Henning Boecker · Charles H. Hillman
Lukas Scheef · Heiko K. Strüder *Editors*

Functional Neuroimaging in Exercise and Sport Sciences

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This book is dedicated to our families

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Preface

Regular physical exercise is associated with substantial health benefits. Recent evidence holds not only for cardiovascular effects promoting "physical health", but also for the central nervous system believed to promote "brain health". Moderate physical exercise has been found to improve learning, memory, and attentional processing, with recent research indicating that neuroprotective mechanisms and associated plasticity in brain structure and function also benefit. Physical exercise is also known to induce a range of acute or sustained psychophysiological effects; among these are mood elevation, stress reduction, anxiolysis, and hypoalgesia. To date, there is an important body of literature from animal exercise research that has allowed unraveling neurobiological mechanisms at the behavioral (e.g., water maze-type tests), cellular (e.g., neurogenesis, neuroangiogenesis), and humoral (e.g., neurotrophic factors, inflammatory cytokines) levels. For obvious reasons, the majority of the human literature in exercise research has been based on behavioral and indirect assessments of neurotrophic factors and released neurotransmitters in the blood.

Today, modern functional neuroimaging techniques afford direct measurement of the acute and chronic relation of physical exercise on the human brain, as well as the correlation of the derived physiological in vivo signals with behavioral outcomes recorded during and after exercise. A wide range of imaging techniques have been applied to human exercise research, ranging from electroencephalography (EEG), magnetoencephalography (MEG), near-infrared spectroscopy (NIRS), and magnetic resonance imaging (MRI) to positron emission tomography (PET). All of these imaging methods provide distinct information, and they differ considerably in terms of spatial and temporal resolution, availability, cost, and associated risks. However, from a "multimodal imaging" perspective, neuroimaging provides an unprecedented potential to unravel the neurobiology of human exercise, covering a wide spectrum ranging from structural plasticity in gray and white matter, network dynamics, global and regional perfusion, and evoked neuronal responses to the quantification of neurotransmitter release.

Accordingly, the scope of this book is to provide the current state of the human neuroimaging literature in the emerging field of the neurobiological exercise sciences and to outline future applications and directions of research, including clinical imaging studies in patients, which are as yet still in their infancy. The introductory Part I (Chaps. 1–4) provides an overview of mechanisms by which "brain health" is promoted through exercise, as derived from basic animal research. In Part II (Chaps. 5–13), the relevant methodological background is summarized for brain imaging applications in the exercise sciences; notably, this section encompasses detailed introductions to imaging methods, fitness evaluations, exercise training recommendations, as well as fitness-associated parameters (from neuropsychological tests indices to neurohumeral factors) that should be considered in imaging analyses of exercise studies. The subsequent part of the book will cover the current state of imaging applications in the following principal fields of research: the relation of exercise on brain perfusion, metabolism, and structure (Part III, Chaps. 14–17), the relation of exercise on cognitive processing (Part IV, Chaps. 18–20), and, finally, the relation of exercise on affective processing (Part V; Chaps. 21 and 22).

The editors of this book are very grateful to all authors for contributing their valuable expertise to this book. Deep thanks also go to Ms. Ann Avouris from Springer Publishing Co. who launched this project after attending a workshop by H. Boecker & C. Hillman entitled "Imaging the Effects of Physical Exercise on Brain Function" at the Organization for Human Brain Mapping (OHBM) Annual Meeting 2009 in San Francisco. "Functional Neuroimaging in Exercise and Sport Sciences" was developed with the understanding that neuroimaging will play a fundamental role for unraveling the impact of physical exercise on the human brain in the future and, on these grounds, hopefully for fostering further research into the prevention and treatment of brain disorders. While several other books are aimed at the neurobiological underpinnings of exercise, we believe that a unique feature of this book is that it is focused specifically on the important role of neuroimaging in the field of exercise and body–brain interactions. The book sheds light on the relation of exercise to various domains, for instance, structural plasticity, as measured with MRI-based morphometry methods; functional coherence and connectivity, as measured with EEG and resting state fMRI; "executive control" and other cognitive functions, as measured with task-related fMRI and event-related brain potentials (ERPs); neuroangiogenesis, as determined with MRI-based cerebral blood volume measurements; or neurotransmitter trafficking, as quantified by PET ligand activation studies, etc. Most importantly, this book makes the point that the exercise sciences should – in the future – be a joint research initiative of exercise scientists, neurobiologists, neuropsychologists, neuroimagers, and experts from other related disciplines.

We hope that "Functional Neuroimaging in Exercise Sciences" will be of interest to researchers working in the various fields subsumed by the term "exercise sciences", but also to a wider readership interested in this emerging field, including

doctoral students, post-doc scientists, exercise and health prevention specialists, or simply people who have (or want to have) a deeper understanding in how exercise promotes "brain health".

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Contents

Part I
Theoretical Background, Animal Models, and Basic Sciences