Understanding Fever and Body Temperature

A Cross-disciplinary Approach to Clinical Practice

Edited by
Ewa Grodzinsky · Märta Sund Levander

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"At a time of increasing challenges regarding the provision of a healthcare and concerns around the use of antibiotics to manage infection, this book is timely addition to the field. The book provides a varied approach to exploring the use of body temperature measurement, including an interesting historical underpinning which acts a helpful refresher to the subject area. The integration of physiological and immunological knowledge offers a fresh perspective on the subject area which will be of interest to a wide multi-professional international audience. The final chapter consolidates learning from each chapter through a series of scenarios and questions."

—Nicola Carey, Reader in Long Term Conditions in the School of Health Sciences and member of the Faculty of Health & Medical Sciences, *University of Surrey*

"*Understanding Fever and Body Temperature* is a well written book on the fascinating topic of fever. The authors approach the subject from many angles, an approach made possible by expertize in several different areas related to fever and the measurement of body temperature. As a result, the book will be useful for a wide range of readers including people interested in thermometry and those meeting febrile patients as part of their profession."

—David Engblom, Professor of Clinical and Experimental Medicine (IKE), *Linköping University, Sweden*

"*Understanding Fever and Body Temperature* is an interesting and exciting book and a cross-disciplinary compendium to all aspects of body temperature: History, measurements, basic thermal physiology and immunology, clinical evaluation of body temperature, etc. Also the book does away with traditional thinking and acting in particular as regards fevers. The special and peculiarity of the book is the pedagogical approach "problem-based-learning": Reflections at the end of every chapter, a lot of patient scenarios from clinical practice and many very important clinical implications. So the book will be of interest and importance to all professionals in Health-Care"

— Susanne Herzog, Specialist Nurse of Intensive Care, MScN, *University of Applied Sciences, Diakonie Bielefeld, Germany*

"A very interesting book! This book helped me understand and learn in-depth information about body temperature and fever. It has definitely helped me a lot during medical school".

—Andrew Toros, medical student at
Linköping University, Sweden

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Foreword

In our daily lives, our body temperature is constantly changing due to natural biorhythms, active processes such as exercise, or passive processes such as exposure to cold or warm environments. The body's thermoregulatory defense system, acting through both physiological and behavioral mechanisms, normally prevents such changes from becoming too great and causing harm. Although such changes in body temperature pose little danger to our health, it is interesting that human beings often use dramatic terms to describe them. 'I'm freezing' and 'I'm boiling hot' are common subjective phrases in English, and similar terms are found in most other languages. These qualitative overstatements presumably stem from the age-old awareness of the health risks not only of illness but of exposure to extremes of ambient temperature, even though in the past the reasons were poorly understood. An enormous leap forward in our understanding of the importance of a regulated body temperature came with the development of thermometry. By providing quantitative information on body temperature, thermometry has played a major role in our understanding of body temperature variability. The present volume revolves around thermometry, taking the reader on a journey from the past to the present. Yet, while the emphasis is on the clinical importance of obtaining accurate, quantitative measurements of body temperature, the reader is also introduced to the most recent thinking on their clinical interpretation, especially in relation to fever. These ideas have arisen in a cross-disciplinary collaboration, using evidence-based practice to integrate physiological and immunological knowledge. The editors, Ewa Grodzinsky and Märta Sund Levander, have collaborated closely with international

experts in essays on a range of topics, including historical perspectives on temperature measurement, temperature measurement technology, the clinical evaluation of body temperature, and basic thermal physiology and immunology. The volume concludes with a number of patient scenarios that bring all these insights together. Although primarily a textbook that lends itself particularly well to a problem-based learning approach, *Understanding Fever and Body Temperature: A Cross-disciplinary Approach to Clinical Practice* will also be of interest to all health-care professionals.

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March 2019

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Märta Sund Levander, Reg. Nurse, Ph.D., is an associate professor, a senior research scientist and university lecturer at the Medical Faculty Linköping University, Sweden. She teaches nursing students at the undergraduate, specialist, and advanced levels. She has several years of clinical and research experience as a specialized nurse, especially in critical care, eldercare, infection control, and research and development. Her contribution to this book is in the area of history and the assessment and evaluation of body temperature and its clinical implications.

Contributing writer Rosita Christensen is a lecturer at the Karolinska Institute in Stockholm and teaches students at both the undergraduate and the specialist level within the subjects of physiology and anatomy. She is trained in physiology, with a focus on environmental physiology, at the

[1] Ewa Grodzinsky and Märta Sund Levander are the editors of this book. They have worked closely in writing the chapters, for which they are personally responsible, and with editing the chapters of their co-authors.

Karolinska Institute and is a specialist in naprapathy, with an M.Sc. in Health Care Pedagogics. She has several years of clinical experience as a chiropractor and in sports medicine, critical care, and eldercare. Her contribution to this book is within physiology and thermoregulation.

Contributing writer Francis E. Ring was Professor of Medical Imaging and Head of the Medical Imaging Research Unit at the University of South Wales in the UK. Ring unfortunately passed away before he could see this work published. He had over 50 years of research experience in the studies of human body temperature and was a pioneer within the field of thermography and biomedical engineering—especially thermal imaging. His contribution to this book is a historical review of techniques to measure body temperature and the development of thermometers.

Contributing writer Rob Simpson is a senior research scientist at the National Physical Laboratory (NPL), the UK's National Measurement Institute. He has a Ph.D. in infrared thermal metrology for medical applications from the University of Glamorgan. He currently leads thermal imaging metrology research at the NPL. His Ph.D. studies involved the development of new and novel reference standards for diagnostic medical thermal imaging. These reference sources were patented, licensed, and commercialized. His contribution to this book is to provide an understanding of how instruments are linked to the international measurement system (SI), and of what factors should be taken into account to ensure confidence in measurements, including measurement standards, traceability, calibration, and other factors.

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CHAPTER 1

Introduction to Understanding Fever and Body Temperature

The year 1871 saw the publication of the magisterial work *Medical Thermometry and Human Temperature*. Based on exhaustive measurements of axillary temperature by the German physician Carl August Wunderlich (1815–1910), the book was the first to define normal body temperature as 37.0 °C (98.6 °F) and 38.0 °C (100 °F) as fever. However, at that time, the physiological mechanisms of thermoregulation were not known, there was little knowledge of immunology and microbiology, and the technology needed for accurate clinical thermometers was in its infancy. Also, Wunderlich's measurements were performed on patients, suggesting that a large number of them may have been febrile. In the late nineteenth century, the English physician Sir Thomas Clifford Allbutt introduced the shorter clinical rectal mercury thermometer, which was later followed by the oral mercury thermometer. It was not until the 1960s that digital devices were introduced together with new techniques for non-invasive measurement of body temperature. The most recently developed thermometers use infrared radiation to estimate body temperature.

Besides advances in the technical aspects of thermometers, there has been progress in the understanding of the physiological and immunological processes which influence body temperature. However, thermoregulation, in terms of the diurnal rhythm and the physiological mechanisms which maintain a stable and balanced internal environment, was not understood until the 1950s. The role of female hormones was not appreciated until the 1970s. By that time, immunology and the full complexity

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of the immune system—the body's defense mechanism for removing foreign agents and restoring tissue structure and physiological function—was beginning to be understood.

The effect of antipyretics on body temperature had been known for decades, as had the results of treatment with penicillin and sulfonamide, but antipyretic use in clinical practice did not become common until the 1970s. During the same decade there was a significant improvement in laboratory methods, making it possible to understand in more detail the effector mechanisms used to eliminate foreign agents and protect the body from destruction, particularly the role of various cells and cytokines. In the 1990s, quality assurance and patient safety were highlighted, and today they are permanent obligations within health care. Together with the demand for evidence-based decision-making, this now forms the basis for ensuring good care. However, even though there has been tremendous development, progress has advanced along two parallel lines (Fig. 1.1).

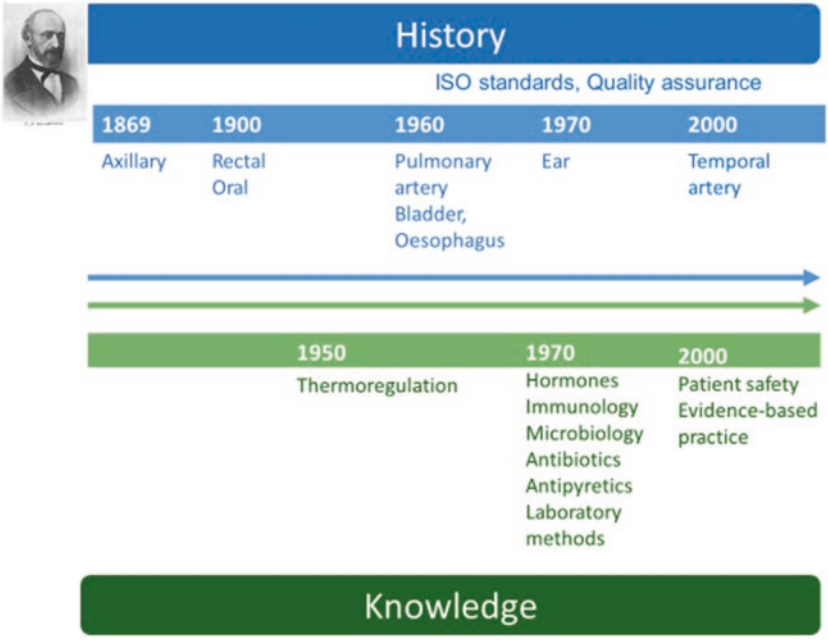

Fig. 1.1 The development of thermometry and physiological and immunological knowledge in relation to assessment of body temperature. (Copyright Grodzinsky, E & Sund Levander, M)

This parallel development has had great impact on current practices and perceptions about body temperature. The concept of fever influences clinical assessment and evaluations of body temperature, and still has a significant impact on decisions in nursing care, medical diagnosis and treatment, and in the ordering of laboratory tests. Today, although there is a general acceptance that body temperature adopts a range of values rather than a fixed temperature, the norm arrived at in the mid-nineteenth century is still the basis for assessment and decisions about body temperature worldwide. In addition, even if the technical accuracy of measurements has become much better, *clinical accuracy*, meaning knowledge about physical influences on the individual's body temperature, such as thermoregulation and hormones, immunological defense against microbes, and the development of laboratory assays, is still not considered important for body temperature assessment. For example, due to the temperature gradients between different sites of measurement, it is impossible to measure or define the 'actual' body temperature as no factor exists which allows accurate conversion of temperatures recorded at one site to estimate the temperature at another. Also, in addition to the temperature differences between different sites in the same individual, there are considerable differences in body temperature between individuals, and therefore we have to assess changes in body temperature as the difference between an individual baseline body temperature and the measured reading, so-called DiffTemp™, and not use a predetermined, universal cut-off value.

When we say that someone has a 'fever', what do we really mean? In the first instance most people think of fever as equating to an elevated body temperature because of infectious disease. In fact, it is common to 'measure fever' more than to measure body temperature. However, fever is essentially defined as:

> a state of elevated core body temperature, which is often, but not necessarily, part of the defense of multicellular organisms (the host) against the invasion of live (microorganisms) or inanimate matter recognized as pathogenic or alien by the host. (IUPS TC. Glossary of Terms to Thermal Physiology. *Pflugers Archives* 1987, 410: 567–87)

Fever is thus part of a larger response in the body, in which many different cells are activated and react in what is called the acute phase response. This response does not mean that the body temperature is permanently elevated or that we experience the activity of the immune cells in the form

of malaise. Immune cells may be continually active, day and night, without reaching the level of inflammation.

Taken together, a great deal is known about thermoregulation, and the factors influencing body temperature, from a technical and physiological viewpoint. It is of great importance to base the assessment and evaluation of temperature on evidence-based medicine and not on tradition or personal belief. Therefore, it is necessary to use knowledge from both of the two parallel lines and to integrate this knowledge to form a basis for evidence-based practice.

In order to use this knowledge in evidence-based practice, collaboration is necessary between professionals and between disciplines such as health care, laboratory science, and medical technology. In the clinical context, this means that health care personnel should work together to provide care which is both high quality and safe. This emphasizes the importance of teamwork and inter-professional learning (IPL), in the form of collaborative practice, inter-professional communication, and respect for one another's competence, so that the group may use their joint expertise to achieve excellence (Fig. 1.2).

The pedagogical approach of this textbook is problem-based learning (PBL). PBL is based on the acquisition of knowledge by problem-solving, using self-directed learning, and a scientific and critical approach. Here, the basis of PBL is inter-professional discussions of scenarios from clinical practice. Such discussion stimulates reflection, and the problem-solving process makes the knowledge accessible and easier to apply in real situations. Our intention with this textbook is that the reader will gain insight into the importance of using knowledge from different disciplines to develop an appreciation of the different aspects of body temperature. In addition, the reader will come to understand the concept of fever in a broader perspective than that traditionally adopted. The book is based on research in the fields of physiology, immunology, laboratory science, nursing care, metrology, technological and scientific developments, and measurement with clinical thermometers related to body temperature. In some chapters, well-established knowledge is presented, along with a recommendation for a general reference source such as a reputable textbook.

However, to understand today's ideas and concepts, we have to consider the perceptions of the past. Therefore, the book starts with two chapters (Chaps. 2 and 3) examining the historical perspective. The following chapters (Chaps. 4, 5, and 6) focus on technical measurement accuracy and on thermoregulation from a physiological and immunological

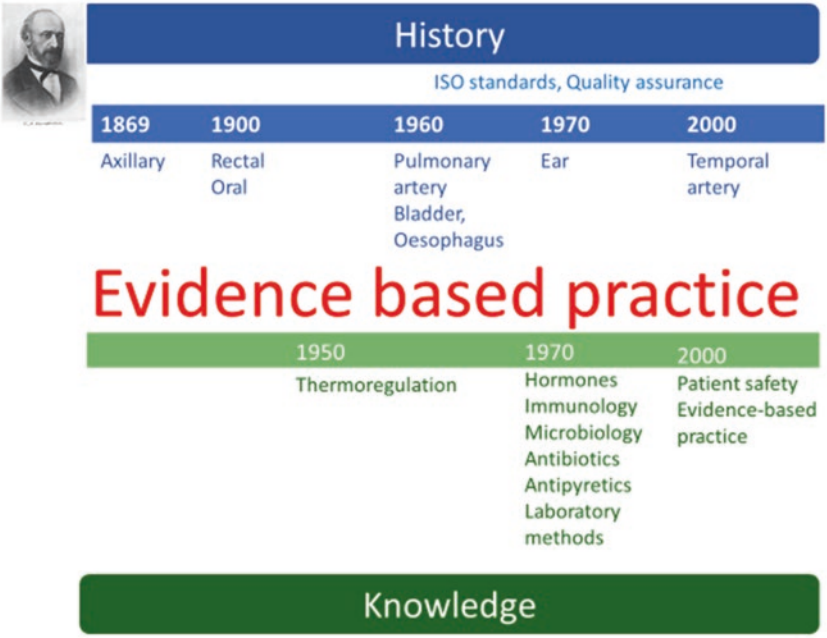

Fig. 1.2 Evidence-based practice based on integration of the two parallel lines of technique and physiological and immunological knowledge in relation to assessment of body temperature. (Copyright Grodzinsky, E & Sund Levander, M)

perspective. Chapter 7 addresses the assessment and evaluation of body temperature, and Chap. 8 looks at inflammatory activity in various conditions. In Chap. 9 we tie everything together and discuss how we can include evidence-based knowledge into clinical practice. In addition, all the chapters include thought clouds. It may not be possible to provide exact answers to the statements or questions in these clouds, but they are meant to encourage the reader's own reflections on the topic. At the end of each chapter there are also reflections, additional questions, and statements, which the reader should be able to answer using the text of the chapter. Throughout the book, we have converted °Celsius (°C) to °Fahrenheit (°F) according to the following formula:

$$^{\circ}\mathrm{C} \times 1.8 + 32 = {}^{\circ}\mathrm{F}.$$