

A COMPARISON STUDY OF THE
MAXIMUM AEROBIC CAPACITY OF CHILDREN
WITH AND WITHOUT INNOCENT HEART MURMURS

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ABSTRACT

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This study was designed to investigate the differences in maximum oxygen consumption (VO_2) in children with and without an innocent heart murmur. Data was collected on 15 children diagnosed with an innocent heart murmur and 15 children aged and sex matched to the murmur group as selected from a local elementary school. The testing utilized the Bruce treadmill protocol to help access maximum VO_2 , maximum HR and endurance time. The procedures included pre-test interviews, motivational techniques and a test criteria for the attainment of "true" maximum VO_2 . The results indicated normal responses to the maximum exercise testing with limited re-test evaluations necessary. There were no significant differences in weight, maximum HR and endurance time ($P > .05$). There was a significant difference ($P < .05$) in maximum VO_2 with the children diagnosed with an innocent murmur attaining a higher mean maximum VO_2 (54.68) than those of the paired control group (44.04). Conclusions support no cardiovascular impairment in children with innocent murmurs in their ability to perform high levels of work. This information is recommended to be used in the avoidance of restricting children with innocent heart murmurs from participating in physical activities and in the attainment of personal life insurance.

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DEDICATION

I would like to dedicate this thesis to my best friend, Terry J. Allen, whom by sharing a smile provided constant encouragement and support which enabled me to succeed in my graduate education.

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CHAPTER I

INTRODUCTION

Heart sounds and murmurs can be prime sources of essential information on the discovery and evaluation of many common diseases of the heart and blood vessels (Rushmer & Morgan, 1968). Congenital and valvular defects are generally discovered through auscultation of affected infants and children. Physicians can detect the lesions and/or obstructions by careful evaluation of the sounds and murmurs produced during the contraction and relaxation of the cardiac cycle. Further diagnostic procedures may include electrocardiography, X-rays, cardiac catheterization and echocardiograms.

An innocent heart murmur, often referred to as functional or incidental, has been identified as a sound produced by a normal functioning heart (Castle & Craige, 1960; Epstein, 1958). Luisida and his associates (1958) considered it impossible to separate innocent murmurs from organic murmurs. They maintained that the innocent murmur is in reality an organic murmur caused by either a rheumatic process or a mild bacterial lesion of the valve. The subject of the innocent versus the significant murmur remains a very important problem in cardiology and, if diagnosed carefully by a physician, these sounds are given no clinical significance because they are not believed to represent cardiac or systemic disease. Misdiagnosis of children with innocent murmurs contribute a significant percentage of patients referred to specialty clinics for cardiac evaluation. As a result of these evaluations, irreversible physician and

parental induced disability occurs. This disability may result in restriction from high exerting physical activities and athletic participation.

Moller (1977) stated that "innocent murmurs are a common problem present in half of all school age children" (P. 281). They have been shown to be more prevalent in children during "spurts" of growth and those approaching puberty (Fogel, 1960). A study by two cardiologists revealed that 60% of those infants studied had murmurs in the newborn period (Lessoff & Bridgen, 1957). A total of 96% of these subjects were diagnosed as having innocent murmurs, contrary to those associated with a congenital defect. A survey of 119 children, aged one to ten years old, revealed over 90% to have a common vibratory murmur (Appleyard & Joseph, 1976). These 119 patients had been referred to a pediatric cardiology clinic for examination of an abnormal heart sound. Although the incidence of innocent murmurs are high in children, they are found to disappear with age (Marienfield, et al. 1962).

Many physicians and physiologists refer to innocent heart murmurs as representative of a strong and normal functioning heart (Contratto, 1943; Moller, 1977; and Elston, 1978). The heart is a muscular structure which works through dynamic contraction to transport blood throughout the human body. A very physically active child requires a strong heart to help supply his/her energy demands. Innocent heart murmurs may be the result of the physical performance of a highly active myocardium and circulatory system (Van der Hoeven, 1973; Sabbath, et al. 1979).

Although literature reveals innocent murmurs conventional by pediatricians, many family physicians and parents will elicit caution when

permitting the child to participate in strenuous physical activity (Fogel, 1960; Scott, 1978). A common method of determining the ability of the heart to tolerate stress from physical activity is to administer a graded exercise test (Eliestad, 1969). This exercise test can be used to measure a child's maximum oxygen consumption (VO_2). A measurement of an individual's VO_2 provides valuable information about their maximal work power and the functional capacity of the oxygen transport system (Astrand, 1967). A comparison of the performance between children with and without innocent murmurs in a maximum oxygen consumption test has not been investigated. A conclusion about the level of physical fitness and maximal performance of children with innocent murmurs can be drawn by knowing their maximum oxygen uptake and how this measure compares to children without a murmur.

Purpose of Study

The purpose of the present study was to measure the maximum aerobic capacity of children with and without innocent heart murmurs. A measurement of their maximum oxygen consumption provided data on their cardiovascular system's efficiency and endurance during the stress of exercise. A statistical comparison was made between the two groups to determine significant differences in performance. This information could then provide a recommendation concerning the ability of a child with an innocent heart murmur to participate in physical activities that require high levels of aerobic power.

Need for the Study

An important part of a child's education is the teaching of concepts and skills for developing individual physical fitness. Physical fitness has been defined as "the ability to do work and to recover quickly and completely from doing this work" (Cumming, 1967, P. 868). The American Association for Health, Physical Education and Recreation (1969) has proposed that the achievement of optimum physical fitness during the formative years is fundamental to the maintenance of fitness throughout adulthood. The lack of physical exercise has been related to the development of coronary heart disease (Cumming, 1967; Gordon, 1971; and Paffenbarger, 1975). It is necessary to teach children proper behavior patterns that endorse life long fitness. Tillman (1971) has suggested that to avoid the danger of an inactive lifestyle being established in children, parents should make every effort to develop and encourage opportunities for participation in physical activity. Parents and teachers who are given the responsibility of providing opportunities for children with innocent murmurs often question their ability to perform high levels of physical activity. These questions and doubts lead parents, teachers and sometimes physicians to restrict the development of optimal physical fitness by curtailing the child's activity level.

A measurement of the maximum aerobic capacity, the best single measurement of physiological fitness, in children with innocent murmurs will provide data that will give sufficient evidence as to health dangers involved in the performance of high exerting physical activity.

The need for this study arises from not only the question of these murmurs restricting children from physical activity, but also other

psychological and social factors that may affect their lives. Unfortunately, many individuals are refused life insurance because mandatory physical examination reveals the presence of a heart murmur. In a conference held between representatives of various life insurance companies and physicians specializing in cardiac problems, expected mortality rates were classified and assigned to normal individuals and those with organic and functional murmurs. When compared to an expected mortality of 100% in normal people, those of organic origin had a mortality of 187%, but those listed as functional had less than the standard mortality of only 45% (Manning, 1977). Further questions and doubts as to the seriousness of innocent murmurs occurs when found to be present in high performance athletes (Davis, 1977). Research studies have shown physiological variations in the contractility of the heart (Van der Hoeven, 1973) and viscosity of the blood (Sabbath, et al. 1979) to be different in those children diagnosed with an innocent murmur.

Standard norms for maximum oxygen consumption VO_2 in children with or without innocent murmurs have not been developed. Maximum values measuring endurance time, heart rate and oxygen levels have been collected in large sample groups, but have not been statistically validated as normative values (Kramer, 1964; Klimt, 1976; and Cumming, 1978).

The lack of standardized norms in conjunction with the social implications for the child with an innocent murmur precipitates a need for a statistical comparison in the physical work capacity or maximum VO_2 with children having no diagnosed innocent heart murmur.

Delimitations

The following variables were carefully selected and controlled in the design of this project. The delimitations of this study were:

1. Experimental group subjects were 15 children aged 5 to 11 medically diagnosed with an innocent heart murmur from the Gundersen Clinic, Ltd., Skemp-Grandview Clinic and The Family Practice Center of La Crosse, Inc.
2. Control group subjects were 15 children age and sex matched to the experimental group.
3. All subjects lacked prior experience in treadmill testing or medical contraindication to stressful exercise.

Limitations

The external factors that were uncontrollable limitations of the study were:

1. The subjects motivation to perform maximum performance levels in the graded exercise test.
2. Individual differences in their physiological response to graded exercise tests.
3. Individual differences in maturation and growth levels.
4. Lack of control over the subjects' daily health, dietary and extracurricular activity patterns.

Assumptions

The following assumptions were made about the design and procedures of this study. They were:

1. All subjects reached their maximum oxygen consumption.

2. All subjects lacked prior testing experience on a treadmill.
3. All values were correctly recorded by the instrumentation and technician in charge.

Definitions of Terms

Aerobic; the use of oxygen in the production of energy during exercise.

Anaerobic; the absence of oxygen in the production of energy during exercise.

Auscultation; the act of hearing and interpreting the sounds produced by the heart.

Diastolic; the part of the cardiac cycle which represents relaxation of the muscle (especially of the ventricular) and dilatation during rapid filling of blood.

Electrocardiogram (EKG); a graphic tracing of the electric current produced by the excitation of the heart muscle. The EKG can be used to determine the physical condition of the contracting heart. It also provides a measurement of heart rate.

Innocent heart murmur; a benign sound not produced by any anatomical or diseased state of the heart.

Maximal exercise; the optimal level of physical work an individual can perform while exercising.

Maximum oxygen consumption (VO_2); the maximum amount of oxygen an individual can utilize per unit time. This represents the power or work capacity of the aerobic (oxygen) system. It is expressed in milliliters of oxygen per minute per kilogram body weight.

MET; a term characterizing resting metabolic rate. It is considered equal to an oxygen uptake of 3.5 milliliters per kilogram body weight per minute.

Phonocardiography; the graphic registration of the sounds produced by the action of the heart.

Pre-ejection time; a period in the cardiac cycle which represents a static contraction of the heart muscle prior to the ejection of blood. The heart has completed its filling phase and has closed its mitral and aortic valves. This time is used to indicate heart muscle contractility.

Respiratory exchange ratio (RER); this is the calculated ratio between the amount of CO₂ expired from the lungs and the amount of O₂ taken up.

Septal defect; an imperfection or absence of tissue within the dividing walls of the heart's cavities.

Stenosis; a narrowing or constriction of a canal.

Submaximal exercise; an exercise rate less than maximal, usually expressed as a percentage of maximal heart rate or oxygen uptake.

Systolic; the contractile or emptying phase of the cardiac cycle.

Viscosity; the resistance of the blood characterized by the flow of one layer over another.

CHAPTER II
REVIEW OF LITERATURE

Introduction

Research in the physiology of children has been conducted in an increasing number of laboratories and important progress in this field has been accomplished. Dynamic stress testing can and has been used to evaluate the pediatric patient. Investigations on the exercise physiology of children and their progressive physical work capacity has led to the development of tests and procedures in determining the fitness level of normal children and those with heart and lung disease (Godfrey, 1970). However, methods used for exercise testing in children must be suited to the child and to the purpose of the test. Motivational techniques in the form of play and competition is necessary to obtain the child's complete cooperation, especially in the pre-school years (Hermanse & Oseid, 1971; Jordan, 1978; Thoren, 1978).

Measurement of Maximal Oxygen Consumption

A universally accepted method of determining physical work capacity or maximum aerobic power is to measure the amount of oxygen an individual can take in, transport and utilize at the highest level of exercise intensity that can be achieved (Astrand, 1967). Measuring maximum oxygen consumption (VO_2) has been performed on children as young as four years old (Cumming et al. 1978) and has been determined as the best indicator of cardiovascular fitness (Astrand, 1967).

Research has shown treadmill exercise tests to yield a higher maximum VO_2 than bicycle ergometer tests (Glassford, et al. 1965). Performance on a treadmill test requires a greater muscle mass and increased oxygen supply to active tissues (Hermanson & Salton, 1969). A treadmill test offers conditions of exercise (walking and running) that belong to the daily physical activities of a child (Klimt, 1971).

Maximum Exercise Testing

Methods of testing children and adults have led to controversy in the usage of maximum or submaximum exercise intensity. Submaximum exercise testing in children has been based on heart rate response to a pre-determined workload. Moccilin, et al. (1971), developed the W_{170} method of determining physical work capacity and estimating maximum VO_2 . The purpose of developing this method was to set up an indirect technique in determining maximum VO_2 from a heart rate response (\bar{r}_{170}) at a pre-determined workload (Watts). The 19 children (13 to 14 years old) were tested indirectly by the W_{170} method and directly through computer analysis of expired gases. The results showed individual differences in heart rate response to the workload (Watts). Estimation of maximum VO_2 from regression values achieved in the W_{170} test and direct measurement methods showed lower values in the W_{170} test. A similar study (Hermansen & Oseid, 1971) tested the ability of the Astrand and Rhyning nomogram to estimate maximum VO_2 from heart rate at a submaximal workload. The 20 prepubertal boys studied showed 10-20% lower maximum VO_2 values in those estimated by the nomogram. Gutin and associates (1977) showed that in children, physical training reduced submaximal heart rate without affecting their maximum VO_2 , implying that maximum VO_2 and submaximal heart rates are to some

extent independent of each other. Although submaximal tests may be sufficient in comparing an individual's functional capacity pre and post medical treatment, it nonetheless does not allow for differences in a child's maximum heart rate on their overall response to exercise testing. With this information a more accurate exercise test would utilize a direct method (analysis of expired gases) when comparing the maximum VO_2 of children.

Protocols

Protocols used in testing children on treadmills have been developed to correspond with the age and physical capacity of the child being tested. Jordan (1978) has reviewed all possible implications of varying protocols. One method keeps the speed constant and raises the grade of the treadmill. This makes the child climb a tremendous hill in a fast walk, which tends to make the leg muscles extremely tired and often causes early termination of the test. Other protocols rely on speed and not inclination, which sometimes resulted in children becoming uncoordinated and thus hindering measurements. Cumming, et al. (1978), found the Bruce Protocol (Bruce, et al. 1973) (Appendix J) to be suitable for testing children with an exercise capacity as low as 5 METS. The Bruce protocol provides a quick increase in grade and speed, allowing the child to reach maximum intensity within 18 minutes. This protocol is suitable for children as young as four years and provides a slow speed in the first stage for a necessary warm-up.

Repeated measurement of maximum exercise tests in children have shown to be highly reproducible and reliable (Van Watershoot, et al. 1977; Cumming, et al. 1978; and Rozanski, et al. 1979).

Cumming, et al. (1978) and Rozanski, et al. (1979) both performed two separate maximal treadmill exercise tests according to the Bruce Protocol. Cumming, et al. (1978) performed a study to test the suitability of the Bruce Protocol in young children. A portion of his research included testing the reproducibility of results. Twenty normal school children aged 7 to 13 years performed the Bruce test on two occasions 3 to 10 days apart. The endurance times (13.9 ± 2.1 min for trial 1 and 13.7 ± 1.9 min for trial 2) gave a correlation co-efficient of 0.94. Rozanski, et al. (1979) performed two separate tests on 19 children (5 to 15 years old) with chronic ventricular arrhythmias. Their results found no statistically significant difference between the first and second exercise test in any child with regard to mean maximal heart rate achieved (192 ± 22 versus 196 ± 19 beats/min) or mean maximal systolic blood pressure (162 ± 32 versus 162 ± 26 mm Hg). Van Watershoot, et al. (1977) tested the reliability and reproducibility of maximal VO_2 measurements in children. The experimental procedures included a criteria to establish the presence of a "true" maximum VO_2 during an exercise test. This criteria was based on the presence of a plateau in VO_2 as work load is increased. Two test sessions were conducted on 66 ten year old ice hockey players. The protocol consisted of a continuous speed (4.1 mph) with a raise in grade every two minutes. A plateau was considered to have been reached if the oxygen uptake increased by only 2.1 ml/kg min or less over the last two workloads of the test. The results showed a correlation co-efficient of 0.74 in those children able to reach the criteria in both tests. In a test-retest comparison, the reproducibility of max VO_2 was high although the criteria was not always reached.

The researchers agreed that the values obtained are dependent on the motivation of the child to work to near exhaustion and on the skill of the technicians in the handling of young children.

Physiological Response to Exercise

Differences in the response to exercise between boys and girls have shown to be nonsignificant before the age of 12 (Astrand, 1960). Beyond the age of 12, improved physical performance is due to the maturity of the neuromuscular function, improved coordination and body size (Astrand, 1967; Thoren, 1978). Pre-pubescent boys and girls will vary slightly in their maximum heart rate or oxygen consumption levels during exercise. Small differences in maximum VO_2 in boys and girls of the same age may be due to maturation level and somatotype. Forbes (1964), using a whole body scintillation counter, suggested that the lean body mass to height ratio is similar both for boys and girls age 7 to 12 and slight differences in maturation will not affect physical performance before puberty.

Normative values on the hemodynamic response of children during exercise is not available, yet several investigators have provided individual research data on children's physiological response to exercise and training (Gilliam, 1971; Thoren, 1971; Cumming, 1967; Skinner, et al. 1971; Astrand, 1960). Values obtained during maximal exercise have shown to be consistent among the literature published. Heart rate response and maximal heart rates are high in young children (>195 beats/min) and slowly decrease with age (Thoren, 1978). Gilliam (1971) investigated the exercise response in children ages 6 to 13. Prior to initiating a physical training program, the children were brought to a volitional maximum exercise intensity. Gilliam found no significant

differences in the maximal heart rates of the different age groups or between the boys and girls studied.

Maximum VO_2 measures the amount of oxygen that can be utilized by the lungs and transported to the working muscles. At a high exercise intensity, an increase in workload may not be accompanied by an increase in VO_2 (Astrand, 1967). At this point the VO_2 values may plateau indicating a maximum oxygen uptake has been reached (Astrand, 1967). Reported values on a healthy child's aerobic capacity (max VO_2) ranges from 34 ml/kg/min to 60 ml/kg/min (Astrand, 1970; Klimt, 1971; Thoren, 1978; Cumming, 1967). These values are proportionally higher than those reported by the Committee on Exercise of the American Heart Association, which found maximum VO_2 as low as 38 ml/kg for men in the age group 20 to 29 years and 34 ml/kg/min for women of the same age in the United States (Thoren, 1978). The respiratory exchange ratio (RER) has also been used to indicate an individual has reached his/her maximum VO_2 . A normal progression of the RER is to increase slowly at the start of exercise, level off during submaximal work and continue to reach or exceed 1.0 (Thoren, 1978; Klimt, 1971; Skinner, 1971). Klimt (1971) tested 48 five year old children and measured the effect of treadmill exercise on oxygen consumption (VO_2), heart rate, pulmonary ventilation and respiratory exchange ratio (RER). At a submaximal workload of 4 km/hr a leveling off or "steady state" was reached. All parameters, including VO_2 had increased and became constant. After five minutes of recovery a second workload of 4 km/hr at a 15% grade showed a step increase in all variables. No "steady state" was reached and maximum values were measured. The RER decreased during the sub-

maximal workload then increased during the submaximal workload then increased during the following recovery time. This was due to higher intake of oxygen compared to air volume ventilated per minute. During maximal testing the RER initially dropped and then increased readily throughout the workload. Heart rates reached as high as 208 beats per minute. The girls tended to have the higher heart rates, whereas the boys measured nonsignificantly higher VO_2 .

Innocent Heart Murmurs and Exercise Testing

There has been a limited amount of data presented on children with innocent heart murmurs and their response to exercise. One of the most exclusive experiments conducted included testing children with innocent murmurs and establishing maximum endurance times using the Bruce Treadmill Protocol (Cumming, et al. 1978). In this study 327 children with innocent murmurs were given a maximal exercise test. Ages of these children ranged from four to fourteen years. Mean endurance times of both the boys and girls of different ages ranged from 9.5 to 14.1 minutes with mean maximal heart rates ranging from 193 to 206 beats per minute. All testing was conducted using various motivational techniques. The purpose of these tests were not to evaluate the child with a murmur, but to determine the value of the Bruce Protocol and to determine how endurance times correlated with direct measures of maximal oxygen uptake and weight to height ratios. Results indicated the ratio of weight to height (used to determine obesity) has a negative correlation to endurance times. The results also revealed negative correlations between the heart rates for stages 2 and 3 of the Bruce test and endurance times indicating those with slower heart rates during the submaximal portion of

the test had a longer endurance time. Unfortunately, no values were compared to children without murmurs nor was the correlation (0.85) between maximal oxygen uptake and endurance time taken from the innocent heart murmur sample. This correlation was conducted on 54 athletes 10 to 18 years old. The study did show the protocol and estimation of endurance times valuable in clinical testing.

Cumming (1978) later continued his research on children using the Bruce protocol (Bruce, et al. 1973), endurance testing and percentile ranks. The testing included obtaining maximal heart rates and endurance times in 830 children classified with mild, moderate and severe heart defects. These results were then compared using percentiles with the 327 children previously tested with an innocent heart murmur. A third sample group of 388 healthy children received the same maximal exercise test in their school. The overall age range for all sample groups was 4 to 20 years old. The study was conducted over a three year period using the same supervising technicians.

The results indicated that the children with moderate to severe heart defects (septal defects and stenosis) were unable to score above the 50th percentile of the children with innocent murmurs. A total of 21% of the children with heart defects scored below the 10th percentile level while 47% scored below the 10th percentile level of values obtained from the school group. Even though the children with the innocent heart murmurs were not directly compared to the school group on the percentile chart, their endurance times were lower. This explains the endurance times being closer between those children with heart defects and children with innocent murmurs. Cumming explained these differences between

the school group and children with innocent murmurs as being due to the environmental conditions of testing. The normal children were tested in their school with other children cheering them on (competition) during the test. Although the investigator first describes his second group as children with innocent murmurs, he finishes the article with labeling them normal clinic patients. Consideration was made for the fact that they were attending the clinic for other medical reasons and this may have affected their results. Godfrey (1970) suggested that exercise tests might be used to differentiate between innocent murmurs and mild structural heart disease, yet data using endurance times as the main criteria does not support their view. Cumming, et al. (1978), were able to show a high correlation between the endurance times and actual VO_2 of athletes, however, the inability to sustain long periods of exercise and pain may result in underestimation of maximum VO_2 in normals (Astrand, 1970).

Innocent Heart Murmurs

Incidence

In the past years there have been numerous research studies emphasizing the incidence of innocent heart murmurs in school age children (Thayer, 1925; Schwartzmann, 1941; Friedman, et al. 1949; Appleyard & Joseph, 1976). Differences in the interpretation of murmurs may be due to the method of auscultation or the training of the physician making the diagnosis. Reports on the presence of innocent murmurs in a given school age population range from 7% (Richard, et al. 1955) to 96% (Lessoff & Brigden, 1957). With a highly sensitive stethoscope, a graphic study revealed a 100% incidence of the innocent systolic murmur in children

(Paulen, S. & Mannheimer, 1957). Physicians who are experienced in the interpretation of heart sounds consider it unusual to find the absence of an innocent murmur in a healthy child (Moss, 1970; Elston, 1978).

Contratto (1943) studied the cardiac status of 2856 Harvard College students. The results found 12.3% of the students had systolic murmurs. Follow-up studies using X-rays and electrocardiograms revealed 11.6% to have innocent murmurs. Unfortunately a fairly large number of these students had previously been restricted in their activities because of the presence of a heart murmur.

Diagnostic techniques have been used to determine the significance of innocent murmurs in athletes. Davis (1977) revealed a case study in which a professional basketball player was referred to a cardiac clinic for evaluation of a loud systolic murmur and abnormal electrocardiogram (EKG). The athlete's EKG showed inverted T waves which often suggests ischemia (lack of blood supply to the heart) in a cardiac patient. X-rays showed an enlarged left ventricle. During a stress test his EKG became normal when his heart rate reached maximal levels. In a cardiac catheterization, results showed clear coronary arteries. The murmur was accentuated at maximal exercise. All responses were considered normal and the athlete was allowed to pursue his professional career.

Although innocent murmurs have a high incidence rate in children and young adults, they are found to disappear with age (Marienfeld, et al. 1962). Marienfeld, et al. (1962) conducted a 20 year follow-up study on 139 children with phonocardiographic innocent murmurs. The subjects were first examined in 1939 and diagnosed with a marked systolic vibratory murmur. Twenty years later, the investigators located 96 of the

subjects for extensive re-examination. Only two were presented with heart disease, presumably related to the childhood murmur. A total of 80% of the subjects re-examined were found to have a complete disappearance of the previously diagnosed murmur.

Characteristics

Children are commonly referred to cardiologists for clinical evaluation of a heart murmur. A cardiologist will use the fundamental characteristics of innocent murmurs to help distinguish them from organic disease. These characteristics are primarily based on the intensity and location of the murmur. Often children who may have congenital disease will be asymptomatic and are discovered through routine auscultation of the heart (Harvey, 1976). Moller (1977) and Scott (1978) have both provided information on the common features of innocent murmurs. They include:

1. Intensity must be lower than a grade III on a level of I-VI.
2. Duration of the murmur is very short.
3. Innocent murmurs may be associated with normal heart sounds, mainly splitting of the second sound. Evaluation must include listening for change in intensity and degree of splitting.
4. They usually vary with posture, exercise, respiration and common childhood infestations (fevers, colds and flu).
5. Heart size and volume capacity will be within normal limits.

6. Innocent murmurs can be almost always found during systolic, except for the Venous Hum, which has a diastolic component.

7. The murmur should not be associated with cardiac symptoms, such as chest pain or shortness of breath.

The most common innocent murmurs have been named on the basis of their distinguishing characteristics. Epstein (1958), Castle & Craigie (1960), Harvey (1976) and Moss (1970) have all given description of their sound frequency, intensity and location. There are five common innocent murmurs. Careful evaluation of these murmurs will help differentiate them from serious heart abnormalities. They are:

1. Vibratory Murmur. This murmur is commonly called Still's murmur, which may be musical in nature because of possible fluctuating wake of blood or normal vortex shedding of the muscle fiber (Moss, 1970). Vibratory murmurs are low to moderate in grade and frequency and can be best heard over the third to fourth intercostal spaces of the rib cage. A phonocardiographic tracing reveals a uniform wave pattern in contrast to the complex pattern of mitral valve stenosis (Fogel, 1960). Many children found with Still's murmur have been associated with high physical activity and low mortality rates (Manning, 1977).

2. Pulmonic Ejection Murmur. This murmur occurs during the rapid phase of blood ejection into the pulmonary artery. The timing occurs during mid-systole. An ejection murmur is best heard over the pulmonary artery between the second and third left intercostal space. The sound may increase with exercise, but may never exceed a grade III intensity. It is most closely evaluated in terms of the second heart sound. This

is important to help distinguish it from murmurs produced by atrial septal defects or mild pulmonic stenosis (Moss, 1970; Fogel, 1960; Castle & Craige, 1960).

3. Venous Hum. This murmur represents the increased blood flow in the neck. Its maximal intensity may be associated with fever, anemia and exercise. This murmur differs from the rest because it is a continuous murmur that has an accenuated diastolic phase. A venous hum can also be easily distinguished from organic disease because movement of the head or compression of the neck vessels may alter the sound (Scott, 1978). Innocent "thrills" were found to be associated with 500 children examined with a venous hum (Bujack, et al. 1976). Although the thrill has been shown to be common, it still may lead to unnecessary catheterization because of their similarity to organic heart lesions (Harvey, 1976).

4. Cardiorespiratory Murmur. Normal contraction of the heart causes compression of a portion of lung tissue. As a result of this contact between the heart and lung tissues, a loud high pitched screeching murmur may exist. It is almost always systolic in time and varies in intensity during the phases of respiration. Inflammation of the heart's protective sac (pericarditis) or lower respiratory infections may change the sound's intensity (Castle & Craige, 1960).

5. Carotid Bruit. Auscultation may find sounds originating in the right carotid artery. This sound occurs during the time of rapid ejection of blood into the vessel. It can be distinguished from aortic stenosis because of inaudibility at the aortic area (Fogel, 1960).

Research on Innocent Heart Murmurs

In recent years studies have been conducted to investigate factors that may participate in the production of innocent ejection murmurs (Sabbath, et al. 1979; Van der Hoeven, et al. 1973). Flow murmurs such as the venous hum and carotid bruit are accentuated by recognized physiologic circumstances that produce high flow. These circumstances are caused by conditions of anemia, infection and exercise. Ejection murmurs (pulmonic and vibratory) are commonly determined to be a cause of turbulent blood flow (Sabbath & Stein, 1976). The viscosity of blood is one of the rheologic factors that has been studied for its contribution to the production of the bloods turbulence believed to produce heart murmurs (Thayer, 1925). Sabbath, et al. (1979) investigated the viscosity of blood of fourteen women (18 to 22 years old) that had an innocent ejection murmur and 26 (same age) that had no murmur. All had normal blood counts, but those subjects with an innocent murmur had a significantly lower hematocrit ($P < 0.01$) and consequently the viscosity of blood in these subjects was lower. The diminished blood viscosity increases the tendency toward turbulent flow and this may contribute to the audibility of the murmur.

Van der Hoeven, et al. (1973) studied the hemodynamic aspects of left ventricular function in 15 children with vibratory murmurs and 15 matched controls. The study measured exclusively the pre-ejection time (PET) during the cardiac cycle and revealed that those children with vibratory murmurs had significantly lower ($P < .05$) PET than children without a murmur. The findings suggested that some vibratory murmurs may be attributed to a higher contractility in the myocardium, resulting in a peak

flow through the aortic ostium. PET was found to return to average values in children whose murmurs had later disappeared.

Studies have also been conducted to help localize where murmurs may originate and what parts of the cardiac cycle they may be found (Stein & Sabbath, 1977; Stuckey, 1957; Liebman & Sood, 1968). Innocent ejection murmurs are normally thought to be of pulmonary origin. Stuckey (1957) studied 228 children with ejection murmurs and found 96 to be of aortic origin. Murmurs that originate in the aorta closely resemble those of aortic stenosis and may need further investigation. Stein & Sabbath (1977) used interarterial sound equipment to measure ten subjects with audible vibratory murmurs and found the murmur to have a greater amplitude within the aorta than within the pulmonary artery. In those patients that experienced premature ventricular contractions during the study showed an even greater increase in the audibility of the murmur at the aortic valve. Both studies conclude that the aortic valve may have less compliance against the strong contraction of the left ventricle.

Although diastolic murmurs have always been considered abnormal, Liebman and Sood (1968) reported on nine normal children with diastolic murmurs. Their study used intracavitary phonocardiography within the left ventricle of children referred for evaluation of a systolic murmur. The children had normal EKGs and cardiac X-rays. Multiple parameters of right and left heart catheterizations were normal in all. Results indicated that the filling phase within the left ventricle, especially in a supine position may produce audible sounds. These sounds are hard to distinguish using a normal stethoscope, but may be important in clinicians responsible for diagnosing a significant murmur.

Additional sounds such as gallops or clicks may be produced in children because of other medically reversible conditions such as acute anemia (Moller, 1977). Growth of the blood vessels may cause dilation and change in the elasticity of the large vessels that may be involved in the production of these abnormal clicks (Harvey, 1976).

Summary

The field of exercise physiology has produced several studies revealing the effects of exercise and training on children (Saltin & Astrand, 1967; Skinner, et al. 1971; Klimt, 1971; Thoren, 1978). Normal values on the exercise response in children can be extrapolated from data reported in the literature (Hermansen & Oseid, 1971; Gilliam, 1971; Thoren, 1978; Cumming, 1978). Before puberty the exercise responses of boys and girls will not be significantly different (Astrand, 1960). The Bruce treadmill protocol (Bruce, et al. 1973) has been shown to be suitable for children as young as four years old (Cumming, et al. 1978). Children are capable of producing a maximal effort on a treadmill exercise test thus allowing a measurement of maximum VO_2 to be used as a tool to evaluate cardiovascular fitness. The reliability of maximum exercise tests in children are shown to be high (Van Watershoot, et al. 1977; Rozanski, et al. 1979). The validity of the maximum exercise test can be facilitated by motivational techniques, patience and understanding of children's emotional responses (Jordon, 1978).

The prevalence of innocent heart murmurs in children is high (Appleyard & Joseph, 1976) and the uncertainties associated in their diagnosis often cause physicians, teachers and parents to restrict the activity level of these children (Fogel, 1960; Moss, 1970; Harvey, 1976;

Scott, 1978). Characteristics of innocent heart murmurs have been reported to help distinguish them from heart disease (Moller, 1977; Moss, 1970; Scott, 1978). These characteristics may have similarities to those murmurs associated with organic disease (Epstein, 1958; Harvey, 1976). Research on the exercise response of children with innocent murmurs has been limited to the measurement of endurance time and maximal heart rates while attending a medical clinic for evaluation (Cumming, et al. 1978; Cumming, 1978). Physiological differences in innocent heart murmur children can be seen in reported values on lower blood viscosity (Sabbath, et al. 1979) and shorter pre-ejection times of their cardiac cycle (Van der Hoeven, 1976).

CHAPTER III
METHODS AND PROCEDURES

The purpose of this study was to compare the physical working capacity of two groups of children (boys and girls) with an age range of 5 to 11. The experimental group consisted of 15 children medically diagnosed with an innocent murmur. The 15 control group children were age and sex matched to the experimental group from applications received from a local elementary school.

Administrative consultation and approval was necessary prior to testing any children. Permission was granted by the University Human Use Committee, La Crosse Board of Education and Mr. Terry Witzke, Principal of Emerson Elementary School (Appendix A). Referral forms and instructions for patient participation were submitted under the direction of Dr. P. K. Wilson and Dr. A. C. V. Elston, to the Gundersen Clinic, Ltd., Skemp-Grandview Clinic, Ltd., and the Family Health Center of La Crosse, Wisconsin (Appendix B & C).

Every child selected was assessed for maximal oxygen consumption (VO_2) on a treadmill graded exercise test. Preliminary pilot testing was conducted to evaluate the consistency and accuracy of the procedures and equipment. The actual testing of the children's cardiovascular endurance and physical work capacity was evaluated by measuring the level of oxygen utilized by the body during peak maximum exercise. This was represented by an increase in the respiratory exchange ration (RER) and a plateau of oxygen levels (Klimt, 1971; Van Watershoot, 1977). All testing was conducted over a twelve week period.

Subject Selection

Experimental group subjects were obtained through referrals made by physicians of La Crosse, Wisconsin. Physicians were requested to fill out a referral form (Appendix B) for any child between the ages of 5 to 11 that had been clinically diagnosed with an innocent heart murmur. The child's parents were presented with a form that included the purpose of the study, testing procedures and application for participation (Appendix C). The physicians returned the referral by mail with information pertaining to the child's medical history. The parents of the 15 experimental group subjects cooperated by returning the signed parental consent. These children were then scheduled to be tested in the study.

Children for the control group were selected from the Emerson Elementary School of the La Crosse, Wisconsin, Public School District. The purpose of the experiment and procedures were explained to every Kindergarten through fifth grade class. The children were shown pictures of the treadmill and apparatus to collect expired air with both the children and their teachers given the opportunity to ask questions. Various physiological information such as increase in heart rate, blood pressure and oxygen consumption was discussed as normal exercise response. Dates on testing and the location of the Human Performance Laboratory were provided. Each child was then given an application and consent form to be completed by their parent(s) or guardian(s) (Appendix D). Homeroom teachers collected the completed forms and returned them to the principal investigator at the University of Wisconsin - La Crosse. Over 100 application forms for the control group were returned. The subjects for the study were selected on the basis of age and sex, which were matched to those children

referred with an innocent heart murmur. Age matching included using birth dates to keep the paired children within a six month range. Birth dates which fell within 12 weeks before or after the innocent murmur child's birth date was acceptable. Each child's physician from the control group was contacted by letter (Appendix E) to determine any contraindications for their participation in the study. The primary physician was also requested to inform the investigator if they were aware of an innocent heart murmur to be present in these children. Any response was to be made within five days or the researcher assumed no innocent murmur and/or contraindication existed. Each letter was personally delivered to insure physician's availability to comply with the request.

After selection and clearance was made for each child, letters with information on the experimenter's background and requirements for participation were sent to each child's parent (Appendix F). This letter also gave a tentative date for a pre-test interview. Follow-up telephone calls were made then for final scheduling.

Pre-Test Interview

Prior to testing each subject and parent(s) were required to attend a 30 minute orientation session. The primary purpose of this session was to familiarize the subjects with the procedures and environmental conditions of the study. On each subject a file was maintained which included: (1) returned application form, (2) referral form (experimental group only), (3) informed consent (Appendix G) for testing and (4) data evaluation sheet (Appendix H). A brief discussion with each child and parent(s) or guardian(s) was held to review the purpose and need of the study. Information on the application was checked for accuracy or possible changes.

Each parent was asked to read and sign the informed consent. Questions as to its implications and purpose were discussed.

Instructions on the proper procedures of the test included practice on getting on and off the treadmill safely. The handrails were used for balance while placing one foot on the moving belt. When the children felt comfortable, they placed both feet on the treadmill and walked for three to five minutes. Keeping a balanced stride was emphasized along with concentrating on the focus point (colorful poster) that was directly in front of the treadmill. Each subject was also fitted and familiarized to the head gear, mouth piece and nose clips used to collect expired gases. Electrodes were also placed on one subject and demonstrated for their purpose in determining heart rate during exercise. Final instructions were given for wearing proper exercise clothing and avoiding heavy meals two hours prior to the test. Scheduling included one hour time blocks subjective to availability of the parents and children.

Motivational Techniques

To help insure the attainment of an accurate measure of the subjects maximal oxygen consumption several motivational techniques were employed. Various methods of verbal encouragement were employed to persuade each child to perform the test well. Parents were asked to encourage their children to try his/her best. A battery operated buzzer was connected to the treadmill to be used as an emergency stop button. This made the children feel safer and less reluctant to perform at maximal levels. Pictures of cartoon characters were hung in front of the treadmill in order to give a visual stimulation and a focus point for balance. The children were allowed to take home strips of their exercise EKG and computer readout. In-

formation on the results of the study was made available to all subjects and their families (Appendix I). This information was also provided to the physicians that participated in referring their patients with innocent heart murmur (Appendix I).

Test Description

The IMC treadmill (Model 200) was used for all tests. The Beckman Metabolic Measurement Cart (MMC) was used to analyze the expired gases. Calibration of the treadmill was conducted on each day of testing which usually consisted of five to eight tests. Calibration of the MMC included a check and adjustment of the volume, temperature and barometric pressure. The IB-2 (carbondioxide analyzer) and OM-11 (oxygen analyzer) were calibrated with standardized gas samples (Scholander, 1947). Additional adjustments were also made on the turbine, drierite crystals and air circuit systems when necessary (Woolf, T. A., 1975, Pp. 40-47).

Prior to testing each subject's height and weight was recorded. The subjects were instructed to rest in a supine position for five minutes. A bi-polar lead system (CM-5) was connected to the appropriately prepared areas (Sheffield & Roitman, 1976). The Quinton (Model 609) exercise cardiometer was used to record the electrocardiogram (EKG). A resting heart rate was recorded while the subject remained in the supine position. The head gear, mouthpiece and noseclips used to collect expired air were carefully fitted and secured. The MMC was programmed for the proper weight and set to provide data every 60 seconds (Woolf, 1975, P. 10). Final instructions were given to each subject to use the emergency buzzer to make the experimenter aware of test termination. Subjects were encour-

aged to exercise to physical exhaustion of maximal intensity. The treadmill handrails were used for balance when necessary.

The Bruce Treadmill (Bruce, et al. 1973) test protocol was administered (Appendix J). A heart rate count was recorded every three minutes by running a six second strip on the cardiometer. The oxygen levels and RER were provided every minute by the MMC. Each subject continued until peak maximum oxygen levels were achieved. This was determined by a plateau of oxygen levels and a RER approaching or exceeding 1.0. Maximum heart rate and the total time of the test was recorded at the sound of the emergency buzzer. The automatic STOP button on the Beckman Cart recorded the final oxygen consumption measurement.

An eight minute recovery period was administered on each subject at a 1.7 mph speed and 0% grade. Heart rates were monitored and recorded every two minutes. After eight minutes each child was asked to sit until resting heart rates returned to normal.

Statistical Analysis of the Data

In order to evaluate the statistical comparison of maximum oxygen consumption in children with and without innocent murmurs a student's "t" test (Downie & Heath, 1974, P. 124) for independent groups was utilized. It was necessary to find the mean (\bar{x}) and the standard deviation (SD) of both groups (Table I) in order for the values of maximum oxygen consumption to be evaluated by computer. The .05 level of significance was used to test the null hypothesis of no difference between the group means. This basic statistical tool was the only test necessary to determine the significant difference of the maximum aerobic capacity of children with innocent murmurs.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to compare differences in the maximum aerobic capacity of children with and without innocent heart murmurs. A treadmill exercise test and subsequent computer analysis of expired gases (Beckman Metabolic Cart) was utilized to measure maximal oxygen consumption (maximum VO_2). This measurement in conjunction with maximal heart rate and endurance time was statistically evaluated to determine if any significant differences in cardiovascular efficiency were apparent (ability to utilize oxygen during maximal exercise) between the experimental and control groups of the study.

Subjects

Data was collected on 15 children (experimental group), referred by pediatric physicians, with an innocent heart murmur. Fifteen children (control group) were then selected on the basis of age and sex and matched to those children in the experimental group. Both groups consisted of nine males and six females, aged five to ten years. Each subject had been cleared medically by their personal physicians and reported to have no contraindication to exercise testing. The referral forms (Appendix E), which requested characteristics of the innocent murmur, indicated 53% of the experimental group were diagnosed with systolic ejection murmurs (pulmonic), 34% with a continuous vibratory murmur and 13% were not given. All murmurs were labeled low in grade (<III) and intensity, as diagnosed through normal auscultation.

Although not experimentally controlled, each child participated in regular physical education classes at his/her respective elementary school. Only one child examined had been previously involved in an organized athletic program. Delimitations of the study eliminated any subject with prior experience in treadmill exercise testing.

Data Collection

All testing was conducted at the Human Performance Laboratory at the University of Wisconsin - La Crosse, during the months of April to June, 1979. During a pre-test orientation session, subjects were eliminated from the study if they were unable to perform at a fast pace (3.2 mph to 4.0 mph) on the treadmill with reasonable amount of coordination and balance. As part of the testing procedures and to help eliminate inadequate test performance, parents were asked to cooperate by making sure their children received a proper amount of sleep, avoided a heavy meal and did not participate in physical activities preceding their maximum exercise test.

The success of the testing was dependent upon the motivation of the subjects. Those children who were highly competitive performed well in exhibiting maximal effort. Some children needed constant encouragement to work harder at the higher intensity workloads. Verbal encouragement by the parents and investigator elicited positive responses. The criteria used to measure "true" maximum $\dot{V}O_2$ in the subjects were (1) a plateau of maximum $\dot{V}O_2$ levels (≤ 5 ml/kg/min in two consecutive stages); (2) peak values of maximum $\dot{V}O_2$ at the completion of exercise; (3) a respiratory exchange ratio (RER) approaching or exceeding 1.0; and (4) subjects' physical characteristics at the completion of maximal exercise. Common charac-

teristics included sweating, high ventilation rates and the need to use the treadmill handrails for balance. When necessary, re-test evaluations were held three to four days after the initial test.

A post-test research design was implemented to compare maximum oxygen consumption of the experimental and control groups. The data collected indicated all children had normal hemodynamic responses to exercise. This included a steady increase in oxygen levels and heart rate as the intensity of the workloads increased (Figures 1 and 2). A plateau of oxygen levels and heart rate occurred during submaximal workloads (stages 2 and 3 of the Bruce Protocol) and then proceeded to show a continual rise in values until maximum levels were reached. Both the heart rate response and maximum VO_2 values were comparable to those reported in previous research (Kliment, 1971; Thoren, 1978). Research on endurance times were also available in the literature for both normal children and those with innocent heart murmurs (Cumming, et al. 1978; Cumming, 1978). The values obtained for endurance times in this study revealed the responses to be above the range reported for children five to ten years old (Appendix K). There were no abnormal responses in either group during exercise or recovery which would indicate the inability of their cardiovascular system to tolerate maximal intensity workloads. This was determined by observing the electrocardiograph, heart rate and physical tolerance during the test and recovery period.

Results

At the completion of exercise testing the data for both the experimental and control group were evaluated for mean (\bar{x}), standard deviation (SD) and numerical range of the (1) weight (pounds); (2) maximum VO_2

Figure 1

Mean Heart Rate Response with Increasing Workloads

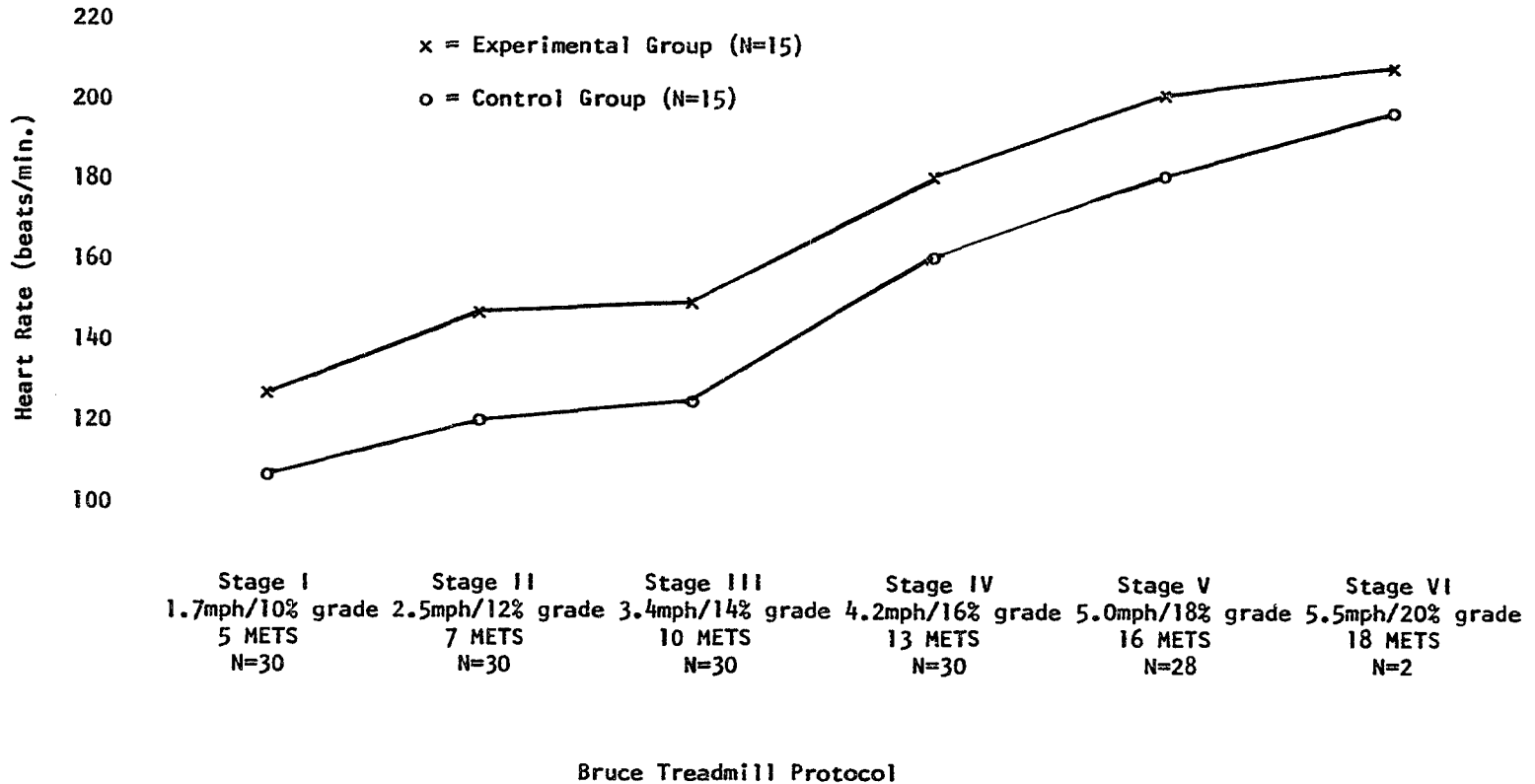
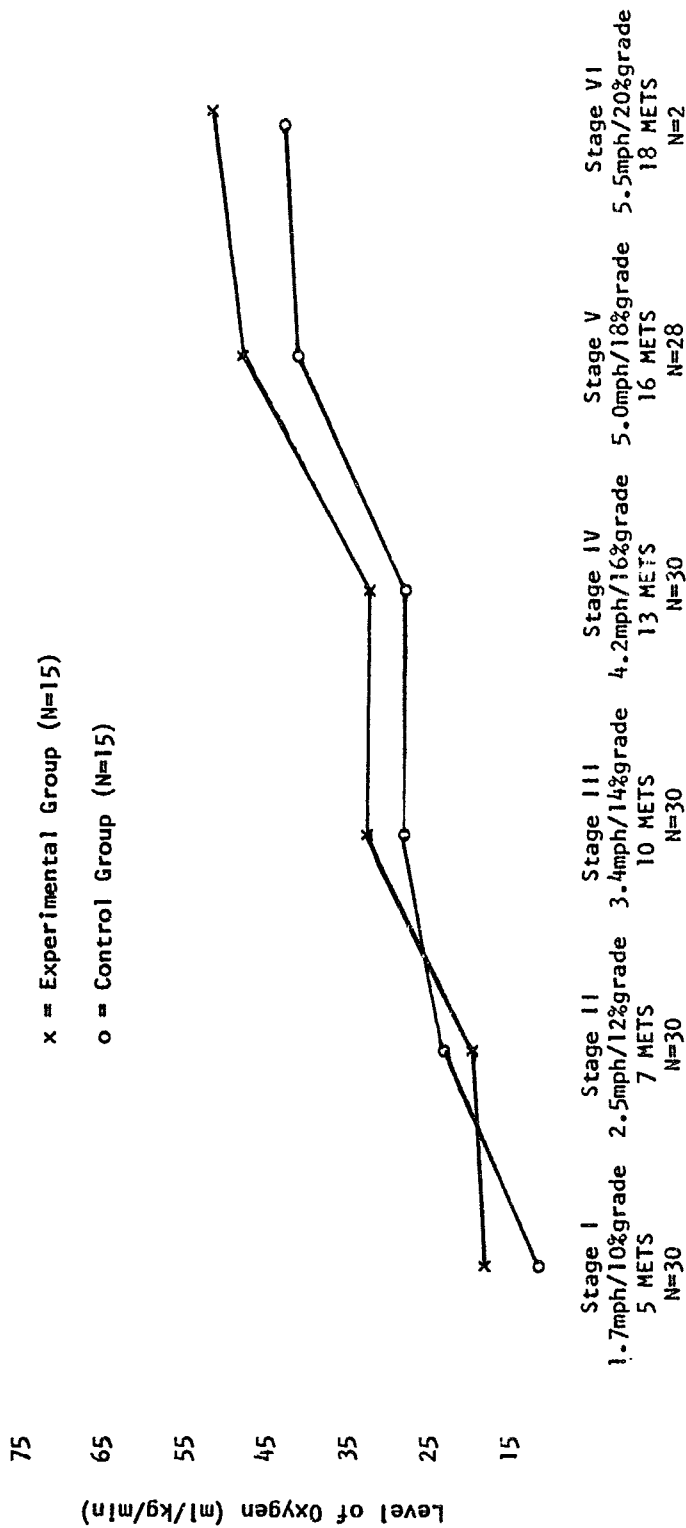


Figure 2

Levels of Oxygen with Increasing Workloads



Bruce Treadmill Protocol

(ml/kg/min); (3) maximum heart rate (beats/min); and (4) endurance (min) (Table 1).

A statistical evaluation using the student's t-test (Downie & Heath, 1974, P. 98) was utilized to test for significant differences between the experimental (innocent heart murmur children) and control groups (Table 2). The data revealed no significant differences in weight ($P > .05$), maximum heart rate ($P > .05$) and endurance times ($P > .05$). There was a significant difference ($P < .05$) between maximum VO_2 , with the experimental group reporting a higher mean maximal VO_2 (54.68 ml/kg/min) than the controls (44.04 ml/kg/min). Maximum heart rates were within the normal range (195 to 210 beats/min) of recent data published on children (Thoren, 1978). Endurance times for the children (5 to 11 years old) with innocent heart murmurs ranged higher (10.48 to 18.2 min) than those reported by Cumming, et al. (1978) (Appendix K).

Discussion

The purpose of this investigation was to compare the maximum aerobic capacity of children with and without innocent heart murmurs. The need for the study resulted from the high incidence of innocent murmurs among children (Fogel, 1960; Harvey, 1977) and the restrictions in the physical activity resulting from their presence. An increased interest in developing and maintaining physical fitness early in life, and the avoidance of social implications (refusal of life insurance) due to medical diagnosis of an innocent murmur has led to the necessary testing and evaluation of children with innocent murmurs. As a result, more consistent criteria for evaluating its incidence and characteristics have been developed (Moss, 1970; Moller, 1977; Scott, 1978). An evaluation using graded

Table 1
Experimental and Control Group Characteristics

Experimental's Variables (n=15)	Mean	Standard Deviation	Range
Age (years)	7.8	1.7	5-10
Weight (lbs.)	56.9	10.2	39-72
Maximum VO ₂ (ml/kg/min)	54.68	8.0	43.6-71.0
Maximum Heart Rate (beats/min)	202.2	10.11	188-220
Endurance Time (minutes)	15.03	2.07	10.48-18.2
Control Group Variables (n=15)	Mean	Standard Deviation	Range
Age (years)	7.8	1.7	5-10
Weight (lbs.)	60.9	11.0	48-81
Maximum VO ₂ (ml/kg/min)	44.04	10.3	30.0-62.0
Maximum Heart Rate (beats/min)	199.3	13.4	180-220
Endurance Time (minutes)	13.85	1.84	11.75-17.15

Table 2
 Significance of the Differences Between
 the Control and Experimental Variables

Variables	Experimental Group (means)	Control Group (means)	t-Value	df	Significance Level
Maximum VO ₂ ml/kg/min	54.68	44.04	3.13	28	.05
Weight (lbs)	56.9	60.9	1.02	28	*
Maximum Heart Rate (beats/min)	202.2	199.2	.675	28	*
Endurance time (min)	15.03	13.85	1.64	28	*

*nonsignificant ($P > .05$)

exercise testing can serve as a diagnostic tool in distinguishing those children with innocent murmurs from those with organic disease (Godfrey, 1971).

The present study made a statistical comparison between the maximum VO_2 of children with and without murmurs, to provide information on the efficiency or possible limitations of their cardiovascular system. Children possessing a significant heart defect might not (depending on its severity) be able to tolerate the stress of exercise because of their inability to transport blood efficiently. There is limited data available on the exercise response of children with innocent heart murmurs. There is also a lack of values validated as norms for the measurement of maximum VO_2 in children. Therefore, the results of this statistical comparison of maximum VO_2 would provide a direct method for determining the cardiovascular efficiency as it compares to those children without a murmur.

As the results indicated, the experimental group (children with innocent murmurs) measured a higher mean maximum VO_2 (54.68 ml/kg/min) than the controls (44.04 ml/kg/min). This was statistically a significant difference at the .05 level. These values cannot be due to weight differences which were not found to be significantly different (Table 2). Endurance time was also not significantly different between the groups. The findings indicated that children with innocent murmurs consumed and utilized a higher level of oxygen per kilogram body weight. The present findings can be used to question the results of Cumming (1978) who found the endurance time of innocent heart murmur children to be higher than those with heart defects, but lower than those tested from a normal school population (Table 3). Using percentiles for the purpose of ex-

Table 3

*Endurance Times of 712 Patients with Heart Defects
Aged 6 to 20 Years: Comparison of Overall Results
Using Normal School and Innocent Heart Murmur Children

Level of Heart Defect	Endurance Time (Percentile Level)	Percent of Patients	
		Murmur Children	Normal School Children
SEVERE	10th	21	47
	11th to 25th	15	16
MODERATE	26th to 50th	26	16
	51st to 75th	23	9
MILD	76th to 90th	11	7
	90th	3	5

(Cumming, 1978, P. 616)

*This study measures the endurance time of a sample group similar to those children tested in the present investigation.

plaining the results, Cumming (1978) found 47% of children with heart defects to score below normal school children and only 21% to score below the children with innocent murmurs in total endurance time. The lower values for endurance time in children with innocent heart murmurs may be due to the environmental testing conditions of a medical clinic. Children with murmurs examined by Cumming had been attending the clinic for other medical reasons, which may have affected these findings. Cummings school children, who were identified as normal, were tested within a classroom setting which could have enhanced the motivational effects on their performance. Endurance time may not be an adequate predictor of cardiovascular fitness due to the many factors other than the aerobic system which contribute to physical performance. This can be illustrated by comparing the relationship between the endurance time and maximum VO_2 of the subjects in the present and those by Cummings (1978). A correlation coefficient of 0.70 was found between the endurance time and maximum VO_2 of the experimental group and 0.21 of the control group in this study. The correlation for the experimental group was significant ($P < .05$) whereas the correlation of the control group was not ($P > .05$). Cumming (1978) was able to demonstrate a better relationship (0.88) between these two variables when he tested a group of 22 athletes. Physiologically the athlete is capable of utilizing both the aerobic and anaerobic systems more effectively. This may enable him/her to endure longer bouts of activity of maximal intensity. Therefore, unless used in a clinical setting or for the purpose of testing athletes, endurance time can be questioned as an accurate measure of cardiovascular fitness. A direct measure of maximum VO_2 as used in this investigation provides a more adequate indication of cardiovascular fitness than does endurance time alone.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

An investigation was conducted to collect data for evaluating the maximal aerobic capacity of children diagnosed with innocent heart murmurs. The evaluation included a statistical comparison between children with innocent heart murmurs and those without murmurs. The need for the study emphasized both the social and physiological implications (restriction from physical activity and life insurance) of children diagnosed with innocent heart murmurs. The underlying etiology of innocent murmurs often leaves parents and teachers with a questionable doubt about the ability of the children with innocent heart murmurs to perform high levels of activity. Research has developed the use of graded exercise testing in children as a useful tool on the diagnosing of functional capacity (Godfrey, 1971; Thoren, 1978; Jordan, 1978). Further investigation has reported maximum VO_2 as the best indication of cardiovascular fitness (Astrand, 1967) and the hemodynamic response of children to these tests have been reported (Klimt, 1971; Cumming, et al. 1978). Although physicians have supplied information on the characteristics of innocent murmurs to help distinguish them from organic disease, physiological research has provided data (Van der Hoeven, 1977; Sabbath, et al. 1979), which may be used to interpret structural differences in their cardiovascular system.

The experimental and control group for this investigation consisted of 15 children who were matched by age and sex. Each child went through

a pre-test interview to explain the procedures used in maximal exercise testing. During the actual testing each child was assessed for maximum VO_2 , maximum heart rate and total endurance time. The test, using the Bruce Protocol (Bruce, et al. 1973), lasted approximately 20 minutes. Exercise responses such as plateau of maximum VO_2 , RER approaching or exceeding 1.0 and physical tolerance were used to determine if the peak oxygen level was a "true" maximal effort or if re-test evaluations were necessary. Success of the test was dependent on the child's willingness to participate and his/her motivation to produce a maximal effort. The results showed there were no significant differences ($P > .05$) in weight, maximal heart rate and total endurance time between the two groups. Maximum VO_2 was significantly different ($P < .05$) with the experimental group attaining a higher maximum VO_2 than the control group.

Conclusions

The purpose of the study was to compare the maximal aerobic capacity of children with and without innocent heart murmurs. The results indicated children with innocent heart murmurs produced a significantly higher maximum VO_2 as measured during a treadmill exercise. Other variables measured (maximum heart rate, weight and endurance time) were not significantly different. With this information the following conclusions were made:

1. Healthy children with innocent heart murmurs are not restricted by their cardiovascular system in utilizing oxygen during a maximal exercise test.

2. The measurement of endurance time alone did not provide an adequate indication of aerobic capacity. This information can be used to in-

investigate previous research on children with innocent heart murmurs, where endurance times were measured and compared to normal school children (Cumming, 1978).

3. The physiological responses of children with innocent heart murmurs are normal in accordance with published data on normal heart rate and electrocardiographic response (Thoren, 1978).

4. The use of motivation and pre-test evaluations were helpful in obtaining a "true" maximum VO_2 during graded exercise testing. This was indicated by a plateau of oxygen levels, an RER approaching 1.0 of the inability of the child to continue exercising at high intensity workloads.

Recommendations

The following are recommendations for the application of this data and for continued study in this area of research:

1. Children who are diagnosed with an innocent heart murmur under the guidelines established by auscultation of their intensity, duration and frequency should not be limited in their participation in exercise or athletic activities.

2. Further research using direct methods of maximal oxygen consumption and the simultaneous measurement of cardiac output should be completed on a larger sample of children with innocent heart murmurs.

3. Physiological differences in the contractility of the heart muscle and viscosity of the blood (Van der Hoeven, 1977; Sabbath, et al. 1979) should be investigated to determine their normality and affect on the functional capacity of the cardiovascular system.

4. Information which is given to parents and teachers about children with innocent murmurs should be carefully monitored and interpreted

in order to eliminate any possible physiological and psychological harm.

A final and personal recommendation would be in making sure testing conditions and equipment being used in children are conducive to their differences in body size. Careful administration of exercise testing should include the psychological aspect (motivation and patience) of obtaining sensitive and specific data.

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APPENDIX A

CENTER FOR EDUCATION PROFESSIONS

WILLIAM SCHMIDT, DIRECTOR

Memorandum

January 17, 1979

To Whom It May Concern:

This is to verify that Patricia Ignagni, a graduate student in Cardiac Rehabilitation, has the approval of the Center for Education Professions to carry out a graduate study which will involve physical fitness testing of elementary children as a part of her thesis completion.

We would very much appreciate any assistance you might give her in carrying out this study.

William A. Schmidt

William A. Schmidt, Director
Center for Education Professions

WAS/kp

ok Katherine Cappellet - Finance Board of

APPENDIX B

La Crosse Exercise Program
Graduate Study
Physician Referral Form

Child's name _____ Date _____

Address _____ Phone _____

Height _____ Weight _____ Sex M or F

1. Date of last examination _____
2. Please check any of the following conditions which are pertinent to this participant.
 - A. _____ Absolute contraindications - Any physical limitation that would eliminate participation in this study.
 - B. _____ Relative Contraindications (these will be considered for entrance into the study upon review by the medical advisor and thesis committee).
 - _____ Severe Hypertension
 - _____ Significant Cardiac Dysrhythmia
 - _____ Significant Valvular Disease
 - _____ Chest Pain
 - _____ E. cpe
 - _____ Significant Musculoskeletal disorder
 - _____ Asthmatic Disorder

3. List any medications this patient may be on _____

4. Could you please supply the following information to help in the data collection of this study (optional).

A. Blood Pressure _____ Systolic _____ Diastolic _____

B. Heart Rate _____

C. Characteristics of the Innocent Murmur (location, intensity and frequency). _____

.....

I have examined the above applicant and approve his/her participation in this research study. Any exercise limitations have been listed above.

Signed _____ M.D. Phone _____

Name of Physician _____ Address _____

Return to: Patricia Ignagni, Graduate Assistant, La Crosse Exercise Program, University of Wisconsin - La Crosse, 54601

APPENDIX C

TO: Parents of 1st-6th Grade Children

FROM: Patricia Ignagni, Graduate Student, La Crosse Exercise Program,
University of Wisconsin - La Crosse, 54601

RE: Work Capacity Study

Dear Parent or Guardian:

The Graduate Program of the University of Wisconsin - La Crosse is proposing a study comparing the physical work capacities of school children with and without innocent heart murmurs. This study will be coordinated by Patricia Ignagni, Graduate Assistant, of the University of Wisconsin and the La Crosse Exercise Program. Medical supervision of this study will be provided by D. A. C. V. Elston, Pediatric Cardiologist, La Crosse, Wisconsin.

This letter is to inform you that your child _____ is eligible upon your approval, to participate in this study. Their participation has been approved by _____, M.D. The purpose of the study is to gather data in order to evaluate the physical work capacity of the above-named children. All testing will be performed on a treadmill, which is a motor driven belt upon which one walks or runs. The speed and elevation of the belt is adjustable and will be determined by the procedures selected by the research team. The study is very simple and basic and involves NO procedures that would be provoking to the children (i.e., needles, blood samples, etc.). The children will be asked only to walk and run on the treadmill while breathing into a mouthpiece which will collect expired air for analysis.

At the conclusion of testing you will be given the results of your child's test along with an evaluation of their level of cardiovascular fitness. Testing is tentatively scheduled to begin March 27, 1979, and will involve one 45 minute session for each subject selected. Prior to testing, the parents and the subject will be scheduled to come to an orientation-practice session. This will involve approximately one-half hour and will acquaint the subject and parents with the equipment and procedures. The orientation and testing will be held in the Human Performance Laboratory, Mitchell Hall on the campus of the University of Wisconsin - La Crosse. You will be notified by letter and telephone as to when the orientation will be scheduled.

Should you consent to your child's possible participation in this study, please fill out the attached form and return it immediately to your Pediatrician's secretary or mail it to Patricia Ignagni at the address listed above.

Your cooperation in this matter is greatly appreciated. This study will provide valuable information about the work capacity of children involved and will afford you and your child the opportunity to develop a greater understanding of the heart and circulatory systems.

TO: Parents of 1st-6th Grade Children
Page Two

Student's name _____ Age _____ Sex M or F

Student's address _____ Birthdate _____

Has your child ever participated in a study similar to this? _____

When and Where? _____ Date of last Physical Exam _____

Any Physical Handicap? _____

Parent or Guardian's signature _____

Telephone: Home _____ Work _____

APPENDIX D

TO: All 1st-6th Grade Parents

FROM: Patricia Ignagni, Graduate Student, La Crosse Exercise Program,
University of Wisconsin - La Crosse, 54601

RE: Work Capacity Study

Dear Parent or Guardian:

The Graduate Program of the La Crosse Exercise Program is proposing a study comparing the physical work capacities of school children with and without innocent heart murmurs. This study will be coordinated by Patricia Ignagni, Graduate Assistant, La Crosse Exercise Program. Medical Supervision of this study will be provided by A. C. V. Elston, Pediatric Cardiologist, La Crosse, Wisconsin.

The purpose of this study is to gather data in order to evaluate the physical work capacity of the above-named groups of children. All testing will be performed on a treadmill, which is a motor driven belt upon which one walks or runs. The speed and elevation of the belt will be adjustable and will be determined by the procedures selected by the research team. The study is very simple and involve NO procedures that would be frightening or provoking to the children (i.e., needles, blood samples, etc.). The children will be asked only to walk or run on the treadmill while breathing into a mouthpiece, which will collect expired air for analysis.

At the conclusion of the testing you will be given the results of your child's test along with an evaluation of their level of cardiovascular fitness. Testing is tentatively scheduled to begin March 27, 1979. Prior to this testing session, the parents and the subject will be scheduled to come to an orientation-practice session. This will involve approximately one-half hour and will acquaint the subject and parents to the equipment and procedures. The orientation and testing will be held in the Human Performance Laboratory on the campus of the University of Wisconsin - La Crosse. You will be notified by letter and phone as to when the orientation will be scheduled.

Should you consent to your child's possible participation in this study, please fill out the attached form and have your child return it by March 15, 1979, to his/her homeroom teacher. Your child's physician will be contacted concerning any medical considerations.

Your cooperation in this matter is greatly appreciated. This study will provide the investigators with valuable information concerning the work capacity of the children involved. It will also afford you and your child the opportunity to develop a greater understanding of the functions of the heart and circulatory systems.

TO: All 1st-6th Grade Parents
Page Two

Student's name _____ Age _____

Address _____ Birthdate _____

Sex: M or F Height _____ Weight _____

Has your child ever participated in a study similar to this? _____

If so, when and where _____

Family Physician _____ Phone number _____

Parent or Guardian's signature _____

Telephone: Home _____ Work _____

APPENDIX E

Letter to Primary Physicians

TO: _____, M.D. of _____ Clinic

FROM: Patricia Ignagni, Graduate Student, M.S. Adult Fitness/Cardiac
Rehabilitation, University of Wisconsin - La Crosse

RE: Physical Work Capacity Study

This letter is to inform you that your patient _____ has been selected to participate in a research study at the Human Performance Laboratory, UW-L. _____ has consented to their child's participation which will include one 45 minute session, with a 15 minute treadmill test. This test will require a maximal effort during which EKG and blood pressure will be monitored. The child will also be required to wear a mouthpiece that will collect their expired gases for analysis. A. C. V. Elston, Pediatric Cardiologist will make himself available by telephone in case of any emergency. All equipment has been adjusted for the child's safety.

The purpose of the study is to compare the physical work capacity of children with and without innocent heart murmurs. If you are aware of an innocent murmur present in the above child or if there are any contraindications that will limit this child's participation in this exercise test, please contact me at 785-8686 within five days of this letter. If I have not heard from you by this time, I will assume there are no medical limitations restricting this child's physical effort in this study.

If you have any questions regarding this matter, please feel free to contact me. Thank you for your time in this matter.

APPENDIX F

Practice-Orientation Letter

TO:

FROM: Patricia Ignagni, Graduate Student, University of Wisconsin - La Crosse

RE: Follow-up letter regarding your child's participation in the physical work capacity study

DATE:

Your child's application to participate in the physical work capacity study has been received. I appreciate your interest and look forward to meeting you and your child. In my capacity as a Certified Graded Exercise Technician and Graduate Student, I have had the opportunity to effectively measure the cardiovascular fitness level of many children and adults. My interest in children and the importance in cardiovascular fitness has encouraged me to conduct research in this field. The research project is in partial fulfillment of my masters degree in Adult Fitness/Cardiac Rehabilitation. It is important at this time to set up an interview date. This will help in the orientation of the testing procedures.

Again, the purpose of this study is to test the physical fitness level of your child. All procedures in the testing will be carefully supervised by trained technicians. The test itself involves running on a belt driven treadmill. As your child exercises, his/her expired gases (through normal breathing) will be collected and examined by a computer. The entire test will take approximately 45 minutes. All physical signs such as heart rate and blood pressure will be monitored.

If you have any questions regarding this matter, or if you cannot make the scheduled interview date, please contact me at 785-8686, during the day or evenings at 782-8443. Your cooperation is greatly appreciated. I hope that the testing will be an educational experience for you and your child.

The interview session will be held in the Human Performance Laboratory, second floor, Mitchell Hall, University of Wisconsin - La Crosse.

Scheduled Interview Date

APPENDIX G

Master of Science Degree
 Adult Fitness/Cardiac Rehabilitation
 University of Wisconsin - La Crosse

Informed Consent

Treadmill Exercise Test

I, _____, allow Patricia Ignagni and assistants to administer a treadmill exercise test on my child, _____, at the Human Performance Laboratory on the campus of the University of Wisconsin - La Crosse. I understand the procedures of this test have been approved by B. Altman, Ph.D., Glen Porter, Ph.D., and Philip K. Wilson, Ed.D., the supervising thesis committee. The procedures will also be medically supervised by A. C. V. Elston, Pediatric Cardiologist, Gunderson Clinic, Ltd. Dr. Elston will make himself available within a phone call reach of any emergency.

I understand that there are no techniques involved that will hurt or scare my child. He or she will walk and run on a motor driven treadmill while both electrocardiograms and blood pressure will be monitored. Your child will also be wearing a mouthpiece that will be connected to a computer used to measure oxygen levels during the test. The difficulty of the test will be progressively increased by both an increase in speed and elevation of the treadmill until a maximum effort has been achieved. This maximum effort will be characterized by an increase in heart rate, blood pressure and muscle fatigue.

Every effort will be made to conduct the test in such a way as to minimize discomfort and risk. However, I understand that there are potential risks involved with exercise tests. These include signs of lightheadedness, fainting, leg and chest discomfort, and rarely heart attacks or sudden death. I further understand that the laboratory and technicians are properly equipped and prepared for such emergency situations. I accept the risks associated with the above procedures in testing my child.

 (Signature of Parent)

 (Witness)

 (Date of Test)

APPENDIX H

DATA SHEET

Child's Name _____ Date _____
 Height _____ Weight _____ Age _____
 Resting Heart Rate _____ Resting Blood Pressure _____ / _____
 Birthdate _____

<u>Stage</u>	<u>Heart Rate</u>	<u>Blood Pressure</u>
1.7 @ 5%	_____	_____ / _____
1.7 @ 10%	_____	_____ / _____
2.5 @ 12%	_____	_____ / _____
3.4 @ 14%	_____	_____ / _____
4.2 @ 16%	_____	_____ / _____
5.0 @ 18%	_____	_____ / _____
2 minute recovery	_____	_____ / _____
4 minute recovery	_____	_____ / _____
6 minute recovery	_____	_____ / _____
8 minute recovery	_____	_____ / _____

Total Time of Test _____

Any abnormalities or special considerations _____

APPENDIX I


 The UNIVERSITY of WISCONSIN - LA CROSSE

LA CROSSE, WISCONSIN 54601

(608) 785-8000

July 17, 1979

Dear

I have recently completed the analysis of the data collected during the maximum treadmill exercise tests taken at the University of Wisconsin-La Crosse. Your participation in this testing helped to evaluate and compare the cardiovascular fitness of children with and without innocent heart murmurs.

The results showed that all the children had normal responses in their heart rate and oxygen consumption throughout the test. These results were important because they provided information on the ability of children with innocent heart murmurs to perform well during maximum exercise and therefore presents no differences in their capability to participate in physical activities and athletics. Please, be aware though, that this information should be used in children with innocent murmurs under the consultation of their physician. Below you will find the data we obtained from your visit to the Human Performance Lab:

Weight _____
 Maximum Heart Rate _____
 Maximum Oxygen Consumption _____
 Endurance Time _____

Maximum Oxygen Consumption-the maximum amount of oxygen a person can utilize during exercise. This value is used to measure cardiovascular fitness.

I would like to thank you for your time and cooperation in helping complete this project. If you have any questions concerning this data, please feel free to call me (782-8443)

Sincerely,

Patti Ignagni



July 17, 1979

To:

From: Patricia Ignagni, Master of Science, Adult Fitness-Cardiac Rehabilitation, University of Wisconsin-La Crosse

RE: Comparison study of the maximum aerobic capacity of children with and without Innocent Heart Murmurs

As part of my requirements as a graduate student in Adult Fitness/Cardiac Rehabilitation, I proposed a study comparing the maximum aerobic capacity of children with and without innocent heart murmurs. To help in the attainment of subjects, contacts were made to you and other physicians in the La Crosse area to request assistance in referring children(5 to 11 years old) with innocent heart murmurs. The study has recently been completed and enclosed you will find the data collected on 15 children with and 15 children without an innocent murmur during a maximal treadmill exercise test.

I would like to extend my appreciation for your interest and cooperation in this project. It is hoped that you will use this information with the children diagnosed with an innocent murmur and in the consultation with their parents and teachers. If there are any questions concerning this data, please feel free to contact me(782-8443).

ENC: Abstract
Data
Conclusions and recommendations

APPENDIX J

Bruce Treadmill Test Protocol

Stage	Speed (miles/hour)	Grade (%)	Approximate Oxygen Cost (ml/kg per min)
1	1.7	10	18
2	2.5	12	25
3	3.4	14	36
4	4.2	16	46
5	5.0	18	56
6	5.5	20	63
7	6.0	22	70

(Cumming, 1978, P. 70)

APPENDIX K

Bruce Treadmill Test Endurance Times (min)
in Clinic Children with Innocent Heart Murmurs

Percentiles								
Age Group (yr)	no.	10	25	50	75	90	Mean	SD
Boys								
4-5	40	8.1	9.0	10.0	12.0	13.3	10.4	1.9
6-7	28	9.7	10.0	12.0	12.3	13.5	11.8	1.6
8-9	30	9.6	10.5	12.4	13.7	16.2	12.6	2.3
10-12	31	9.9	12.0	12.5	14.0	15.4	12.7	1.9
13-15	26	11.2	13.0	14.3	16.0	16.1	14.1	1.7
16-18	12	11.3	12.1	13.8	14.5	15.8	13.5	1.4
Girls								
4-5	36	7.0	8.0	9.0	11.2	12.3	9.5	1.8
6-7	34	9.5	9.6	11.4	13.0	13.0	11.2	1.5
8-9	26	9.9	10.5	11.0	13.0	14.2	11.8	1.6
10-12	28	10.5	11.3	12.0	13.0	14.6	12.3	1.4
13-15	24	9.4	10.0	11.5	12.0	13.0	11.1	1.3
16-18	12	8.1	10.0	10.5	12.0	12.4	10.7	1.4

no. = number of subjects
SD = standard deviation

(Cumming, 1970, P. 70)