SENSORIMOTOR CONTROL OF GRASPING:
PHYSIOLOGY AND PATHOPHYSIOLOGY

The human hand can take on a huge variety of shapes and functions, providing its owner with a powerful hammer at one time or a delicate pair of forceps at another. The universal utility of the hand is even more enhanced by the ability to amplify the function of the hand by using tools. To understand and appreciate how the human brain controls movements of the hand, it is important to investigate both the healthy motor behavior and dysfunction during everyday manipulative tasks. This book provides a contemporary summary of the physiology and pathophysiology of the manipulative and exploratory functions of the human hand. With contributions from scientists and clinical researchers of biomechanics, kinesiology, neurophysiology, psychology, physical medicine and rehabilitation, it covers the development of healthy human grasping over the lifespan, the wide spectrum of disability in the pathological state and links basic motor research with modern brain sciences.

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Preface

The numerous skeletal and muscular degrees of freedom of the hand provide the human with an enormous dexterity that has not yet been achieved by any other species on earth. The human hand can take on a huge variety of shapes and functions, providing its owner with a powerful hammer at one time or a delicate pair of forceps at another. The universal utility of the hand is even more enhanced by the ability to amplify the function of the hand by using tools. True opposition between the thumb and index finger is only observed in humans, the great apes and Old World monkeys. The human thumb is much longer, relative to the index finger, than the thumb of other primates and this allows humans to grasp and manipulate objects between the tips of the thumb and index finger. Humans have more individuated muscles and tendons with which to control the digits and have evolved extensive cortical systems for controlling the hand. In addition to its manipulative function the hand is a highly sensitive perceptive organ, orchestrated by myriads of tactile and somatosensory receptors, which enables humans to perceive the world within their reach. Taken together all these phylogenetic developments have provided humans with the ability to interact with each other, make love and war, and also to shape the world. To understand and appreciate how the human brain controls movements of the hand, it is important to investigate both the healthy motor behavior of the hand and its dysfunction during everyday manipulative tasks.

Over the past three decades exciting novel achievements have enhanced our knowledge of the physiology and pathophysiology of human grasping. When trying to summarize what we know today about the physiology of human grasping we have to look back at the origins of its research. There is no doubt that the modern era of research on the kinematics and kinetics of human grasping started in the early 1980s with the epoch-making studies from the groups around Marc Jeannerod in Bron, France, and Roland Johansson in Umeå, Sweden. These researchers provided us with the first detailed descriptions of the kinematics of human grasping and the dynamic control of isometric grip forces when handling objects in the environment. Inspired from these early works, Alan Wing, Randy Flanagan, Hans Forssberg, Kelly Cole and Andrew Gordon, among others, carried on in this “orphan” field of research over the next decade. Thereafter, several scientists have been walking in the footsteps of these first-hour researchers, including ourselves. Consequently, the methodology of kinematic and kinetic analysis of grasping movements has rapidly found its way into clinics and aided in discovering the characteristics of impaired grasping in a huge number of neuromotor disorders.
variety of neurological, psychiatric and orthopedic disorders. Today, motor laboratories all over the world have established kinematic and kinetic investigation of grasping both in clinical and research settings and knowledge is still growing given the increasing number of citations each year in the PubMed database (www.ncbi.nlm.nih.gov/sites/).

It was our intention to bring together first-hour and last-generation neuroscientists and clinical researchers in the field to compile a contemporary summary about what we know today about the physiology and pathophysiology of the manipulative and exploratory functions of the human hand. The book is separated into four major sections: methodology, physiology of grasping, pathophysiology of grasping and therapy of impaired sensorimotor control of the hand. It covers the development of healthy human grasping over the lifespan and the wide spectrum of disability in the pathological state, and links basic motor research with modern brain sciences. The book focuses on, but is not limited to, grasping. Several additional aspects of the physiology and pathophysiology of fine motor performance of the hand, such as writing, multi-digit coordination and bimanual motor performance, are also covered. The book addresses scientists and clinical researchers from the areas of biomechanics, kinesiology, neurophysiology, psychology, physical medicine and rehabilitation. We are glad to have succeeded in pooling knowledge from “dinosaurs” in the field as well as from young scientists and clinical researchers from all over the world. This allows the book to contain basic knowledge from kinematic and kinetic recordings of the early days, and novel aspects regarding central control processes and models derived from more recent advances in technology, such as neurophysiology and neuroimaging.

When it comes to acknowledgments, we have to admit that there are many people without whom we certainly would not have arrived at this stage along our way through the world of grasping research. So we wish to direct our apologies to all those who are not mentioned here, despite their valuable support that is much appreciated. This is in particular to our team members, to all the doctoral students and to our clinical teachers. We wish to thank our families for their patience and constant support over the years. We both wish to dedicate this book to Norbert Mai, who inspired us to focus on the pathological aspects of grasping many years ago. Norbert died too early and we will always remember him for his visionary genius. Finally, we would like to thank Alison Evans, Anna-Marie Lovett and Martin Griffiths from Cambridge University Press for their assistance and guidance in making this project a success.