}_2$	for one minute situps

Each of the above seven null hypotheses were tested for the four age groups 20-29, 30-39, 40-49, and 50 and over. Thus, 28 t-tests were performed.

A one way analysis of variance procedure was followed to determine if the subject age groups varied in the amount of change from pretest scores to posttest scores. The null hypothesis stated

$$H_o : G_1 = G_2 = G_3 = G_4$$

which, if accepted, would mean that the groups were equal in terms of test score change. This null hypothesis was used for all seven test items making a total of seven analysis of variance procedures. The .05 significance level was chosen for the level of acceptance or rejection of the null hypothesis. The null hypotheses tested were:

1. $H_o : G_1 = G_2 = G_3 = G_4$ For maximum workload
2. $H_o : G_1 = G_2 = G_3 = G_4$ For maximal oxygen uptake
3. $H_o : G_1 = G_2 = G_3 = G_4$ For maximal oxygen uptake relative to body weight

4. $H_o : G_1 = G_2 = G_3 = G_4$ For percent fat

5. $H_o : G_1 = G_2 = G_3 = G_4$ For trunk flexion

6. $H_o : G_1 = G_2 = G_3 = G_4$ For grip strength

7. $H_o : G_1 = G_2 = G_3 = G_4$ For one minute situps

Administration of Test

Pretesting was performed December 15-28, 1977. First quarter post-testing was performed May 1-15, 1978. In some cases testing had to be scheduled at later times due to illness or fire calls.

The fire department personnel were divided into three groups for testing purposes. The first group was composed of administrative officers. The second group was composed of station houses one and two. The final group was composed of the remaining station houses (three through seven). Group two and three were further divided into shifts worked thus necessitating three subgroups since fire fighters work 24 hours followed by a 48 hour off duty period. All testing was performed while the fire fighters were on duty and subject to fire call response. Testing was scheduled to begin at 8:30 a.m. on the assigned day.

CHAPTER IV

RESULTS AND INTERPRETATION OF DATA

The major purpose of this investigation was to evaluate the efficacy of the initial stage of the physical fitness program implemented by the Salem (Oregon) Fire Department. Data from 96 Salem fire fighters engaging in the physical fitness program was complete enough to be included in the data analysis. The data was organized by age grouping the fire fighters for each parameter under consideration. Group change between pre and post measures was the criterion of interest. A paired t-test was used to test for statistical significance of group change. The effect of age on amount of group change was determined through one way analysis of variance.

Initial Physical Fitness Levels

Studies conducted on other fire fighter populations indicate that fire fighter physical fitness levels, when the fire fighters are not engaged in a fitness program, are, at best, average (24, 54, 79, 104). Using the Salem fire fighter age group mean values given in Table I and locating this value in Appendix H indicates that the Salem fire fighters, as a group, fared no better in their physical fitness ratings.

Results of Age Group t-Test

Tables II through VIII break down the data and present the t-values for each variable tested under the null hypothesis that no change in age group mean values would be demonstrated as a result of engaging in the physical fitness program.

Age Groups 20-29, 30-39, 50 and Over

Grip strength proved to be the only fitness measure which did not show a significant mean difference. This lack of significance appeared

Table I. Initial ($\bar{X}_1$) and First Quarter ($\bar{X}_2$) Age Group Mean Values for Seven Test Items Obtained on 96 Salem Fire Fighters

	Mean and Standard Deviation	N	20-29	N	30-39	N	40-49	N	50 & over
Maximum Workload (kgm/min)	$\bar{X}_1$	34	1340	21	1279	16	1158	25	1062
	S.D.		251		237		214		183
	$\bar{X}_2$	34	1518	21	1367	16	1248	25	1155
	S.D.		230		168		202		192
Maximal Oxygen Uptake (L/min)	$\bar{X}_1$	34	3.117	21	2.950	16	2.697	25	2.474
	S.D.		.578		.529		.481		.408
	$\bar{X}_2$	34	3.496	21	3.145	16	2.891	25	2.686
	S.D.		.560		.380		.489		.487
Maximal Oxygen Uptake (ml/kg·min)	$\bar{X}_1$	34	38.1	20	34.8	14	31.7	24	31.0
	S.D.		8.0		7.7		5.5		6.9
	$\bar{X}_2$	34	42.9	20	37.6	14	36.1	24	34.0
	S.D.		6.8		6.9		5.0		6.7
Percent Fat (%)	$\bar{X}_1$	34	25.58	20	25.6	15	23.5	25	24.9
	S.D.		12.73		6.52		5.05		7.97
	$\bar{X}_2$	34	23.61	20	23.5	15	20.8	25	22.0
	S.D.		12.47		5.32		4.47		6.73
Trunk Flexion (Inches)	$\bar{X}_1$	33	15.89	21	16.0	16	16.03	25	12.58
	S.D.		3.91		3.75		4.13		4.02
	$\bar{X}_2$	33	17.24	21	16.9	16	16.06	25	13.68
	S.D.		3.69		3.38		3.81		4.13
Grip Strength (kg)	$\bar{X}_1$	34	62.94	21	63.71	16	61.88	25	55.92
	S.D.		8.31		8.98		9.98		7.94
	$\bar{X}_2$	34	64.62	21	66.57	16	65.06	25	57.64
	S.D.		7.96		7.55		6.47		6.65
1 Min. Situps (number)	$\bar{X}_1$	32	40.19	20	28.90	15	23.20	21	19.57
	S.D.		7.46		9.61		7.92		9.12
	$\bar{X}_2$	32	44.78	20	32.40	15	28.13	21	25.86
	S.D.		6.25		9.40		7.50		10.04

Table II. Initial and First Quarter Age Group Mean Values for Maximum Workload (kgm/min).

Age Group	N	Test	$\bar{X}$	50	two tailed r	two tailed t
20-29	34	Pre	1340	251	.613[b]	4.87[b]
		Post	1518	230		
30-39	21	Pre	1279	237	.727[b]	2.48[a]
		Post	1367	168		
40-49	16	Pre	1158	214	.601[a]	1.94
		Post	1248	202		
50+	25	Pre	1062	183	.853[b]	4.54[b]
		Post	1155	192		

[a]Significant at .05 level

[b]Significant at .01 level

Table III. Initial and First Quarter Age Group Mean Values for Maximal Oxygen Uptake (L/min)

Age Group	N	Test	X	50	two tailed r	two tailed t
20-29	34	Pre	3.117	.578	.608[b]	4.38[b]
		Post	3.496	.560		
30-39	21	Pre	2.950	.529	.696[b]	2.36[a]
		Post	3.145	.380		
40-49	16	Pre	2.697	.481	.681[b]	2.00
		Post	2.891	.489		
50+	25	Pre	2.474	.408	.853[b]	4.16[b]
		Post	2.686	.487		

[a]Significant at .05 level

[b]Significant at .01 level

Table IV. Initial and First Quarter Age Group Mean Values for Maximal Oxygen Uptake Relative to Body Weight (ml/kg·min)

Age Group	N	Test	$\overline{X}$	50	two tailed r	two tailed t
20-29	34	Pre	38.1	8.0	.650[b]	4.46[b]
		Post	42.9	6.8		
30-39	20	Pre	34.8	7.7	.813[b]	2.77[a]
		Post	37.6	6.9		
40-49	14	Pre	31.7	5.5	.693[b]	3.94[b]
		Post	36.1	5.0		
50+	24	Pre	31.0	6.9	.888[b]	4.54[b]
		Post	34.0	6.7		

[a]Significant at .05 level

[b]Significant at .01 level

Table V. Initial and First Quarter Age Group Mean Values for Percent Body Fat (%)

Age Group	N	Test	$\overline{X}$	50	two tailed r	two tailed t
20-29	34	Pre	25.6	12.73	.479[b]	4.46[b]
		Post	23.6	12.47		
30-39	20	Pre	25.6	6.52	.433[b]	3.74[b]
		Post	23.5	5.32		
40-49	15	Pre	23.5	5.05	.756[b]	3.19[b]
		Post	20.8	4.47		
50+	25	Pre	24.9	6.73	.401[b]	4.24[b]
		Post	22.0	4.02		

[a]Significant at .05 level

[b]Significant at .01 level

Table VI. Initial and First Quarter Age Group Mean Values for Trunk Flexion (inches)

Age Group	N	Test	$\overline{X}$	50	two tailed r	two tailed t
20-29	33	Pre	15.89	3.91	.875[b]	4.05[b]
		Post	17.24	3.69		
30-39	21	Pre	16.0	3.75	.914[b]	2.72[a]
		Post	16.9	3.38		
40-49	16	Pre	16.03	4.13	.856[b]	.06
		Post	16.06	3.81		
50+	25	Pre	12.58	4.02	.966[b]	2.60[a]
		Post	13.68	4.13		

[a]Significant at .05 level

[b]Significant at .01 level

Table VII. Initial and First Quarter Age Group Mean Values for Grip Strength (kg)

Age Group	N	Test	$\overline{X}$	50	two tailed r	two tailed t
20-29	34	Pre	62.94	8.31	.604[b]	1.35
		Post	64.62	7.96		
30-39	21	Pre	63.7	8.98	.683[b]	1.95
		Post	66.57	7.55		
40-49	16	Pre	61.88	9.98	.782[b]	2.01
		Post	65.06	6.47		
50+	25	Pre	55.92	7.94	.763[b]	1.66
		Post	57.64	6.65		

[a]Significant at .05 level

[b]Significant at .01 level

Table VIII. Initial and First Quarter Age Group Mean Values for 1-Minute Situps (number)

Age Group	N	Test	$\overline{X}$	50	two tailed r	two tailed t
20-29	32	Pre	40.19	7.46	.758[b]	5.30[b]
		Post	44.78	6.25		
30-39	20	Pre	28.90	9.61	.847[b]	2.97[b]
		Post	32.40	9.40		
40-49	15	Pre	23.20	7.92	.750[b]	3.49[b]
		Post	28.13	7.50		
50+	21	Pre	19.57	9.12	.817[b]	4.91[b]
		Post	28.86	10.04		

[a]Significant at .05 level

[b]Significant at .01 level

in all age groups. All other measures were significant at the .05 level with many significant at the .01 level. All demonstrated change occurred in the direction of improvement.

Age Group 40-49

This age group proved to be the exception in that significant changes were demonstrated only in maximal oxygen uptake relative to body weight, percent fat, and one minute situps. No significant change was demonstrated for maximum workload, maximum oxygen uptake (L/min), trunk flexion, or grip strength. The trend in scores was, however, in a positive direction and those scores which were significant were significant at the .01 level. Again, all demonstrated change was in the desired direction.

Results of Between Groups Analysis of Variance

Figures 15 through 21 indicate the relative age group change on each physical fitness parameter measured. Visual inspection of these figures shows that although absolute scores usually decreased with each successive age group (starting with the 20-29 group) the relative amount of change from pre to post test stayed relatively constant. Table IX contains the F ratio for each of the analysis of variance items. The F statistic was not significant in any of the test items. Thus, as can be observed by visual inspection of the figures and determined by analysis of variance, age did not effect the amount of change observed in each test item.

Interpretation

The null hypotheses that age group mean values for the physical fitness parameters being measured would not change as a result of the physical fitness program is rejected for all measures except grip strength. In the 40-49 age group the null hypothesis is retained, however, for maximum workload, maximum oxygen uptake (L/min) and trunk flexion in addition to grip

Table IX. Between Groups Analysis of Variance Determining the Effect of Age on Seven Test Items

Variable Age X	NdF	Mean Squares	F
Maximum Workload (kgm/min)	3	55958.85	1.84
Maximal Oxygen Uptake (L/min)	3	.23	1.41
Maximal Oxygen Uptake (ml/kg·min)	3	27.31	1.11
Percent Fat (%)	3	7.22	0.81
Trunk Flexion (inches)	3	4.97	1.32
Grip Strength (kg)	3	8.75	0.19
1 Min. Situps (number)	3	27.25	0.96

[a]Significant at .05 level

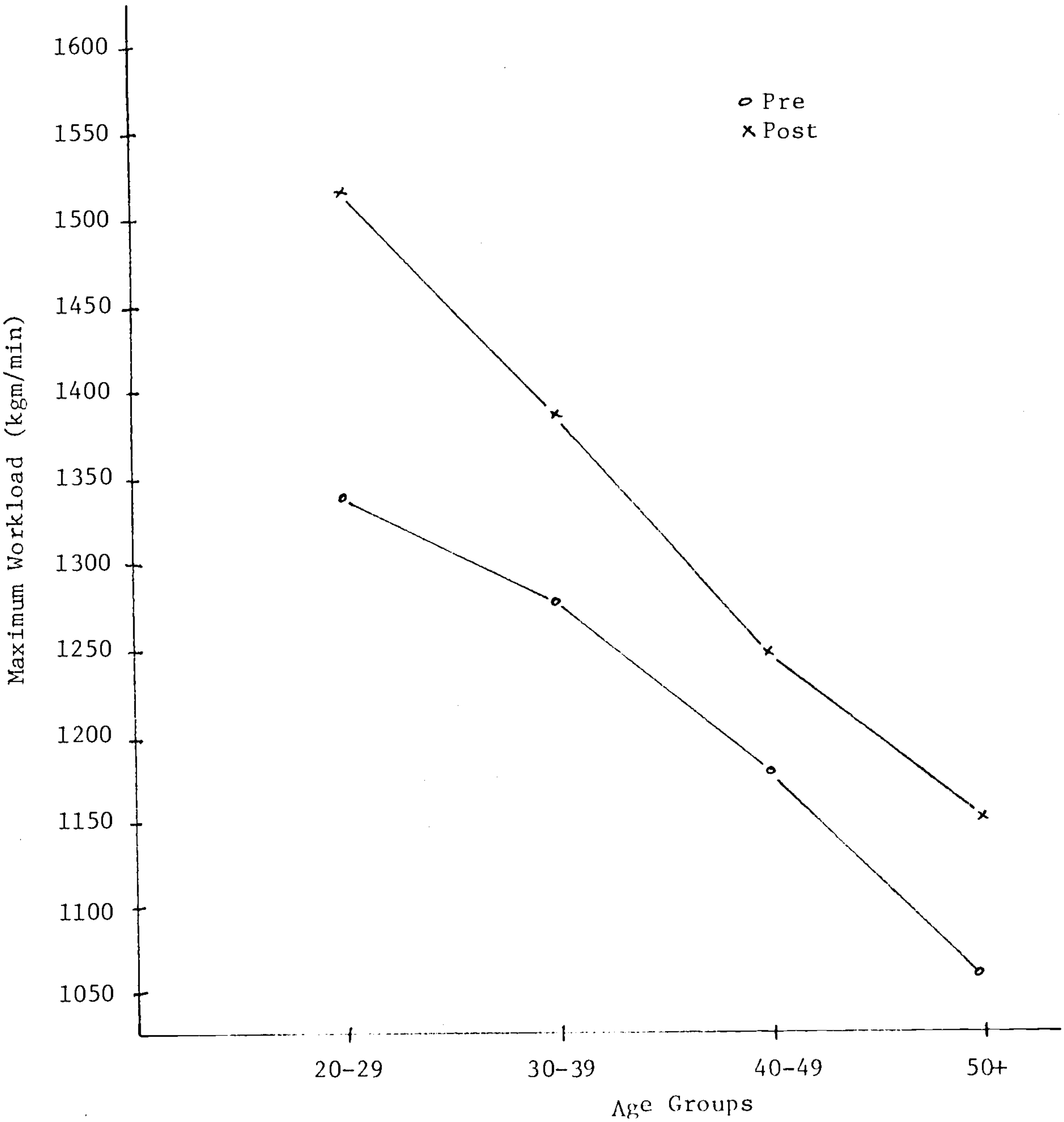

Figure 15. Pre and post physical fitness age group mean test scores for maximum workload (kgm/min)

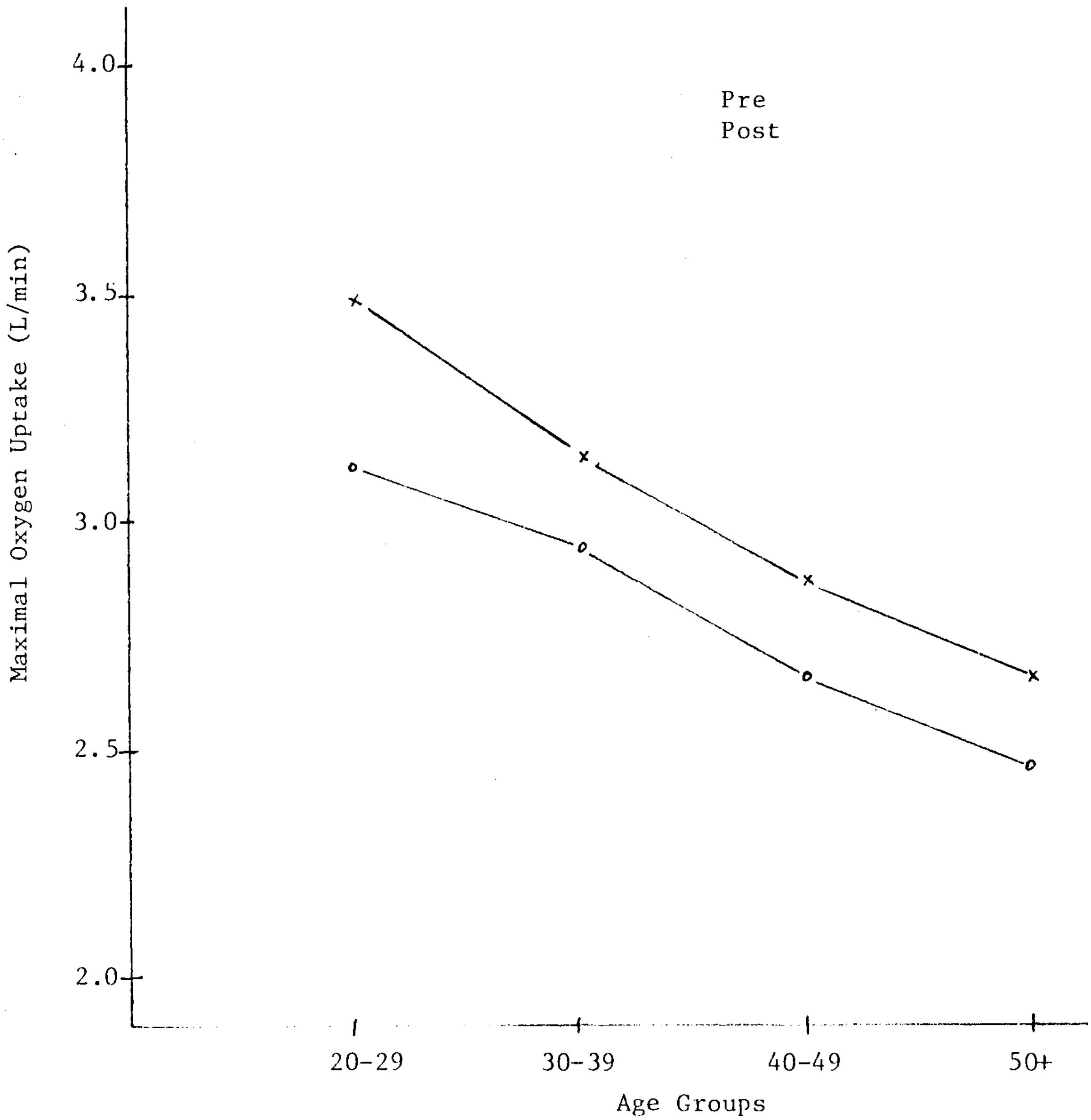

Figure 16. Pre and post physical fitness age group mean test scores for maximal oxygen uptake (L/min)

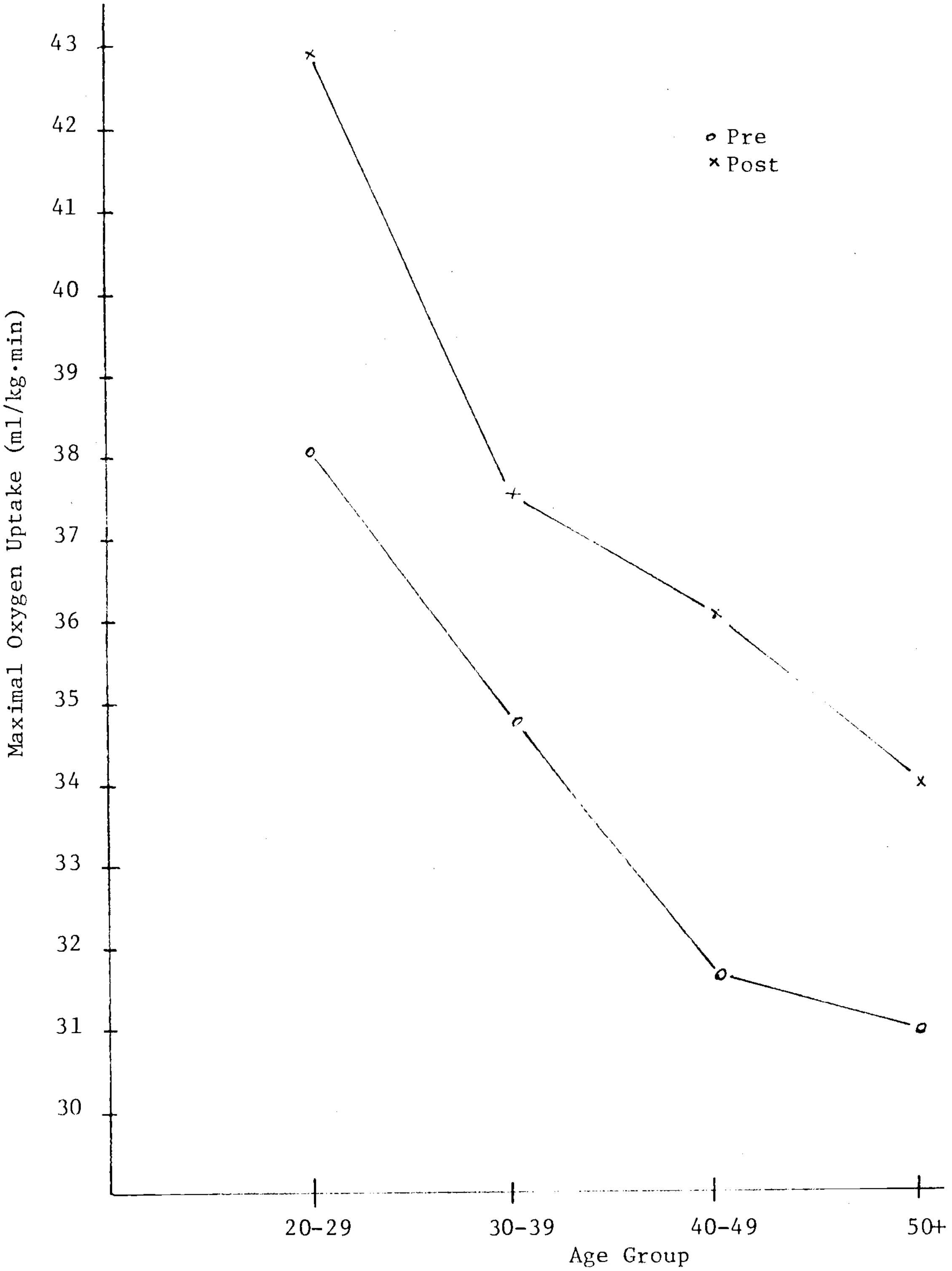

Figure 17. Pre and post physical fitness age group mean test scores for maximal oxygen uptake relative to body weight (ml/kg·min)

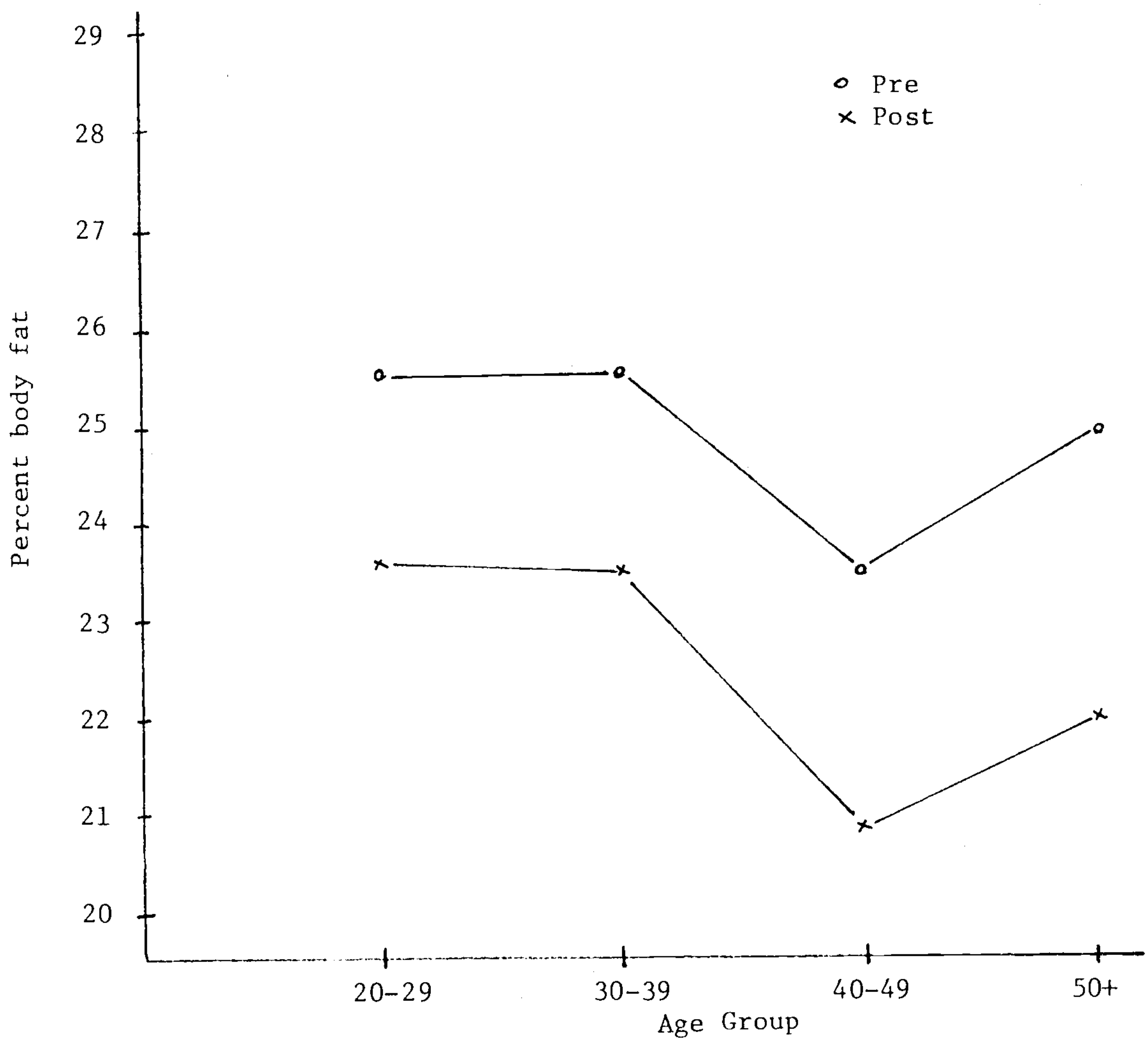

Figure 18. Pre and post physical fitness age group mean test scores for percent body fat (%)

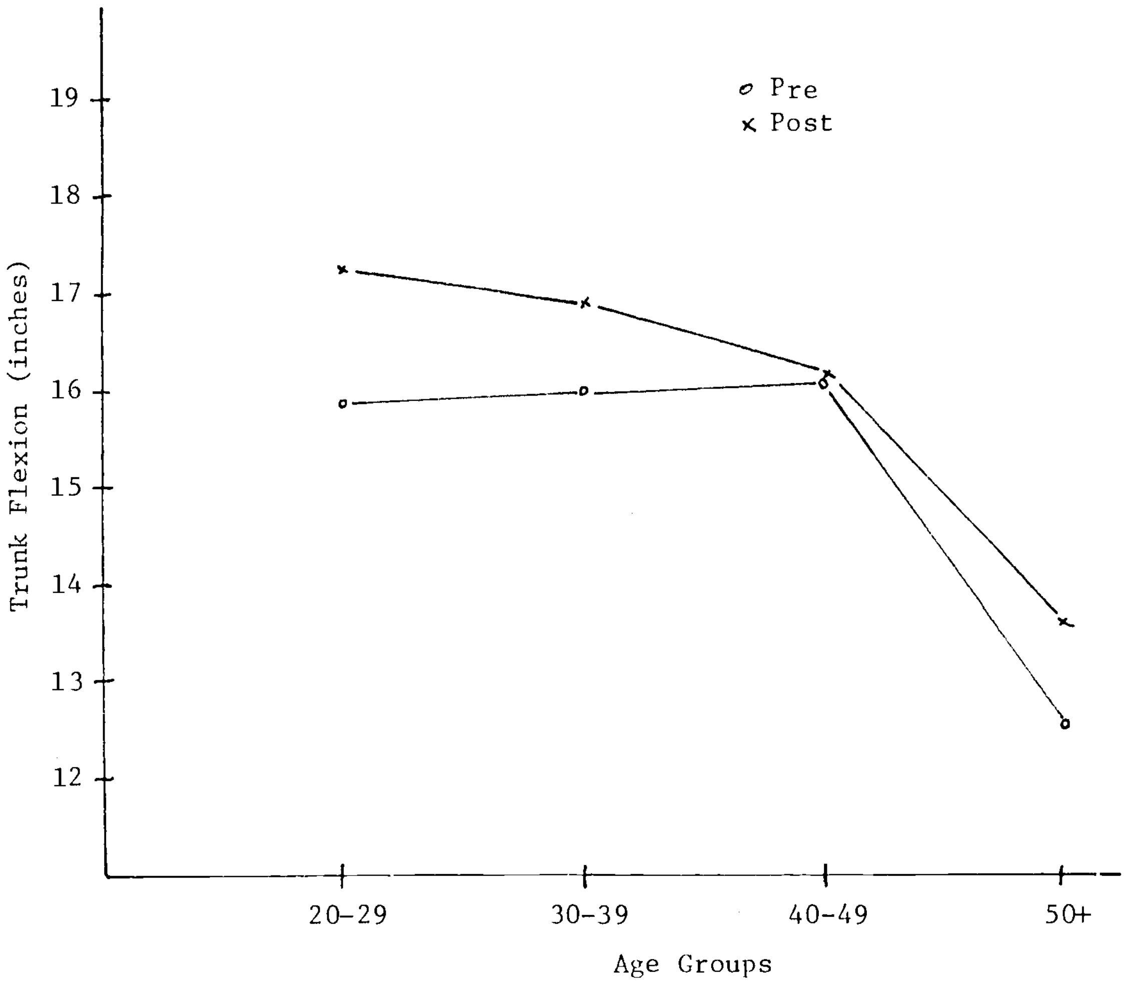

Figure 19. Pre and post physical fitness age group mean test scores for trunk flexion (inches)

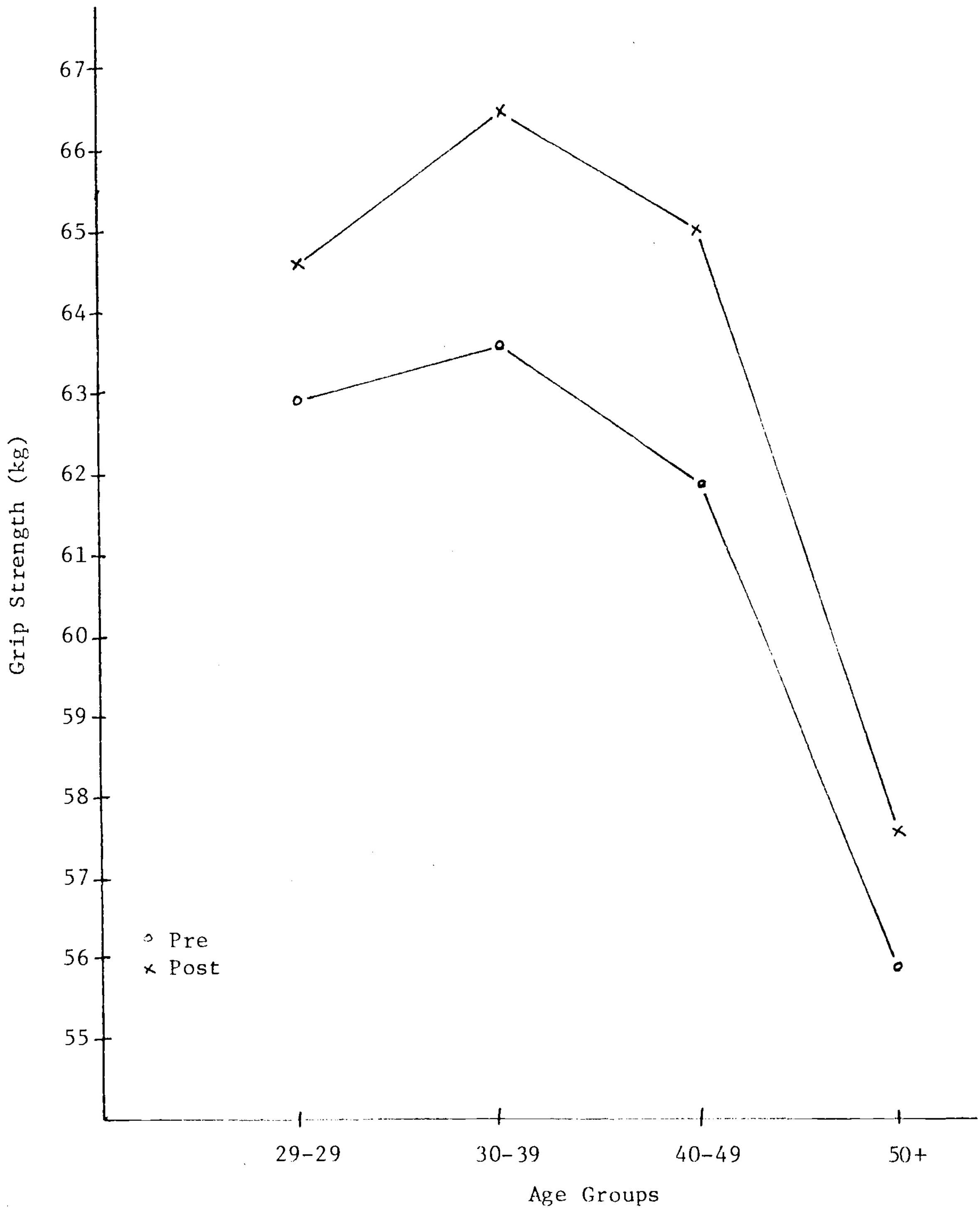

Figure 20. Pre and post physical fitness age group mean test scores for grip strength (kg)

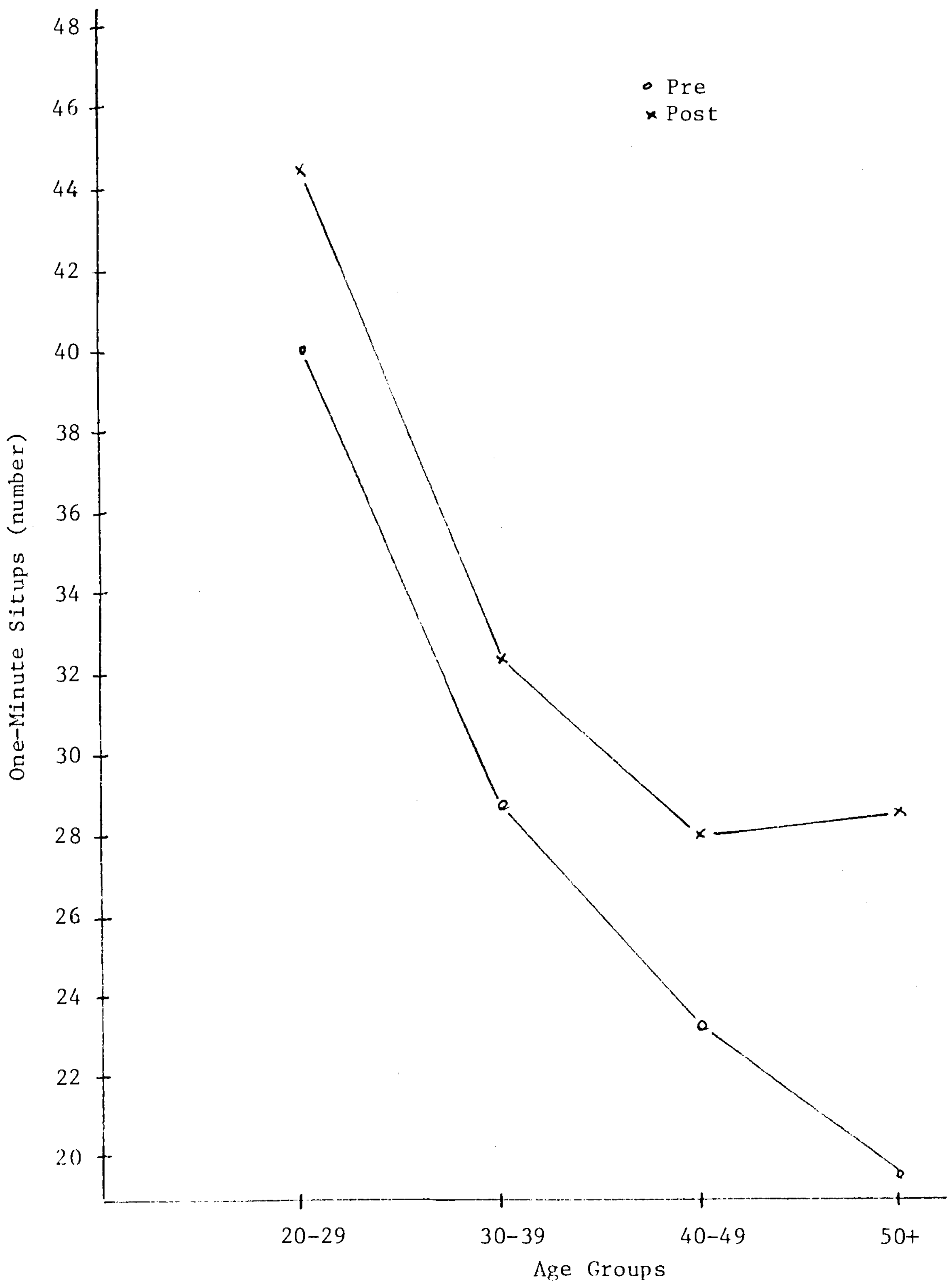

Figure 21. Pre and post physical fitness age group mean test scores for 1-minute situps (number)

strength. In all other cases in all age groups the alternative hypothesis is accepted.

The null hypotheses that age would not make a difference in relative change from pre to post test scores is retained for all seven test items.

Table X and Table XI report values for the same or similar physical fitness measures as obtained in this study and for the same or similar populations. An exception, however, is the measure of trunk flexion. A search of the literature has failed to surface results directly comparable to the results of this study. Other than the YMCA standards listed in Table XI the closest measures reported use a similar test but a different measuring scale. The measuring scale used for these trunk flexion scores can approximate the YMCA measures by adding 15 inches to the reported scores. This is only an approximation, however, since in the YMCA test the subject stretches his hands out on the floor and in the other tests the subject stretches out to an elevated platform.

Discussion

Interpretation of the results of this investigation must proceed beyond a final mathematical expression. In a study in which all subjects are not volunteers certain variables which cannot be controlled are brought into play. Such is the case with this investigation. The physical fitness program followed by the Salem fire fighters was mandatory for all uniformed personnel. The subjects of this investigation had no choice for or against participation in the program. Since participation was mandatory it may not be assumed all fire fighters openly embraced this program. Motivation, then, becomes an important concept in result interpretation. Those fire fighters who were personally interested in improving their fitness level had a greater motivation to do so than

Table X. Some Results from Other Researchers for the Measures of Maximal Oxygen Uptake (MVO_2) and Percent Body Fat

Source	N	Age	State of Training	Pre and Post or Normative	MVO_2 L/min	MVO_2 ml/kg·min	Percent Body Fat	Training Program
YMCA (73)	-		Untrained	Normative				
		20-29		Exc.	3.9-4.0	56-58	8-10	
				Good	3.7-3.8	52-54	12-14	
				Avg.	3.2-3.6	44-50	16-20	
				Fair	2.8-3.0	38-42	22-24	
				Poor	2.6-2.7	34-36	26-28	
		30-39		Exc.	3.7-3.8	52-54	as above	
				Good	3.5-3.6	48-50		
				Avg.	2.8-3.4	40-46		
				Fair	2.5-2.7	36-38		
				Poor	2.3-2.4	32-34		
		40-49		Exc.	3.5-3.6	48-50	as above	
				Good	3.2-3.4	44-46		
				Avg.	2.6-3.0	36-42		
				Fair	2.2-2.4	32-34		
				Poor	2.0-2.1	28-30		
		50-59		Exc.	3.1-3.2	45-57	as above	
				Good	2.8-3.0	41-43		
				Avg.	2.3-2.7	33-39		
				Fair	2.0-2.2	27-31		
				Poor	1.8-1.9	23-25		
Ekblom (30)	8	20	Untrained	Pre	3.15±___			16 wks, dash, interval and endurance running
				Post	3.68±___			
Wilmore, et al. (106)	20	17-59	Untrained	Pre		41.56±5.90		3 wks, 12 min/day, jogging
				Post		44.03±6.68		
	20	17-59	Untrained	Pre		42.96±7.11		3 wks, 24 min/day, jogging
				Post		47.12±6.56		

(Continued)

Table X. - Continued

Source	N	Age	State of Training	Pre and Post or Normative	MVO_2 L/min	MVO_2 ml/kg·min	Percent Body Fat	Training Program
DeVries (26)	68	52-58	Untrained	Pre		33.1±7.6	21.3±4.4	6 wks, 3/wk, combination, calisthenics, running, jogging, stretching
				Post		35.5±7.03	20.4±4.3	
Davis, et al. (24)	100	not given	Prof. Fire Fighters					Not engaged in training program
				Exc.		45.2±__	14.8±__	
				Good		43.1±__	18.1±__	
				Avg.		39.2±__	20.3±__	
				Fair		35.2±__	25.0±__	
				Poor		34.9±__	28.5±__	
Pollock, et al. (83)	19	28-29	Untrained	Pre	3.03±__	37.7±5.73	18.0±2.43	20 wks, 2/wk jog, run, walk, 30 min sessions
				Post	3.53±__	44.0±4.95	18.9±3.35	
				Pre		36.7±6.45	19.6±4.61	20 wks, 4/wk, 30 min sessions; job, run, walk
				Post		49.3±5.05	18.6±4.67	
McDonough, et al. (65)	15	40-49	Untrained	Normative		36.8±5.4		Habitually sedentary men
	7	50-59	Untrained	Normative		33.1±5.8		
	19	40-49	Active	Normative		49.9±4.3		Habitually active men
	32	50-59	Active	Normative		37.6±5.1		
White and Hunt (104)	NG	NG	Active Fire Fighters	Pre		27.21	22%	16 wk fitness program
				Post		36.37	19%	
Shvartz, et al. (92)	7	19.7 ±1.3	Trained	Normative	4.16±.16	60.1±3.7		
	7	21.3 ±0.6	Untrained	Normative	3.41±.38	47.7±3.6		
	7	19.0 ±0.6	Unfit	Normative	2.48±.22	35.7±3.3		

Table XI. Some Results from Other Researchers for the Measures of Trunk Flexion, Grip Strength and 1-Minute Situps

Source	N	Age	State of Training	Pre and Post or Normative	Trunk Flexion (inches)	Grip Strength (kg)	1-Min Situps (number)	Training Program
YMCA (73)			Untrained	Normative				
				Exc.	22-23	66-70	35-39	
				Good	20-21	58-62	30-34	
				Avg.	14-18	46-54	20-29	
				Fair	12-13	38-42	15-19	
				Poor	10-11	30-34	10-14	
Montoyne and	212	20-24		Normative				
Lamphiear* (69)	212	20-24				102.4±16.8		
	198	25-29				103.6±15.6		
	221	30-34				103.4±16.8		
	248	35-39				101.9±17.3		
	203	40-44				101.4±16.1		
	126	45-49				95.6±16.1		
	144	50-59				89.4±16.1		
Carver and Winsman (19)	149	19-39	Trained	Normative		60.78 8.61		Combat ready Special Forces soldiers
Matthew** (64)			Untrained	Normative				
	38	6 Gr.			1.18±3.01			
	46	5 Gr.			-1.01±2.52			
	42	4 Gr.			- .92±2.61			
Cotten, D.** Amer. Corr. Therapy Journal 26:24-26, 1972	37	18-19	Untrained	Normative	3.8±2.0			
Bernauer and Bonanno (11)	241		Untrained	Normative		54.88±10.06	17±4.3 (30 sec only)	
Pipes (79)	20	21-29	Fire Dept. Recruits	Pre			39.9±7.0	10 wks combined interval and circuit training
				Post			50.3±5.6	

*Hand grip measures reported are for left and right hand.
**Used a variation of the YMCA test. Rough equivalents may be obtained by the addition of 15 inches to the reported means.

those fire fighters just going through the motions. Since the program was designed to allow the fire fighters to work at their own rate it is entirely possible that fire fighters disinterested in the program could show little or no gain in fitness by not stressing themselves sufficiently. The motivational concept must be kept in mind when considering the data for the 40-49 age group.

The 40-49 age group showed improvement in only one-half the number of variables the other age groups improved in. If one considers first of all the loss in percent body fat demonstrated by this group it becomes immediately apparent why maximal oxygen uptake relative to body weight improved while maximal oxygen uptake expressed in L/min did not. The loss in body fat results in more oxygen being made available for use by working muscles without the amount of uptake having to increase.

If a lack of motivation resulted in the lesser improvement of the 40-49 age group some additional questions are raised. Why was there improvement in any variables for this group? Why did only the 40-49 age group not show improvement in any of the variables other than grip strength? The answers to these questions need to be found and dealt with by the Salem Fire Department.

A lack of significant improvement for all age groups in hand grip strength demonstrates that, as the literature suggests (54), hand grip strength is a stable measure not showing change during physical fitness programs.

A previous research study suggests that age is not a factor in determining the amount of change from pre to post test scores (106). The importance of such a statement should not be overlooked. By examining the absolute score values it becomes apparent that the older age groups are at the lower level of the fitness scale and thus are at greatest risk while fire fighting. However, further consideration surfaces the fact that these age groups may benefit as much as the younger age groups from the physical fitness program which demonstrates the value of this program for all age groups.

A final observation should be made concerning these results. The r value is reported in Tables II through VIII. In all cases the reported value is significant at the .05 level. Such a result demonstrates that the shift in scores from pre to post were a result of overall group improvement and not biased by a few high scoring individuals within the group.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Fire fighting is the most dangerous occupation in the United States. Job related injury, morbidity, and mortality is an accepted hazard of the fire service. The role of physical fitness as an ameliorating agent is a subject currently under investigation. Preliminary studies have indicated that increasing the level of physical fitness within fire fighter populations results in an associated drop in job related injuries, morbidity, and mortality. As a result of these preliminary studies fire departments are becoming interested in initiating physical fitness programs for their fire fighters. The city of Salem, Oregon is one such fire department.

For a physical fitness program to be warranted in terms of time involvement, financial expense and group morale, it is necessary that the program be efficacious. The purpose of this study was to determine if, indeed, the physical fitness program followed by the Salem Fire Department was producing measurable change in physical fitness parameters selected for job related importance by the Salem YMCA.

Procedures

One hundred fifty Salem fire fighters were tested for maximal working capacity, maximal oxygen uptake, maximal oxygen uptake relative to body weight, percent body fat, trunk flexibility, grip strength, and one minute timed situps. Data for 96 of these fire fighters was complete enough for inclusion in the data analysis.

Physical fitness testing preceded the physical fitness program. The fire fighters were then retested three months into the program. All tests were conducted by the staff of the Salem YMCA utilizing established YMCA procedures.

The physical fitness program involved a group led session each work shift. The fire fighters engaged in progressive calisthenics, stretching, and aerobic exercise. Each fire fighter worked at his own level. The aerobic phase involved jogging, cycling, or bench stepping and was performed on an individual basis following the group session.

Data Analysis

The fire fighters test scores were grouped according to age. A paired t-test for each paired measure within each age group was performed on the pre and post group mean values of each physical fitness parameter. The .05 level of significance was chosen for rejection of the null hypothesis in this investigation.

To assess the effect of age on the amount of change in the variables an ANOVA procedure was followed. Significance level was set at .05.

Conclusions

Analysis of the data, summarized in Table XII, leads to the following conclusions:

1. Maximum workload mean scores improved significantly for the age groups 20-29, 30-39 and 50 and over.

2. Maximal oxygen uptake mean scores improved significantly for the age groups 20-29, 30-39, and 50 and over.

3. Maximal oxygen uptake relative to body weight improved significantly for the age groups 20-29, 30-39, 40-49 and 50 and over.

4. Percent body fat mean scores improved significantly for the age groups 20-29, 30-39 and 50 and over.

Table XII. Summary of t-Values for Age Group Means

VARIABLE	AGE GROUP 20-29	30-39	40-49	50 and over
Maximum Workload (kgm/min)	4.87[b]	2.48[a]	1.94	4.54[b]
Maximal Oxygen Uptake (L/min)	4.38[b]	2.36[a]	2.00	4.16[b]
Maximal Oxygen Uptake (ml/kg·min)	4.46[b]	2.77[a]	3.94[b]	4.54[b]
Percent Fat (%)	4.46[b]	3.74[b]	3.19[b]	4.24[b]
Trunk Flexion (Inches)	4.05[b]	2.72[a]	.06	2.60[a]
Grip Strength (kg)	1.35	1.95	2.01	1.66
1 Min. Situps (Number)	5.30[b]	2.97[b]	3.49[b]	4.91[b]

[a]Significant at .05 level

[b]Significant at .01 level

5. Trunk flexion mean scores improved significantly for the age groups 20-29, 30-39 and 50 and over.

6. Grip strength mean scores did not show significant improvement in any age group.

7. One-minute situps mean scores improved significantly for the age groups 20-29, 30-39, 40-49, and 50 and over.

8. Age was not a factor in determining amount of change from pre to post test scores for maximum workload.

9. Age was not a factor in determining amount of change from pre to post test scores for maximal oxygen uptake.

10. Age was not a factor in determining amount of change from pre to post test scores for maximal oxygen uptake relative to body weight.

11. Age was not a factor in determining amount of change from pre to post test scores for percent body fat.

12. Age was not a factor in determining amount of change from pre to post test scores for trunk flexion.

13. Age was not a factor in determining amount of change from pre to post test scores for grip strength.

14. Age was not a factor in determining amount of change from pre to post test scores for one-minute situps.

Recommendations

This investigation has demonstrated that, on the whole, the physical fitness program being followed by the Salem Fire Department is a valuable tool for increasing the physical fitness level of the Department's fire fighters. Recommendations for further study or consideration include the following:

1. An alternative measure to grip strength should be used for

evaluating changes in muscular strength. This investigation, in agreement with previous studies conducted by other researchers, indicates that grip strength is a stable measure.

2. Possible causes for the inconsistent performance of the 40-49 age group should be investigated.

3. Longitudinal evaluation of the physical fitness program should be conducted to assess continuing change.

4. Longitudinal evaluation of the physical fitness program as an accident, injury, morbidity deterrent should be investigated.

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APPENDICES

APPENDIX A

OREGON STATE UNIVERSITY

Committee for Protection of Human Subjects

Chairman's Summary of Review

Title: An Evaluation of the Initial Stages of the Salem Fire Department Physical Fitness Program

Program Director: Arthur R. Dernbach

Recommendation:

x Approval

___ Provisional Approval

___ Disapproval

___ No Action

Remarks: OSU appears to be involved only in the statistical evaluation of data which others have gathered. The program director should be sure to take all precautions necessary to preserve confidentiality.

Date: July 18, 1978 Signature: ___

If the recommendation of the committee is for provisional approval or disapproval, the program director should resubmit the application with the necessary corrections within one month.

APPENDIX B

Determination of Ideal Body Weight*

Actual Body Weight

Percent Fat	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240
6	134	140	145	151	157	162	168	173	179	185	190	196	201	207	213	218	224	229	235	241	246	252	257	263	269
8	131	137	142	148	153	159	164	170	175	181	186	192	197	203	208	214	219	225	230	236	241	246	252	257	263
10	129	134	139	145	150	155	160	166	171	177	182	187	193	198	204	209	214	220	225	230	236	241	246	252	257
12	126	131	136	141	147	152	157	162	168	173	178	183	189	194	199	204	210	215	220	225	231	236	241	246	251
14	123	128	133	138	143	148	154	159	164	169	174	179	184	189	195	200	205	210	215	220	225	230	236	241	246
16	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240
18	117	122	127	132	137	142	146	151	156	161	166	171	176	181	186	190	195	200	205	210	215	220	225	229	234
20	114	119	124	129	133	138	143	148	152	157	162	167	171	176	181	186	190	195	200	205	210	214	219	224	229
22	111	116	121	125	130	135	139	144	149	153	158	162	167	172	176	181	186	190	195	200	204	209	214	218	223
24	109	113	118	122	127	131	136	140	145	149	154	158	163	167	172	176	181	186	190	195	199	204	208	213	217
26	106	110	115	119	123	128	132	137	141	145	150	154	159	163	167	172	176	181	185	189	194	198	203	207	211
28	103	107	111	116	120	124	129	133	137	141	146	150	154	159	163	167	171	176	180	184	189	193	197	201	206
30	100	104	108	113	117	121	125	129	133	137	142	146	150	154	158	162	167	171	175	179	183	188	192	196	200
32	97	101	105	109	113	117	121	125	130	134	138	142	146	150	154	158	162	166	170	174	178	182	186	190	194
34	94	98	102	106	110	114	118	122	126	130	134	137	141	145	149	153	157	161	165	169	173	177	181	185	189
36	91	95	99	103	107	110	114	118	122	126	130	133	137	141	145	149	152	156	160	164	168	171	175	179	183
38	89	92	96	100	103	107	111	114	118	122	125	129	133	137	140	144	148	151	155	159	162	166	170	174	177
40	86	89	93	96	100	104	107	111	114	118	121	125	129	132	136	139	143	146	150	154	157	161	164	168	171

On the left axis locate the estimated percent fat and on the horizontal axis locate the subject's actual body weight. The "ideal weight" (lean body weight plus 16% fat) is found at the intersection of these two variables.

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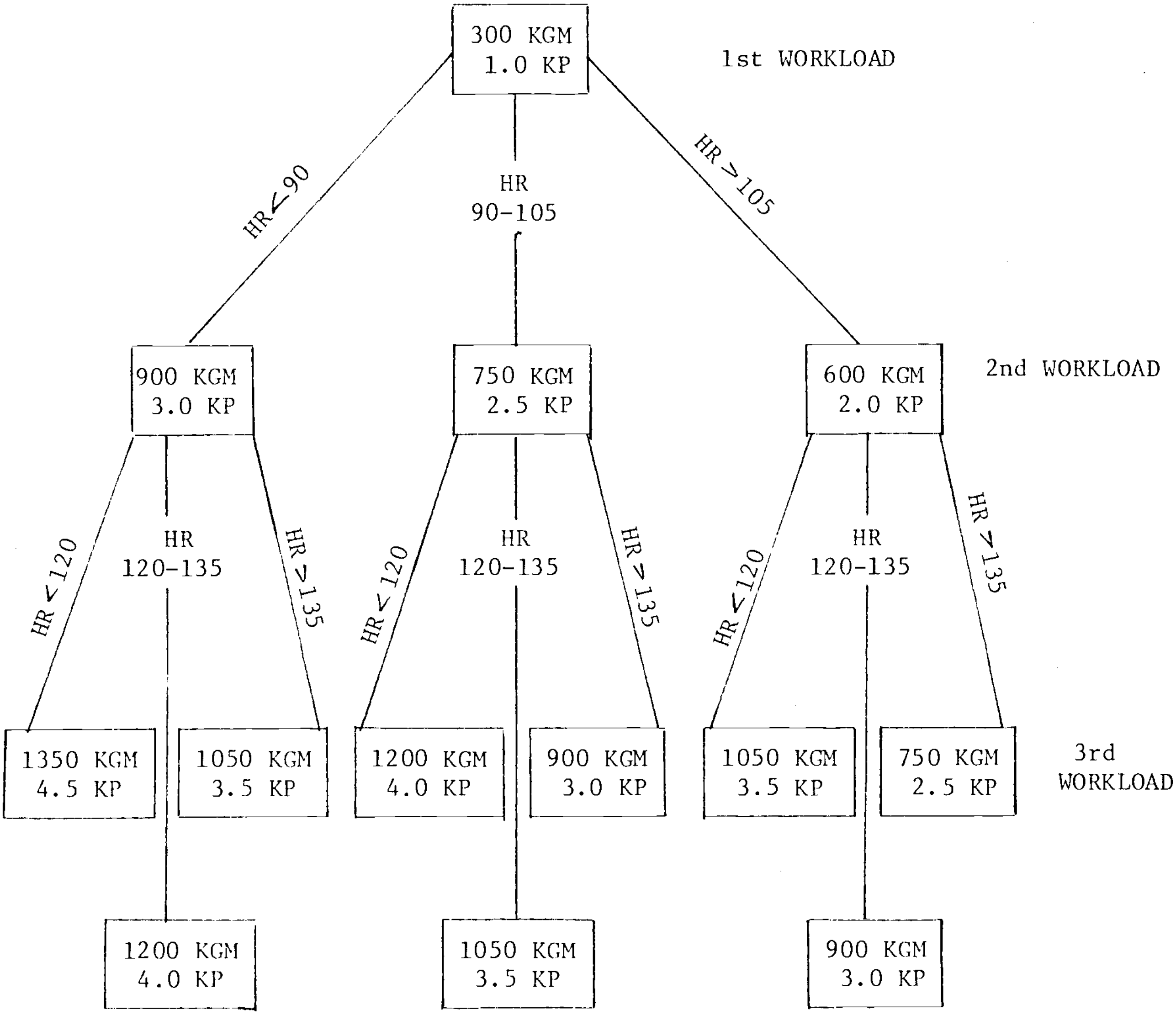
*Adapted from: Myers, C., L. Golding, W. Sinning. The Y's Way to Physical Fitness, Rodale Press, Inc., p. 44, 1973.

APPENDIX C

Guide to Setting Workloads*

Directions:

1. Set the 1st workload at 300 kgm/min (1.0 KP)
2. If HR in 3rd min is:
   Less than (<) 90, set 2nd load at 900 kgm (3 KP)
   Between 90 and 105, set 2nd load at 750 kgm (2.5 KP)
   Greater than (>) 105, set 2nd load at 600 kgm (2.0 KP)
3. Follow the same pattern for setting 3rd and final load.



*Adapted from Myers, C., L. Golding, W. Sinning. The Y's Way to Physical Fitness, Rodale Press, Inc., p. 64, 1973.

APPENDIX D

Heart Rate Versus Workload Plot for Estimating Maximum Workload and Oxygen Consumption*

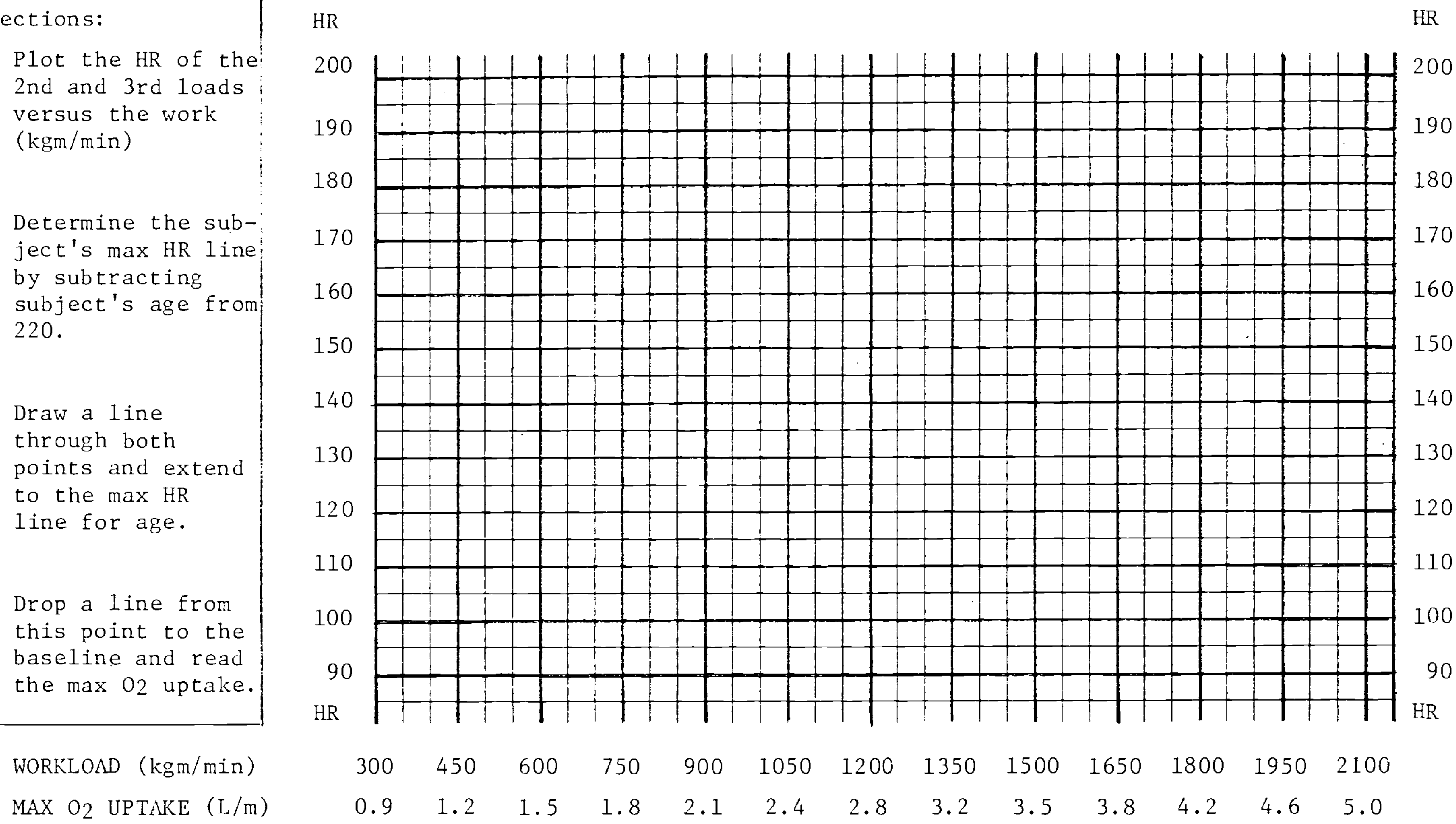
Directions:

1. Plot the HR of the 2nd and 3rd loads versus the work (kgm/min)

2. Determine the subject's max HR line by subtracting subject's age from 220.

3. Draw a line through both points and extend to the max HR line for age.

4. Drop a line from this point to the baseline and read the max O_2 uptake.



*Adapted from Myers, C., L. Golding, W. Sinning. <u>The Y's Way to Physical Fitness</u>, Rodale Press, Inc., p.35, 1973.

APPENDIX E

Subjects Fitness Testing Score Sheet*

PHYSICAL FITNESS EVALUATION

Test Battery A

NAME______________________________ DATE______________

AGE__________ BIRTHDATE______________ WEIGHT__________________lb

HEIGHT________________ WEIGHT__________________kg

RESTING HR____________________ RESTING BP__________________mmhg

---

1. PHYSICAL WORKING CAPACITY TEST

Workload	Heart Rate		
	______________	2nd min	
300 kgm	______________	3rd min	
	______________		1st WORKLOAD
	______________	2nd min	
_____kgm	______________	3rd min	2nd WORKLOAD
	______________		
	______________	2nd min	
_____kgm	______________	3rd min	3rd WORKLOAD
	______________		

2. BODY COMPOSITION

   Waist girth ______________cm
   Pectoral Skinfold ______________mm
   Right Wrist Diameter ______________cm

3. FLEXIBILITY

   Trunk Flexion__________in

4. MUSCULAR STRENGTH

   Dominant Hand Grip________________kg

5. MUSCULAR ENDURANCE

   Timed 1-min Sit-ups________________no.

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*Adapted from Myers, C., L. Golding, W. Sinning. The Y's Way to Physical Fitness, Rodale Press, Inc., p. 55, 1973.

APPENDIX F

Personal Profile

I. ENDURANCE TEST SCORES:

Your test shows a heart response of _____ BPM (beats per minute) for an exercise load of ______, and ______ BPM at _______ workload. Based upon these scores we can predict your maximum VO_2 at _______. VO_2 maximum is the amount of oxygen you are able to use at maximum effort. We consider a VO_2 from ______ to _______ good. Another score we use to determine your fitness is your FAI which stands for Functional Aerobic Impairment. This means that if we took a cross section of people your age they would have no or zero impairment. If you have a positive score that means you have some impairment, but if you have a negative score that means you are in better condition than the average person your age. Your FAI is ______%. Your endurance fitness classification is _________.

II. OTHER TESTS:

The amount of body fat you have is _______%. We would like to see you between _______% and _________%. This means your ideal weight should be _______ lbs.

Your flexibility test score is ______ inches. You should be able to score 15 inches or more to insure adequate range of motion at the joints. Your grip strength of ______ and timed sit-ups of _______ are indicative of a _______ muscular endurance classification.

III. EXERCISE PRESCRIPTION:

You should exercise three times per week and work up to a duration of 45 minutes each session. We feel that you should work up to 20-30 minutes of cardiovascular exercise, such as walking, swimming, or jogging, with your heart rate within your training effect range. This range for you is ______ to _______ beats per minute. This range is based upon 80% of your maximum heart rate (which is approximately 50% of your physical working capacity.) Count your heart rate for 15 seconds immediately following your work phase and before you cool down, then multiply by 4 to get BPM heart rate. When doing these cardiovascular exercises you should warm up for ______ minutes and cool down for _______ minutes.

APPENDIX G

GRADED EXERCISE PROGRAM

LEVEL I

First Four Months

BEGINNING FITNESS

WARM-UP AND FLEXIBILITY: (duration 6-8 minutes)

NO.	EXERCISE	REPETITIONS
1.	ARM CIRCLING	30 FORWARD; 30 REVERSE
2.	SIDE BENT	10 LEFT; 10 RIGHT
3.	HEAD ROTATION	5 LEFT; 5 RIGHT
4.	HALF KNEE BEND	10
5.	SPLIT STRETCHER	5 LEFT; 5 RIGHT
6.	CALF STRETCHER	3 EACH LEG
7.	KNEE LIFT	10 EACH LEG
8.	BACK STRETCH	1 EACH LEG
9.	STANDING LEG RAISE	15-20 EACH LEG

CARDIOVASCULAR ACTIVITY: (duration 10-12 minutes)

NO.	EXERCISE	REPETITIONS
1.	STATIONARY RUNNING (slow).	100-1 min. 15 sec.
2.	*BENCH STEPPING (slow)	20 per min. for 3 min.
	*ROPE SKIPPING (slow)	80 per min. for 2 min.
	*choose one each workout	
3.	STAIONARY RUNNING (slow)	100-1 min. 15 sec.
4.	SIDE STRADDLE HOP	10
5.	STATIONARY RUNNING (slow)	100-1 min. 15 sec.
6.	HEEL RAISE	10
7.	STATIONARY RUNNING (medium)	100-1 min. for 2 min.
8.	SIDE STRADDLE HOP	10

SHAKE EACH LEG FOR 10 SECONDS

CONDITIONING EXERCISES: (duration 4-5 minutes)

NO.	EXERCISE	REPETITIONS
1.	*PUSH-UP BENT KNEE	10
	*PUSH-UP FULL LENGTH	10
	*choose one; depends on member's condition	
2.	*SIT-UP BEGINNING	10
	*SIT-UP MODIFIED	5 plus
	*choose one; depends on member's condition	
3.	PRONE SIDE LEG RAISE	5 EACH LEG

APPENDIX G (Continued)

LEVEL II

Months Five through Eight

INTERMEDIATE FITNESS

WARM-UP AND FLEXIBILITY: (duration 6-8 minutes)

NO.	EXERCISE	REPETITIONS
1.	ARM CIRCLING	30 FORWARD; 30 REVERSE
2.	SIDE BEND	10 LEFT; 10 RIGHT
3.	HEAD ROTATION	5 LEFT; 5 RIGHT
4.	HALF KNEE BEND	10
5.	SPLIT STRETCHER	5 LEFT; 5 RIGHT
6.	CALF STRETCHER	3-5 EACH LEG
7.	KNEE LIFT	10 EACH LEG
8.	BACK STRETCH	1 EACH LEG
9.	STANDING LEG RAISE	15-50 EACH LEG

CARDIOVASCULAR ACTIVITY: (duration (12-14 minutes)

NO.	EXERCISE	REPETITIONS
1.	STATIONARY RUN (slow)	100-1 min. 15 sec.
2.	*BENCH STEPPING (medium)	24 per min. for 3 min.
	*ROPE SKIPPING (medium)	100 per min. for 2 min.
	*choose one each workout	
3.	STATIONARY RUNNING (slow)	100-1 min. 15 sec.
4.	SIDE STRADDLE HOP	10
5.	STATIONARY RUNNING (slow)	100-1 min. 15 sec.
6.	HEEL RAISE	15
7.	STATIONARY RUNNING (medium)	100-1 min. for 2 min.
8.	SIDE STRADDLE HOP	15
9.	STATIONARY RUNNING (fast)	100-50 sec.

SHAKE EACH LEG FOR 10 SECONDS. BENCH STEPPING: 12- or 15-inch BENCH MAY BE USED.

CONDITIONING EXERCISES: (duration 6-8 minutes)

NO.	EXERCISE	REPETITIONS
1.	*PUSH-UP BENT KNEE	15
	*PUSH-UP FULL LENGTH	15
	*choose one; depends on condition of member	
2.	*SIT-UP BEGINNING	15
	*SIT-UP MODIFIED	5 plus
	*SIT-UP ADVANCED	15
	*choose one; depends on condition of member	
3.	PRONE SIDE LEG RAISE	8 each leg

APPENDIX G (Continued)

LEVEL III

Nine Months and On

ADVANCED FITNESS

WARM-UP AND FLEXIBILITY: (duration 6-8 minutes)

NO.	EXERCISE	REPETITIONS
1.	ARM CIRCLING	30 FORWARD; 30 REVERSE
2.	SIDE BEND	10 LEFT; 10 RIGHT
3.	HEAD ROTATION	5 LEFT; 5 RIGHT
4.	HALF KNEE BEND	25
4A.	HALF KNEE BEND, ONE LEG (Alternate)	15-25 EACH LEG
5.	SPLIT STRETCHER	5 LEFT; 5 RIGHT
6.	CALF STRETCHER	3-5 EACH LEG
7.	KNEE LIFT	10 EACH LEG
8.	BACK STRETCH	1 EACH LEG
9.	STANDING LEG RAISE	25-50 EACH LEG

CARDIOVASCULAR ACTIVITY: (duration 15-17 minutes)

NO.	EXERCISE	REPETITIONS
1.	STATIONARY RUNNING (slow)	100-1 min. 15 sec.
2.	*BENCH STEPPING (fast)	30 per min. for 4 min.
	*ROPE SKIPPING (fast)	125 per min. for 3 min.
	*choose one each workout	
3.	STATIONARY RUNNING (slow)	150-2 min.
4.	SIDE STRADDLE HOP	10
5.	STATIONARY RUNNING (medium)	150-1 min. 30 sec. for 3 min.
6.	HEEL RAISE	15
7.	STATIONARY RUNNING (medium)	150-1 min. 30 sec. for 3 min.
8.	SIDE STRADDLE HOP	15
9.	STATIONARY RUNNING (fast)	100-50 sec.

SHAKE EACH LEG FOR 10 SECONDS: REPEAT TWICE. BENCH STEPPING: 12-, 15- or 18-INCH BENCH MAY BE USED.

CONDITIONING EXERCISES: (duration 10-12 minutes)

NO.	EXERCISE	REPETITIONS
1.	PUSH-UP FULL LENGTH	20
2.	SIT-UP BENT KNEE	20
3.	PRONE FLUTTER KICK	30
4.	PRONE SIDE LEG RAISE	10 EACH LEG

APPENDIX H

Physical Fitness Rating Scale*

RATING	WORKLOAD (kgm/min)	MAXIMAL OXYGEN UPTAKE (L/min)	(ml/kg)	PERCENT FAT (%)	TRUNK FLEXION	GRIP STRENGTH	1 MIN. SITUPS
Excellent	1800	4.2	35	8	23	70	50
	1700	3.9	51	10	22	66	48
Good	1600	3.7	48	12	21	62	46
	1500	3.4	45	14	20	58	44
Average	1400	3.2	42	16	18	54	42
	1300	3.0	39	18	16	50	40
	1200	2.8	36	20	14	46	38
Fair	1100	2.5	33	22	13	42	36
	1000	2.3	30	24	12	38	34
Poor	900	2.1	27	26	11	34	32
	800	1.9	25	28	10	30	30

*Adapted from Myers, C., L. Golding, W. Sinning. The Y's Way to Physical Fitness, Rodale Press, Inc., p. 56, 1973.