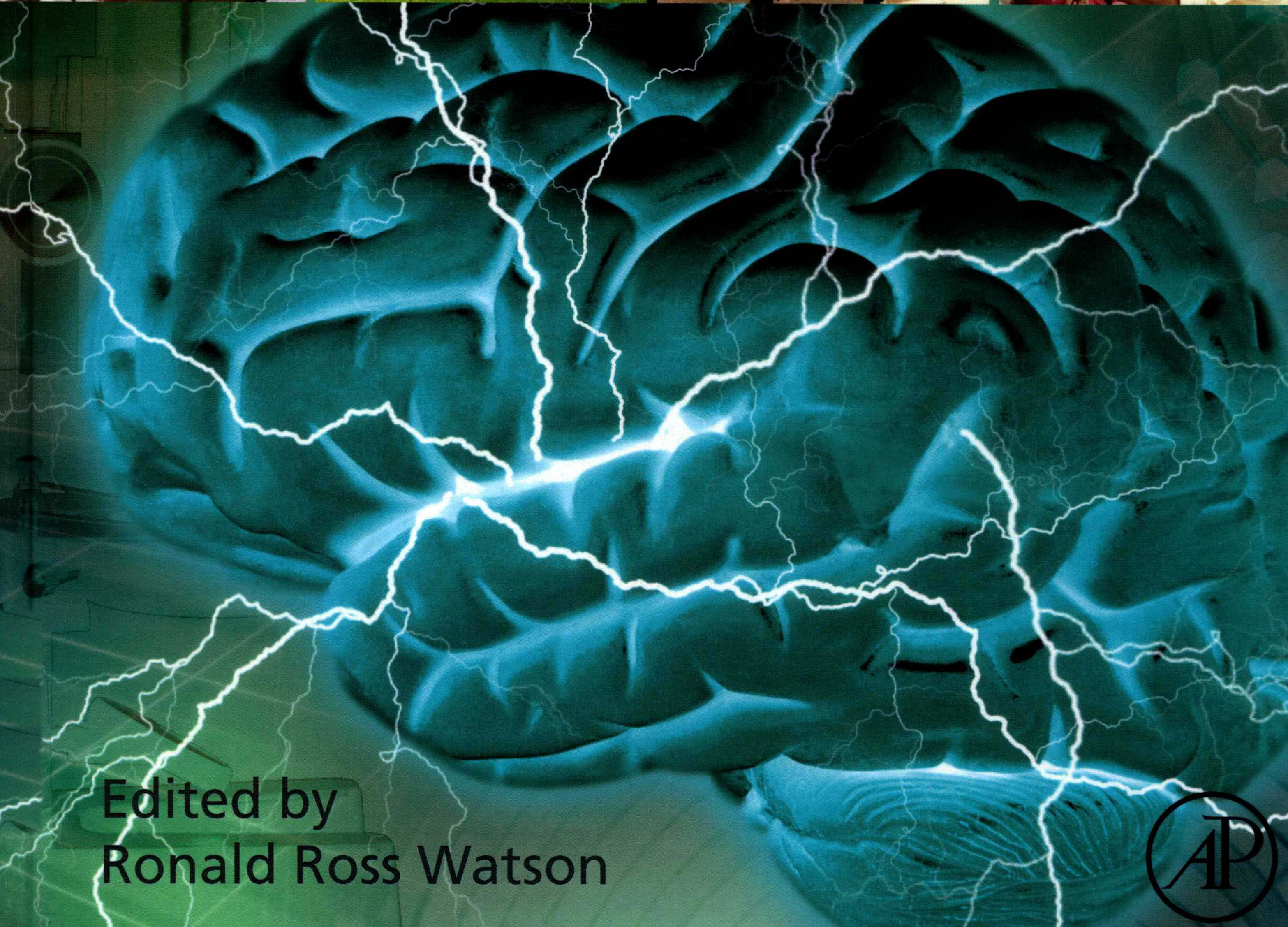
Physical Activity and the Aging Brain

Effects of Exercise on Neurological Function



Edited by
Ronald Ross Watson

PHYSICAL ACTIVITY AND THE AGING BRAIN

EFFECTS OF EXERCISE ON NEUROLOGICAL FUNCTION

Edited by

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Preface

Physical activity including planned exercise in prevention and modification of neurological complications due to advancing age is beginning to be explored and will be described.

I. Overview of Exercise and Neurological Changes. Begega starts with the basics of physical exercise and its effects on nerves and their growth and function. In particular she reviews neurological networks as modified by activity or lack thereof. Neurological changes in infants and youth are subject to physical activity as described by Herting and Keenan. Such effects are the building components for the aged neurological system and changes in structure and function induced by exercise. Ravikiran, Vani and Anand describe changes in the brain proteome during planned exercise as an example. Damasceno, Fonseca, and Wanner describe the actions of exercise on brain temperature, as exercise can increase temperature and may affect brain functions.

II. Drugs of Abuse With Exercise to Modify Neurological Structure and Function. Currently the last decade or two of life result in many chronic, frequently incurable diseases with huge medical costs and health problems. Understanding the biology of chronic degenerative diseases of adults opens the way for therapies at hand for the aging adults. Mandyam, Somkuwar, and Fannon review the neurological effects of a drug of abuse and methamphetamine. Then they describe the potential of exercise to act as a therapy for this addictive substance. Brain transmission affects exercise and physical activity. Zheng and Hasegawa review pharmacological methods to change brain neurotransmission and how these can affect exercise and physical capacity and activity. The endocannabinoid system is modified by exercise-induced molecules similar in structural binding capacity to cannabinoids from marijuana. Yoder and Watson review this system affected by exercise as an opportunity for innovative therapies.

III. Factors Modulating Exercise in Aging and Neurological Consequences Hiura and Nariai review blood flow during exercise in athletes which affects the movement of modulators to the brain including nutrients. This review serves as a model for exercise in changing nutrient needs by building muscle and preventing major loss of food consumption with old age. Uhlendorf and her group review neuroprotection in growing and especially aging brains in protection from neurological disease. Seniors are getting progressively older and more numerous with each generation. The number and percentage of the population of many developing countries are continuing to increase. For example the front cover of *Time Magazine* (February 23, 2015) shows a child with the headline *"This baby could live to be 142 years old."* This book looks at a tool at hand for seniors and their medical advisors to protect the brain and treat neurological diseases using physical activity. Díaz-Castro and his group of expert authors and researchers review the role of a well-known natural hormone that affects the brain and regulates sleep. They review the role of melatonin on the brain and body during strenuous exercise.

IV. Exercise as Therapy for Neurological Diseases. Exercise and physical activity has the potential to treat and overcome a variety of neurological diseases and especially damage. For examples Cowan and Ichiyama review spinal cord neurological injuries. They focus on the actions of exercise in spinal cord rehabilitation and recovery. Bonavita and Tedeschi describe the changes in a variety of brain organs and functions due to physical activity. Neural structure, cognition changes, and connectivity are modified by exercise and reviewed by this group. Parkinson's disease is susceptible to exercise modulation. Watson, Welman, and Sehm describe neuroplasticity and motor function changes during exercise therapy. Another significant neurological disease is Alzheimer's disease. Stein and Pedroso describe physical activity in Alzheimer's disease and its effects on the brain and neurological function. Hormones such as corticosteroids change structure and function. Perrey describes corticoid-induced reorganization in response to physical activity and exercise. Snigdha reviews the role of exercise in enhancing memory activity in the aging brain.

V. Lifestyle Exercise Affecting Neurological Structure and Function in Older Adults. Shah and Martin describe the role of exercise synergistic actions of exercise and physical activity during brain training on the actions of nerves and neurological functions. Beurskens and Dalecki provide an overview and description of exercise on neurological functions. Leelayuwat discusses the actions of nutritional antioxidants and antinociceptives on improving exercise-induced muscle damage. Aral and Pinar finally describe the immune systems and their changes on neuroplasticity.

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The work of Dr. Watson's editorial assistant, Bethany L. Stevens, in communicating with authors and working on the manuscripts was critical to the successful completion of the book. The support of Kristi L. Anderson is also very much appreciated. Support for Ms. Stevens' and Dr. Watson's work was graciously provided by Natural Health Research Institute www.naturalhealthresearch.org. It is an independent, nonprofit organization that supports science-based research on natural health and wellness. It is committed to informing about scientific evidence on the usefulness and cost-effectiveness of diet, supplements, and a healthy lifestyle to improve health and wellness and reduce disease. Finally, the work of the librarian of the Arizona Health Science Library, Mari Stoddard, was vital and very helpful in identifying key researchers who participated in the book.

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PART I

OVERVIEW OF EXERCISE AND NEUROLOGICAL CHANGES

CHAPTER

1

Effects of Physical Activity on the Cerebral Networks

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Abstract

It is well documented that ageing is accompanied by a decline in cognitive functions such as, memory, attention, and speed of information processing. Different nonpharmacological approaches have been proposed for the purpose of promoting health, such as, mental training, mediterranean diet, and physical exercise. This is because their benefits on both cognitive and cerebral function have been proven. Numerous studies have targeted the design of intervention programmes favoring these neuroplasticity processes such as exercise programmes. This intervention type have been shown, both in humans and rodents studies, to have benefits on neuroplasticity, neurogenesis, and levels of brain-derived neurotrophic factor, among others. Hence, any physical activity must be accomplished in order to maintain them as long as possible.

WHAT IS COGNITIVE AGEING?

In the past few decades, research in ageing and ageing-related cognitive changes have experimented a great breakthrough. It is well documented that ageing is accompanied by a decline in cognitive functions such as, memory, attention, and speed of information processing (Salthouse, 2012, 2000; Swain et al., 2012). Speed of information processing is defined as "the amount of information that can be processed per time unit or the speed at which a series of cognitive operations can be done". This difficulty reduces as how fast we process the information from the environment and affects other processes like short-term memory and information interference, which favors a higher distractibility in elderly people. Elders' attentional capacity is reduced and is accompanied by more distractibility and proactive interference.

In this case, proactive interference refers to the process by which we are not able to reduce the influence of previous-learned information so we can successfully perform the new-information required task (Bartko et al., 2010). Namely, besides difficulties in memory processes (Bamidis et al., 2014), executive functions were also affected in the elderly people. In light to this situation, it seems obvious that life quality is diminished as independence is compromised in everyday-activities (Vance et al., 2012), leading to emotional impairments which have been related to ageing, such as major depression and anxiety. This is a discouraging scenario for elderly population, but in recent years the field of Neuroscience has developed numerous ageing-related studies in order to know how to intervene and achieve the maintenance of these basic cognitive functions or, at least, delay their deterioration. Thus, different nonpharmacological approaches have been proposed for the purpose of promoting health, such as, mental training, mediterranean diet, and physical exercise. This is because their benefits on both cognitive and cerebral function have been proven (Ballesteros et al., 2015).

Regarding to this research, cognitive reserve acquires a special relevance and has been studied by Yaakov Stern's research team, among others. They define cognitive reserve as the ability to make flexible and efficient use of available brain reserve when performing tasks (Stern, 2002). Cognitive reserve has been related to lifestyle and how different circumstances, activities, and habits can positively influence independence and life quality during the ageing process. It has been most often estimated using education and IQ, although other variables have also been used including literacy, occupational complexity, participation in leisure activities, as well as the cohesion of social

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networks. Cognitive reserve can also be related to neurobiological mechanisms like neural compensation and neuronal reserve (Barulli and Stern, 2013), which refer to a subject's ability to use cognitive processes and, therefore, neuronal networks in an effective way, leading to a lower impact of ageing-related functional changes. Neural compensation by Stern (2002) is defined as the use of alternative neuronal networks due to an incapability to use the task-related impaired one, which is a common mechanism in the ageing process. On the other hand, neural reserve is associated with the functional use of the task-related neuronal network, which produces an increase in its activity, or to a functional support of secondary-related networks, which favors task efficacy. As both the processes seem to occur frequently during ageing, cognitive reserve continues to be influenced by circumstances throughout the lifespan. The cognitive reserve could subserve a delay in cognitive deterioration and in age-related dementia. Among the activities, aerobic exercise is seem to have a beneficial effects on cognitive reserve (Ballesteros et al., 2015).

PHYSICAL EXERCISE AND HEALTH

Exercise is commonly known by its wide benefits on health, especially in the muscle strengthening and the prevention of cardiovascular diseases (CVD). However, it positively affects many different aspects of the organism physiology, both in healthy individuals and those at risk of developing a disease or aggravating it. For example, it seems to increase the probability of normal delivery among healthy pregnant women, which means less caesarean cases (Domenjoz et al., 2014). As a matter of fact, exercised mothers and their children have shorter hospital stays, less complications, shorter labor, and less preterm labor than nonexercisers (May, 2012).

Ageing is characterized by a progressive reduction of the regeneration potential, determined by both genetic and environmental factors that lead to an imbalance between repair and accumulation of cellular damage. The decline of cellular function is accompanied by ageing-related, harmless phenotypes like grey hair and wrinkles (Ludlow et al., 2013), also by a loss of physiological integrity and higher vulnerability to death, the main cause for most of the major pathological human diseases such as Alzheimer's and other neurodegenerative diseases, diabetes, certain kinds of cancer, and CVD (López-Otín et al., 2013). Here, we number the benefits of exercise in some main human pathologies.

Several studies have demonstrated associations between active behaviors and age-related health outcomes. For example, it has been documented an inverse relationship between physical activity and all-cause mortality, just the same as a direct relationship between low-cardiorespiratory fitness and disease. On the basis of this, exercise has been included in most of the guidelines for prevention or reduction of CVD mortality, advising at least 30 min of moderate-intensity aerobic activity 5 days per week to gain even years in life expectancy (Schuler et al., 2013). Together with an appropriate diet, this simple recommendations are in order to reduce low-density lipoprotein cholesterol and blood pressure (Wenger, 2014).

It has been demonstrated that exercise stimulates mitochondria biogenesis in the skeletal muscle through oxidative stress, leading to a deceleration of age-related diseases caused by a loss of mitochondria or an impairment in their function, like sarcopenia, cancer, or neurodegenerative diseases (Sun et al., 2015). Physical exercise can be used as a therapy in many different muscle-affected disorders. It can potentially prevent muscle atrophy caused by muscle inflammation, physical inactivity, and systemic glucocorticoid treatments in patients with idiopathic inflammatory myositis (Munters et al., 2014). Moreover, it has been proposed to counteract many of the symptoms in multiple sclerosis, improving and/or maintaining functional ability, aerobic fitness, muscle strength, fatigue, and so on (Latimer-Cheung et al., 2013).

Type 2 diabetes prevalence has been increased in the recent years as it arises from a combination of genetic susceptibility and environmental factors like sedentary life and an unsuitable diet, which nowadays affect a wide range of the population, who become obese as a result of their lifestyle (Stanford and Goodyear, 2014). Therefore, the avoidance of this disease goes through the prevention of muscle atrophy and the reduction of CVD risk by the agency of regular physical activity. Exercise has also shown to reduce tumor incidence, tumor multiplicity, and tumor growth across numerous different transplantable, chemically induced, or genetic tumor models (Pedersen et al., 2015).

Finally, there is a large evidence about exercise benefits on cognitive reserve, as has been thoroughly reviewed by Franco-Martin et al. (2013). This aspect gains importance in the ageing process, in which the total brain weight is reduced from 10% to 20% as well as blood flow decreases about 30–40%, which leads to an impairment of learning and memory, attention, and cognitive functions. Physical endurance and aerobic exercise has been associated with successful cognitive ageing, as it delays or reduces the effects of ageing in the central nervous system (Franco-Martin et al., 2013; Cassilhas et al., 2015). For example, there is an inverse relationship between levels of brain-derived neurotrophic factor (BDNF) as a direct measure of the amount of exercise performed and the severity of cognitive decline due to Alzheimer's disease (Piepmeier and Etnier, 2014). There are strong proofs of the neuroprotective effects of