MULTIPLE DISCRIMINANT ANALYSIS: THE USE OF SELECTED PHYSIOLOGICAL VARIABLES IN THE CLASSIFICATION OF FACULTY FITNESS LEVELS

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CHAPTER I

INTRODUCTION

Statistics on population trends for the United States indicate that this country is rapidly becoming a nation of older people. The absolute number, as well as the proportion of the older population segments, is increasing rapidly. Gorman and Brown (1986) reported that more than 25 million Americans are over 65 with an average life expectancy of 75 years. They stated that for the first time in the history of this country, the number of people over 65 is greater than those under 25. An inevitable consequence of these statistics is that there is an increasing need for scientific investigators to study the entire body of knowledge regarding the physiological changes that occur as a function of the aging process.

A major problem faced by scientists in attempting to understand the effects of the aging process on human performance is evaluation. Firstly, it is extremely difficult to separate the effects of aging per se from those of concomitant disease processes that become more numerous as age progresses. Skinner et. al. (1982, p. 409) stated, "the effects of aging and of cardiovascular diseases on exercise capacity are similar." In addition, environmental factors and generic influence cannot be underestimated. Wessel and VanHuss (1969) have shown that losses in physiological variables important to human performance resulting from age were more highly related to the decreased habital activity level than they were to age itself.

Secondly, the sedentary nature of adult life in the United States makes it very difficult to find old populations for comparisons with young populations at similar activity levels. Thirdly, very little work has been done on longitudinal studies of the same population over a period of time. Skinner et. al. (1982) have recommended the need for more longitudinal and fewer cross-sectional studies on the relationships among exercise, training and the aging process.

Background for Study

The data used for this study were collected as part of a ten-year (1973-82) longitudinal study on several physiological variables related to physical fitness, initiated under the direction of Dr. A.B. Harrison at the Oklahoma State University. At the start of the study, 20 of the 90 male faculty (mean age 43) who volunteered were non-exercisers. The subjects were tested each year on the same variables and their exercise was quantified. Over the years many of the non-exercisers decided to include exercise in their lifestyle.

In 1973 Oldham tested the group (N=85) and found that they were healthier and more fit than average, but there was no relationship between age and fitness levels at that time. However, he did find a strong relationship between activity level and several fitness variables, especially maximal oxygen consumption (VO2max). Mean Vo2max was reported as 39.5 ml/kg/min.

Thomas (1974) retested 65 ofthe original subjects and concluded that increased aerobic points resulted in a lower resting pulse rate. The mean VO2max was 37.0 ml/kg/min.

In 1982 Harrison concluded that the results of the ten-year study (N=65) showed that maximal oxygen consumption could be maintained as an individual aged through using a program of regular aerobic exercise.

Campbell (1987) reassessed the participants (N=51) of the Harrison study and concluded that declines in VO2max observed with age can be forestalled, at least to the age of approximately 62 years, by activity which accumulates 30 or more aerobic points per week. Using univariate techniques in the analysis of her data, Campbell found significant high relationbships between VO2max and percent grade completed on the treadmill as predicted from Cooper's data. Significant differences between age groups on height, weight, vital capacity, VO2max and percent grade were shown. Significant differences were also shown between activity groups only on percent grade and VO2max. However, there was no interaction effect of age and activity group.

Significance of Study

The measurement and analysis of multiple dependent variables is a common practice in current research on exercise and sport. In a content analysis of the 1980 issues of journals representing subdisciplines most closely identified with the study of sport and physical activity (Journal of Motor Behavior, Journal of Sport Psychology, Medicine and Science in Sports, and Research Quarterly for Exercise and Sport), Schutz et. al. (1983) found that of 188 empirically-based articles, approximately 70% used more than one dependent variable. However, despite the extensive use of multiple measures, appropriate data analysis utilizing multivariate statistical techniques are still relatively uncommon. This is regrettable and surprising, especially in the light of the facts that (a) multivariate statistics were developed in the 1930's, (b) extensive literature on multivariate statistics exists in both texts and journals, and (c) adequate computer software is now readily available.

Multivariate data requires analysis by multivariate statistical techniques unless there exists a strong research logic for treating the variables independently. Failure to do so will result in large inflations in type I errors as well as loss of valuable information regarding important interrelationships among the independent variables and between the independent variables and the dependent variables. It seems pertinent then that multivariate techniques be used for appropriate data unless these techniques are inappropriate due to low subject-to-variable ratio, failure of the data to meet necessary multivariate assumptions, or lack of an adequately developed multivariate technique for a specific situation.

Hence, the proposed study is an attempt to identify if the Harrison data base is appropriate for the use of multivariate techniques, and if it is found to be appropriate, an attempt be made in the use of the appropriate multivariate techniques to maximize the information pertaining to the six selected variables in relation to activity levels.

Statement of the Problem

The data used for this study were collected as part of a ten-year longitudinal study of faculty members (N=85) on several physiological variables related to physical fitness, initiated in 1972 under the direction of Dr. A.B. Harrison at the Oklahoma State University. The subjects were tested each year on the same variables and their exercise activity quantified in aerobic points. Over the years, many of the non-exercisers decided to include exercise in their lifestyle.

More specifically, the six variables selected for this study are the subjects' (N=65) age, percent body fat, maximum breathing capacity (MBC), forced expiratory volume (FEV1), lying systolic blood pressure and diastolic blood pressure. The measurements for 1972-73 (first year of longitudinal study), 1977 (fifth year), and 1982 (tenth year) on the above six variables were included in this study. In addition, the self-reported aerobic points earned per week were used to differentiate the subjects into the three activity level groups (low, medium, high).

The purpose of this study was to use multiple discriminant analysis (MDA) to derive the linear combination of the six selected physiological variables (as independent variables) that would discriminate best between low, medium, and high activity levels (as the dependent variable). The main focus of the study was to determine whether or not a statistically significant function could be derived to separate the three activity levels, and to determine which of the independent variables contributed most in discriminating among the three activity groups.

Subproblems for the Study

A secondary purpose of the study was to examine the group means for the six selected physiological variables to profile the differences in the three activity groups. A final subproblem was to compare the differential influences, if any, of the six selected physiological variables on activity level of the subjects for the initial year (1972-73), the fifth year (1977), and the tenth year (1980) in the study.

Research Questions

1. To what extent can group classification, based on activity level, be predicted from the combination of the six selected physiological variables in the study ?

2. Can a statistically significant function be derived to separate low, medium and high activity groups ?

3. Which of the six selected physiological variables contribute most in discriminating between the three groups ?

4. Which of the six selected physiological variables have any differential influences on the activity level of the subjects for the initial year (1972), the fifth year (1977), and the tenth year (1982) ?

Delimitations

a) The subjects were all male university faculty members in age from 38 to 68 years.

b) All subjects had been in the ten-year study since the initial phase beginning 1972-73.

c) The testing of the subjects were carried out in the exercise physiology laboratory at the Oklahoma State University.

Limitations

a) The subjects were all volunteers.

b) There was no attempt to control diet, sleep, and other personal habits of the subjects.

c) the subjects' exercise programs were not supervised.

Assumptions

a) It was assumed that subjects were motivated to give their best effort on all the tests.

b) It was assumed that testing procedures remained reliable throughout the length of the testing sessions.

c) It was assumed that subjects recorded aerobic points correctly or recalled physical activity to their best knowledge.

Definition of Terms

Aerobic points - a system of quantifying aerobic activity by assigning points according to predicted energy expenditure of the activity.

Diastolic blood pressure - provides an indication of peripherical resistance or of the ease with which blood flows from the arterioles into the capillaries.

Centroid - the mean value for the discriminant Z-scores for a particular category or group. The three-group discriminant analysis has three centroids, one for each group.

Cutting score - the criterion (score) against which each individual's discriminant score is judged to determine into which group the individual should be classified.

Discriminant analysis - the appropriate statistical technique when the dependent variable is categorical and the independent variables are metric.

Discriminant loadings - referred to by some as structure correlations; they measure the simple linear correlation between the independent variables and the discriminant functions.

Discriminant weight - referred to by some as discriminant coefficient. Its size is determined by the variance structure of the original variables.

Forced expiratory volume (FEV1) - the volume of the vital capacity that can be forcibly expired in one second after a maximal inspiration. This measurement provides an indication of expiratory power and overall resistance to air movement in the lungs.

Linear combination - also referred to as linear composites, linear compounds, and discriminant variates: they represent the weighted sum of two or more variables.

Maximal breathing capacity (MBC) - the volume of air that can be rapidly and deeply breathed for 15 seconds. This is then extrapolated to the volume that would have been breathed had the subject continued for a minute. This test is an indicator of obstructive lung disease.

Maximum oxygen consumption (VO2max) - the point at which the oxygen consumption plateaus and shows no further increases with an additional workload. This value is assumed to represent a person's capacity for aerobic resynthesis of ATP and is also termed aerobic capacity or maximal aerobic power. This is the definitive criterion for the termination of graded exercise test and is normally used as the criterion of functional capacity.

Systolic blood pressure - indicates the strain against the arterial walls during ventricular contraction thereby providing an estimate of the work of the heart.

Vital capacity - the maximal volume of air that can be expired following a maximal inspiration.

CHAPTER II

REVIEW OF RELATED LITERATURE

The decline in physical performance with age certainly deserves a great deal more emphasis by scientific investigators than it has been accorded in the past. Indeed the entire body of knowledge regarding loss of function with increasing age must be viewed with caution since in very few cases has the effect of habitual physical activity and risk factors relating to coronary heart disease (CHD) been controlled or ruled out.

Studies have shown that regular physical activity can promote favorable changes in work capacity, blood pressure, body composition and blood lipids (Holloszy et al., 1964). Cooper et al. (1976) documented a significant relationship between measured levels of cardiorespiratory fitness and CHD risk factors and suggested that those individuals with higher levels of fitness were at a lower risk for the premature development of CHD.

Morris et al. (1953) found that physically more active London bus conductors had a 30% lesser occurrence of manifestations of CHD and 50% fewer myocardial infarctions than the bus drivers. Similar studies of railroad yard workers (Taylor et al., (1962), postal carriers and clerks (Kahn, 1963), and longshoremen (Paffenbarger et al., 1970) indicated that men in sedentary occupations were more likely to develop CHD than those whose jobs required moderate to heavy physical activity. After following a group of longshoremen for 22 years, Paffenbarger and Hale (1975) discovered that the age-adjusted coronary death rate for high activity workers was significantly less than that for medium and low activity workers.

Grimby et al. (1966) compared well-trained cross country runners and skiers (age 45-55 years) to their younger counterparts and concluded that training in youth gave rise to a widening of the maximal a-VO2 difference and an increase in stroke volume that persisted into middle age. Pollock, Miller and Wilmore (1974) investigated a group of Master's runners (N=25) of ages 40-75 years and discovered that although maximal performance and oxygen intake decreased with age, a dramatic reduction did not occur until after age 60.

Morris et al. (1973) found hat men who spent their leisure time engaged in vigorous exercise had one-third the risk of developing CHD than those who did not. Paffenbarger et al. (1978) discovered that the risk of first heart attack was greater in men whose energy expenditure was less than approximately 2000 kcal per week. In a more recent study

Paffenbarger et al. (1986) found that subjects (n=16,936; ages 35-74 years) who expended more than an estimated 2000 kilocalories per week had death rates 25 to 33% lower than those whose caloric expenditure was less than 2000 kilocalories per week. They also discovered that there was no additional benefits at above 3500 kilocalories per week suggesting that physical activity, not necessarily intense physical training, might be the modality to a reduction of heart disease mortality.

Aging and Endurance Running

Despite the public concept that sport success is terminated shortly after one leaves college, the distance runner has demonstrated that performance can be improved well into the third decade of life. Some early evidence showed that both male and female endurance performers obtain their greatest success between the ages of 25 to 35 years of age. The average age for the competitors (1964 Olympic Games) in the 5000 meters, 1000 meters and the marathon races were 27.0, 27.7, and 28.3 years respectively (Hirata, 1966). Nason (1966) reported that the average age of all the Boston Marathon champions from 1897 to 1965 was 27.1 years with a range from 18 to 42 years.

Despite the degenerative influence of aging, many runners continue to compete successfully in long races until late in life. Clarence DeMar won his seventh Boston Marathon at the age of 42 years, placed seventh at the age of 50, and finished 78th in a field of 153 runners at the age of 65 (Nason, 1966; Dill, 1965). The current international emphasis on endurance has produced a considerable number of men older than 40 who have completed the marathon in less than 2 hours and 36 minutes at speeds averaging better than a 6 minute-mile.

More recent observations of trained endurance runners over the age of 60 have revealed exceptionally high VO2 values. Pollock et al. (1974) have reported a value of 61.1 ml/kg/min for a 60-year-old runner who had performed a 2 hour 51.7 minute marathon. The highest VO2max values reported for a man over age 70 was that of 41.3 ml/kg/min for a 72-year-old distance runner (Wilmore et. al., 1974). Considering the aging influence, it is apparent that endurance training strongly counteracts the aging effects of aging on cardiorespiratory endurance as measured by VO2max.

Regardless of variations in structure, the successful distance runner is characterized by a low body fat content (Costill, 1967). Skinfold estimates of body fat of distance runners at the 1968 U.S. Olympic marathon trials averaged 7.5% of total body weight. This is roughly 9% less than normally active men of similar age (Costill et. al., 1970).

A runner's vital capacity, the maximal volume of gas that can be expelled from the lungs, by forced effort following a maximal inspiration, can be significantly enlarged with years of training (Bock, 1963). One study observed vital capacities (BTPS) of approximately 5.71 liters for 17 cross-country runners (Arstila & Koivikko, 1966). The mean vital capacity of average, untrained men of the same age is 4.8 liters (Comroe et. al., 1963).

Maximum breathing capacity (MBC) is the maximum volume of air that can be breathed per minute. While a normal male is said to have an MBC of from 125 to 170 liters per minute, a group of 10 college cross-country runners had a mean MBC of 207.5 liters per minute (Bowers & Costill, 1967). During exhaustive running, highly trained distance runners have been able to breath over 120 liters per minute for more than 20 minutes (Costill, 1970). Among untrained men such a large minute volume is normally attained only during the final minutes of exercise, and can be maintained for only a very short period.

Under very controlled conditions, resting and basal heart rates have been found to correlate quite highly (r=-0.61 and 0.65 respectively) with cross-country running performance (Costill, 1967). This finding seems to explain bradycardia among athletes trained for endurance competition. Since the athlete can deliver the same cardiac output at a lower heart rate during exercise, this permits a greater period of diastole (heart rest). Hence, cross-country runners have been reported to have normal systolic blood pressure (120-122 mm/Kg) and low diastolic values (50-63 mm/Hg) (Costill, 1967).

Aging and Physical Work Capacity

Many studies have shown that there is a gradual decline in VO2max with age for adults of both sexes. For men, the maximal values were found at mean age 17.4 years, and they declined to less than half those values at mean age 75. For women, the maximal values were found in the age group 20-29, and they fell off by 29% in the age group 50-65 (DeVries, 1966).

Dehn and Bruce (1972) suggested that the rate of decline for men may be slower in those who are physically active. Similar findings were reported by Drinkwater et. al. (1975) for women. Kasch and Wallace (1976) monitored the progress of 16 middle aged men (mean age 44.6 at the start of study) who were actively involved in a supervised endurance exercise program for a period of 10 years, and reported that VO2max as measured on the treadmill had not declined, maximal pulmonary ventilation increased, and there was no gain in body weight during the course of the study. They concluded that the usual 9-15% decline in VO2max and 10% gain in body weight from ages 45 to 55 could be forestalled by regular endurance exercise.

A ten-year longitudinal study by Harrison (1984) also showed VO2max could be maintained for subjects (N=65; mean age 43 at initial year of study) who had performed adequate amounts of aerobic type activity as determined by aerobic points earned per week. These subjects were not on a supervised exercise program and were self-motivated by their desire to improve their health and fitness. Hodgson and Buskirk (1977) have summarized the data from many cross-sectional studies which suggests that active athletic subjects start at higher VO2max values and at age 60 are still at or above the level of the sedentary 20 year olds, although the rate of decline is similar.

In other studies, significant improvements in the oxygen transport system in a group of 15 sedentary middle aged men (mean age 47) was found after two years of training, three days a week of 60 minutes duration (Kasch et. al., 1973); VO2max improved by 30% in a small sample (N=11) of elderly men and women (mean age 63) after a year of training (Seals at. al.,1984); and VO2max increased by 12% for 88 elderly males (mean age 62.9) following a year of walk-jog program performed three times a week (Thomas et. al.,1985).

DeVries (1970) reported significant improvement in the oxygen transport capacity of 112 older men (mean age 70) after a 6-week training program. Minute ventilation and oxygen pulse at heart rate 145 improved by 35.2% and 29.4% respectively and vital capacity improved by 19.6%. Significant improvements were obtained in percent body fat and both systolic and diastolic blood pressure. He concluded that the trainability of older men with respect to physical work capacity is probably greater than had been suspected and not dependent upon having trained vigorously in youth.

However, a few studies have shown only slight or no increases in VO2max in older individuals with training (Benestad, 1965; Niinimaa and Shephard, 1978), but the overwhelming evidence is that gains up to 42% in the elderly has been reported depending upon the initial level of fitness, length of training program, and intensity of the exercise (Barry et al., 1966; Ehsani et al., 1982; Pollock et al., 1976; Seals et al.,1984; Sidney and Shephard, 1978; Suominen et al., 1977; Tzankoff et al.,1972).

Aging and Percent Body Fat

It is well documented in the literature that it is typical for aging humans to increase their weight. Brozek (1952) reported a mean increase of approximately 27 pounds of fat while the fat-free body weight has actually decreased from age 20 to 55, concluding that in order to maintain at a constant proportion of body fat as one ages, weight must not only be maintained at a constant level but it must be decreased.

Pollock et al. (1978) reported that the average individual over 25 years of age gains about one pound of added weight per year. They also stated that at the same time bone and muscle mass decreased by approximately 0.25 to 0.50 pound each year. Shephard (1978) reported that weight increased up to age 50 when it will progressively declined accompanied by an increase in body fat and decrease in lean body mass. The decline in lean body mass that occurs with increasing age has been reported by many investigators (McArdle et al., 1986; Shephard, 1978; Storer et al., 1985).

McArdie et al. (1986, p. 567) explained that "higher relative fat values could be in part due to the fact that aging causes the skeleton to become demineralized and porous, thereby reducing the body density because of the decrease in bone density." It has also been shown in many studies that increases in body fat with age can be reduced significantly in older men and women who maintain active lifestyles (Pollock et al., 1974; Vaccaro et al., 1984; Wilmore et al., 1974).

It is conceivable from the above mentioned research findings that the loss in fat-free weight may represents disuse atrophy of muscle tissue and, if vigorous exercise is maintained, does not have to be a necessary component of the aging process.

Aging and Pulmonary Function

There are two tissues that offer elastic resistance to breathing, the lung tissue itself and the wall of the thoracic cage. During inspiration, the muscles must work against this elastic resistance, which then aids in the expiration phase through elastic recoil. This relationship between force required (elastic force) per unit stretch of the thorax is called compliance, and it may be thought of as the elastic resistance to breathing. Turner et al. (1968) have suggested that lung compliance increases with age, but the thoracic wall compliance decreases with the aging process (Mittman et al., 1965; Rizzato and Marazzini, 1970; Turner et al., (1968). Turner et al. (1968) also found that the older individual may do as much as 20% more elastic work at a given level of ventilation than the young, with most of the additional effort performed in moving the chest wall.

It has been firmly established that vital capacity declines with age (Norris et al., 1956; Morris, Shock, & Falzone, 1962; Pemberton & Flanagan, 1956; Robinson, 1938); and there appears to be no strong evidence for any change in total lung capacity, and consequently residual volume increases with age (Norris et al., 1956). However vital capacity, forced expiratory volume, maximal ventilation and peak expiratory flow rate have been found to decrease with age (Clarke, 1977; Shephard, 1878).

Aging and Blood Pressure

The importance of blood pressure as the driving force for the circulatory system and hypertension (higher than normal levels of blood pressure) as a determinant of the hazard and incidence of CHD has been emphasized in research literature.

The tendency for resting blood pressure to increase with age has been reported (Astrand, 1968; Piscopo, 1985; Rodeheffer et al., 1984; Shephard, 1978; Skinner et al.,1982), but with wide differences among populations (Piscopo, 1985). Blood pressure also increases under submaximal and maximal conditions and even more so with age (Julius et al., 1967; Skinner et al., 1982). Smith and Serfass (1981) noted that the increased blood pressure was due to increased resistance to blood flow with age. They suggested that it could be related to the stiffening of the vessels and/or fatty deposits on the walls of the vessels.

Barry et al. (1966) reported significant increases in post exercise systolic blood pressure and blood lactate concentration in older subjects (mean age 72) after three months of rhythmic endurance training on a stationary bicycle ergometer, and DeVries (1970) found significant improvements in both systolic and diastolic blood pressure after a 6-week training program. Other studies have been shown that regular physical activity can promote favorable changes in blood pressure (Holloszy et al., 1964), and a significant relationship between measured levels of cardiorespiratory fitness and diastolic blood pressure has been documented (Cooper et al., 1976).

Among older individuals with known coronary risk factors, studies have indicated that endurance training programs have reduced systolic and diastolic blood pressure and decreased serum triglycerides (Bonanno and Lies, 1974; Boyer and Kasch, 1970; Holloszy et al., 1964). Ehsani and others (1982) studied the effects of intense and prolonged exercise training on the heart using echocardiography on a small group (N=8) of middle aged men (mean age 52) with coronary artery disease, and reported that systolic pressure at a given work load was significantly lowered after training. They concluded that prolonged and vigorous exercise training in selected patients with coronary disease could elicit cardiac adaptations.

Summary

All the effects of physical conditioning on losses in functional capacities caused by aging described in this literature review can only be said to accompany the aging process. It must be emphazised that causal relationships have not been established. Changes in these various functional capacities may result from the combination of at least three factors: (1) true aging phenomena, (2) unrecognized disease processes whose incidence and severity increase with age, and (3) disuse phenomena or the increasing sedentary nature of one's lifestyle as one grows older.

Skinner (1970) summarized the subject by stating that the present evidence suggested that cardiac or respiratory systems were not responsible for the decline in the capacity for physical work with age. He suggested that limitation should be sought either in the central nervous system or in the peripheral tissues. Smith and Serfass (1981) reported that current research suggests that 50% of the decline frequently attributed to physiological aging is, in reality, disuse atrophy resulting from an inactive lifestyle in today's affluent society.

All the data discussed so far seem to agree that the older human organism is trainable and that the capacity for improvement percentage-wise is probably not greatly different from that of the young. However, the capacity for maximal achievement is severely compromised since the older subject normally starts from a lower level. Clearly aging, training, physical activity, and the effects of CHD interact in a complicated manner to influence the quality and quantity of life.

CHAPTER III

METHODS AND PROCEDURES

Background of Data Base Used For Study

The data used for this study were collected as part of ten-year (1973-82) longitudinal study on several physiological variables related to physical fitness, initiated under the direction of Dr. A.B. Harrison at the Oklahoma State University. At the start of the study, 20 of the 90 male faculty and administrators (mean age 43) who volunteered were non-exercisers. The subjects were tested each year on the same variables and their exercise quantified. Over the years many of the non-exercisers decided to include exercise in their lifestyle.

More specifically, the six variables selected for this study are the subjects' (N=65) age, percent body fat, maximum breathing capacity (MBC), forced expiratory volume (FEV1), lying systolic pressure, and diastolic blood pressure. The measurements for 1972-73 (first year of longitudinal study), 1977 (fifth year), and 1982 (tenth year) on the above six variables were included in this study. In addition, the self-reported aerobic points earned per week were used to differentiate the subjects into the three activity level groups (low, moderate, and high).

Selection of Subjects

The subjects were 65 male faculty and administrators at Oklahoma State University with varied fitness levels and exercise habits. They had been participants in the Harrison longitudinal study since the initial phase of testing during 1972-73. For the purpose of this study, the initial year of testing will be referred to as 1973 with the fifth year (1977) and the tenth year (1982). The mean age of the subjects at the start of the study was 43 years. The subjects were all volunteers and to be included in this study they must have been tested in the initial year, in the fifth year, and in the tenth year.

Personal Data Collected

A complete medical history was taken for each subject. This included family history of coronary heart disease and a risk appraisal of the subject. Any condition that would contraindicate participation in an exercise tolerance test was included in this information. Any medication that could affect exercise response and questions on personal health habits, lifestyle, and exercise activity were also included.

Analysis of the data required that the subjects be grouped by physical activity level. Physical activity level was determined by the amount of aerobic points earned per week, and these points were recorded as reported for those subjects who had kept a record. For those who did not keep a record of aerobic points, an inquiry as to their physical activity and exercise habits were made. Points were assigned to activity based on the subjects' response to the questions utilizing the aerobic point-value system described by Cooper (Cooper, 1970).

The subjects were reminded of all procedures, and any risks associated with the testing protocols were explained. An informed consent was signed as required by Oklahoma State University and the Health and Fitness Center. The written consent confirmed that the subjects understood the procedures, made aware of risks involved, and agreed to participate in the study.

Administration of the Test

Subjects were tested on all variables at one testing session, and all testing took place in the Health and Fitness Center laboratory in the School of HPELS at Oklahoma State University. The subjects came properly dressed for the tests.

Body Composition

Height and weight were measured on a Detecto scale.

Three skinfold sites (triceps, abdomen, and chest) were measured using the Lange skinfold calipers and recorded to the nearest millimeter, and percent body fat was determined using the Best Nomogram method.

Forced Expiratory Volume (FEV1)

A Collins 9-liter respirometer was used to determine forced expiratory volume (FEV1) for one second. The subject was seated and breathed through a mouth piece which was connected to the respirometer by a valve system. The speed of the recording drum was set at 32 mm/min. Prior to beginning the test, the subject was given directions as to how to perform the test and a nose clip was placed on the subject.

Maximal Breathing Capacity (MBC)

Maximal Breathing Capacity (MBC) was measured on a 100-liter Collins Tissot tank. The subject was in a standing position and a nose clip was attached to the subject prior to taking the test. The subject was instructed to breathe forcefully and quickly into the tank by way of a one-way breathing valve attached to a rubber hose connected to the tank. The subject was encouraged to adjust his breathing rate and depth so as to force as much air as possible into the tank for 15 seconds.

The volume of air was obtained by calculating figuring the difference between the initial reading and the final reading on the kymograph drum and multiplying the volume by 4 to obtain liters per minute. The score so derived was multiplied by a correction factor of 1.332 for the Tissot tank and then further corrected to BTPS to obtain the MBC score.

Blood Pressure Measurements

Blood pressure was taken with the subject in the lying down position using a mercury sphygmomanometer. The first kortokoff sound was recorded as the systolic pressure. The fourth kortokoff sound or the disappearance of sound was recorded as the diastolic pressure.

Analysis of Data

The subjects were grouped by activity level for purposes of statistical analysis. The determination of activity level was made on the basis of an average of points earned per week. Subjects earning 10 or fewer points per week were classified in the low activity group. Those earning 11 to 29 points per week were placed in the moderate activity group and those with 30 or more in the high activity group.

Statistical analysis of all data was completed on the

IBM mainframe computer at the Oklahoma State University computer center using the System for Statistics (SYSTAT) package. Multiple Discriminant Analysis (MDA) was utilized to derive the linear combination of six independent variables (age, body percent fat, MBC, FEV1, systolic pressure, and diastolic pressure) that will discriminate best between the low, moderate, and high activity levels (dependent variable). This was achieved by the statistical decision rule of maximizing the between-group variance relative to the within-group variance. The result was a single composite discriminant score for each individual in the analysis. By averaging the discriminant scores of all the individuals within a particular activity group, the three centroids for the three groups were arrived at. The centroids indicated the most typical location of an individual from a particular group, and a comparison of the group centroids showed how far apart the groups were along the dimension being tested.

The test for the statistical significance of the discriminant function is a generalized measure of the distance between the group centroids. It was computed by comparing the distribution of the discriminant scores for the three groups. If the overlap in the distribution is small, the discriminant function separates the groups well. If the overlap is large, the function is a poor discriminator between the groups.

The application and interpretation of the discriminant analysis can be divided into three major stages: (1) derivation, (2) validation, and (3) interpretation. The derivation stage involved determining whether or not a statistically significant function could be derived to separate the three groups. The validation stage involved developing a classification matrix to evaluate further the predictive accuracy of the discriminant function, and the interpretation stage involved determining which of the six independent variables contributed the most to discriminate between the groups.

CHAPTER IV

RESULTS AND DISCUSSION

Data Used For Study

The data used for this study was collected as part of a ten-year (1973-82) longitudinal research on several physiological variables related to physical fitness, initiated under the direction of Dr. A.B. Harrison at the Oklahoma State University Health And Fitness Center. At the start of the study, 20 of the 90 male faculty and staff volunteers (mean age 43) were non-exercisers. The subjects were tested each year on the same variables and their exercise activity quantified in aerobic points. Their exercise programs were not monitored closely but over the years many of the non-exercisers felt the need to add exercise to their lifestyle.

Variables Selected For Study

More specifically, the six variables selected for this study are the subjects' (N=65) age, percent body fat, maximal breathing capacity (MBC), forced expiratory volume (FEV1), lying systolic blood pressure, and diastolic pressure. The measurements for 1973 (first year of longitudinal study), 1977 (fifth year), and 1982 (tenth year) on the above six variables were included in this study. In addition, aerobic points earned per week were used to differentiate the subjects into the three activity groups. Table I shows how the subjects were assigned to the groups.

TABLE I

ASSIGNMENT OF SUBJECTS TO GROUPS

Year	Activity Group	Average Aerobic Points (per week)	Number of Subjects
1972 (N=65)	Low	10 or less	23
	Moderate	11 to 29	29
	High	30 or more	13
1977 (N=65)	Low	10 or less	21
	Moderate	11 to 29	27
	High	30 or more	17
1982 (N=65)	Low	10 or less	19
	Moderate	11 to 29	16
	High	30 or more	30

Group Means For the Six Predictor Variables

The System for Statistics (SYSTAT) package was used to analyze the data. For each of the criterion groups, a mean score on each predictor variable was computed by averaging the scores of individuals in that particular group. In Table II there is a row of six means (one for each predictor variable) associated with each of the three criterion groups.

TABLE II

GROUP MEANS FOR THE SIX PREDICTOR VARIABLES

Year	Group	Syslyn	Diaslyn	Fev1	Mbc	Pctbf	Age
1973	1 (n=23)	123.3	76.9	95.7	153.2	19.7	43
	2 (n=29)	120.7	72.5	104.2	161.3	18.8	43
	3 (n=13)	121.8	73.4	93.0	158.3	17.4	39
1977	1 (n=21)	121.7	79.3	94.0	149.0	22.3	46
	2 (n=27)	122.3	77.7	105.8	148.2	19.7	48
	3 (n=17)	118.8	72.1	101.5	161.6	17.5	43
1982	1 (n=19)	129.0	81.4	104.6	139.0	22.0	53
	2 (n=16)	128.9	78.8	102.0	149.2	19.3	53
	3 (n=30)	124.8	77.1	107.9	163.7	18.4	47

Each row is thus referred to as the group's mean vector. Hence there are as many "elements" as there are predictor variables for each mean vector.

Wilks' Lamda Test of Significance

The first step in a multiple discriminant analysis involved determining whether the various predictor variables can, as a set, differentiate between the criterion groups. This was done by testing to see whether the mean vectors of the three criterion groups were different from one another. The null hypothesis was that the common elements in the mean vectors were identical to one another. This was the test of equal vectors and is conveniently measured by the Wilks' Lamda statistic (Wilks, 1932). Table III shows the rsults of the tests with its' equivalent F-tests (dfs 12, 114). The null hypothesis of identical mean vectors was not rejected

TABLE III

TEST OF EQUAL MEAN FACTORS

Year	Wilks' Lamda	Equivalent F-Statistic	df	(P)
1973	0.770	1.328	12, 114	0.213
1977	0.657	2.220	12, 114	0.015
1982	0.701	1.846	12, 114	0.049

for 1972 at the 0.05 level. This means that there was no difference between the criterion groups in terms of their mean scores on each of the predictor variables, and it would be counterproductive to develop prediction equations based upon these predictor variables for such prediction equations would not facilitate accurate predictions of group membership. However, the three-group discriminant analysis involving the six physiological variables yeilded highly significant F-ratios (equivalents of Wilks' Lamda tests) of 2,220 and 1.846 (df's 12 and 114; $p > 0.05$) for the 1977 and the 1982 data. The six predictor variables did discriminate among the three activity groups.

The Discriminant Function Prediction Equations

Since the multivariate tests were highly significant for only the 1977 and 1982 data, it was decided that the 1972 data be dropped from further discriminant analysis. The dependent variable canonical coefficients from the computer output for the 1977 and 1982 were utilized to produce discriminant equations. These coefficients (refer Table IV) had been standardized by the the within-group standard deviations so that magnitude comparison across variables with different scales can be made. Since these were not raw coefficients, there was no need for a constant. The scores produced by these coefficients had overall zero mean and unit standard deviation within groups.

As shown in Table IV, there were two possible prediction equations from the computer output for three-category discriminant analysis. The discriminant equations would have involved the same predictors but the numerical coefficients associated with the predictors would not be the same in each of the functions. If the coefficients in the two equations

TABLE IV

THREE-GROUP DISCRIMINANT EQUATIONS USING DEPENDENT VARIABLE CANONICAL COEFFICIENTS

Year	Function	Syslyn X1	Diaslyn X2	Fev1 X3	Mbc X4	Pctbf X5	Age X6
1977	1	0.163	-0.202	0.947	-0.355	-0.448	0.166
	2	-0.023	0.551	0.437	-0.543	0.373	0.295
1982	1	-0.101	0.180	0.093	-0.577	0.678	0.412
	2	0.698	-0.631	-0.363	0.254	-0.230	0.644

Note: $Z = W1X1 + W2X2 + W3X3 + W4X4 + W5X5 + W6X6$

where Z = discriminant score
W = canonical coefficient
X = independent variable

were equal to one another for each predictor variable, it would be redundant to have two equations.

Using the Various Discriminant Function Equations

Earlier the statistical significance of the discriminant functions had been shown. Unfortunately, the level of significance of these statistics is a very poor indication of the equation's ability to discriminate between groups. In order to determine the predictive ability of a discriminant function, a classification matrix as given in Table V was constructed with the help of the output from the computer. The entries under the column labeled "Actual Total" represent the number of individuals actually in each of the three groups and the entries on the diagonal of the matrix (under "Predicted Group") represent the number of individuals correctly assigned to their group by the discriminant function. Hence, for the 1977 data, the number of individuals actually in and correctly assigned were 12, 20, and 6 for actual groups 1, 2, & 3 respectively. The numbers off the diagonal represent the incorrect classification. Thus, the the percentage classification accuracy of the discriminant function was 57.1 % for actual group 1, 74.1 % for actual group 2, and 35.3 % for actual group 3. The overall classification accuracy (hit ratio) was 58.5 %.

TABLE V

CLASSIFICATION MATRIX FOR ACTIVITY LEVEL GROUPS

Actual Group	Actual Total	Predicted 1	2	Group 3	Maximum chance criterion
1977					
1 (Low)	21	12	7	2	21/65 = 32.3 %
2 (Medium)	27	3	20	4	27/65 = 41.5 %
3 (High)	17	4	7	6	17/65 = 26.2 %
Total	65	19	34	12	

Percent correctly classified (hit ratio) = 58.5 %
Proportional chance criteria = 34.5 %

Actual Group	Actual Total	Predicted 1	2	Group 3	Maximum chance criterion
1982					
1 (Low)	19	12	1	6	19/65 = 29.2 %
2 (Medium)	16	3	5	8	16/65 = 24.6 %
3 (High)	30	4	1	25	30/65 = 46.2 %
Total	65	19	7	39	

Percent correctly classified (hit ratio) = 64.6 %)
Proportional chance criteria = 35.9 %

Similarly, for the 1982 data, individuals correctly assigned to their groups were 12, 5, and 25 for actual groups 1, 2, and 3 respectively. The percentage classification accuracy of the discriminant function for actual groups 1, 2, and 3 were 63.2 %, 31.3 %, and 83.3 % respectively and the overall classification accuracy (hit ratio) was 64.6 %.

The maximum chance criterion is simply the highest probability of occurrence if one simply determined the chance classification based on the sample size of the largest group. Thus, the maximum chance criterion were 41.5 % and 46.2 % for the 1977 and 1983 data respectively.

The proportional chance criterion is calculated by summing the squares of the proportions in each group. Thus, the proportional chance criteria for the two years under study were 34.5 % and 35.9 % (refer Table V).

Since the maximum chance criterion is greater than the proportional chance criterion for both 1977 and 1983, the former is the criterion to be outperformed for both years when determining whether the discriminant functions are valid predictors. For the 1977 data, the hit ratio of 58.5 % exceeds the maximum chance criterion substantially (greater than 25 percent), so it can be concluded that the discriminant model is valid. Similarly, it can also be concluded that the discriminant model for 1983 is valid (hit ratio of 64.6 % far greater than maximum chance criterion of 46.2 %).

In summary, it should be noted that the question of classification accuracy is crucial. If the percentage of correct classifications is significantly larger than would be expected by chance, an attempt can be made to interpret the discriminant functions in the hope of developing group profiles. However, if the classification accuracy is no greater than can be expected by chance, whatever structural differences appear to exist merit little or no interpretation. Thus, from the above conclusions, the differences in score profiles obtained from this study could provide meaningful information for identifying group membership.

CHAPTER V

INTERPRETATION AND CONCLUSION

Since the discriminant functions had been found to be statistically significant and the classification was acceptable, it is appropriate to determine the relative importance of each independent variable in discriminating between the groups. A popular and accurate approach involves what is called stretching the vectors. A vector is merely a straight line drawn from the origin (center) of the graph to the coordinates of a particular variable vector (refer Table VI & Figure 1. The length of each vector is an indicator of the relative importance of each predictor variable in discriminating among the groups. From interpretation of the plots in Figure 1, function I is the primary source of differences between the low activity group 1 and the medium activity group 2 versus the high activity group 3. The directions of the vectors indicate that function I corresponds most closely to diaslyn (lying diastolic blood pressure), age, and MBC (maximal breathing capacity); and fairly closely to pctbf (percent body fat). Thus, the distinguishing characteristics of low activity subjects are that they have high scores in percent body fat and diastolic

TABLE VI

COORDINATES FOR STRETCHED VECTORS

Predicted Variable	Function	Discriminant Loading	Univariate F-Value	Appropriate Coordinate
1977				
Syslyn	1	-0.001	0.435	-0.0004
	2	0.267		0.1161
Diaslyn	1	-0.271	3.457	-0.9368
	2	0.683		2.3611
Fev1	1	0.751	4.824	3.6228
	2	0.102		0.4921
Mbc	1	0.050	1.228	0.0614
	2	-0.445		-0.5465
Pctbf	1	-0.512	3.967	-2.0311
	2	0.538		2.1342
Age	1	0.133	1.600	0.2128
	2	0.488		0.2128
1982				
Syslyn	1	0.263	0.954	0.2509
	2	0.348		0.3319
Diaslyn	1	0.387	1.711	0.6622
	2	-0.119		-0.2036
Fev1	1	-0.136	0.486	-0.0661
	2	-0.442		-0.2148
Mbc	1	-0.640	4.671	-2.9894
	2	-0.165		-0.7707
Pctbf	1	0.593	4.237	2.5125
	2	-0.434		-1.8389
Age	1	0.481	3.343	1.6080
	2	0.719		2.4036

blood pressure. Visual inspection of function I indicated that FEV1 (forced expiratory volume) is closely associated with it. Moreover, systolic blood pressure, age, and

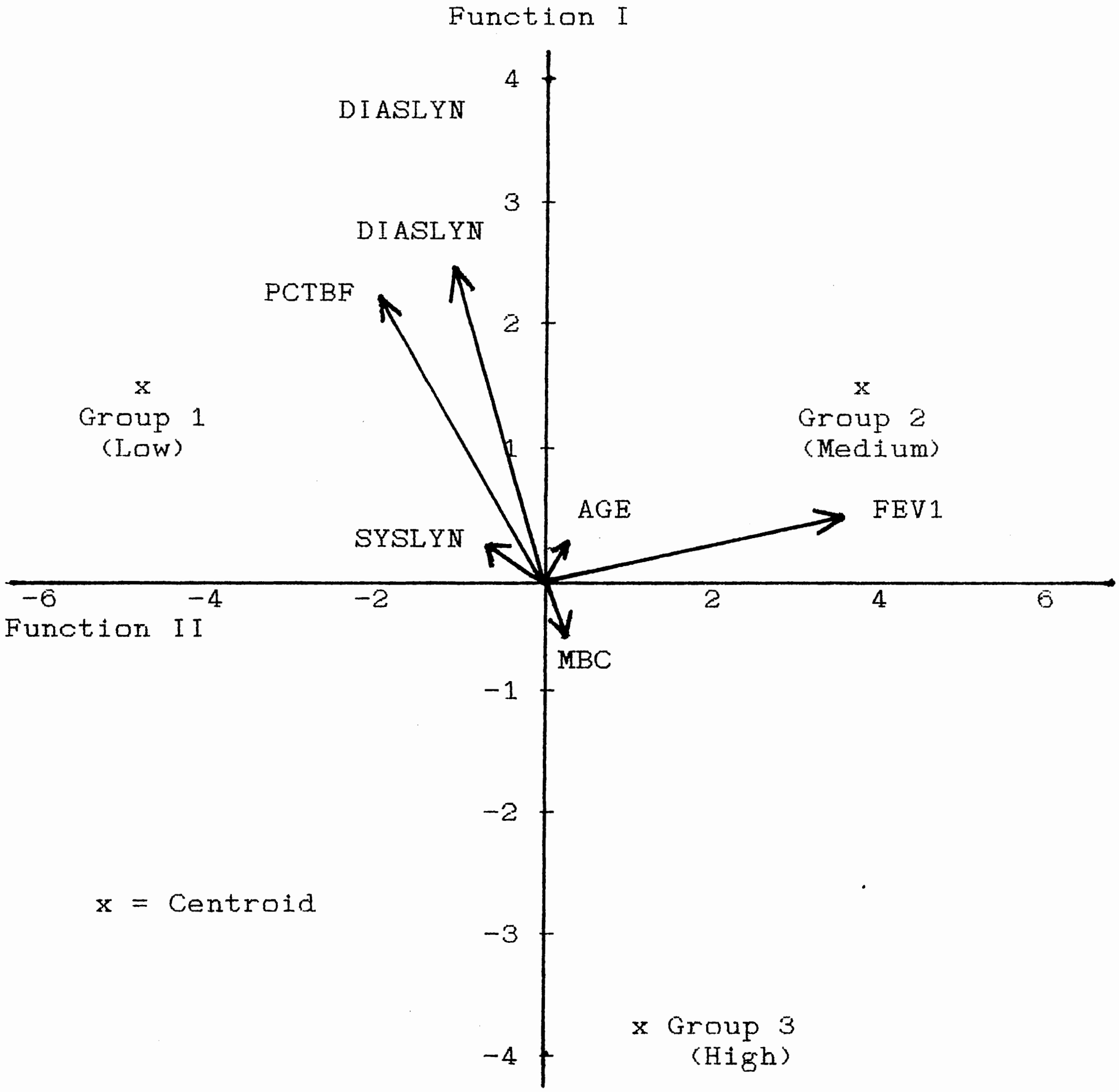

Figure 1. Plot of Stretched Attribute Vectors (1977)

maximal breathing capacity are not greatly influenced by the different activity levels of the subjects.

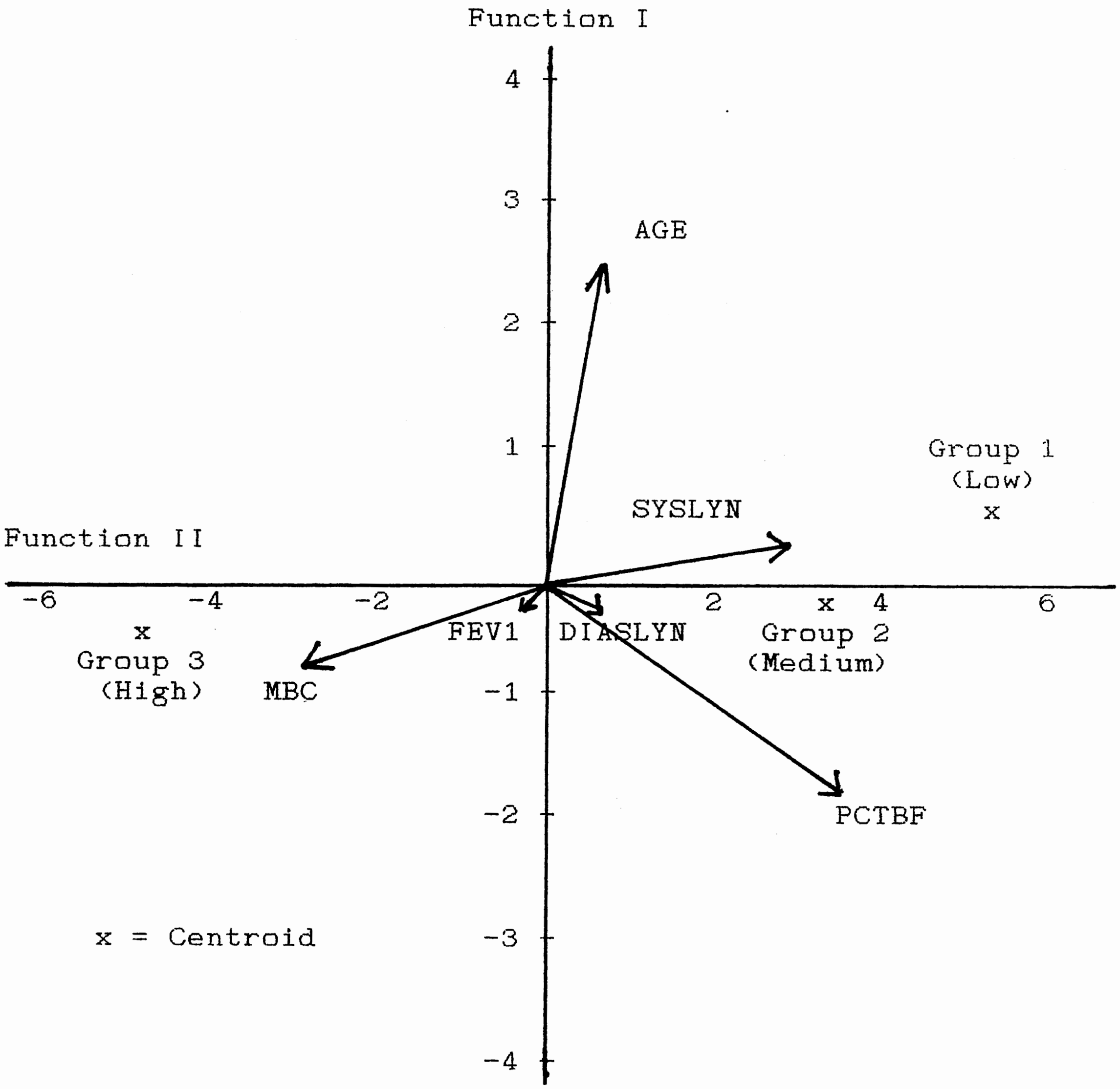

Figure 2. Plot of Stretched Attribute Vectors (1983)

Turning to figure 2, it is interesting to note that after a lapse of five years, function I is now the primary source of differences between the low activity group and the medium activity group as opposed to the second function. The directions of the vectors show that function I remains similarly related to age and systolic blood pressure. However, function II now corresponds more closely to diastolic pressure and maximal breathing capacity, and fairly to percent body fat. Visual inspection of the vectors also shows that the distinguishing characteristics of the low and high activity groups are they now have high scores in age and mbc respectively. However, systolic blood pressure, diastolic blood pressure, and fev1 are not greatly influenced by the three activity groups.

Conclusions

From the above results, it is probable that group classification, based on activity level, may be predicted from the combination of the six selected physiological variables used in this study. This means that in the future, subjects with similar background can be screened into the three different activity groups without having to resort to more time-consuming and laborous exercise testing. However, it is cautioned that the resulting discriminating functions derived from this study be extensively validated using more diversified subjects of similar age groups, be carried out before attempts be made to use them for field-screening of subjects.

Recommendations

1. The discriminating functions derived from this study need to be extensively validated using more diversified subjects of similar age groups.

2. The relative small sample size (n=65) used to derive the discriminant functions in this study is not completely satisfactory. More studies using at least 100 subjects or more are needed.

3. More longitudinal studies utilizing multivariate methods are needed in order to understand further the complex interaction of the true aging phenomenon, the unknown disease processes, and the disuse atrophy.

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