PHYSICAL ACTIVITY AND AGING

ROY J. SHEPHARD

Physical Activity and Aging

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CROOM HELM LONDON

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PREFACE

Aging might seem a depressing theme for a book. Stephen Leacock, the Canadian humourist, suggested: 'About the only good thing you can say about it is, it's better than being dead.' Nevertheless, it is a topic we can hardly avoid. A combination of a rapidly falling birth rate and the conquest of acute disease is confronting many governments with the practical problems of a rapidly expanding geriatric population. Individually, we must also face old age and make our personal adaptation to it. I was startled recently to hear one of my daughters acknowledge that she was getting old. At the ripe age of seventeen, her judgement was based on the fact that she now knew the former pop stars discussed in the evening paper under the heading 'Whatever became of . . .'. Most of us first begin to appreciate aging in its social context – the weddings of our friends give place to christenings, marriages of the younger generation, and then a geometrically increasing progression of funerals! As we approach the half century, the limitations of our own bodies become painfully apparent. Books are suddenly printed in abominably small type, friends mumble in a ridiculously unintelligible fashion, and even the weekly bag of groceries becomes a burden. For the first time in our lives, we appreciate the significance of research that promises to halt or even reverse the inexorable loss of body function.

The problems of a geriatric society are felt most acutely by the older social democracies of Western Europe, and it may seem presumptuous even to discuss questions of senescence from the comfort of a young nation such as Canada. Our one claim to geriatric fame is Pierre Joubert. Joubert was a French Canadian bootmaker, born in Charlesbourg, Quebec on 15 July 1701. Despite recent legends from the Caucasus, Joubert retains the distinction of attaining the greatest authenticated age in the world. He died in Quebec City on 16 November 1814, having lived for 113 years, 124 days. Dr Tache, official statistician to the Canadian government of 1870, made a careful examination of his credentials, and concluded that the proofs were irrefutable. His story underscores the challenge of geriatric investigation. Fewer people are dying in early old age. But despite two centuries of earnest research, we remain unable to check the underlying process of senescence; still, there is a ceiling of 112-114 years that apparently cannot be surpassed.

The present book makes no attempt to solve this ultimate mystery. Rather, it explores how far we can improve our adaptation to the early part of old age through an increase of personal fitness. Research is presented that suggests such an approach holds a great potential, not only for the extension of personal happiness, but also for the avoidance of national bankruptcy. The substantial but scattered information on physical activity and aging is drawn together into a single volume that should appeal not only to the gerontologist but also to many other scientists interested in human performance – the physiologist, the physical educator, the ergonomist and the physiotherapist. In preparing the book, I have drawn frequently upon the wisdom and experience of a number of close colleagues and co-investigators; it is a great pleasure to acknowledge my debts to Dr Terence Kavanagh, Medical Director of the Toronto Rehabilitation Centre, Dr Cope Schwenger, Professor of Health Administration at the University of Toronto, and two exceptional graduate students, Dr Kenneth Sidney and Mr Veli Niinimaa.

The general plan of the book is evident from the page of contents. After discussing definitions and techniques, the aging of cells and of organs is reviewed in the specific context of physical activity. The normal activity patterns of the old person are examined, together with their attitudes to physical exercise, and the implications for nutrition are discussed. A training plan for the elderly is considered, and the likely response of the body to increased activity is indicated. The elderly athlete is presented as an extreme case of sustained training. Final chapters review the interactions of physical activity with some of the common diseases of old age, and the economic implications of an aged and increasingly dependent population.

No easy solutions are found to the overall decline in biological function. However, the point is made that quite moderate training can set back the deterioration of physiological work capacity by an average of eight to nine years; assuming a much smaller change in death rates, this would reduce by two thirds the proportion of the population who must accept a final period of physical incapacitation. If the present book does no more than encourage senior citizens and their advisers to exploit this important possibility, the labour of its writing will be well repaid.

Toronto, 1977 Roy J. Shephard

1 INTRODUCTION

Scope of Text

From early antiquity, medical science has been fascinated by the gradual loss of function that occurs with aging. One compelling reason for this interest has been the universality of the aging process, its threat extending to both the eager investigators and their anxious patrons. The philosopher's stone was sought not only to translate base metals into gold, but also to yield an elixir that would allow the alchemist leisure to contemplate his new found wealth (Comfort, 1963).

Taoists believed that the secret lay in preserving the essence of life (the semen), and sages such as Wei Po-Yang (second century AD) claimed substantial extension of their life span through a combination of detachment from worldly cares and a complicated ritual of general and sexual gymnastics. If in fact the Chinese philosophers attained longevity, this reflected their privileged place in society, and the year 1978 still finds us far from success in our search for a general elixir of life. We can induce small extensions of life-span in experimental animals by changes in diet or environmental temperature, and by treatment with antioxidant chemicals. Nevertheless, the strategy of geriatric medicine remains the piecemeal treatment of senile disability rather than any more general attempt to slow the rhythm of a seemingly limited duration biological clock (Comfort, 1973).

Partly because many fundamental questions of aging have yet to be resolved, the main focus of the present book is upon the practical problems of human aging rather than theories describing the decline and fall of the common fruit-fly (Drosophila). While it is superficially attractive to be able to study senescence in many generations of insects over a short time interval, observations such as deterioration in the cuticle of an arthropod have less than immediate relevance to the urgent problems of a growing geriatric population. The emphasis of this volume is further upon aging in an active man, rather than the senescence that can be detected through studies of basal function, and the behaviour of the whole body is discussed in preference to observations at the cellular and sub-cellular levels, for the issue of prime concern to society is whether a senior citizen can meet the physical demands of independence during everyday life.

In this introductory chapter, we will attempt a definition of aging, propose a classification of the elderly, and deal with such practical issues of experimental design as the selection of 'normal' subjects, the choice between cross-sectional and longitudinal studies, and the statistical distribution of geriatric data.

Subsequent chapters will examine cellular aspects of aging, changes of gross function, normal activity patterns of the elderly, techniques for increasing the activity of the senior citizen, specific characteristics of the elderly athlete, the general impact of physical activity upon the pathology of aging and goals for a geriatric society.

The Definition of Aging

While it is possible to describe certain manifestations of aging at the cellular and the sub-cellular levels of organisation the overall process is best defined in terms of man as a whole. Two related concepts are a diminished capacity to regulate the internal environment (impaired homeostasis), and a reduced probability of survival.

Homeostasis

Rowlatt & Franks (1973) explained senescence as 'a progressive loss in the individual of physiological adaptability to the environment culminating in death'. Their view can be illustrated in terms of the reaction to a severe haemorrhage; the chance of death following a given blood loss increases logarithmically with age (Simms, 1942). Presumably, the feedback mechanisms stabilising the blood volume of a younger person are no longer fully operative in the elderly. Similar impairment of control mechanisms develops in many other homeostatic systems, including the regulation of blood sugar (Silverstone *et al.*, 1957) and of body temperature (Pickering, 1936; Burch *et al.*, 1942). The old person thus becomes progressively more vulnerable to environmental threats, and mortality is increased by extremes of heat and cold. In the United Kingdom, for example, many senior citizens still develop hypothermia, sometimes with fatal consequences. One problem is that through a deterioration of sensory receptors and loss of central information processing an old person may develop an inappropriate thermal preference, not realising that he is becoming chilled (Watts *et al.*, 1972; Fox *et al.*, 1973). Such hazards are compounded by a limited ability to increase metabolism and to minimise heat loss (Wagner *et al.*, 1974).

While a severe cold challenge can develop because of a limited income or failure to detect a falling house temperature, in the modern

North American world of air-conditioned buses and subway cars, enclosed shopping malls and centrally-heated homes, such difficulties are not very prevalent. Indeed, the main threat to homeostasis can come from within the body. Physical activity increases the demands on many body systems by a factor of at least ten, and a complicated series of feedback loops must be activated to conserve the constancy of the internal environment. In reviewing the biology of aging, it thus seems particularly appropriate to consider data in the context of the performance of external work.

Survival

Other factors being equal, the overall survival prospects of an individual depend on his capacity for homeostasis. However, if there were no senescence, homeostasis would be equally well-developed at all ages. Deaths due to accidents, disease and other forms of stress would then occur in random fashion, with a constant percentage of the residual population dying over each successive time interval (Figure 1.1). This type of curve is found in some animal species that are exposed to a hazardous environment, since very few individuals survive to the age of senescence. The alternative possibility is to live in a well-protected environment, where most of the deaths are due to senescence. The survival curve then has a relatively rectangular form, with a sudden drop in the percentage of survivors once a critical age has been passed. In practice, most survival curves have a form that is intermediate between these two extremes.

Mathematicians have found much amusement in trying to fit equations to such data. The first attempt was by Gompertz (1825). He suggested that the mortality rate R_m at time t was given by an exponential function related to the number of survivors n and a hypothetical mortality rate R_0 typical of zero time:

$$R_m = -\frac{1}{n} \times \frac{dn}{dt} = R_0 e^{\alpha t} .$$

A linear function should thus be obtained by plotting the logarithm of the death rate against age (Figure 1.2), the rate of aging being indicated by the slope constant α.

Other authors have attempted to improve on his formula by adding a second component of mortality A that is independent of age:

$$R_m = R_0 e^{\alpha t} + A .$$

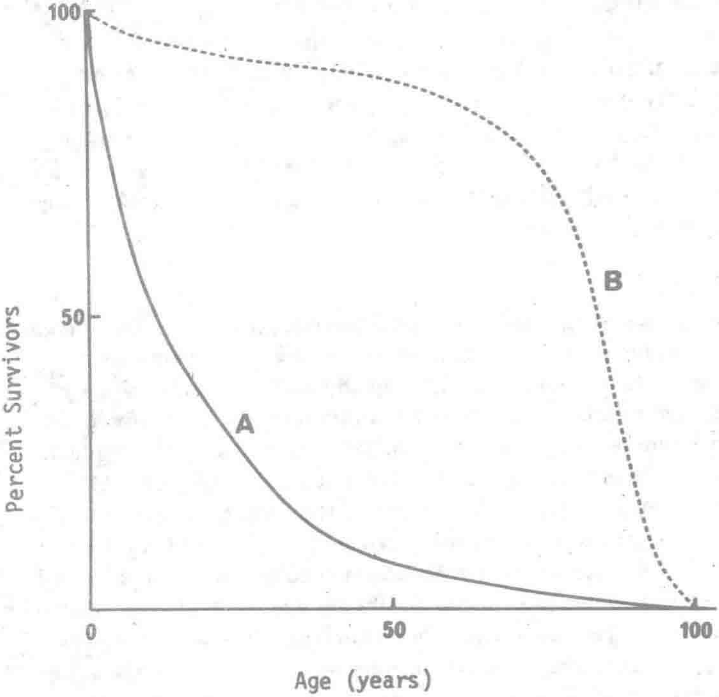

Figure 1.1 Survival Curves. Population A is showing a constant and random mortality due to natural causes. Population B is showing a sudden increase of mortality with the onset of senescence.

A third suggestion has been to allow an initial interval of early adulthood b before senescence begins to take effect:

$$R_m = R_0 e^{\alpha(t - b)} .$$

However, it seems unlikely that any simple formula will do more than approximate the complex interactions between environment and senescence. For example, such factors as the development of immunity to common diseases and the learning of caution in the operation of a motor vehicle will distort the semi-logarithmic plot, leading to an underestimation of aging from Gompertz-type curves.

Improvements in environmental conditions reduce the frequency and extent of challenges to homeostasis, thus displacing the Gompertz

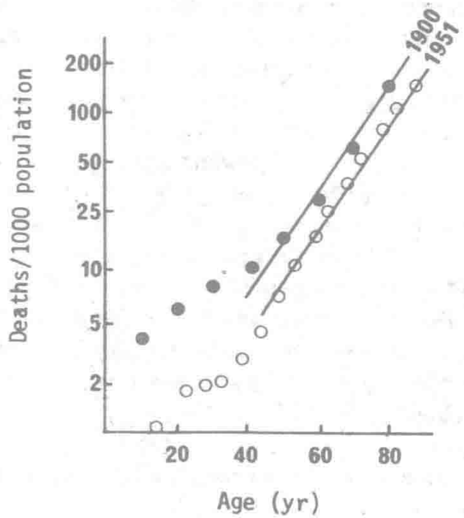

Figure 1.2 Gompertz plots relating deaths/1,000 population (logarithmic scale) and age of population. Data for USA, 1900 and 1951 (after Shock, 1967).

curve to the right (Figure 1.2) without much change in the slope of the relationship (Shock, 1967). While some authors have interpreted this as a reduction of physiological age, there is little question that the real explanation lies in the decreased environmental challenge. If the population of 1951 had been confronted with the environment of 1900, they would not have survived any better than their forbears!

One final complication may be noted. In most countries, the environment has changed perceptibly while subjects have been aging. The slope of the Gompertz relationship thus reflects the combined influence of senescence and alterations in the environment.

Classification of the Aged

Group Classifications

Dividing points in any system of age classification show a direct relationship to the age of the speaker or the writer. Many of my undergraduate students would propose quite seriously that a thirty-year-old person could be included in a study of elderly subjects! Even published reports on the exercise tolerance of the elderly are too commonly based on people in the age range 40-60 years. This makes