Applied Exercise Physiology: A Personal Perspective of the Past, Present, and Future

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Editor's Note: To commemorate a year of celebration for its 50th Annual Meeting in May 2003 and its 50th anniversary as an organization in 2004, the American College of Sports Medicine and Exercise and Sport Sciences Reviews is pleased to publish personal historical perspectives from leading sports medicine and exercise science professionals. This article is one in a series of articles based on the impact ACSM and ESSR has had on the fields and disciplines covered in this journal.

During the past 50 yrs, since the founding of the American College of Sports Medicine in 1954, our understanding of how the body responds physiologically to a single bout of exercise and adapts to the chronic stress of exercise training has increased dramatically. This knowledge explosion has resulted from both technological advances and an increase in the number and quality of exercise scientists. Technological advances are discussed below. The increase in exercise scientists is best indicated by the fact that there were fewer than 100 members in the ACSM during its first 2 yrs of existence, whereas today's membership exceeds 20,000. Not all of today's members are exercise scientists, but that has been true since the beginning. Further, the quality of graduate education has been exceptional, with many mentors interested in the personal and professional development of their students.

Technological advances have been extraordinary. This is demonstrated clearly by the following examples: measuring oxygen uptake during exercise, and data analyses and manuscript preparation. In the 1950s, exercise oxygen uptake was measured while either walking, jogging or running on a treadmill, or pedaling a cycle ergometer. To conduct a single graded maximal test of 12 to 15 min required the assistance of approximately four technicians and up to 4 h for the collection of the raw data necessary to calculate oxygen uptake. Expired air was generally used while analyzing the exercise response. Up to the 1950s, only a few exercise physiologists were actively engaged in studying world-class athletes in an attempt to better understand the physiological determinants of elite sprint and endurance performances. Notable in this respect were Sid Robinson, Ph.D., at Indiana University, a former colleague of David Bruce Dill, Ph.D., at the Harvard Fatigue Laboratory, and Thomas Cureton, Ph.D., at the University of Illinois. Dr. Cureton's classic monograph, Physical Fitness of Champion Athletes, published in 1951, stimulated considerable interest among exercise physiologists in profiling elite athletes. Albert R. Behnke, M.D., physician and Captain in the U.S. Navy, who pioneered the development of body
composition assessment, was one of the first to study elite athletes with his 1942 article in the Journal of the American Medical Association (with W.C. Welham) on the body composition of the Washington Redskins professional football team.

Early research focused on somatotype, weight, general motor fitness and strength, flexibility, heart size (by radiography), ECG, brachial pulse wave, breath holding, and maximal oxygen uptake and oxygen debt. In the 1960s, Jonas Bergstrom, M.D., Ph.D., reintroduced the muscle biopsy technique, with an application to histologic and biochemical studies in exercise physiology. This allowed physiologists to understand better the concept of fiber types and led to the fiber typing of elite athletes in a variety of sports. Not surprisingly, we learned that sprint-type athletes have a predominance of fast twitch fibers, whereas endurance-type athletes have a predominance of slow twitch fibers. Early studies in the 1970s suggested that fiber type did not change with training; thus, it was considered to be genetically established. However, more recent studies in the late 1990s and early 2000s, suggest that training can alter fiber type, but to a relatively small degree.

The muscle biopsy technique also allowed scientists to obtain a much better understanding of muscle metabolism and how best to fuel muscle for competition. This opened up the area of sports nutrition and helped us understand the relative importance of fat and carbohydrate as primary energy sources during exercise of varying intensity. Although the energy available in fat stores is considerable, we learned that carbohydrate stores are limited, but can be increased through endurance training and dietary manipulation (e.g., carbohydrate loading). Because carbohydrate is the primary energy source for high intensity aerobic activity, considerable research subsequently has been conducted and continues to be conducted today on how to best restore and enhance carbohydrate stores after high-intensity training and competition.

In a related area, back in the 1950s, water was generally not allowed on the field during practice or actual competition. Towels were kept in buckets of water, and athletes were allowed to suck on these towels during breaks in practice or competition. A number of heat-related deaths occurred, particularly in high school football players during the months of August and September. In the early 1960s, water was finally allowed on the field, but this was not accepted by all coaches and trainers. In 1965, University of Florida scientists developed the formulation for what we now know as “Gatorade,” introduced as the first major commercial sports drink in 1967. This precipitated considerable research among exercise physiologists, either trying to disprove or prove the efficacy of a sports drink. After more than 35 yrs of research, we now know that water is good, but a sports drink may be better for many situations. We also have learned that too much water can be a serious health risk (hyponatremia).

Finally, the area of sport physiology was forced to deal with issues specifically associated with the sudden emergence of girls and women in sport in the 1970s. In the 1950s and 1960s, few girls and women participated in sport or in recreational activity. The Civil Rights Act of 1964 prohibited job discrimination on the basis of gender. In 1972, the Women’s Equal Rights Amendment, although never ratified, increased awareness of women’s rights under the law. Most significantly, the U.S. Education Amendment (Title IX) passed in 1972 forbade gender discrimination in any institution receiving federal funds. By the mid-1970s, many more girls and women were exercising and competing in sport. Unfortunately, few data were available on the capabilities of girls and women. Many in the medical and scientific community were concerned about the possible risks associated with their participation in high-intensity activity. Although this might sound medieval, it was certainly true at this period in time, as evidenced by the fact that women were not allowed to run in marathons and girls’ basketball was confined to a half-court game, that is, a girl could only play offense or defense, but not both. Girls and women were not allowed to participate in the long jump or triple jump for fear of damage to the uterus!

How times have changed! Girls and women are now actively engaged in almost every form of activity and competition and are performing remarkably well. There are increased risks, such as an apparent greater susceptibility to significant knee injuries, but these generally can be controlled. In the 1970s, the medical and scientific community became aware of the fact that a significant number of women athletes had become amenorrheic. For many years, the cause was unclear, but in the 1980s we learned that secondary amenorrhea was associated with bone mineral disorders. In the 1990s, the Female Athlete Triad was discovered, linking disordered eating to secondary amenorrhea, and secondary amenorrhea to bone mineral disorders. Further research has demonstrated clearly that a prolonged period of energy deficit (caloric intake < caloric expenditure) is the trigger for this triad.

**INDIVIDUAL RESPONSES TO TRAINING**

This last section discusses one of the most significant research findings in the applied exercise physiology area over the past 30 yrs. Many exercise physiologists have conducted training studies, obtaining pretraining and posttraining values for key physiological variables, allowing us to understand better the sequence of changes that occur to improve performance. Continuing the example of VO$_2$ used in the opening paragraphs, changes in VO$_2$max consequent to aerobic endurance training have been the most widely accepted marker of change in aerobic capacity. For years, researchers reported the mean (= the SD or SE) pretraining and posttraining values for VO$_2$max and the mean change in VO$_2$max after training. In the late 1980s, several researchers started looking critically at the individual subject responses and found considerable variability in the changes in VO$_2$max resulting from an identical training stimulus. Reported percentage improvements in VO$_2$max ranged from 0% to 50% or higher after up to 1 yr of training, indicating some people are highly responsive to aerobic training and others demonstrate little or no response. It should be noted that these data come from highly controlled studies where multiple measures of VO$_2$max were obtained both before and after training and where each exercise session was monitored carefully by exercise technicians and computers.

How can this be? It has been determined recently that heritability accounts for up to 50% or more of a person’s VO$_2$max. Further, the maximal heritability estimate of the VO$_2$max response to training is nearly 50%. Scientists are now exploring potential genes that control this response to training. This likely will take many years, considering all of the physiological variables that contribute to the determination of VO$_2$max. Therein lies the challenge for the future! Most of us who entered exercise physiology in the 1950s and 1960s came out of physical education backgrounds, and our competitive nature helped to compensate for our lack of knowledge and understanding in the basic sciences, allowing us to move the field forward. Today, many of our best scientists have been trained in physiology, biochemistry, molecular biology, and related disciplines, and their students are being trained by the best. The table has been set—now go feast!