Editorial

Exercise physiology: From performance studies to muscle physiology and cardiovascular adaptations

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The passing of Professor Bengt Saltin on September 12, 2014 truly marks the end of an era. As editor of the Journal of Applied Physiology and one of Bengt’s many collaborators and colleagues, I wanted the Journal to celebrate his many seminal contributions by means of an Editorial. Professor Bente Kiens, who is both a colleague of Bengt’s and a Consulting Editor for the Journal, was asked to write it. Thanks to Bente and her colleagues for the impossible task of distilling an enormous body of work into about 1,000 words.

—Peter Wagner, Editor

WITH THE DEATH OF Professor Bengt Saltin on the 12th of September, 2014, one of exercise physiology’s giants has left us. During his long career, Bengt published 446 papers and alone in 2014 he published 7 papers. His H-index of 99 is one of the highest in exercise physiology. His scientific influence in the field has been tremendous. His main interest was the study of cardiovascular and metabolic systems during exercise, the adaptations to training, and later on the health effects of exercise. This editorial is offered as a brief portrait celebrating his main scientific contributions. As such, it is necessarily incomplete, but it serves to underscore, and pay tribute to, his huge influence in the science of exercise physiology and biochemistry.

Bengt Saltin was trained as a medical doctor at the Karolinska Institute in Stockholm, Sweden, where his early work was performed and where he became professor in 1968. Together with Jonas Hultman, who had introduced the muscle biopsy technique, Bengt Saltin published his most cited paper (1,116 citations) in 1966 describing the influence of diet composition on muscle glycogen concentration and furthermore the importance of muscle glycogen for endurance during exercise (2). A subsequent large series of experiments provided much of the foundation for the textbook knowledge of muscle glycogen use at various exercise intensities, fiber type differences, and muscle metabolism during various sport activities.

One of his many seminal studies was the 1966 Dallas Bed Rest and Training Study (6), in which Bengt, together with Jere Mitchell submitted five 20-yr-old men to 3 wk of bed rest and 8 wk of subsequent heavy endurance training and were the first to describe the profound detrimental effects of inactivity on cardiovascular performance. Fortunately, 8 wk of heavy exercise training reversed the detrimental effects. Re-evaluation of the same subjects 30 and 40 years later revealed that the average decline in cardiovascular performance by 3 wk of bed rest in 20-yr-old men was the same as the subjects displayed by 30 years of aging.

Although a Swede, most of Bengt’s career was spent in Denmark. In 1973 he was appointed professor at the August Krogh Institute at the University of Copenhagen in Denmark. Here he followed in the footsteps of the “three musketeers”: Professor Erling Asmussen, Erik Hohwü-Christensen, and Marius Nielsen, as professor August Krogh referred to them. Bengt took upon himself to further develop the Copenhagen research traditions, building a vibrant research community and conducting seminal experiments in metabolism and circulation in collaboration with a large number of international guest researchers. Bengt wanted to create an exercise model in which blood flow and metabolism in a defined muscle mass could be measured during exercise. The result was the one-legged knee-extensor model, which is still used in Copenhagen and has been copied in many other laboratories. Because only the quadriceps femoris muscle, which in most young adults weighs ∼2.5 kg, is engaged during leg kicking, the maximal blood flow to the working muscle in this model is not limited by the pump capacity of the heart. The quadriceps muscle is also a muscle that lends itself to muscle biopsies, and cannulation of the femoral artery and vein together with blood flow measurements allows the quantification of substrate exchange across the thigh. Among Bengt’s many findings was that the maximal blood flow per kilogram active muscle mass was significantly larger than previously thought possible (1, 5) but also that when additional muscle groups were involved in the work, the competing demand for blood flow led to a reduction of flow due to increased sympathetic outflow (8). His interest in the molecular mechanisms involved in control of exercise-induced vasodilatation in muscle was one he followed for many years and kept working on until his death. The knee-extensor model was also used in metabolic studies to study training adaptations in muscle and how these influenced muscle metabolism and blood flow during exercise (3).

A highlight of Bengt’s career came when he was appointed director of the Copenhagen Muscle Research Center (1994–2004) supported by the Danish National Research Foundation. The Copenhagen Muscle Research Centre integrated the various muscle research groups in Copenhagen into a forceful center, which boosted Danish muscle and exercise science by inclusion of additional methods like microdialysis, cell culture work, stable isotopes for metabolic measurements, and molecular biology. Furthermore, because of Bengt’s leadership by ways of encouragement rather than dictatorship, the center provided means that made it possible for the next generation of exercise and muscle physiologists to develop their own research profile.

Bengt Saltin’s research interests were broad. In addition to basic cardiovascular and muscle physiology, he was also interested in the physiological effects of acute and chronic hypoxia and he explored this topic with expeditions to the Himalaya and the Andes mountains. One of his interests was to study the so-called lactate paradox, by which is meant that...
adaptation to chronic hypoxia leads to lower plasma lactate concentrations during exercise compared with exposure to acute hypoxia, despite persistent arterial hypoxemia. As it turned out, his studies showed that the lactate paradox was a transient phenomenon (4), findings that created an international debate.

Like many others in the field of exercise physiology, Bengt’s focus over the years changed from performance-related studies to health effects of physical activity. He was one of the first to report the beneficial effects of exercise training in type 2 diabetes (7). Later on he was primarily interested in the cardiovascular adaptation to chronic heart disease and particularly how a limited cardiac reserve impinged on leg blood flow during exercise and how training of the leg muscles could improve leg perfusion. He also studied cardiovascular regulation in hypertension and the effect of exercise.

Bengt Saltin had an enormous energy and drive to understand the physiological processes during exercise. His influence has been paramount not only in Scandinavia but in the global scientific community. Always active, always engaged in science, and always willing to help others progress in science, we have lost an outstanding scientist, good friend, and inspirational leader.

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