Chapter 2

History of the Human Energy Reserarch Laboratory

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There is obvious need for a continuous, systematic, and logically directed attempt to add to the body of knowledge in every academic discipline. The Department of Kinesiology at Michigan State University has recognized and addressed this need for many years through its various research programs. One major component of research has been in the area of exercise physiology. The overall direction of that research effort has been to study the anatomical and physiological effects of different types, intensities, and durations of physical activity in subjects of all ages and both sexes. The primary goal has been to enhance human health and well being; a secondary goal has been to improve human work and sports performance.

The Human Energy Research Laboratory, in its various forms and locations, has been the site of most of the investigations related to exercise physiology that have been conducted under the auspices of Michigan State University during the last half century. The history of the laboratory provides a practical (and for many a nostalgic) review of past and present accomplishments. It is hoped that the report which follows will not only provide historical perspective for the Centennial Celebration of the Department of Kinesiology but that it also will be useful to the reader who is interested in or involved in developing and organizing a similar laboratory.

Acknowledgments

Identifying those who have made the Human Energy Research Laboratory possible is a most difficult but important task because crucial help has been received so often from so many. First it is necessary to mention the sponsorship and guidance of Michigan State University, the College of Education, and the Department of Kinesiology (previously known as the Department of Physical Education and Exercise Science from 1989 to 1997; the School of Health Education, Counseling Psychology and Human Performance from 1985 to 1989; the Department of Health, Physical Education and Recreation from 1955 to 1985; and the Department of Physical Education, Health and Recreation at the time of the inception of the laboratory in 1950).

Many other administrative and academic units within the university also deserve credit for their invaluable assistance in the pursuit of research funding, the design of investigations, the collection of data, and the publishing of the results of various studies. These units are listed alphabetically, using their current titles, in Appendix A.

The individual most responsible for the formation and initial success of the laboratory was its founder and first Director, Dr. Henry J. Montoye. His efforts forever will be gratefully appreciated. Also deserving of particular acknowledgments are Mr. Clarence "Biggie" Munn and Dr. Gale Mikles who chaired the Department throughout the critical formative years of the laboratory and who provided the continuous support necessary for the laboratory to become a viable research entity. A list of laboratory faculty and staff members over the years may be found in Appendix B.

Special recognition is due the many master's and doctoral students from this and associated university departments who, while gaining practical research experience, made essential contributions through their work and dedication to the development and continued operation of the laboratory. Even before leaving the university, many of these students became principal authors or co-authors of influential articles published in nationally and internationally prestigious scientific journals. Collectively, these former students have gone on to become present and future leaders in their chosen professional settings and, in some cases, directors of similar laboratories. Thus it is with great pride that a list of those students who earned doctoral degrees, and who either had major responsibilities in the laboratory or completed their dissertations using the laboratory, is presented in Appendix C. Hopefully, that list is complete. If not, an apology is extended to anyone whose name accidentally has been omitted. A similar list of students who earned master's degrees was not attempted because large numbers, inadequate records, and failing memories ensured too many mistakes. However, the valuable contributions of those students also is appreciated and gratefully acknowledged.

The Early Years

For lack of a better method of organization, this report will be presented in approximate chronological order with internal emphasis placed first upon laboratory locations and then upon the type(s) of research conducted at each site. To avoid duplicate coverage of similar topics, only a few representative investigations have been selected for discussion in detail.

The Catacombs: Jenison Fieldhouse Basement Rooms

In September 1949, Dr. Henry Montoye joined the physical education faculty of Michigan State University as its first exercise physiologist. The sum total of the research equipment on hand at that time was a grip dynamometer and a spirometer for measuring vital (lung) capacity. These were stored in a closet and covered with

dust. They obviously had not been used for some time. When the grip dynamometer was checked in the Mechanical Engineering Department, it was found to be surprisingly accurate. After a few minor repairs, the spirometer also functioned well. Of course, there was no laboratory, as such, but these instruments did prove to be useful in a tests and measurements course. In spite of severe limitations, Dr. Montoye was able to complete several research projects during the first years of his tenure. His efforts then were enhanced greatly with the appointments of Dr. Wayne Van Huss in 1953 and Dr. Janet Wessel in 1956.

Dr. Van Huss was an important addition because of his background in exercise physiology—in particular the measurement of aerobic and anaerobic energy metabolism parameters. He also was a pioneer in the use of animal models for the study of exercise-induced changes in skeletal and cardiac muscle function. Philosophically, Dr. Van Huss brought a fresh approach to the content, construct, and conduct of required physical education programs at the collegiate level.

Dr. Wessel, also a highly respected exercise physiologist, made major contributions to understanding the effects of exercise in women of all ages. This line of investigation had been largely neglected prior to Dr. Wessel's work; and her longitudinal cohort of middle-aged and elderly test subjects remains unequaled to this day. Outside of her laboratory work, Dr. Wessel championed physical education for disabled children and youth, an effort which culminated in the wellknown "I Can" program.

About 1950, two storerooms were discovered in the basement of Jenison Fieldhouse at the level of the handball courts. The rooms were being used to store old sports trophies. However, someone previously had neglected to close a water valve; and the basement, including those two rooms, had been flooded to within a few feet of the ceiling. Mr. Ralph Young, who then was Director of Athletics and Chairman of the Department of Physical Education, Health and Recreation, gave his permission to convert the two rooms into laboratory space if they could be renovated appropriately. Fortunately, at that time the Fieldhouse was being repainted; and, for a bribe of a couple of "fifths," the two rooms were included. Thus, the first laboratory, as yet unnamed, came into being.

Initially, research interest centered upon the development of new and improved methods of timing running events, a topic of importance to both physical education and athletic programs. In addition, small grants were obtained to study the effects of vitamin B12 supplementation on growth and physical performance in young boys and to investigate the patterns of electrocardiographic tracings obtained on trained athletes.

Two early funded investigations deserve special mention. The first of these, a study of the longevity and morbidity of former college athletes at Michigan State University, was initiated in 1955. Critical physical and behavioral characteristics of former varsity athletes were compared with those of matched control subjects who attended the university at the same time but did not participate in athletics. The youngest subject

in the study was born in 1919. The initial results were published in several scientific journals as well as in a 1957 monograph. Fortunately, it has been possible to extend the data collection on this unique sample through the life span of most of the subjects. As a consequence, there have been several follow-up reports. As might be expected from the results of more recent investigations, this pioneer study showed that persistent adult behavior has a much greater effect on adult health and longevity than does the early physical fitness which may be inferred from participation in collegiate varsity sports. Clearly, a broadly based longitudinal study of this type provides an excellent opportunity for valuable research. Of course, in such a study one might anticipate a few interesting exceptions to the general findings. An example is the one nonathlete gentleman who lived a happy and amazingly healthy life into his late nineties while drinking about fifteen "shots" of liquor and smoking two packs of cigarettes per day. (So far it has been impossible to verify the rumor that this remarkable fellow was killed by a jealous husband.)

Another early research project was the impact testing of protective headgear. Football helmets were studied. A constant blow was provided by a pendulum, with an accelerometer attached, which could be drawn back a fixed distance and then released electronically. A wooden head was constructed with another accelerometer inside. The head was placed in a helmet and hung so that when the pendulum swung forward it would strike the helmet at a known location. Upon impact, the acceleration of the head and the deceleration of the pendulum were both recorded. This was designed to simulate a knee striking the head of football player. Once consistency was established, it was possible to compare helmet designs and materials. Over the years, manufacturers have made a number of major equipment alterations based upon the results of this study.

Progress: The Quonset Huts

About 1956, some Quonset huts, located just south of Jenison Fieldhouse, became available. These Quonset huts had been used for temporary student housing during the rapid growth of the university following World War II. However, when additional permanent housing was constructed, the Quonsets no longer were needed and thus were scheduled to be torn down. Through the help of Mr. Munn, two of the buildings were reserved for use as laboratory space to supplement the two rooms in the fieldhouse. Although these facilities still were modest, it should be recalled that there were only a few research laboratories in physical education departments throughout the country at that time.

The two Quonset huts that were assigned to the department had not been used for some time and needed renovation, but there were no funds available for the purpose. Consequently, Dr. Montoye, Dr. Van Huss and a few graduate students became decorators. They painted the interiors of the huts and attempted to seal the windows. However, their skill at insulation left something to be desired. During the winter, the temperature difference between the floor and the ceiling could reach 10 to 15 degrees.

Funds were limited except for those obtained through research grants. Therefore, because some of the studies in progress were related to the area of nutrition, help was sought from the Department of Foods and Nutrition. Dr. Margaret Ohlson, the chairperson of that department and a respected research scholar, saw the advantages of interdisciplinary investigations. She thus made funds available to buy, among other things, a motor-driven treadmill. The A.R. Young Company in Indianapolis, a manufacturer of agricultural conveyer equipment, built the only human treadmills commercially available at that time. The one purchased by Michigan State University was about the fourth or fifth to be produced; and it served well, in nearly constant use, for over twenty-five years.

The early crossing of disciplinary lines, a policy established by Dr. Montoye, was a fortunate direction to take and one which was encouraged as the university rapidly transformed itself from being primarily an agricultural college into an internationally recognized research institution. Multidisciplinary studies are common in most universities today; however, the cooperation, which was so prevalent across this campus in the 1950's and 1960's, probably could not have been achieved in a more mature university having firmly established departmental boundaries which, at that time, frequently fostered "turf protection." To the credit of everyone involved, interdepartmental collaboration has been continued and, indeed, greatly broadened at Michigan State University as time has passed.

As a consequence of the open-minded and scholarly environment which prevailed, a large number of joint projects and publications were completed during these formative years of the laboratory by faculty and student members of this and other academic units. Most notably, there were team efforts with the Departments of Foods and Nutrition, Physiology, Electrical Engineering, and Animal Husbandry as well as with the Student Health Service.

Several lines of research were initiated during this period. For example: a grant from the National Diary Council was used to evaluate the effects of milk ingestion on the physical performance of endurance athletes; NIH provided funds for one of the original investigations of the effects of regular exercise on total serum cholesterol in adults; the relationship between knee extension strength and subsequent knee injuries in high school football players was studied; and a series of tests was conducted to assess the validity and reliability of laboratory instruments and procedures used to measure energy metabolism.

Underground Again: The Women's Gymnasium

About 1957, an addition to the Women's Gymnasium (now known as the Intramural Sports Circle Building) was built. With the help of Mr. Munn, several vacated shower and locker rooms were made available to replace the Quonset huts and the Jenison Fieldhouse basement rooms. In the new facility, the laboratory finally was given a name. It was called the "Human Energy Research Laboratory" (HERL).

As compared to the situation that existed before, the new and expanded quarters permitted the laboratory staff to take a more comprehensive approach to research within the broad field of exercise physiology. Obviously, both males and females, young and old, participate in numerous types, intensities, and durations of physical activity. Furthermore, when one considers the extent and nature of the changes that may be produced by different regimens of exercise in the various systems of the body (muscular, skeletal, respiratory, neural, hormonal, etc.), the complexity of the field becomes evident. It is not surprising then that the researchers felt as if they were kids in a candy store. There was so much to be done.To make matters even more propitious, the move into the Women's Gymnasium came at a financially opportune time. The bipartisan political climate in Washington D.C. was entering an era in which support of basic and applied research was viewed with continuously increasing favor. Indeed, for the next 25 to 30 years, including one uninterrupted period of 21 years, the HERL had essentially adequate external funding to carry out all of the research projects the faculty and staff could handle. Of course, the quest for research moneys remained an arduous and largely unloved task; but funding could be obtained if sound research proposals were constructed carefully. As a consequence, skilled personnel and available time replaced space and money as the primary limiting factors in the HERL.

To help alleviate this new but welcome problem, Mr. David Anderson was hired as a laboratory technician in 1960. He provided essential assistance to both faculty members and graduate students in the areas of biochemical analyses, energy metabolism determinations, body composition measurements, and numerous other laboratory procedures. David also maintained the department's reprint files of research articles and provided much of the graphic artwork needed for publications and presentations.

In the Fall of 1961, Dr. Montoye accepted a position in the Department of Epidemiology, School of Public Health, at the University of Michigan and joined a team of investigators who were conducting a very large research study centered in Tecumseh, Michigan. He was sorely missed here as he had provided superb leadership in the establishment and early development of the laboratory. When Dr. Montoye left, Dr. Van Huss became Director of the HERL, and a search was instituted to find a replacement faculty member.

Dr. William Heusner was hired from the University of Minnesota in the Fall of 1962. In addition to being an exercise physiologist, he brought with him undergraduate degrees in mathematics and physics as well as 13 years of practical coaching experience at the collegiate level. This varied background proved to be useful as different research projects were undertaken in the laboratory over the coming years.

Also in 1962, Ms. Jo Ann Janes was hired as secretary of the HERL. Most university secretaries must handle, in addition to standard English, the unique language(s) of one or at most two disciplines. Due to the nature of the research conducted in the HERL, Jo Ann has had to deal with the languages of anatomy, biochemistry, nutrition, physics, physiology, and statistics. She has done so with ease. Overall, she has been so valuable

to the operation of the HERL that she really has become the day-to-day manager of the laboratory.

Dr. Arthur Steinhaus, an internationally recognized scholar and one of the early leaders in exercise physiology, retired from his position as Dean of George Williams College in 1963. A great talent was going to waste. Fortunately, funds were located to hire him as a Visiting Professor, and he came to Michigan State University in 1966. He worked closely with the faculty and staff of the HERL until his death in 1969. Due to his experience, Dr. Steinhaus was able to serve as a highly respected consultant on several major research projects.

Because research in exercise physiology is so diverse and often unprecedented, necessary instruments, equipment, and supplies may not be available in stores or even listed in scientific supply catalogs. New investigative concepts frequently require totally original approaches or at least innovative uses of existing methods and materials. Mr. Robert Wells, who had worked for several years in the HERL on an hourly basis, was hired in 1967 as a Specialist to serve as a laboratory technician. Bob's ingenuity as a design engineer was tested repeatedly, and he played a prominent role in the success of the laboratory.

By the early to middle 1970's, the research load in the HERL was becoming more than the faculty and staff could handle along with their regular teaching and service commitments. Consequently, Dr. Kwok-Wai Ho was hired in 1976 as an additional exercise physiologist. Dr. Ho, a political refugee from mainland China and a former member of the Chinese National Basketball Team, had just completed his Ph.D. degree at Michigan State University. His outstanding teaching ability, his unique experiences in China, and the fact that he already was integrally involved in a large number of ongoing HERL research projects made him the ideal person for the position.

Studies Using Human Subjects. Between 1957 and 1982, numerous research projects in exercise physiology were conducted directly or indirectly through the HERL in the Women's Gymnasium. For example, the study of the morbidity and longevity of college athletes was continued. In addition, multiple investigations with human subjects were conducted in each of the following broad areas: the relationships between various fitness variables and physical performance; the effects of different pre-exercise activities, including warm-up procedures, on physical performance; methods of measuring habitual physical activity in adult men and women; the immediate and long-term effects of selected physical activities in children and youth with disabilities; changes in the ballistocardiographic records of athletes during training; the effects of habitual physical activity and age upon selected physiological and anthropometric variables, body composition, and adaptations to submaximal exercise in adult men and women; the relationship between dietary vitamin C and physical performance; the effects of moderate altitude (simulated) on endurance performance; techniques of measuring energy expenditure and body composition in children and adults; the relationships between physical activity and aging; comparisons of the effects of various acute and long-term exercise regimens on growth, bone structure, muscle vascularity

and function, cardiovascular function, respiratory function, body composition, and physical performance; the acute effects of various inspiratory and expiratory resistances; the effects of physical training on menarche; the relationships between the ingestion of sodium bicarbonate and quality of performance, energy metabolism during and after exercise, and postexercise acid-base balance; the energy metabolism, lactate profiles, and other characteristics of elite competitive swimmers; and the effects of weightlessness on selected blood and bone parameters (a federally funded review of literature). These and other areas of investigation were supported by the National Institutes of Health, the American Heart Association, the National Aeronautical and Space Administration, the U.S. Army Chemical Warfare Service, the U.S. Olympic Committee, the Florida Citrus Commission, and the MSU All-University Research Grant Program.

Obviously, it would be nonproductive in this context to attempt to describe in any detail each of the individual studies that were conducted. However, a brief discussion of two of the previously mentioned areas of investigation will serve to illustrate, in general terms, the type of work that was being done in the HERL throughout the 1960's and 1970's on human subjects. The first, a series of descriptive studies was undertaken by Dr. Wessel to provide much needed data on the complex relationships between advancing age, habitual physical activity, exercise tolerance, and associated measures of health in adult women. At the time the work was begun, there was no pertinent information of this type. Volunteer women between 20 and 69 years of age were recruited as subjects. Detailed health and physical activity histories were completed, personal physician approvals were sought, and those with marked health problems were eliminated from the study for obvious reasons. The remaining subjects then were tested periodically to keep their health and activity records up to date as well as to measure their serum cholesterol levels, anthropometric characteristics, body compositions, maximum oxygen uptakes, and cardiovascular and respiratory responses to the stress of a subject-limited treadmill run to exhaustion. As might have been anticipated even then, the results obtained on women in this early study parallel those found both before and after in men and fully support the benefits of an active lifestyle.

During the Vietnam War, the U.S. Army Chemical Warfare Service developed a gas mask that was designed to keep out almost all conceivable chemical and biological warfare agents. The only problem was that the inspiratory and expiratory resistances were so high that the mask also tended to keep out air. There was real question as to the level of work which could be performed by a person wearing the mask—an important concern considering the physical activity that might be expected of a soldier in an emergency situation. The HERL was asked to study the problem, and Dr. Van Huss agreed because of the interesting physiology involved. In that era, the effects of respiratory resistances too often were ignored when systems for measuring energy metabolism during strenuous exercise were established. Young male volunteers were used as subjects for the study. Wearing masks with varying filter elements, army boots, and fatigue uniforms, they were tested on the treadmill at a series of predetermined

speeds and grades. Intramask pressures and gas flow rates were measured along with ventilations, oxygen uptakes, and work capacities. The results showed that with increasing respiratory resistances oxygen uptake decreased, work capacity decreased, and the energy cost for any given workload increased. The data were submitted to the army with design recommendations and also proved to be invaluable in answering some of the then existing questions related to energy metabolism instrumentation.

Studies Using Animal Subjects. The primary objective of the HERL always has been to enhance human health and work performance. However, almost from the inception of the laboratory it was evident that the scope of research would be severely restricted if only humans could be used as subjects. Both ethical and practical limitations apply as to what can be studied in and learned from human subjects. For example, a controlled investigation of the effects of prepubertal exercise programs on future muscle fiber profiles in adolescents and adults would be difficult to conduct on humans, regardless of the benefits to be derived from such a study. Children cannot be matched and assigned randomly to experimental and control sports activity groups; even small and relatively painless needle biopsies are hard to justify in children and youth who cannot legally consent to such procedures; and the time required for a longitudinal study of this nature is unrealistic. Therefore, although it was widely recognized that research results obtained on animals may not be translated directly to humans, the decision quickly was made that, for some lines of investigation, animal models would have to be used to supplement the information that could be obtained on humans.

Originally there was resistance to the housing of animals in the HERL. Concern was expressed about potential offensive odors as well as the possibility of animals escaping into other parts of the Women's Gymnasium. However, after a window exhaust system was installed in the proposed animal quarters and it became obvious that animals could not escape from their cages, there was general support for animal experimentation by both male and female faculty members throughout the department.

One of the earliest problems was to identify a suitable animal model. The establishment of a facility for large animals such as dogs and cats, or especially primates, simply was not feasible. The albino rat was known to be a good model for muscle physiology; however, great differences in body fat and trainability exist between strains. The Sprague-Dawley rat finally was determined to be the small animal of choice; and, with only a few exceptions, it was used routinely in the HERL.

Because the work to be done was in the field of exercise physiology, methods had to be developed to simulate human programs of progressive physical activity. In particular, quantifiable regimens of low-intensity, long-duration exercise (e.g., endurance running) and high-intensity, short-duration exercise (e.g., sprint running) were needed. Programs specifically to develop strength (e.g., weight lifting) and power (e.g., high jumping) also were desired. To complicate matters, each of these structured routines had to be adaptable to either continuous periods of exercise or to a more uptodate

interval training format. A method of allowing and evaluating unstructured voluntary activity also was required.

The voluntary activity problem was the easiest to solve. A home cage was fitted with an attached running wheel which was accessible to the animal through a small door in the side of the cage. A counter recorded the number of revolutions of the wheel which then could be converted to the distance run during each 12- or 24-hr period. (One little rascal, who apparently liked to watch but not participate in exercise, compiled an outstanding voluntary activity record until it was discovered that each night he would lie in his home cage, reach through the door, and push the wheel around with one paw for several hours. His voluntary activity data were not included in any analyses, and careful observation revealed no other animals with this deceitful behavior pattern.)

Because mice are known to be able to run on a motor-driven treadmill, treadmill running was tried first as a means of implementing a structured regimen of exercise for the rat. However, the animals had to be taught to run on the treadmill, and many simply never learned to move at any pace faster than a slow walk. Perhaps they had difficulty understanding why the belt underneath was moving while nothing on either side was passing by.

Swimming was used next, but to avoid having the dominant animals climb on top of the other animals as well as to prevent the animals from bobbing in shallow water (a very relaxing and enjoyable activity as any competitive swimmer can verify), each animal had to be placed alone in water at least 30 inches deep. Consequently, plexiglass tubes, 12 inches in diameter and 36 inches tall, were used so as to provide a small "swimming pool" for each animal. To achieve a measurable and progressive workload, swimming times gradually were increased and lead fishing weights, of 1% up to 8% of the animal's body weight, were attached to the base of each animal's tail. However, each animal's fur trapped varying and unknown amounts of air—a problem which neither shaving the animals nor using a detergent in the water satisfactorily solved. In summary, although it was used in some of the earlier studies, swimming was very difficult to control and thus was considered to be a gross exercise stressor, certainly not an ideal independent variable for precise experimental work.

It was known from the voluntary activity data that, in contrast to the results obtained using a treadmill, rats will run in wheels. Therefore, so as to be able to impose specific workloads, a motordriven exercise wheel was constructed. However, some of the animals apparently considered this apparatus to be an amusement park Ferris wheel. They held onto the bars that formed the floor of the wheel and rode happily around. The motor, not the rat, was doing the primary work.

The intriguing concept of an exercise wheel could not be dismissed easily, so a rat-driven wheel became the next project. A training device, eventually called a "controlled running wheel," was developed which could be programmed to conduct automatically an entire exercise session consisting of one or more bouts of exercise with specified

rest periods between bouts. Each bout, in turn, could consist of one or more work intervals alternated with an appropriate number of rest intervals during which the wheel would be braked. The required running speed during the work intervals could be preset and controlled as could the durations of the work and rest intervals. For example, on a given day one animal, which was being trained for sprint running adaptations, might have been expected to complete three bouts of exercise with 5 min of rest between bouts where each bout consisted of 30 repetitions of a 10-sec work interval alternated with 29 repetitions of a 20-sec rest interval. In this case, the animal might have been required to run at the relatively fast pace of 6.5 ft/sec during each of the 30 brief work intervals. Another animal, which was being trained for endurance running adaptations, might have been expected to complete only one bout of exercise consisting of a single continuous work interval of 60 min at the relatively slow pace of 2.0 ft/sec.

The critical design problem, of course, was how to get the animal to comply with a desired exercise routine when the rat, not a motor, was controlling the speed of the wheel during the work intervals. That problem was not as difficult to solve as it might appear. A small electric current was applied as needed through the bars forming the running surface of the wheel. A shock received via the bars was neither painful nor harmful to the animal (i.e., a person placing the palm of a hand on the bars would experience only a mild tingling feeling). However, the sensation was disturbing to the animals; and, in order to avoid the slight shock, they instinctively ran. Thus this electrical stimulus was used as the basis for a conditioned response. At the beginning of each work interval, the brake on the wheel was released and a light came on as a signal to the animal that the shock would soon follow. The animal quickly associated the preceding light signal with the following shock and began to run as soon as the light came on. The brief programmable interval between the light and the shock was called the "acceleration time." If the animal started to run and brought the wheel up to the preset speed during the allotted acceleration time, the light turned off automatically and the animal received no shock. If the preset speed was not reached during the acceleration time, the light stayed on and the animal did receive shock until the desired speed was achieved—at which time both the light and the shock were discontinued. If at any time during a work interval the wheel speed dropped below the preset value, the light and shock sequence was repeated. This procedure worked surprisingly well. The animals quickly learned to respond to the light signal in order to avoid the shock. Typically, after three 45-min learning periods, at least 95% of the animals ran shock-free for at least 95% of the total work time.

The conditioned response protocol was modified and incorporated into the design of a successful rat weight-lifting device in which the animal wore a belt around the waist with a weight attached. When the animal stood normally on all four feet, the weight was supported by a subfloor of the apparatus. When, in response to a light signal, the animal stood up on its hind legs to grasp a vertical bar that was lowered from above, the weight was raised off of the floor. Two 45-min learning sessions usually were sufficient

for 95% of the animals to be 95% compliant. After a 12-week training period, a rat typically was able to complete 5 bouts of 10 repetitions each while lifting an attached load of at least 300% of its body weight.

The same protocol was used to develop a rat high jumping apparatus. The animals quickly learned that, to avoid a mild but disturbing shock, they should jump onto a ledge overhead (a "safe" area) whenever they saw a warning light signal. One learning session usually was sufficient to get 95% cooperation from 95% of the animals. To date, the rat world record for the vertical jump is 81 cm (32 in.).

If proper precautions are taken, animal experiments are much more easily controlled than are human experiments. The procedures used in the HERL to minimize the effects of extraneous factors included: equivalent daily handling of all control as well as experimental animals, maintenance of a constant environmental temperature, maintenance of a constant light-dark cycle, and the establishment of a pattern for the rotation of home cage locations.

Using the techniques previously described for the conduct of studies on animals, numerous investigations were undertaken to identify the effects of specific regimens of exercise, conducted at various ages and under diverse conditions, on different structures and functions of the body. Parameters associated with the muscular, cardiovascular, respiratory, skeletal, neural, digestive, and hormonal systems were studied. Exercise became an intervening factor of interest and/or a dependent variable itself when studied in conjunction with nutritional alterations, brief exposure to radiation, ergogenic aids, anxiety-inducing stressors, and acute or chronic diseases. The National Institutes of Health, the National Science Foundation, the Michigan Heart Association, the Kellogg Foundation, and the MSU All-University Research Grant Program supported these animal investigations.

The Muscular Dystrophy Study deserves special mention because of its unique nature. For several years, investigations had been conducted in the HERL to help identify the histochemical and biochemical alterations that occur in skeletal muscle as a result of various regimens of prepubertal exercise. During those earlier studies, it was noted that, on occasion, some stages of the supposedly beneficial cellular adaptations that take place with training are very similar to selected stages of the detrimental cellular changes that routinely are seen in the muscular dystrophies (hereinafter referred to as a homologous group of diseases by the singular designation "muscular dystrophy"). Because at that time too little was actually known about muscular dystrophy, including its genetic etiology, several questions naturally came to mind: What, if any, are the relationships between the changes that occur during training and those that occur during muscular dystrophy? Might the dystrophy-like changes at the cellular level seen with some regimens of exercise really be a result of overtraining? Should such changes be considered to be indicative of some type of myopathy? Is it possible that strenuous training programs produce transient or even permanent myopathies in human age-group athletes? In what manner do selected types, intensities, and durations of exercise

affect the onset and course of muscular dystrophy? This last question was addressed first because any answer(s) to it should shed light on possible answers to the other questions.

Muscular dystrophy is a disease that is expressed in muscle, and the primary function of muscle is to produce movement. Therefore, one might have expected, even then, to find a wealth of information concerning the effects of specific programs of exercise on dystrophic muscle. Such was not the case. A careful review of related literature located only a few pertinent articles, and the results of those were conflicting. About one-third showed that exercise definitely is of benefit to the subject with muscular dystrophy; about one-third strongly suggested that exercise is contraindicated; the results of the final one-third were equivocal. The discrepancy was caused by the generic application of the word "exercise" which often is used indiscriminately to cover various regimens of physical activity ranging from indoor gardening and slow walking to heavy weight lifting and marathon running.

Finding no definite answers in the literature to the questions posed, the decision was made to initiate a study of muscular dystrophy in the HERL. A trainable animal model was sought and found in the BIO 53.58 strain of Syrian hamster which breeds 100% true for a Duchenne type of muscular dystrophy. Funding then was requested and received from the National Institutes of Health to conduct a series of investigations designed to determine the efficacy of using each of several well-defined and quantifiable regimens of exercise, introduced prior to the appearance of clinical symptoms, as a means of managing (not curing) the disease. The detailed results of those studies are too extensive to include here, but the most interesting observations can be summarized with ease. The average total life span of the animals was not altered significantly by any of the exercise regimens used. However, the "useful" life span, during which the animal was able to move around and function in a reasonably normal manner, was altered by all programs of moderate or higher intensity. Endurance exercise, which requires an aerobic metabolic adaptation in the slow-twitch skeletal muscle fibers, increased the useful life spans of the animals by as much as 30 to 50%. Other activities such as sprint running and weight lifting, which require anaerobic metabolic adaptations in the fast-twitch skeletal muscle fibers, decreased the useful life spans of the animals by 30 to 50%. Although these results obtained on dystrophic hamsters may have important implications for human subjects with muscular dystrophy, they definitely should not be applied to nondystrophic humans. The detrimental effects of anaerobic exercise seen in the animals can be traced directly to the specific type of cellular degeneration caused by the disease.

Daylight: Erickson Hall

In 1981, industrial arts was discontinued as a teacher education specialty in the College of Education. Thus two large and commodious rooms (with windows) were vacated in Erickson Hall. The space became available at an auspicious time because a large multiple-college grant to institute an employee health promotion program at the

university had just been submitted to the Kellogg Foundation. Employee health and wellness was a new and popular idea on this campus and, indeed, across the entire country. Requests were forwarded to the Dean of the College of Education and to the Provost to make the vacated space available to the HERL for human testing. Temporary permission was granted, and a new Center for the Study of Human Performance (CSHP) was created in the fall of 1982. Although all of the HERL work with human subjects was moved into the CSHP, the animal investigations and the offices of the laboratory faculty and staff remained in the HERL which still was located in the Intramural Sports Circle Building (formerly called the Women's Gymnasium). Therefore, the CSHP really should be thought of as a special-purpose annex to the HERL.

Instruments for the measurement of certain biomechanics variables related to gait analysis were incorporated in the design of the new CSHP. Therefore, Dr. Dianne Ulibarri and Dr. Eugene Brown, the two departmental biomechanists, immediately became members of the laboratory faculty. A number of interesting and valuable research projects were completed in the area of biomechanics, but those are presented elsewhere during this Centennial Celebration.

The transfer of all exercise physiology investigations involving human subjects into the CSHP provided an opportunity to bring two important laboratory protocols up to date. In the 1950's when the HERL first was formed, energy metabolism determinations were limited to the collection of expired air in Douglas bags, the sampling of that gas over mercury in glass collection flasks, the determination of gas volumes by slow wet-test meters, the analysis of oxygen and carbon dioxide concentrations by Haldane chemical analyzers, and the calculation of results using hand calculators. A skilled technician could obtain the results of a single treadmill run in three to four hours. Gradually instrumentation and procedures were improved to include direct sampling of gasses passing through fast flow meters, infra-red carbon dioxide analyzers, paramagnetic oxygen analyzers, and direct input for computerized data reduction and graphing. These modifications had been made in the HERL as they became available, but they were further integrated into the system developed for the CSHP. Not only could the results of a treadmill run be obtained in both tabular and graphic form within a minute or so after the completion of that run, but the reliability and validity of the results were improved greatly.

Body composition information often is eagerly sought by subjects and investigators alike. However, the determination of body composition presents special problems. Even when body composition calculations are based upon body density data obtained during underwater weighing, which usually is considered to be the "gold standard" protocol for such measurements, the procedure frequently is administered imprecisely due to technical difficulties. Originally in the Intramural Sports Circle Building, a chair was suspended in a swimming pool so that a totally submerged subject could be weighed by means of a load cell attached to a supporting cable. Weight was recorded at the end of a maximal exhalation thus leaving only a small residual volume of buoyant

air in the lungs. Of course, a correction for that residual volume had to be included in the body density and final body composition calculations. (Most hydrodensitometric body composition technique errors occur in the determination, or estimation, of residual volume.) In the HERL, residual volume was measured using a standard 7-min rebreathing routine during which the subject remained submerged. Theoretically the procedure was very good, but 7 min is too long a time for the average individual to breathe through a mouthpiece and valve while submerged. Reliability was a problem.

Other procedures used to measure residual volume present different problems. If the subject is allowed to keep his or her head out of the water while rebreathing, there may be less anxiety; however, gas pressures in the lungs are quite different than they are when the subject is being weighed while totally immersed. In some cases, residual volume is measured with the whole body out of the water, and the subject then is expected to attain an equal residual volume while being weighed underwater. Even competitive swimmers, who are completely at ease in water, seldom are able to achieve that equality.

After moving into the CSHP, many of the difficulties associated with body composition determinations were resolved. A tank was built with a convenient platform for the test administrator and with a subject chair that could be carefully positioned so that the top of each person's head remained at a fairly constant distance below the water level. Underwater weight was measured with a strain gauge at the end of an exhalation in essentially the same manner as before. The critical improvement came in the measurement of residual volume, which was determined by a brief three-breath nitrogen rebreathing technique administered immediately following the determination of the subject's underwater weight. In fact, whether or not the subject actually reached residual volume was of no consequence. The procedure measured the volume of air that was in the lungs at the time the subject's underwater weight was recorded. An electronic gas analyzer provided nearly instantaneous results, and a second determination then was made right away. If the two percentage-of-fat values differed by more than 1%, which seldom happened, additional measurements could be taken. The reliability problem was solved.

An interesting series of investigations was conducted with the Youth Sports Institute (YSI). Age-group runners and wrestlers were recruited for a longitudinal study that was designed to evaluate, and follow over time, various anatomical and physiological variables including energy metabolism and work capacity. The results will be discussed elsewhere during the Centennial Celebration, but it is appropriate to note here that, to the credit of the YSI, that work represents one of the most comprehensive efforts of its type ever undertaken.

The 1980's and early 1990's marked a period of rapid personnel change for the HERL. Dr. Wessel retired in the fall of 1983, Dr. Van Huss retired in the fall of 1986, and Dr. Ho left to take an administrative position at the University of Hawaii in December of 1986. Dr. Carol Rodgers and Dr. Marc Rogers, two excellent young exercise physiologists, were hired in the fall of 1987. They continued the work with human subjects in

the CSHP; however, funds for the animal studies conducted in the HERL had run out in 1986, and shifting faculty interests made the search for renewal funds impractical.

To continue the personnel changes, Dr. Heusner retired in the fall of 1989, and Dr. Rogers left to take a faculty position at the University of Maryland in the fall of 1990. Bob Wells took early retirement in 1992 to establish his own consulting business. The CSHP was closed as of January 1, 1993 when the College of Education reclaimed the space in Erickson Hall, and Dr. Rodgers returned to Canada later that spring to join the faculty at the University of Toronto.

An era had ended, but it was a very productive era. Research and service activities had been continuous for over forty years leading to a large number of book chapters and monographs, well over four hundred publications in peer-reviewed national and international journals, and probably twice that number of research-based presentations to professional and other interested groups.

Recent History

A new era began with the appointments of Dr. Jeanne Foley in the fall of 1993 and Dr. James Pivarnik in the fall of 1994. Dr. Foley had completed her master's degree in physical education at Michigan State University but then transferred to the Department of Physiology for her doctoral degree. When she returned to this department, she brought with her a new and engaging research interest in the application of magnetic resonance imaging (MRI) techniques to the study of metabolism and blood flow in exercising muscle. Dr. Pivarnik came to Michigan State University from Baylor College of Medicine. In addition to a very broad background in many areas of exercise physiology, his special interest was in maternal and pediatric exercise. The unique combination of interests and skills represented by Dr. Foley and Dr. Pivarnik provided the basis for a strong new research team as the era got underway.

Basic Laboratory and Space

When Dr. Pivarnik arrived in the fall of 1994, there was no functional Human Energy Research Laboratory. Some of the equipment that had been most recently used was stored on the deck of the old pool in the IM Sports Circle Building. It apparently was placed there after the CSHP in Erickson Hall was closed. The space in Room 3 of the IM Sports Circle Building was full of file cabinets, animal cages, and other equipment that had seen better days. Thus, there was a bit of work to do in order to rejuvenate the HERL.

Little by little, things began to take shape and the laboratory was up and running by the spring semester of 1995. As before, the HERL is housed at 3 IM Sports Circle Building. About 1500 square feet of laboratory space is available which is divided into a number of separate rooms. This arrangement accommodates small research studies that require privacy as well as teaching which uses larger spaces.

The laboratory currently houses three indirect calorimetry units. This allows for both resting and exercise metabolic studies where cardio-respiratory responses can be measured. A telethermometer unit permits the monitoring of temperature regulation during these tests. Electrocardiograph (EKG) units are interfaced with the indirect calorimeters so that electrical activity of the heart can be evaluated during testing.

Exercise modalities include four motorized treadmills, five cycle ergometers, one arm ergometer, and a ski machine. Sphygmomanometers are available to monitor blood pressure, and heart rate telemetry units are used when EKG analysis is not required.

Also available is equipment for body composition analysis via hydrodensitometry, as well as other "field"techniques such as bioelectrical impedance (BIA), near infrared interactance (NIR), and anthropometry. Basic blood biochemistry analysis equipment also is available.

Finally, a number of physical activity measurement modalities are available including heart rate monitors with storage and downloading capabilities as well as several types of accelerometers, activity monitors, and pedometers.

Teaching

Laboratory classes were resumed in the spring semester of 1995. Physiological Evaluation and Exercise Prescription (KIN 811) was taught that semester. Apparently, this class had not been offered in some time due to inadequate equipment and space. This is a graduate level course in exercise testing and laboratory techniques. Besides being able to teach basic laboratory skills, a strength of the class is the student project component. With the equipment that is available, students develop and run their own research projects utilizing the techniques learned in class.

Since there were no similar offerings available for undergraduates, Laboratory Experiences in Exercise Physiology (KIN 411) was developed and first taught in the fall of 1996. While some of the techniques are the same as those presented in KIN 811, the emphasis is more on fitness evaluation and exercise prescription. These are skills needed by many undergraduate students who plan on careers in corporate or clinical exercise/fitness programs. The class has become a great success, and feedback from students "out in the field" has been very positive. They, as well as their employers, consider it one of the most important classes students should have. Soon, KIN 411 will change from being an elective to a required class for those majors with a corporate/clinical program emphasis.

Most recently (fall of 1998), a class in EKG interpretation was added. It was a great success and will be continued. In fact, soon it will be incorporated into the general curriculum. Once again, this is a "must have" offering for any student who plans to be involved in clinical exercise testing.

The laboratory setting is one where traditional classroom teaching takes a back seat. It is not only a place where students discuss, listen, and learn theory, but a place to

"do" and put theory into practice. Thus, some of the best "teaching" in the HERL has occurred when students, many of them undergraduates, simply stop by to see what is going on. An open door policy in this area is practiced with the stipulation being that, if you show up, you will be asked to work. This work occasionally may occur either before or after "normal business hours" as is usual in research settings. To stimulate such interaction, Friday morning "HERL Group" sessions are held that cover a number of topics. Sometimes specific research ideas are discussed; sometimes there is participation in pilot data collection. If a student has an idea to share, that is the time and place to do it. The point is to involve the students as much as possible in day-to-day HERL operations. The only rule is that you come in with the attitude that no one knows it all and that everyone's thoughts and opinions are important. A variety of students, faculty, and physician fellows attend these sessions.

Service

The current service commitment of the HERL is divided into three major areas: MSU athletic teams, clinical testing, and product evaluation.

The Department of Kinesiology has had a long tradition of exercise testing with the MSU men's ice hockey team. While this testing has occurred in a number of locations over the years (e.g., Center for the Study of Human Performance, MSU Sports Medicine Clinic, Munn Ice Arena, etc.), all testing now is done in the HERL. Results from treadmill and body composition evaluations are shared with the MSU Sports Medicine staff and team coaches as an integral part of their preseason and postseason player evaluations. Since 1995, testing efforts have been expanded to include the men's basketball, women's field hockey and, most recently, women's crew teams. In addition, body composition testing is done on the football linemen each spring and fall. This relationship with MSU athletics is not only a service to the various teams involved, but it also provides valuable experience for the students who help with all phases of the tests and evaluations.

In concert with MSU Sports Medicine, the HERL also is where exercise tests are performed as part of a clinical workup. Examples include testing individuals with suspected exercise-induced bronchospasms and cardiovascular fitness evaluations of athletes recovering from injury or illness. In addition to exercise tests, body composition analysis for members of the community are provided as this is the only laboratory in the area with hydrodensitometric capabilities.

Finally, there is the opportunity to interact with a number of clothing, shoe, and other athletic equipment manufactures for product testing. While this usually is thought of as a "service," some of the projects do cross over into the area of research.

Research

Most studies in the laboratory reflect the interests and expertise of the faculty members. In Dr. Pivarnik's case, that interest is exercise during pregnancy and the postpartum period as well as physical activity and fitness in children, particularly adolescent females. Following are highlights of some recent HERL research efforts.

One of the first studies completed in the HERL, after the arrival of Dr. Pivarnik in 1994, took place in the spring of 1995. The test-retest reliability of treadmill testing in adolescent females was examined. This is an important issue if one is interested in determining such measures in a setting where more than one test occasion is not feasible. The results showed that the protocol in use is extremely reliable and that investigators can have confidence in results from a single test. This study was presented at both regional and national meetings and was published in the *Research Quarterly for Exercise and Sport* in 1996.

In 1996-97, it was possible to test the validity and reliability of a newly developed combination heart rate monitor/accelerometer. The potential use for this device is great given researchers' interest in finding accurate ways to accurately measure physical activity, particularly in children. However, the results showed that under HERL laboratory conditions of treadmill and cycle exercise, the device did not measure up to its potential. This novel study recently was published in the *Research Quarterly for Exercise and Sport* (March 1999).

In 1997-98, the opportunity was presented to take the "show on the road" and do some comprehensive fitness and physical activity testing at a local Middle School. Fifth-grade girls were the subjects since this is an age where fitness and activity habits appear to decrease in young girls. Some of the results have been presented at regional and national American College of Sports Medicine meetings and have been submitted for publication to *Pediatric Exercise Science.*

In the Fall of 1999, a similar study will be done, but this time using children attending Charter schools in the Lansing area. The number of Charter schools in Michigan is growing at a rapid pace. Thus, the time for studying physical activity/fitness behaviors in such students is now. The Charter school presents a unique dichotomy in that the parents typically have a very strong "buy-in" to their children's programs and are very willing to go along with innovative curricula. On the other hand, Charter schools may be relatively under funded, which may make it more challenging to provide quality physical education and activity programs for their students. How this may affect the children's physical activity behaviors and/or fitness levels is unknown.

Using slightly older subjects, it has been possible to do an elaborate bone density and body composition study on virtually every female varsity athlete at MSU. The student investigator used dual energy x-ray absorptiometry (DXA) as her criterion measure and developed appropriate regression equations from the body composition field techniques of BIA and NIR. Thus, the most definitive body composition prediction

models for athletic women to date were developed. The data will be presented at the 1999 American College of Sports Medicine meeting, and a paper currently is under revision for the *Journal of Applied Physiology*.

In the area of pregnancy and exercise, an NIH funded study is in its second year. The purpose of that investigation is to evaluate methods used to measure physical activity in pregnant women. These data are crucial for investigators to be better able to monitor the effects of physical activity on birth outcome. Previous data are equivocal, and one of the major reasons likely is the inability to accurately measure physical activity throughout advancing gestation and the postpartum period.

Currently, funds are being sought for other studies related to physical activity and pregnancy. One proposal is to explore the possibility of using maternal vascular fluid shifts during exercise as a predictor of pregnancy-induced hypertension. Another proposal is related to the use of physical activity during the postpartum period as a way to reduce obesity in women.

The importance of bringing money into the HERL cannot be overstated. It allows for the conduct of quality research, for delivering services to the community, and for providing the laboratory with the equipment and supplies needed to teach undergraduate and graduate classes. While acquisition of adequate funding is an ongoing struggle, in recent years the laboratory has been fortunate to secure enough money (through various grants and contracts) to support a number of ongoing projects.

In closing, another milestone in the history of the HERL should be mentioned. David Anderson retired in the summer of 1998 after 38 years of service to the laboratory and department. His help and input when Dr. Pivarnik first arrived in 1994 is greatly appreciated. David certainly is missed but not forgotten.

Appendix A

Michigan State University Units Which Have Participated in the Development and Productivity of the Human Energy Research Laboratory

Departments	Anatomy
	Biochemistry
	Electrical Engineering
	Food Science and Human Nutrition
	Materials Science and Mechanics
	Mechanical Engineering
	Osteopathic Manipulative Medicine (old Biomechanics)
	Pathology
	Pediatrics and Human Development
	Pharmacology and Toxicology
	Physical Medicine and Rehabilitation
	Physiology
	Radiology
	Small Animal Clinical Sciences
	Statistics and Probability
Office of the Provost	
Student Health Service	

Appendix B

Faculty and Staff Members of the Human Energy Research Laboratory and Their Dates of Tenure

David J. Anderson, 1960-1998

Jeanne M. Foley, 1993-present

William W. Heusner, 1962-1989

Kowk-Wai Ho, 1976-1986

Jo Ann Janes, 1962-present

Henry J. Montoye, 1949-1961
Adjunct Professor, 1996-present

James M. Pivarnik, 1994-present

Carol D. Rodgers, 1987-1993

Marc A. Rogers, 1987-1990

Arthur H Steinhaus, 1966-1969

Wayne D. Van Huss, 1953-1986

Robert L. Wells, 1967-1992

Janet A. Wessel, 1956-1983

Appendix C

Doctoral Students Who Either had Major Responsibilities in the HERL or Who Completed Their Dissertations Using the Laboratory and/or Its Equipment

1959
Aix Harrison

1960
John Alexander
Perry Johnson
Richard Nelson

1962
Dale Hanson
Wynn Updyke

1963
Sheldon Fordham

1964
William Horwood
Donald Stolberg

1965
Patricia Austin
Robert Kertzer
David Lamb
Michael Maksud
Anita Small

1966
Jerome Weber

1967
Kenneth Coutts
Ione Shadduck

1968
Victor Edgerton
Dee Edington
Leroy Gerchman
Mary Lou Stewart

1969
Richard Bell
Francis Koenig
Paul Robinson

1970
Barry Brown
Robert Ruhling

1971
Mildred Evans
Dan Klein

1972
Alfred Reed
Thomas Tillman

1973
Thomas Gilliam

1974
Michael Greenisen
Robert Hickson

1975
Mary Green
Kwok-Wai Ho

1976
Ann Irwin
Roland Roy

1977
Ada Loveless
Gerald Nester
Elizabeth Watkinson

1978
Charles Beach
Gary Hunter

1979
Asghar Khaledan

1982
Brian Curry
Kenneth Stephens

1983
James Rankin

1984
Bryan Smith

1985
Bonnie Smoak

1986
Bradley Wilson

1987
Thomas Kurowski
Timothy Quinn
Chester Zelasko

1988
Sharon Evans

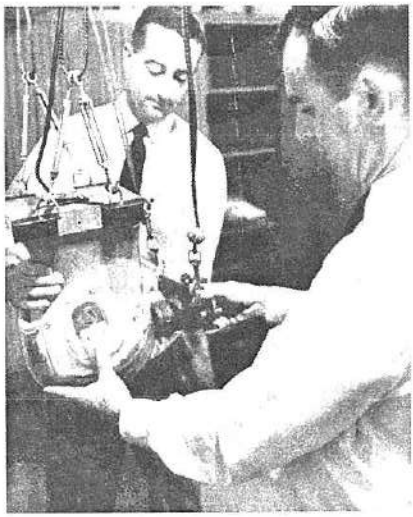
1991
Brian Leutholtz
Jonathon Robison

1992
Beth Garvey

1993
Jaci VanHeest

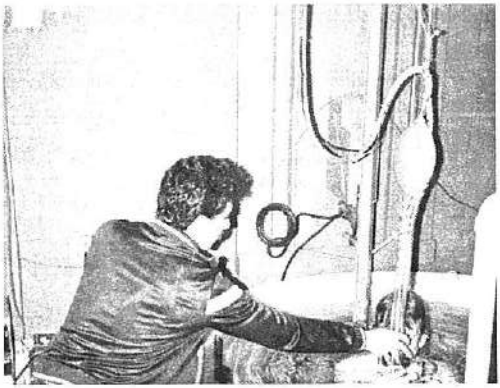
1994
Glenna DeJong

1997
Joseph Carlson

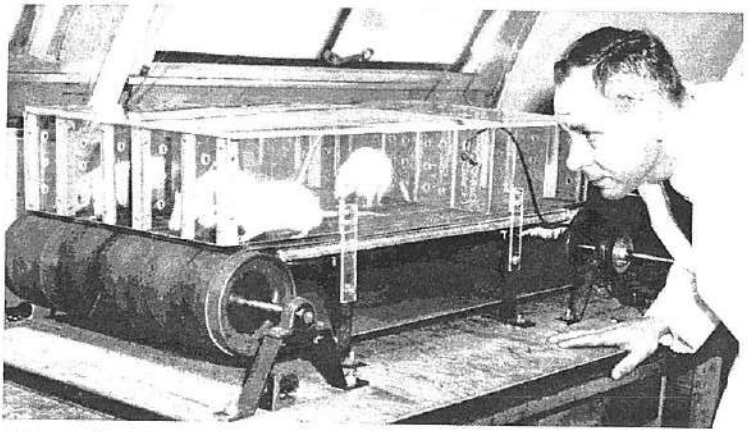


Testing the shock resistance of football helmets (unidentified person, Wayne D. VanHuss, Quonset Hut, 1950s)

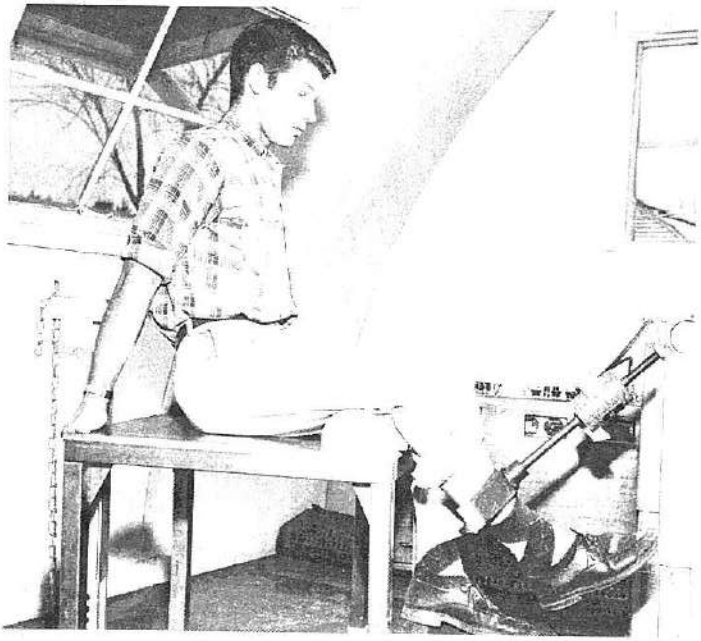
Effects of exercise on cardiovascular health in laboratory rats (Henry J. Montoye, Quonset Hut, 1950s)



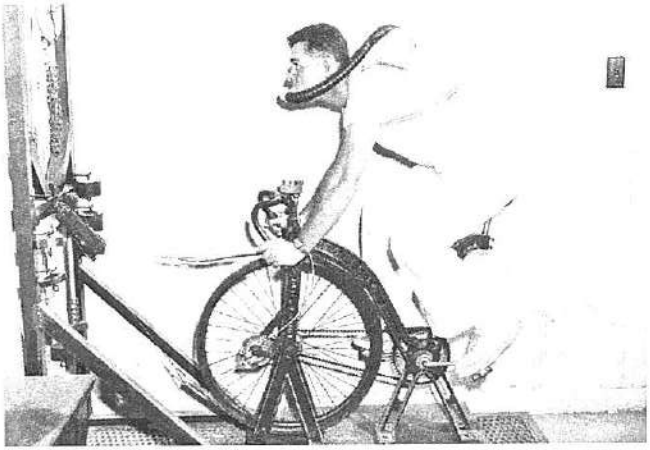
Effects of exercise on longevity in laboratory rats (Ross McNab, Quonset Hut, 1950s)



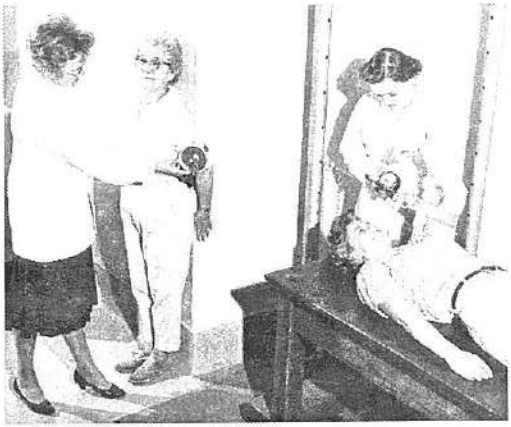
Effects of exercise on the heart in small animals (Henry J. Montoye, Quonset Hut, 1950s)



Measuring knee extension strength with strain gauge (unidentified student, Quonset Hut, 1950s)



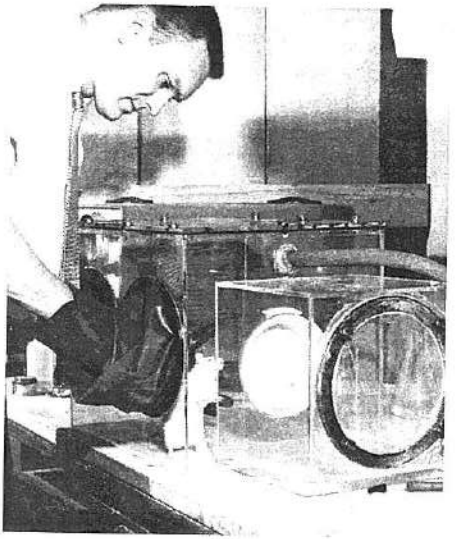
Measuring energy expenditure on the bicycle ergometer (unidentified student, basement of Jenison, 1953)



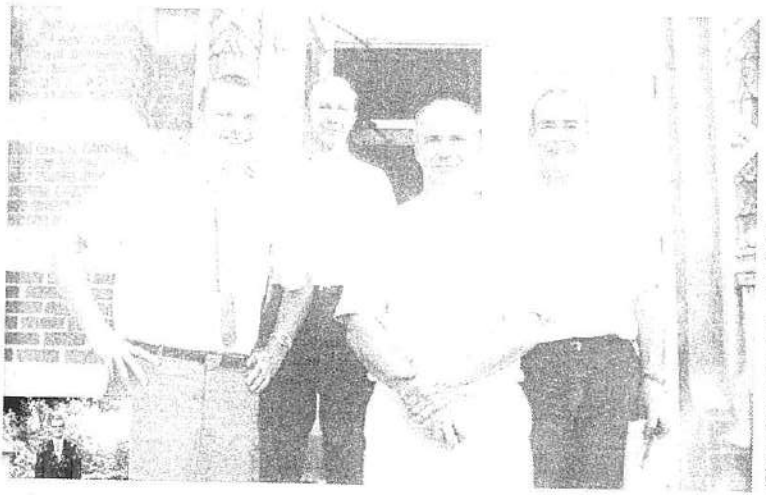
Flexibility and strength measurements on women (Janet Wessel, unidentified woman, Anita Small, Geraldine Barnes, Women's IM, 1960s)

Measuring energy expenditure on the treadmill (Geraldine Barnes, Women's IM, 1960s)

Skinfold measurement (Lenore Kalenda, Geraldine Barnes, Women's IM, 1960s)



Stimulation chamber for laboratory rats (William W. Heusner and friend, Women's IM, 1960s)



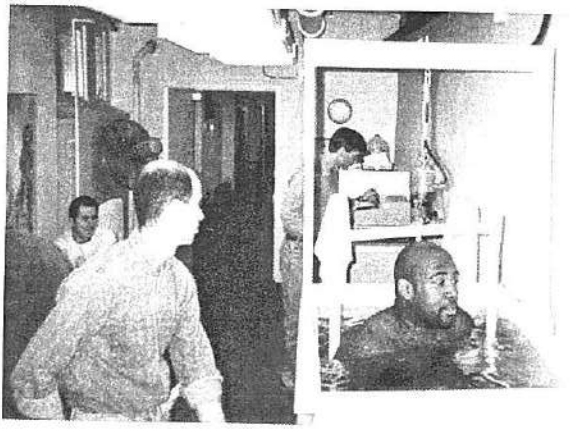
(Photo donated by Robert O. Ruhling)

July 31, 1970, 6:00 p.m. following the Final Oral Ph.D. Examination of Robert O. Ruhling (lower left). His committee Dr. William W. Heusner, Physical Education; Dr. Stuart D. Sleight, Veterinary Pathology; Dr. Rexford E. Carrow, Anatomy; Dr. Wayne D. Van Huss, Chair, Physical Education.

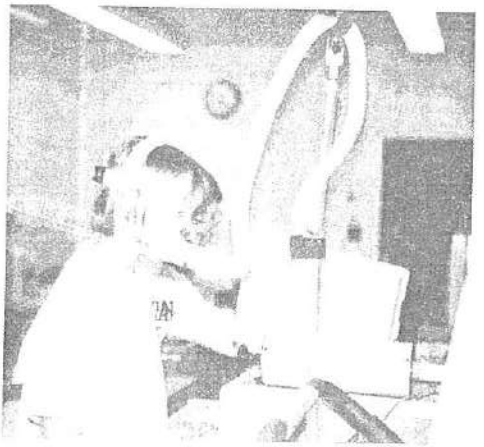
Hydrostatic weighing (Al Bransdorfer, unidentified person, CSHP-Erickson, 1985)

Physiological testing of MSU Sports Teams (IM Sports Circle, 1990s)

Exercise testing with the Douglas bag system (Trish Bransdorfer, unidentified person, Carrie Fitzgerald, Sharon Evans, Ted Kurowski, CSHP-Erickson, 1985)



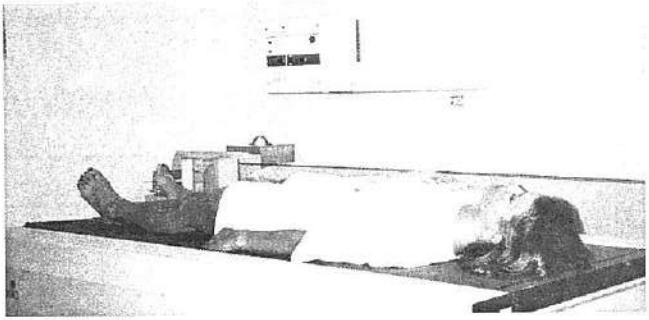
Hydrostatic weighing of a football player (IM Sports Circle, 1990s)



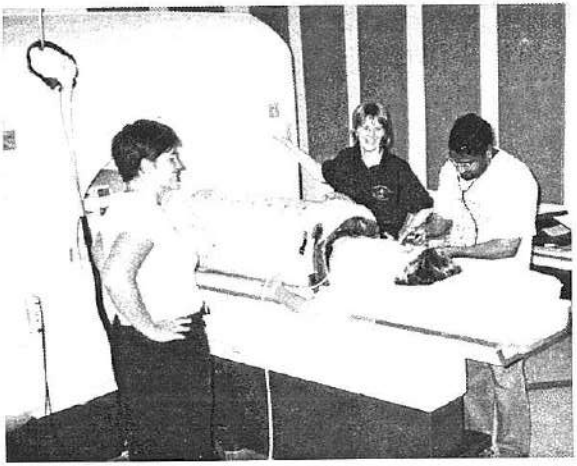
Measuring maximum oxygen uptake in adolescent girls (IM Sports Circle, 1990s)

Reliability and validity of the Mini-Logger activity monitor (IM Sports Circle, 1990s)

Participants in physical activity and fitness in sixth grade girls at Otto Middle School, 1997



Use of DEXA to assess bond density and body composition in female athletes, 1998



MSU students and a visiting researcher prepare a subject for entry into the Magnetic Resonance Imagery in a NASA-funded study examining body fluid shifts in response to pressure changes (Amy Machacek, Amy Kent, Dr. Lori Ploutz-Snyder, Roop Jayaraman, 1997)

Jeanne Foley takes the blood pressure of Karin Allor before a session in the MRI, 1998

James Pivarnik draws blood from Omolade Ayeni for a creatine kinase analysis during a delayed muscle soreness study, 1997

Basketball player being prepped for treadmill test (Mateen Cleeves and Lisa Ballenger, 1999)

Roop Jayaraman tests muscle soreness on Omolade Ayeni, 1997