HIGHLIGHTED TOPIC | Mechanisms and Modulators of Temperature Regulation

Mechanisms and modulators of temperature regulation

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Humans have the capacity to regulate internal temperature within a narrow range despite large variations in ambient temperature and metabolic heat generation. Internal temperature increases of as little as 3°C can lead to thermal-related injuries and even death. In its simplest sense, thermoregulation is the balance between heat generation (or accumulation) and heat dissipation. If heat generation/accumulation exceeds heat dissipation, internal temperature will rise. Conversely, if heat loss (or dissipation) exceeds heat generation, internal temperature will fall. Non-thermal factors (such as blood pressure, fluid balance, age, disease, etc.) can impact the body’s ability to respond to a thermal perturbation.

The Journal of Applied Physiology has played a pivotal role in disseminating seminal thermoregulation research, beginning with its first issue published in 1948, where articles were devoted to reflex sweating (14), the effects of temperature on peripheral circulation (1, 11), and both tropical and arctic related experiments conducted on humans and other mammals (7, 9). From these early experiments, notable studies in subsequent years developed our knowledge of the neural circuitry, autonomic effectors, and behavioral aspects of thermoregulation as well as the direct and compensatory changes that occur in the circulatory, digestive, endocrine, immune, integumentary, muscular, nervous, respiratory, and urinary systems. These previous, primarily systems-based studies, describe many of the thermoregulatory questions that are still investigated today. Newer research tools and mechanistic in vivo preparations are also taking the field in new directions as well as addressing important clinical aspects related to thermoregulation.

The objective of this Highlighted Topic series is to present relatively new findings that focus on the mechanisms and modulators of temperature regulation. An emphasis has been placed primarily on human temperature regulation, although we want to acknowledge the substantial contribution from investigators who perform animal studies that have greatly improved our understanding of thermoregulation. Given the limited scope of the Highlighted Topic series, the following three components or themes are emphasized: 1) mechanisms of cutaneous vasodilation and vasoconstriction; 2) alterations in temperature regulation by injury, disease states, and aging; and 3) physiological responses to extreme heat stress. This is by no means a comprehensive list, and we certainly appreciate that there are numerous investigators who perform superb research in areas that are not directly covered within this series.

The first set of papers in the October issue focuses on mechanisms of cutaneous vasodilation and vasoconstriction. Although evaporation of sweat is critical for human thermoregulation, given the fact that several reviews have recently been published on this topic (13, 15, 16), research pertaining to sweating responses was not included in this portion of the series. This section begins with an article by Dr. Minson, who presents a paper entitled “Thermal provocation to evaluate microvascular reactivity in human skin” (12). Herein he addresses mounting evidence that the skin may be used as a window to evaluate microvascular function in both healthy and diseased states. Given the ease and accessibility to evaluate cutaneous vascular responses, confirmation that the skin provides an index of microvascular health could lead to major advancements in the diagnosis of microvascular disease progression. That paper is followed by an article by Dr. Charkoudian entitled “Mechanisms and modifiers of reflex induced cutaneous vasodilation and vasoconstriction in humans” (2). Reflex cutaneous vasodilation and constriction is defined as cutaneous vasomotor responses that are driven primarily by the integration of internal and skin temperatures not at the site of cutaneous evaluation and therefore involve neural reflexes. This is in contrast to the next paper by Drs. Johnson and Kellogg entitled “Local thermal control of the human cutaneous circulation” (8), in which novel mechanisms by which the skin constricts and dilates to local thermal provocations are presented.

The second set of papers in the November issue focuses on a few specific conditions that may adversely affect cutaneous heat dissipation and conservation, leading to increased risks of thermal injury. This section begins with a review by Drs. Holowatz and Kenney entitled “Peripheral mechanisms of thermoregulatory control of skin blood flow in aged humans” (6). Therein they review the consequences of aging with respect to altered control of the cutaneous vasculature, covering the spectrum from the nerves responsible for cutaneous vasoconstriction and dilatation to second messenger systems that have the potential of altering cutaneous vasomotor function in this population. The next paper
by Drs. Davis, Wilson, White, and Frohman entitled “Thermoregulation in multiple sclerosis” (5) discusses the debilitating effects heat exposure has on those who suffer from multiple sclerosis, while addressing mechanisms that may predispose these individuals to compromised temperature regulation. The final paper in this section, presented by Drs. Crandall and Davis, is entitled “Cutaneous vascular and sudomotor responses in human skin grafts” (4). These investigators present data, and associated mechanisms, pertaining to the consequences of skin grafts on cutaneous vascular and sudomotor function, leading to a greater risk of heat-related injuries in patients with a large fraction of their body surface area covered with grafted skin.

The final two papers in the December issue focus on the physiological responses of extreme heat stress. Within that context, Drs. Cheuvront, Kenefick, Montain, and Sawka address in their paper entitled “Mechanisms of aerobic performance impairment with heat stress and dehydration” (3) the consequences, and associated mechanisms, of extreme heat stress with and without dehydration from a work/exercise performance perspective. The final paper in this set by Drs. Leon and Helwig entitled “Heat stroke: role of the systemic inflammatory response” (10) address physiological responses associated with heat stroke that are likely responsible for the ~200 heat-related deaths that occur each year within the United States.

We thank the Journal of Applied Physiology for providing a forum for this Highlighted Topic series, as well as thank the contributing authors for their time and dedication not only in the writing of the presented review articles, but also for important research that they perform. We hope that the reader enjoys these articles and will gain insight into the complexities of temperature regulation that will spur new research into this fascinating area of study.

REFERENCES