Exercise Physiology: A Brief History and Recommendations Regarding Content Requirements for the Kinesiology Major

John L. Ivy

The knowledge base that defines exercise physiology is central to the discipline of kinesiology. By the late 19th century, interest in physical training, physical education, and sports began to emerge in the United States. By the beginning of the 20th century, exercise physiology was being included in college physical education degree programs, and by the end of World War II had become an integral part of the curriculum. Today exercise physiology has developed into a major field of study with many sub-areas of investigation. Although the information and knowledge base in exercise physiology has increased in depth and scope, it is grounded in the fundamentals of biology and human physiology. The basic goal of an exercise physiology course designed for the kinesiology major should provide the student with an understanding of how the physiological systems involved in physical activity respond to an acute bout of exercise, and how these systems adapt to various modes of exercise training and environmental conditions. Course requirements to meet this goal are provided.

Exercise physiology is a fundamental course in, and its knowledge base central to, the discipline of kinesiology. The word “exercise” evolved from the Latin term *exercitius*, which means to “drive forth.” Exercise, as defined by Bouchard and Shephard (1994), is physical activity usually performed on a repeated basis with a specific external objective such as the improvement of fitness, physical performance, or health. However, this definition seems most appropriate for defining the term “exercise training.” A superb definition of exercise is advanced in the textbook *ACSM’s Advanced Exercise Physiology* by Tipton and Franklin (2006). They define exercise as “a displacement of the homeostasis and rest elicited by muscle contractions resulting in movement and increased energy expenditure.” The word “physiology” is derived from the Greek word *physiologia*, meaning “natural science” or the study (logia) of nature (physis). Today “physiology” is defined as the study of the biological functions of living organisms including the organic processes and chemical phenomena of an organism or any of its parts or bodily processes. Therefore, “exercise physiology” can be defined as the study of the functions and adaptations of living organisms, their bodily parts, and their organic and chemical processes as a result of increased energy demand due to muscle contraction.

The author (AAKPE Fellow #386) is with the Dept. of Kinesiology and Health Education, the University of Texas, Austin, TX 78712-0360. E-mail: johnivy@mail.utexas.edu
Brief History

Exercise physiology has a long and interesting history. The importance of exercise for health and well-being can be traced to many ancient cultures. However, Hippocrates (460-370 B.C.) is probably best known as the first to advocate moderate exercise to maintain and improve health status (Berryman, 1992). This relationship between regular exercise and quality of health as advocated by Hippocrates was accepted by Plato (429-347 B.C.), Aristotle (384-322 B.C.), and others and was later included in medical theory as promoted by Galen (129-200 A.D.). Galen believed that trained individuals had superior health, greater muscle tone and strength, accelerated respiration, readier metabolism, and better elimination of excrements (Berryman, 1992).

In his medical text *Canon of Medicine*, Avicenna (980-1037 A.D.), a Persian physician, supported the ideas of Galen that moderate exercise was beneficial for good health because it balanced the body humors and expelled the residues and impurities, while promoting good nutrition and growth. Avicenna also recognized that exercise effects were dependent on the degree and amount and that too much exercise could have adverse effects (Tipton, 2006).

One of the first books on exercise was written by the Spanish physician Cristobal Mendez (1500-1561 A.D.) entitled *Book of Bodily Exercise* (Mendez, 1960). It contained 40 chapters that were grouped according to (1) the benefits of exercise, (2) the divisions of exercise, (3) common exercises and their level of importance, and (4) the time convenience of exercise and its value. Nicolas Andry, a professor of medicine at the University of Paris, in his book *Orthopaedia: or The Art of Correcting and Preventing Deformities in Children*, translated and published in English in 1743, emphasized the value of moderate exercise and muscle strengthening to improve general health and musculoskeletal function. Andry (1743) wrote, “Of all the methods proper for preserving health, and for preventing, and even curing a great number of diseases, there is none equal to moderate exercise.” He continued, “Exercise is much more effectual than medicines for the preservation of health.”

By the 19th century, several new medical textbooks included chapters on the health benefits of exercise. Furthermore, lack of exercise was associated with muscle weakness, poor circulation, and potential for disease (Combe, 1836). According to Tipton (2006), it was also the first time a publication included the words and addressed the subject of exercise physiology. In 1854, William August Stearns, D.D., president of Amherst College proposed the establishment of a department of physical education. With the completion of Brett Gymnasium at Amherst College in 1860 the first physical education program was founded and required all students to perform systematic exercises for 30 min per day, 4 days per week (McArdle, Katch & Katch, 1996). One of the first professors in the department was Dr. Edward Hitchcock, Jr., a Harvard Medical School graduate. Dr. Hitchcock had his research laboratory in Brett Gymnasium and regularly recorded the anthropometric and physiological data of the students (McArdle, Katch & Katch, 1996).

By the end of the 19th century, interest in personal health, hygiene, physical training, physical education, and sports began to emerge (Park, 1992a). In 1892, an academic program of anatomy, physiology, and physical training was established in the Lawrence Scientific School at Harvard University, and George Wells Fitz, a graduate of Harvard Medical School, was appointed head of the program. The
program was established to educate and train graduates as directors of athletic clubs, gymnasium, and the YMCA, and to serve as preparation for the study of medicine. The curriculum was grounded in the basic sciences and contained a formal course in exercise physiology (Park, 1992b). The prerequisites for the exercise physiology course, which was taken in the fourth year of the program, included courses in chemistry, physics, zoology, anatomy, histology, and general physiology (see Table 1). Original research and a thesis were required. Research studies under investigation at the time included the effects of different exercises on the development of ventilation and lung capacity, muscular contraction and fatigue, changes in blood supply with exercise, exercise metabolism, and reaction time. Students were also required to attend a summer course of 5 to 6 weeks and learn to teach physical exercises. A student completing this program of study could enter the second year of medical school at Harvard University. The program, however, was closed in 1899. This was due in part to the popularity of the less rigorous physical training programs for the development of physical education teachers at normal schools. These programs emphasized gymnasium and athletic work and limited the study of the physiological and psychological effects of exercise on the body (Park, 1992b).

Table 1  Anatomy, Physiology, and Physical Training Program:
Lawrence Scientific School, Harvard University (Park, 1992)

<table>
<thead>
<tr>
<th>First Year</th>
<th>Third Yeara</th>
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<tbody>
<tr>
<td>Experimental Physics</td>
<td>General Anatomy and Dissection</td>
</tr>
<tr>
<td>Elementary Zoology</td>
<td>General Physiology (Bowditch &amp; Porter)</td>
</tr>
<tr>
<td>Morphology of Animals</td>
<td>Histology (Minot &amp; Quincy)</td>
</tr>
<tr>
<td>Morphology of Plants</td>
<td>Hygiene</td>
</tr>
<tr>
<td>Elementary Physiology and Hygiene (Fitz)</td>
<td>Foods and Cooking (Nutrition)b</td>
</tr>
<tr>
<td>General Descriptive Chemistry</td>
<td>Medical Chemistry</td>
</tr>
<tr>
<td>Rhetoric and English Composition</td>
<td>Auscultation and Percussion</td>
</tr>
<tr>
<td>Elementary German</td>
<td>Gymnastics and Athletics (Sargent &amp; Lathrop)</td>
</tr>
<tr>
<td>Elementary French</td>
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</tr>
<tr>
<td>Gymnastics and Athletics (Sargent &amp; Lathrop)</td>
<td>Fourth Year</td>
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</tbody>
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<th>Second Year</th>
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<tbody>
<tr>
<td>Comparative Anatomy of Vertebrates</td>
<td>Applied Anatomy and Animal Mechanics</td>
</tr>
<tr>
<td>Geology</td>
<td>[Kinesiology] (Sargent)</td>
</tr>
<tr>
<td>Physical Geography and Meteorology</td>
<td>Physiology of Exercise (Fitz)</td>
</tr>
<tr>
<td>Experimental Physics</td>
<td>Remedial Exercise (Fitz)</td>
</tr>
<tr>
<td>General Descriptive Physics</td>
<td>History of Physical Education (Sargent &amp; Fitz)</td>
</tr>
<tr>
<td>Qualitative Analysis</td>
<td>Forensics</td>
</tr>
<tr>
<td>English Composition</td>
<td>Gymnastics and Athletics (Sargent &amp; Lathrop)</td>
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<tr>
<td>Gymnastics and Athletics (Sargent &amp; Lathrop)</td>
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a At the Harvard Medical School
b At the Boston Cooking School
By the turn of the century, however, courses in exercise physiology started to be included into curricula of physical education programs. The first research laboratories established in physical education departments in the United States for the study of exercise physiology were at George Williams College (1923), the University of Illinois (1925), Springfield College (1927), and the University of California, Berkeley (1934) (McArdle, Katch & Katch, 1996). However, most would agree it was the Harvard Fatigue Laboratory, established in the Business School at Harvard University, and the Physical Fitness Research Laboratory established in the Physical Education Department for Men at the University of Illinois, Urbana-Champaign that had the greatest impact on the emergence of exercise physiology as a discipline in the United States.

The Harvard Fatigue Laboratory, directed by Bruce Dill, Ph.D., attracted many of the great scientists of the early 20th century who were interested in exercise physiology research. During its 20 years of operation from 1927 to 1947 the laboratory is credited with more than 300 peer-reviewed research studies on topics related to work capacity and fatigue, cardiovascular and hemodynamic responses to exercise, oxygen uptake and substrate utilization, exercise recovery, and environmental stress on exercise performance (Horvath, 1973).

The Physical Fitness Research Laboratory was established in 1944 and directed by Dr. Thomas Cureton, Jr. and had as its research focus sports physiology, and the effect of exercise training on fitness, physical performance, and health. Early studies related to reducing plasma lipids also emanated from this laboratory (Berryman, 1996).

While both laboratories contributed significantly to our current understanding of how the body responds and adapts to acute and chronic exercise, and raised the public’s awareness of the benefits of exercise, their major contribution was in all likelihood the training of scientists who would later establish exercise physiology laboratories in physical education departments, science departments, and medical schools throughout the United States.

By the end of World War II, exercise physiology was an integral part of most college physical education curriculums, and as college enrollments increased with increased student funding the number of physical education programs increased in parallel. This resulted in an increase in exercise physiology course offerings and generated a need for exercise physiology textbooks.

Controversy surrounds identification of the first exercise physiology textbook. The French physician Fernand LaGrange published *Physiology of Bodily Exercise* in 1890. The contents included muscular work, fatigue, habituation to work, types of exercise and their effects (Berryman, 1995). However, it has been criticized by present day scholars for its unscholarly presentation and lack of comprehension of the subject matter (McArdle, Katch, & Katch, 1996). These same scholars regard *Exercise in Education and Medicine* by Dr. R. Tait McKenzie and published in 1910 as the first exercise physiology textbook. McKenzie intended his textbook to be for students of physical training, medical students, and teachers. Other early textbooks included *The Physiology of Muscular Exercise* by Bainbridge (1919), *Applied Exercise Physiology* by Lipovetz (1938), and *Physiology of Exercise* by Morehouse and Miller (1948).
By the 1960s there were several exercise physiology textbooks available. Some of the more popular were *Physiology of Muscular Activity* by Karpovich (1959), *Physiology of Muscular Activity and Exercise* by Mathews, Stacy, and Hoover (1964), and *Physiology of Exercise for Physical Education and Athletics* by DeVries (1966). In 1970, Astrand and Rodahl published their classic *Textbook of Work Physiology*, which was the first popular exercise physiology textbook for graduate study. Today a plethora of exercise physiology textbooks by notable exercise physiologists exist, and because of the immense increase in knowledge within the discipline of exercise physiology many exercise physiology sub-disciplines have emerged with textbooks written for these sub-disciplines. Examples include *Clinical Exercise Physiology* by Ehrman, Gordon, Visich and Ketevian; *Children’s Exercise Physiology* by Rowland; *Exercise Physiology for Health Professionals* by Bird; *Sport Exercise and Environmental Physiology* by Waterhouse, Reilly, et al., and *Molecular and Cellular Exercise Physiology* by Mooren.

Course Requirements

Although the information and knowledge base in exercise physiology has become very diverse and has increased in depth and scope, it is grounded in the fundamentals of biology and human physiology, and a basic understanding of anatomy and systems physiology should be prerequisites for an exercise physiology course. It is unlikely that one could gain a true appreciation for exercise physiology without understanding specifics such as the structure and function of skeletal muscle, the cardiac cycle and circulation, the endocrine system and its effect on metabolism, and the bioenergetics of the cell (see Figure 1).

The general applications of exercise physiology can be divided into four basic areas: (1) human performance, (2) fitness, (3) growth, development, and aging, and (4) prevention and rehabilitation from disease. Career goals and profession may dictate emphasis of study. Physical education teachers would most likely be concerned with growth and development and fitness. Coaches and personal trainers would be most concerned with human performance and fitness. Clinical exercise physiologists and health care professionals would be most concerned with prevention and rehabilitation from disease and fitness, and those individuals who would like to pursue a research career would benefit from an in-depth study of all areas. However, knowledge of the acute physiological responses and chronic adaptations to different exercise modes, intensities, and durations should be required of all professionals who use exercise in their practices. This includes the responses and adaptations to the cardiovascular, respiratory, nervous, and musculoskeletal systems and the bioenergetics involved. An appreciation for the influence of environment and nutrition on the acute and chronic effects of exercise should also be encouraged.

The basic goal of a general exercise physiology course should be to develop the student’s understanding of how the physiological systems involved in physical activity respond to a single bout of exercise, and how various modes of exercise training and environmental conditions can modify these systems and their response to physical stress. The course should also develop the student’s ability to apply this knowledge for improving exercise performance, fitness and health and related issues.
Course objectives should include the following:

*To understand:*

1. the basics of the cellular energy systems and how they influence performance;
2. how the energy systems adapt to various exercise training programs;
3. key aspects of the neuromuscular system;
4. the role of skeletal muscle and motor units in the control of movement;
5. how hormones impact exercise metabolism, substrate utilization, and performance;
6. the functioning of the heart and circulatory system during acute exercise and how it adapts to exercise training;
7. the functioning of the cardio-respiratory system and oxygen transport during exercise;
8. the basic aspects of thermoregulation and the impact of various environmental conditions;
9. the basic principles of exercise training and how to use them in designing exercise training programs for fitness and athletic performance;
10. the general causes of fatigue for various exercise modes and intensities;
11. the basic physiological differences between males and females that might impact exercise performance;
12. the impact of nutrition on exercise performance and recovery;
13. the impact of ergogenic aids on exercise performance and have an appreciation for the ethical use of such aids;
14. the influence of exercise training on body composition and weight; and
15. the health benefits of exercise throughout the life span.

In addition, students should acquire an appreciation for the discipline of exercise physiology by introducing them to a brief history of its evolution.

**Topics to be discussed to meet the course objectives:**
1. history of exercise physiology;
2. metabolism and basic energy systems;
3. anatomy and function of the neuromuscular system;
4. neuromuscular adaptations to exercise training;
5. hormonal response and regulation during exercise;
6. cardiovascular response, control, and adaptation to exercise;
7. respiratory exercise mechanics and regulation during exercise;
8. oxygen transport;
9. thermoregulation and the environment;
10. physiology of performance;
11. nutrition, ergogenic aids, and performance; and
12. physiology of health and fitness.

**Exercise Physiology Laboratory Topics**

As discussed earlier, the history of exercise physiology is grounded in the laboratory experience. What is known about the body’s response to acute exercise and adaptation to chronic exercise training has developed from countless laboratory experiments. For the kinesiology student, a laboratory experience is essential for a clear understanding of basic exercise physiology principles used in the evaluation of fitness, performance, and health. The laboratory experience should provide the student with the opportunity to become familiar with the equipment and methodologies related to physiological assessment. It should help the student develop basic skills and competencies in physiological assessment in the laboratory and with field tests. It should help the student become knowledgeable in data analyses and interpretation.

**Exercise physiology laboratory sessions should include:**
1. ergometry — measurement of work and power;
2. circulatory adjustments to exercise — heart rate and blood pressure responses at rest and exercise;
3. pulmonary function — measurement of lung volumes and capacities;
4. maximal aerobic power ($\text{VO}_2\text{max}$) — assessed by indirect calorimetry;
5. maximal aerobic power — assessed by field tests;
6. maximal aerobic power — assessed by submaximal laboratory tests;
7. exercise efficiency and substrate utilization — indirect calorimetry;
8. anaerobic power and capacity — e.g., vertical jump and Wingate test;
9. anaerobic threshold — ventilatory response to graded exercise (relationship to lactate threshold);
10. muscle function — measurements of muscle strength, endurance, and power;
11. body composition analyses—body density assessment, impedance, and skinfolds; and
12. body temperature regulation—changes in skin and core temperature and fluid balance with exercise.

Conclusion

The above recommendations are for the kinesiology major, and health care professionals who prescribe and work with exercise programs in a clinical setting. Courses can and should be developed that provide an appreciation for the benefits of exercise and the principles of exercise training. Courses should also be developed that emphasize various aspects of exercise physiology that support practitioners who teach, work in the fitness industry, coach, consult in sports nutrition, etc. However, such courses should not be substituted for an exercise physiology course that is grounded in basic human physiology and provides a laboratory experience.

References