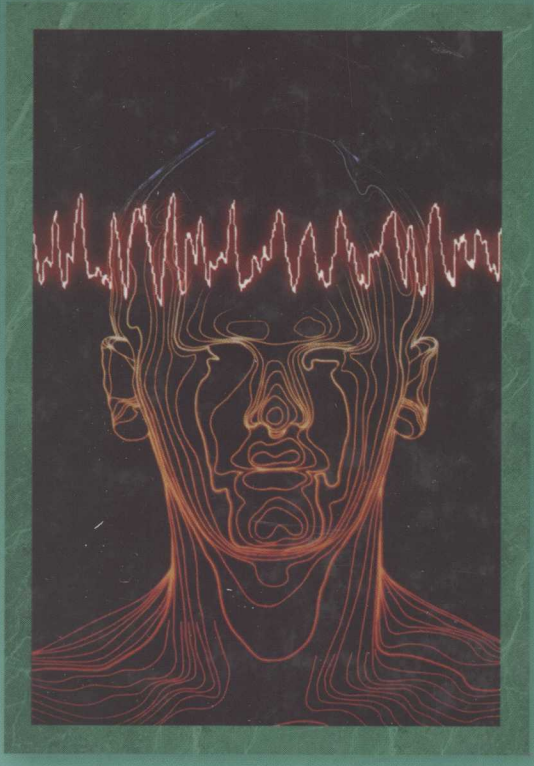
Aging, Exercise, and Cognition Series

Exercise and Its Mediating Effects on Cognition



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volume 2

Exercise and Its Mediating Effects on Cognition

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VOLUME 2

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SERIES EDITORS

PREFACE

Historically, scientists believed that the brain functioned independently of the rest of the body, that what we were born with was what we had to work with, and that little could be done to deflect the inexorable damage done to the brain by the passage of time. Today we are beginning to understand that the brain is much more malleable than was ever thought, that neuronal networks are continually modified, that new neurons can be developed (neurogenesis), and that we can have substantial influence over our brain function.

This edited book is the second of a three-part series designed to assess our knowledge and define research directions regarding active living, cognitive functioning, and aging. Volume 1 of this series reviewed exercise and cognition, measurement issues, and physiological mechanisms that are relevant to this process among older adults. Volume 2 continues to expand our understanding by examining whether and how physical activity could indirectly affect cognitive function by influencing mediators that provide physical and mental resources for cognition: for example, by (a) enhancing physical energy levels by increasing sleep quality and enabling the intake of adequate amounts of food to maintain energy, (b) preventing or postponing disease states such as diabetes and chronic obstructive pulmonary disease, and (c) providing mechanisms that control anxiety and depression. This volume seeks to identify and study key sources of individual variations in exercise and cognition processes. Finally, volume 3 addresses neuropsychological mechanisms associated with exercise and cognition. This series is designed to create synergy across volumes and chapters.

Eighteen contributors met and produced this second volume. As in volume 1, volume 2 includes contributors who are experts in exercise, activity, cognition, neurobiological processes, and aging. Few contributors are experts in all areas, and the volume was produced to encourage synergy in addressing the complex issues involved in exercise, activity, and cognition in old age. Each of the experts prepared a draft review of the state of knowledge for his or her topic. Before coming together in a workshop to present and discuss the contents, all participants read the drafts. A working model was provided, and the experts were asked to relate their work to the model.

Two innovations were included by the editors in volume 2. At the beginning of each chapter, an introduction of the authors is provided followed by editors' notes on how the chapter fits into the general model introduced to organize the volume contents. Following each chapter, highlights of the chapter discussion are summarized to provide the reader a flavor of consensus or controversies associated with the topic. Consistent with volume 1, volume 2 is intended to serve as an up-to-date research reference as well as a classroom textbook on exercise, cognition, and aging.

The workshop was sponsored by the Institute of Gerontology at The University of Texas, the College of Education, the RGK Foundation, the Cain Foundation, the St. David's Foundation, and the Oscar and Anne Mauzy Regents Professorship, all of Austin, Texas. It was held at Austin Lakeway Inn and Resort, Austin, June 20 to 22, 2003. We acknowledge the valuable assistance and participation of Sandy Graham, Mina Rathbun, and Patty Coffman. Anne Marie Jennings was an important collaborator in organizing and editing the Editor's Discussion Summaries.

CONTENTS

PART I

Models and Mediators of Exercise Effects on Cognition

CHAPTER 1

Using Resources and Reserves in an Exercise–Cognition Model

Waneen W. Spirduso, EdD; Leonard W. Poon, PhD;
and Wojtek Chodzko-Zajko, PhD

From previous research literature and many discussions, we know that aging affects cognitive functions, especially those associated with executive processing and functions of the frontal lobe. Not all cognitive processes decline, and those that do may not follow the same pattern of deterioration. In fact, different functions may express a wide variety of age-related states: no change (stability), as may be represented by cultural knowledge; disease-related change, which can be gradual or precipitous as expressed by Alzheimer's disease or other dementias; a steady decline in function, as occurs with most people's short-term memory; and even transient changes, such as occur following small transient ischemic strokes where function slowly recovers over time. Even what seem to be similar cognitive decrements in individuals may have different causes. Given these widely varying patterns of change, researchers have agreed that one thing is very clear: Both between- and within-individual variabilities increase throughout the adult age span.

Individual variability in cognitive functions such as memory and learning comes from many sources, some of which were summarized by Jenkins (1979). Jenkins' "tetrahedron" describes cognitive performances as summations of interactions among four domains: (1) the characteristics of the individual, such as age, skills, knowledge, health, and other resources; (2) cognitive strategies; (3) the nature of the material; and (4) criterion tasks such as recognition, recall, problem solving, and others (figure 1.1). Variations in the interactions of these factors produce inter- and intra-individual variabilities in cognitive performances.

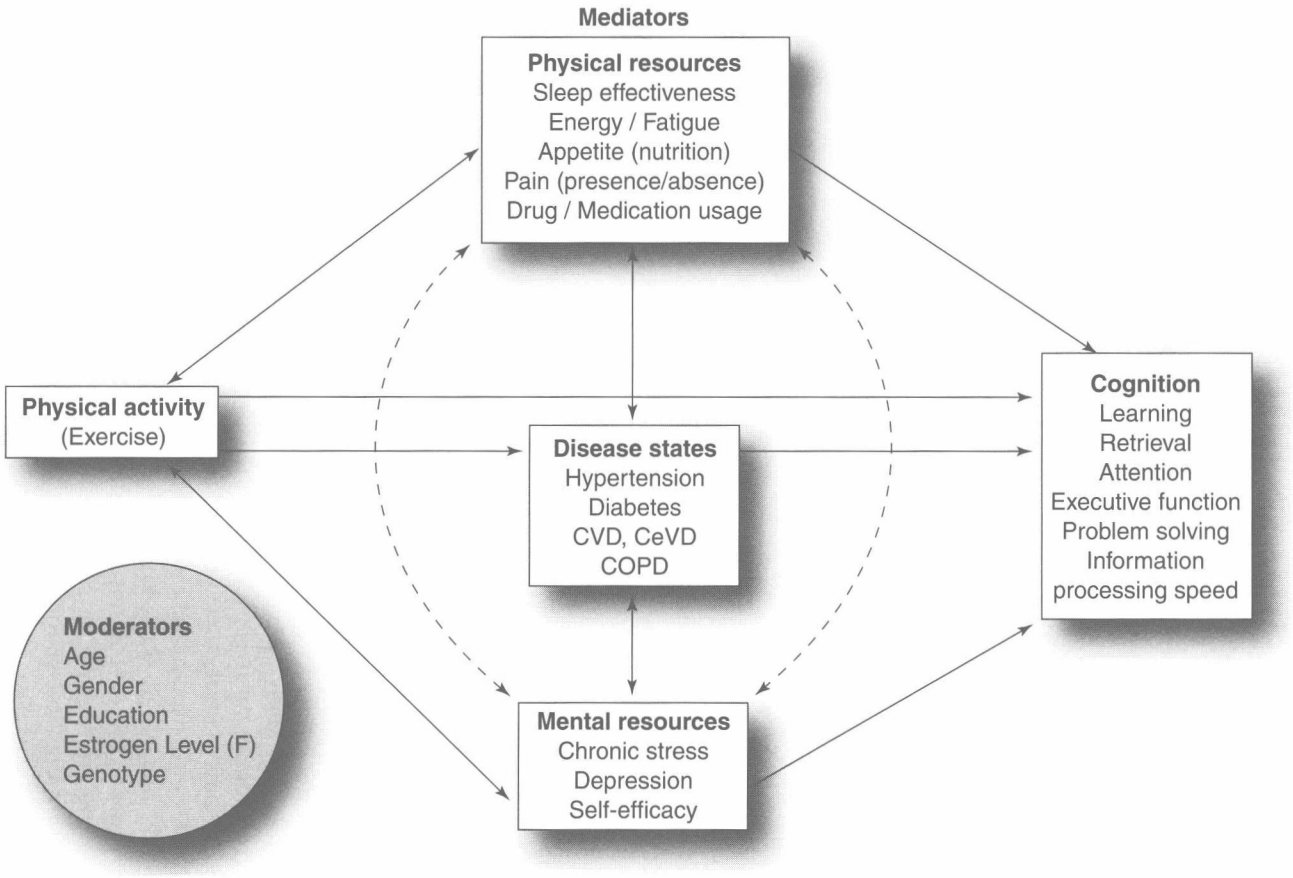

Figure 1.1 Working model of the role of mediators in exercise effects on cognition. F = female; CVD = cardiovascular disease; CeVD = cerebrovascular disease; COPD = chronic obstructive pulmonary disease.

We also know that exercise and physical activity are contextual factors that under specific conditions can improve cognitive functions. Direct influences, such as enhanced cerebrovascular function, are most frequently cited. However, it is highly probable that exercise also enhances cognition through its effects on mediator variables such as depression, sleep, appetite (diet), and energy levels and by postponing or preventing age-related diseases (e.g., diabetes, hypertension) known to affect cognition. It is thought that exercise affects both physical and mental resources or reserves, which in turn may create optimal conditions for cognitive function.

Hence, if we study how exercise could affect physical and mental resources that could in turn affect cognition, then we will begin to understand the facilitative mechanisms of exercise on cognition as individuals age. Indeed, cumulative indirect benefits via mediators may be more cognitively facilitating than direct effects.

The general strategy used to organize this volume was to (1) identify, using current knowledge, the paths—direct or indirect—through which exercise may influence cognition; (2) explore which mediators may most potently interact with aging, exercise, and cognition; (3) recommend directions that future research might take; and (4) determine whether a consensus statement regarding this topic can be generated from this review of the research literature. We propose that a way to study these paths is to identify key sources of individual variation or differences in exercise and cognition processes.

Model of the Effects of Exercise on Mediators of Cognition

To guide the reviews of the literature and the discussions that followed on individual variations in exercise and aging, we developed the model shown in figure 1.1. Some components of cognition that are most frequently studied in aging adults are shown in the right box labeled *Cognition*: attention, retrieval, information-processing speed, executive function, problem solving, and learning. Much of the research on this topic has been on potential direct influences of physical activity, such as increased brain oxygen availability and utilization attributable to improved cardiovascular function, increased glucose regulation, increased neural efficiency, neurotrophic enhancement, neurohormonal adaptations, and beneficial neural morphological changes. These mechanisms are shown in the model as a horizontal arrow directly from *Physical Activity* to *Cognition*.

However, the emphasis of this book is not on the direct and positive effects of exercise on cognition but rather on the indirect paths that exercise might take in positively affecting cognition: that is, how exercise may positively influence mediators of cognition, such as sleep, chronic disease, and depression and thereby indirectly improve cognition.

Mediators and Moderators—What Is the Difference?

Because mediators and moderators play such an important role in the model used by the authors of this book to address their topics, it was important to consider the definition, meaning, and use of mediators and moderators in the research literature of this field. These two terms have typically been used to describe a third variable that might affect the nature of the relationship between an independent variable and a dependent variable. In this model, mediating variables represent broader hypothetical constructs (depression, sleep, disease status) that influence the dependent variable of interest (cognition). Moderators are variables that partition independent variables into subgroups that establish its domains of maximal effectiveness in regard to a given dependent variable (age, gender, education).

The concept of mediators and moderators in models, however, is complex, and Jennifer Etnier (chapter 2) accepted the challenge to address this issue within the context of our model. She discusses various types of mediators, multiple mediator models, and micromediational chains and emphasizes the multiple interactions that most certainly occur among the mediators and the dependent variable of cognition. The interactions of exercise, mediators, and cognition are also influenced by powerful individual moderators such as gender, age, education level, estrogen level (in females), and genotype, shown in the circle in the lower left of figure 1.1.

The fact that most researchers routinely control for many of these mediators and moderators in their studies attests to their belief that these variables do indeed influence cognition and interact with exercise. It is also clear that many of these mediator variables are interrelated and may be based on similar mechanisms. For example, exercise benefits cognition by affecting serotonin and dopamine, and these transmitters also form the basis of a hypothesis to explain positive exercise effects on depression.

Effects of Exercise on Mediators of Cognition

Our hypothesized mediators of cognition are shown as the middle three boxes in figure 1.1: *Physical resources, Disease states,* and *Mental resources.* Physical resources are represented by *Sleep effectiveness, Energy and fatigue, Appetite (nutrition), Pain (presence or absence), and Drug/Medication usage.* The disease states included are several chronic diseases that have been shown to have substantial negative effects on cognition in older adults and have also been shown to be modifiable by exercise: *Hypertension, Diabetes, Cardiovascular disease (CVD), Cerebrovascular disease (CeVD), and Chronic obstructive pulmonary disease (COPD). Mental resources,* the lowest box of the model, includes *Chronic stress, Depression,* and *Self-efficacy.* All of these can have

negative effects on cognition, but self-efficacy can also be a positive force. Here it is shown as a mental resource, although Edward McAuley and Steriani Elavsky (chapter 5) argue that it should precede exercise, because exercise has a powerful influence on self-efficacy.

Exercise, Physical Resources, and Cognition

It has been claimed that exercise positively affects energy levels, sleep patterns, appetite, and other positive health behaviors (*Physical resources*, top box of figure 1.1). These resources include both the functional capacity of the system to perform cognitive tasks and the performance state, which is reflected in the ability of individuals to use their functional capacity. Individual differences and variability are dramatic in terms of both functional capacity and performance. Individuals vary widely in their innate levels of energy, their fatigability, the restorative efficiency of their sleep patterns, and their nutritional needs. Similarly, performance states vary widely both within individuals temporally and between individuals. We all have experienced physical states in which we believed that we did not have the energy to carry out a task, even though the task was mental and not physical. Extreme physical fatigue or sickness, for example, takes a toll on mental tasks. Who can study or do his income tax after a day of hard, physical work or when sick with the flu?

Phil Tomporowski (chapter 6) has suggested that energetics theory focuses on constructs that are used to describe the state of an organism (e.g., activation, arousal, fatigue) and that this theory may be applicable to the question of physical activity and cognition. Energetics theorists (e.g., Hockey, Coles, & Gaillard, 1986) suggest that mental performance is determined by (a) cognition—knowledge and skills (functional capacity), (b) conation—a willingness to expend physical or mental effort (performance state), and (c) affect—feelings and emotions (performance state). These constructs depend heavily on the role of physiologically based processes to explain individual differences in the availability of resources that are required for intensive and sustained goal-directed behavior. Regulation of behavior is explained in terms of brain structures and neurotransmitter systems and in terms of regulation of the autonomic nervous system. Optimal behavioral regulation and performance are assumed to be degraded when these physiological systems are impaired. The impairment of these physiological systems can come from two sources: (1) the workload engendered by the preparation and actual performance of a given task and (2) stressors that are not directly related to the task to be performed.

Sleep effectiveness is a more recognized physical resource that has been linked to health, physical activity, and cognitive function. Sleep is at the same time absolutely necessary for cognitive function and a serious problem in older adults. In chapter 9, Martita Lopez addresses the potential indirect

effect that physical activity may have on cognition as it affects the quality of life, and in chapter 10, Michael Vitiello discusses mechanisms by which sleep enhances cognition and potential ways that physical activity might, by enhancing sleep, also influence cognition.

A sound nutritional status is thought to support optimum cognitive function, providing the nutrients necessary for optimum metabolic activities and high energy levels. In fact, Jim Joseph (chapter 8) builds a good case that certain combinations of antioxidant and anti-inflammatory polyphenolics that are found in fruits and vegetables may ameliorate age-related behavioral and neuronal deficits. Specifically, enhancing the diet with adequate amounts of berries such as blueberries and strawberries might have some benefit for certain types of cognition in old age. Many older adults, for various reasons that include immobility, poverty, poor appetite, ignorance, lack of interest, loss of olfactory sensitivity, gastrointestinal problems, and other illnesses, maintain an inadequate diet. It is highly likely that low levels of this physical resource contribute to poor cognition. Some suggestion has been made that physical activity may enhance appetite, thus enabling older adults to consume enough calories to increase their chance of obtaining recommended daily dietary requirements. However, this particular physical resource and its relationships to physical activity and cognition were not addressed in our workshop.

In the model (figure 1.1), these physical resources are shown to influence cognition, but at the same time they are affected by physical activity. Physical resources also affect mental resources and disease states, which influence cognition. Therefore, exercise can change physical resources, which enhance or degrade disease states, and mental resources, both of which affect cognition.

Prevention or Postponement of Disease States

It is frequently suggested that in addition to directly affecting brain function, exercise also enhances both physical and mental resources or reserves, which in turn may create optimal conditions for cognitive function. Thus, exercise plays an important role in preventing or postponing disease states (middle box of figure 1.1) such as hypertension (Hiro Tanaka and Miriam Cortez-Cooper, chapter 11), diabetes (Don Royall, chapter 12), and chronic obstructive pulmonary disease (Charles Emery, chapter 13) that are known to degrade cognition. Thus, exercise may mediate the negative effects of these and other diseases on cognitive function.

Exercise, Mental Resources, and Cognition

Mental resources are theoretical constructs that describe the notion of finite mental energy in the processing of information. Kahneman (1973) was one of the first to suggest that cognition requires mental effort and that