

Where's The Beef? Commentary on Seiler's *History of Endurance Testing in Athletes*

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For those of you too young to remember, a [popular commercial](#) for Wendy's hamburger sandwich used to challenge McDonald's Big Mac by repeatedly asking the question, "Where's the beef?" to reinforce Wendy's advantage over the Big Mac. In Seiler's *History of Endurance Testing in Athletes*, I posit that his treatment about the history of endurance assessment suffers from deficiencies in both scope and depth. He certainly is entitled to his limited view of things, but in my view his selection of materials to justify the importance of certain events and research makes his treatment short-sighted and limited. The interested reader can consult numerous sources about the history of the exercise sciences and draw their own conclusions about the development of endurance testing and about those individuals who opened up the area for research inquiry.^{5,6,9,16} The depth of the existing knowledge base over the last two centuries has been adequately chronicled, for example, by Tipton,^{34,35} Buskirk,^{5,6} Berryman,^{3,4} and an exercise physiology textbook²⁶ that cite hundreds of references to earlier contributions.

Researchers over the past 120 years have devoted their careers to study aspects of endurance performance testing. Seiler, unfortunately, ignores the most salient ones. The roots of more modern endurance testing began in the early part of the prior century when Dr George Wells Fitz, MD (1860-1934) at Harvard in the 1890s established a "fitness lab" as part of a coordinated effort with the medical school to offer educational training in various aspects concerned with physical fitness. The scholars of that era, including renowned physicians and physiologists Byford, Bowditch, Dougliston, Hartwell, Howell, Kolb, Flint, Lee, Lusk, and Sewell to name a few (each with amazing records of achievement in science even by today's standards), incorporated components of

"fitness" into how they studied human physiology. Those scientists provided the framework about the connections between physiology and exercise. Many of their works included specific "workouts" and recommendations for sporting events including long distance walking and running, rowing, and strength and endurance tasks. And this was long before the VO_2max test was devised (considered by some contemporary exercise physiologists as the "gold standard" measure of cardiovascular fitness or endurance performance, although, I am not in that camp).

The graduates from the Department of Anatomy, Physiology, and Physical Training in the medical school at Harvard at the turn of the 20th century (armed with new knowledge about testing techniques in muscular strength and fitness including the assessment of endurance), eventually became heads of departments and deans in many schools and colleges of physical education in the United States in the early 1920s to 1940s. In the time span 1870 to 1900, father and son Drs Edward Hitchcock and Edward Hitchcock, Jr (both classically trained MDs) established a "state of the art" physical fitness lab at Amherst College during 1885-1900.²⁶ Even before creating the fitness lab, the father and son team penned an 1860 textbook/lab book with ample information about muscle, fitness, and heart and lung function (*Elementary Anatomy and Physiology for Colleges, Academies, and Other Schools*²⁶). Dr Edward Hitchcock, Jr determined the effects of endurance training on muscular function from the requirement that all students at Amherst College participate in strengthening and endurance activities. The lab included dynamometers and lung function equipment to measure "endurance" of muscle and lungs—after it became apparent following the Civil War that many soldiers were in such poor "physical shape"

they could not perform relatively simple but arduous tasks related to long-duration (endurance) marching and warfare. Interestingly, the same had been true during the ancient Greek and Roman military conquests and physical competitions (circa 300-500 BCE) as they prepared to acquire new territories—thus creating new systems of exercise and endurance training to get their legions into the best physical shape to meet their expansion crusades.

Physicians, physiologists, physical culturists, and health and fitness leaders in England, Europe, and the United States following World War One also took up the quest to discover new knowledge about the effects of arduous physical training on bodily functions. In the United States, for example, new research labs were established in many departments of physical education. The leaders of those departments took their academic training in specialized academic units that offered course work and study in the emerging discipline concerned with the physiology of exercise. In fact, one prolific researcher—Dr Thomas Cureton (1901-1993) at the University of Illinois whom Seiler fails to acknowledge—should be called the “father of modern endurance fitness testing.”⁹ His novel contributions to physical fitness testing, particularly endurance tests of performance, would simply amaze the younger generation of exercise physiologists (including those who specialize in physical activity monitoring, motor control, biomechanics, and exercise biochemistry), who probably never have heard of Cureton or his numerous accomplishments in the area of fitness testing. His compilation of years of human exercise and performance research, *Endurance of Young Men* published in 1945, chronicles the results of literally hundreds of laboratory experiments on world-class athletes who ran to exhaustion during an “all-out” run on a treadmill at a constant 7% grade. The purpose of this testing was to develop norms for endurance performance related to maximal oxygen consumption ($VO_2\text{max}$) and other physiological and performance parameters. Other laboratories already in existence in Germany, Italy, South Africa, Russia, and Japan also were studying the multifaceted aspects of fitness and endurance performance. Seiler’s presentation all but dismisses the voluminous body of published research in this area by an international group of researchers who were

advancing new knowledge about endurance and physiology. Many of those scholars from around the world, including Cureton, participated in an invited meeting in Cologne about endurance performance and work capacity several weeks prior to the 1972 Munich Olympics. The edited text by Leonard Larson, *Fitness, Health, and Work Capacity: International Standards for Assessment*,²⁵ represented a unique collection of papers by a respected group of scientists whose contributions remain a rich source of information about physical fitness, endurance, and exercise capacity.

Franklin Henry, a psychologist by training at the University of California Berkeley, who joined the Men’s Department of Physical Education, had been influenced in his research by the classic experiments of physiologist AV Hill (eventual 1944 Nobel Prize winner for studies in muscle physiology) and colleagues in England who were interested in how best to quantify maximal physiologic responses to exercise.²⁹ Hill, a sprint runner, was particularly keen on discovering why some athletes were exceptional in certain events while others withered in competition. In the time period 1940-1960, the results of many studies in the physiological literature became part of the undergraduate and graduate programs in the physical education curriculum at Berkeley. Master and doctoral students (this writer included along with my brother Victor) in the late 1960s explored the topic of intense endurance performance. Studies were subsequently published in the *Research Quarterly*,^{18,21-24} *Medicine and Science in Sports*,¹⁹ and *Ergonomics*¹⁷ (including numerous abstracts and talks presented at national physical education and sports science conferences). Henry and his doctoral students were trying to understand individual differences in endurance performance, as were on-going studies at the Universities of Oregon, Springfield College, Wisconsin, Illinois, Indiana, Michigan, Maryland, San Diego State, Penn State and Florida State Universities, to name a few.

In my opening, I used the terms short sighted and limited because of Seiler’s lack of basic familiarity with the prior mentioned contributions regarding assessment of endurance performance. In addition, environmental physiology laboratories were flourishing in the United States and Europe. These were founded by

mentors from the famous Harvard Fatigue Laboratory^{10,15} (that Seiler does acknowledge) who recruited scholars from around the world to study the physiological effects of exercise (including many endurance tasks) on human responses to heat, cold, altered nutritional states, metabolic “waste products,” and other factors.

One can study the effects of exercise on many aspects of physiology, and also the purer aspects of endurance performance *per se*. For example, by cycling on a Monark ergometer at a constant pedal rate of 60, 70, or 90 rpm at a “demanding” frictional resistance of 4 to 5 kp for 8 to 12 minutes duration, Henry and his students in the early 70s developed a model of endurance performance based on power output decrement during the performance. These studies determined the key parameters of optimal test duration, pedal rate, and frictional resistance.^{17,18,21} The work performed by the subject during each time increment (rpm x frictional resistance) was essentially identical to the integral or area under the minute-by-minute work decrement curve. For an individual with 100% endurance, for example, there would be no decrement in minute-by-minute pedal revolutions. If the exercise power output during the 10 minute performance was 4 kp at 70 rpm (wheel circumference 6 m), then during each minute subjects would have performed $24 \times 70 = 1680$ kpm or 16,800 kpm in 10 minutes, the equivalent of 100% endurance. For individuals unable to maintain the required power output, their endurance score also would be the summation of the minute-by-minute scores, but the total over 10 minutes would be less depending on their inability to sustain the constant power output established at the start of the performance. Based on those experiments, a typical individual achieves an endurance score of approximately 70% (that is, drop-off of 30% from the initial rate they were to sustain during the test). Only about 10% of subjects perform the endurance performance tasks without decrement. Those individuals would correspond to “top” athletes in a given sport, particularly events of short and longer-term endurance such as 400-m and 1500-m events. Oxygen consumption and blood lactate measured simultaneously during exercise showed the contribution of oxygen uptake capacity during the performance in relation to an external criterion

such as an independently measured VO_2max test or anaerobic threshold (AT) assessment measured separately (e.g. a Wingate or variation of the Wingate test). Measuring each subject at least twice on the endurance test (whether a step-up test at a constant stepping rate, or a cycle ergometer ride or run at a constant starting pace), would determine individual differences in endurance related to the physiological measurement. In effect the question becomes, “Does the endurance score relate to the externally measured physiological measurements?” Stated somewhat differently, does the VO_2max or AT (or any other physiological criterion) correlate with endurance or some fraction of the exercise performance? Seiler does not acknowledge this alternative model of how to assess endurance despite ample evidence about its existence.

Henry and his students were interested in discovering the underlying “facts” about endurance performance and how the performance influences physiologic responses. In contrast, the typical physiologist would be more interested in exploring the underlying physiological mechanisms while using an exercise performance test simply to produce the stressor. In contrast, the physical education approach would be to study endurance and then use physiology to explain the individual differences aspect. This approach to endurance measurement, as Henry argued, was the primary domain of the physical educator (or exercise scientist or kinesiologist), and not the primary interest domain of a biochemist or physiologist. The “beef” in this context would be the “facts” discovered about the essentials of the endurance performance task, not the underlying physiological mechanisms. The conflict comes when physical educators abandon their main mission of trying to understand performance and pursues the domain of the physiologist, biochemist, or molecular biologist. Unfortunately, contemporary exercise physiologists want to jump in and use the latest “gizmos” in order to learn something about the athlete’s physiological responses (but not really the “beef” about the endurance task). But I remind the reader that this approach is not a substitute for a defensible measure of endurance performance. Hoping to “help the athlete’s performance” does not provide the “beef” for a better understanding about the underlying characteristics of endurance performance. I would

argue that contemporary sport scientists would benefit greatly by first focusing on the performance to discover as much as possible about what factors explain individual differences in such endurance endeavors. Oxygen analyzers and blood lactate monitors and fancy computer programs are not needed to gather such information. If the researcher wishes to administer a performance test, what choices are available? The Cooper Test? A track run? A situp test? A shuttle run? My hunch is that most exercise physiologists would turn to a variant of the classic "VO₂max test (on a treadmill, cycle, step test, swim, run) to assess "endurance." Does that mean that the VO₂max test can substitute as a measure of endurance performance? Do individuals with a high VO₂max have the most "endurance" on a physical task?

We know that the 12-minute walk-run test promoted by Cooper⁸ (with a correlation he reported of $r=0.90$ between distance run and VO₂max) was an artificially inflated correlation due to the large range of body weights (52 to 123 kg) and ages (17 to 54 y) in his sample of 47 male subjects. Redoing the statistics from that study saw $r=0.90$ decline to only $r=0.30$ when the confounding effects of body weight and age variability were properly accounted for! The conclusions about what is measured from a test with a relationship of $r=0.90$ and $r=0.30$ are indeed quite different!

A statistician might call Cooper's $r=0.90$ a spurious correlation, and would not at all be impressed that this result represented evidence of endurance as Cooper and unfortunately others had legions of researchers believe. I ask: "Would you administer an endurance test if you knew its validity with VO₂max was only $r=0.30$ (less than 10% common variance explained)? Of course you would not (or should not). Individuals with high VO₂max do not "automatically" have the best endurance. I would argue that researchers should go back to the drawing board and study endurance performance per se, and not just use some surrogate physiological measure as a substitute for an endurance criterion as Seiler seems to imply.

The thrust of my commentary is that Seiler did not properly focus on the contributions of the early fitness and physical education researchers who tried to advance the field by quantifying endurance performance and its underlying correlates. There were numerous

splendid contributions from researchers around the world he could have acknowledged (e.g., in England, Scotland, Italy, Germany, South Africa, Japan, Russia, and yes the insightful contributions from Nordic scientists he did mention²). Seiler has focused on typical measurements in "high level" sportsmen rather than the substantial body of knowledge about endurance measurement that the early pioneers pioneered. I also was puzzled why Seiler singled out David Costill as a true pioneer in endurance performance testing. This is not meant in any way whatsoever as a criticism of Costill, whom we feature in our text as one of the leaders in exercise physiology in the area of muscle physiology and exercise metabolism.²⁶ A careful review of Costill's numerous contributions to the field would not warrant listing him as *the* key person in the development of endurance performance testing.

In total, I found Seiler's treatment of the topic of the history of endurance performance devoid of "beef." It is particularly worrisome that the new breed of specialists in the exercise sciences will have little to go on except what Seiler proposes about the history makers of endurance performance testing. In essence, a whole generation of exercise scientists will not know about the early pioneers and their insightful contributions; instead, they will rely on Seiler's treatment as the true state of affairs about the history of endurance testing. One of my major objections is that his incomplete presentation fails far short in this area.

Seiler's view focuses on high-level performers, gizmos of technology, and what the sport scientist apparently can offer to help top athletes perform optimally. I have no problem with that orientation—I just wish Seiler had provided a balanced overview of the history aspects in the development of endurance measurement, and acknowledge those from throughout the world who devoted their careers to advancing our field in this arena. Measuring a relatively few athletes in the laboratory or in the field does not provide a firm understanding about individual differences in endurance performance. One must not confuse VO₂max as a measure of endurance or as a performance test in a pool or on a track without first establishing a defensible criterion of endurance performance. That kind of an endurance scenario requires a new set of parameters waiting to be

discovered (i.e., optimal test characteristics for pacing, duration, load for various performance tasks), just as Cureton,⁹ Henry,^{12,13,29} and others^{1,7,11,14,15,17-24} did in their own discoveries over three to four decades ago!

Professor Robert Park, an accomplished historian, has written extensively about the scholarly contributions of the early fitness and endurance researchers,²⁷⁻³³ and I suspect Tipton^{34,35} and Berryman^{3,4} and Buskirk^{5,6} in their excellent treatments of the topic area might agree with me that the “beef” has been out there for quite some time for all to see and should have been acknowledged.

Postscript. I was invited to present a brief history of endurance performance assessment at the Norwegian sports medicine congress in 2010. Unfortunately, my wife injured her back in a horseback riding accident and I had to cancel the trip. I did my best to provide Professor Seiler with considerable materials about my presentation, which he and I were going to coauthor, with him delivering the presentation. He had the difficult task of taking over for me (with only about six weeks to prepare for the talk), and for that I was very grateful. However, he decided to change the intent and thrust of the talk. I was OK with that, but I was steadfastly opposed to how he changed the thrust of what I would have presented, which I didn't see until months later after Will Hopkins sent me to review what Seiler had submitted for publication in *Sportscience*. My surprise and objection led to an invitation from Will Hopkins to submit a rebuttal to Seiler's presentation. My motivation was to preserve the robust history and give credit to the many scientific contributions from the early American, European, and South African physical education and exercise physiology labs where much of the early work regarding endurance performance assessment was undertaken.

In addition, I had prepared a tribute to many of the pioneers involved in endurance performance assessment fashioned after Apple Computer's [Think Different video](#). I thought this would be a fitting conclusion to the lecture to pay homage to those early pioneers who did "think different" by ignoring the status quo by pushing the science of endurance performance forward. In their own way, they changed the academic world of the emerging discipline of exercise science. The video tribute, which I

would have presented at the end of the talk, was not shown because of time constraints, and, I presume, because Seiler's presentation did not feature many of the scientists and their contributions that I would have included. You can view the video via [this link](#).

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