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Longevity Chance

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Britton Chance pursued his research and sailing until his death at age 97. His 100th anniversary was memorialized in this paper from longevity viewpoint. His lifelong work was very creative. His life was very colorful. His aging was very successful. He has lived a longevity.

Keywords: Aging; exercise; work; redundancy; photobiomodulation.

1. Introduction

Britton Chance was the Eldridge Reeves Johnson emeritus professor of biophysics, physical chemistry and radiologic physics at the University of Pennsylvania. He was born into a family of inventors and engineers who loved ocean sailing on 26 July, 1913. In a remarkable life, he was both a renowned biophysicist and a worldclass yachtsman. His first two marriages ended in divorce, but he was survived by his third wife, as well as 11 children, five stepchildren and numerous grandchildren and great-grandchildren. He pursued his research and sailing until his death on 16 November, 2010, at age 97.[1–3] His life was fueled by what seemed to be such an inexhaustible source of energy that many regarded his death as premature.[2] His 100th anniversary was memorialized in this paper from longevity viewpoint.

2. Successful Aging

Chance's lifespan was 97.3 years old. It was older than the one of sports players (77.4), performers (77.1), professional/academic/religious persons (81.7) or creative (78.5), military (84.7), business (83.3) or political (82.1) workers published in New York Times over the period 2009–2011.[4] His aging was successful.

Chance was mainly a scientist. His group has published many papers in *Nature* and *Science*. Its creativity prime time was in 1962 when, as a first author, Chance has published 4 papers in *Nature* and 2 papers in *Science*. Therefore, his prime age should be 49 years old so that his most possible life span should be 99 according to $\mathbf{y} = 2\,\mathbf{h} + 1$ in which $\mathbf{y}$ and $\mathbf{h}$ are the most possible life span and the prime age, respectively,[5] if the global growth and aging of an individual, which includes body, mind,

emotions and spirit, were supposed to be symmetrical with each other as discussed in Sec. 8. His life span was younger than his most possible life span. It might be due to his death of heart failure in Winter,[2] a peak season of heart failure hospitalization.[6] Healthy centenarians with physical function in the independent range and the absence of hypertension, congestive heart failure, myocardial infarction, peripheral vascular disease, dementia, cancer, stroke, chronic obstructive pulmonary disease and diabetes had significantly longer telomeres than did unhealthy centenarians with physical function limitations and greater than or equal to 2 of the above conditions.[7]

However, the error of his life span from his most possible life span, 1.7%, is so small that Chance's aging should be a successful aging. Chance has outlived the risks for many of the conditions that are common causes of death for those who die in their 70s, 80s and 90s, such as cancer and myocardial infarction. Conditions associated with aging, such as congestive heart failure and degenerative neurological conditions become more prominent as reported causes of death in the oldest centenarians.[8]

Most studies of successful aging have used restricted definitions based on the absence of disability and identified a small number of predictors. Ng *et al.* have examined whether a broad multidimensional definition of successful aging has good construct validity and identified a wider range of predictors that are relevant for multifaceted interventions.[9] Successful aging was determined in 28.6% of respondents among 1281 community-living Chinese elderly of 65 years and above in the Singapore Longitudinal Aging Study cohort and in multivariate models was significantly associated with greater than or equal to 6 years of education (odds ratio (OR) = 2.31), better housing (OR = 1.41), religious or spiritual beliefs (OR = 1.64), physical activities and exercise (OR = 1.90) and low or no nutritional risk (OR = 2.16). All of the factors have played important roles in Chance's successful aging. Among them, physical activities and exercise would then be discussed in detail.

3. Physical Activities

Physical activities are associated with successful aging.[9] Muscle may be one of the major tissues in which adenosine monophosphate-activated protein kinase plays a critical role on longevity and stress resistance,[10] which is the molecular basis of exercise effects on longevity. Moreover, the mean happiness of exercise is the second highest category among daily activities.[11] After studying 13,485 men (mean age, 57.5 years) from the Harvard Alumni Health Study, Lee and Paffenbouger found that light activities (<4 multiples of resting metabolic rate (METs)) were not associated with reduced mortality rates,[12] moderate activities ($4\sim6$ METs) appeared somewhat beneficial, and vigorous activities ($>$ or $=6$ METs) clearly predicted lower mortality rates. After studying 8421 men (mean age, 66 years) from the Harvard Alumni Health Study, Lee *et al.* further found even 1–2 episodes/week generating 1000 kcal/week or more can postpone mortality among those with no major risk factors.[13]

Chance not only studied the bioenergetics of skeletal muscles,[14] but also scientifically did exercise.[1] He biked three quarters of a mile to the University of Pennsylvania for work each day.[15] His parallel, lifelong love affair with sailing, mainly enjoyed in Barnegat Bay, New Jersey, culminated in his gold medal in the 1952 summer Olympics.[1] Each year Chance invited 5–10 classmates and fraternity brothers to join as crew (http://www.med.upenn.edu/biocbiop/chance/sailing/sailing_history.html). They sailed from Philadelphia, to Havana, Jamaica, Grenadines, Trinidad and Tobago, Panama Canal, Pearl Island, and safely back in early August to avoid hurricanes. Another trip was across the Atlantic Ocean to England, France, Spain — the Royal Court of Spain.

4. Work

He worked in his research lab, for 12-h days.[3] The 12-h day work is an overtime work according to Virtanen *et al.*'s study.[16] Virtanen *et al.* have examined the association between overtime work and the onset of a major depressive episode.[16] They found that the OR for a subsequent major depressive episode was 2.43 times higher for those working 11+ h a day compared to employees working 7–8 h a day in prospective analysis of 2123 participants with no psychological morbidity at baseline. However, Chance did not suffer from a major depressive episode. It might be due to his enjoyment of work and exercise.

The time pressure is a particularly important determinant of enjoyment at work.[17] Kahneman *et al.* found that the impact of constant pressure to work quickly on the enjoyment of a regular day is one of the top two among the work circumstances and individual differences, at work and at home.[17] Chance's many papers and many medals indicated that he was not only good at work, but also lived a happy life. As Frey has reviewed, happy people live longer.[18] Happy Chance lived a longevity.

5. Redundancy

Redundancy is generally not compliment, but it academically is. There are at least three paradigms of redundancy. Firstly, genetic redundancy means that two or more genes are performing the same function and that inactivation of one of these genes has little or no effect on the biological phenotype.[19] The two or more genes and their corresponding pathways are called redundant genes and redundant pathways, respectively.[20,21] One fully activated redundant pathway can maintain a normal function on which the exact definition will be discussed in Sec. 8, and the synergitic integration of two fully activated redundant pathways can enhance the normal function.[20,21] Direct photobiomodulation (PBM) may promote the activation of a partially activated redundant pathway so that the modulated dysfunctional function may become normalized, and indirect PBM may promote the activation of the partially activated redundant pathway of one fully activated redundant pathway so that the maintained normal function may be enhanced.[20,21] Secondly, a community whose composition is sensitive and not resilient might produce process rates similar to the original community if the members of the community are functionally redundant.[22] Thirdly, redundancy is also a concept of crucial importance for understanding aging, particularly the systemic nature of aging. Systems that are redundant in numbers of irreplaceable elements deteriorate (that is, age) over time. An apparent aging rate or expression of aging is higher for systems that have higher levels of redundancy.[23] In other words, the higher the redundant levels, the longer the life span.[23] Scientist, inventor and yachtsman are three kinds of lifestyles, but they were integrated in Chance's life. His redundant level was so high that he has lived a longevity.

Chance's time at Penn from student to emeritus was marked by a succession of outstanding achievements, from novel instrumentation to biophysical research strategies.[1] Metabolism was a central theme of Chance's research.[1,2] He studied it with the integration of science and technology. In 1930s, he invented miniature stop-flow instruments and used them to make seminal contributions to our understanding of enzymatic kinetics. In 1950s, he invented the dual-beam spectrophotometer and used it in pioneering investigations of bioenergetics and the redox state in mitochondria. In 1970–1980s, he was a key player in the development of *in vivo* nuclear magnetic resonance spectroscopy, and in 1990s he was a founding father of the field of Biophotonics, especially for biomedical research and clinical practice.

Chance's life is also an integration of research and sailing. Chance was born into a family of inventors and engineers who loved ocean sailing. His capacity for innovation with mechanics, electronics and optics was evident from an early age. [1] During extended family sailing trips he became the qualified radio operator; at age 13, he built his first powerful radio transmitter and became a ham radio enthusiast. By age 17, he had built and patented an automatic ships-steering device incorporating a novel servomechanism. For him, sailing became a lifelong passion as discussed in Sec. 3.[2]

6. Openness

Two facets emerged from the openness adjectives: intellect and creativity. After investigating 1349 men from the Veterans Affairs Normative Aging Study from 1990–1991 to 2008, Turiano *et al.* found only creativity predicted mortality risk in the fully adjusted model, and a 1-SD (standard derivation) increase in creativity was associated with a 12% decrease in mortality risk.[24]

Chance was very open. He married his third wife, Shoko Nioka, in a traditional Chinese ceremony in Taiwan.[25] His openness was especially in creativity. His career was driven by the physics of electronics, radiation and mechanics applied to revealing fundamental mechanisms of biology and physiology and later to developing noninvasive optical devices for medical imaging and clinical diagnostics.[2] He has even paid attention to PBM.[5,20,21] He has edited the only paper published in *Proc Natl Acad Sci USA*

in 2003.[26] As the fourth author, he also published a paper in *J Biol Chem* in 2005.[27]

7. Not to Retire

No effects of retirement age on mortality has been found in Norway and Sweden,[28,29] but retirement age increase has been found to decrease mortality in Germany, USA and Greek.[30–32] Mortality of the not-in-work in later life was found to be consistently higher than the in-work in Finland, Turin and England and Wales.[33]

Chance had never thought much about retirement.[3] He rode a 10-speed bicycle from his West Philadelphia home to work in his research lab six days a week. As he continued to supervise and furnish ideas for medical research, write reports, apply for funds and attend seminars where he kept up to date on the latest findings, Chance was not just providing a service to medical science but contributing to his own longevity.

8. Discussion

Longevity can be formulated in terms of negative feedback and homeostasis which have been discussed by Chance *et al.*[34] Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity according to world health organization. An individual can perform many internal and external functions of body, mind, emotions and spirit. Each function may be maintained by a negative feedback response which was called function-specific homeostasis (FSH).[5,20,21] The quality of an FSH (Q) is called functional fitness. A healthy individual might simultaneously have many kinds of FSH, $\{\mathrm{FSH}_i, i = 1, 2, \ldots, N\}$, and then has $\{\mathbf{Q}_i, i = 1, 2, \ldots, N\}$. Let $\mathbf{Q}\max = \max\{\mathbf{Q}_i, \quad i = 1, 2, \ldots, N\}$. Obviously, **Q**max represents the health level or the quality of life. The aging process is of course under genetic control, but it can also be considered a result of the failure of homeostasis due to the accumulation of damage.[35,36] Aging is defined as the progressive decline of homeostasis that occurs after the reproductive phase of life is complete, leading to an increasing risk of disease or death, which results from a failure of organs to repair deoxyribonucleic acid damage by oxidative stress (nonprogrammed aging) and from telomere shortening as a result of repeated cell division (programmed aging).[37] Therefore, **Q**max is becoming higher in growing and lower in aging.[5] The age when **Q**max is of highest value, **Q**peak, is defined as the prime age, **h**.[5] Crimmins and Finch have shown that increasing longevity and declining mortality in the elderly occurred among the same birth cohorts that experienced a reduction in mortality at younger ages.[38]

The global growth and aging of an individual, which includes body, mind, emotions and spirit, may be supposed to be symmetrical with each other.[5] There were associations between early and later morbidity and mortality.[39] Although the invariant ratio of average adult life span and age at maturity is an illusion,[40] there are different linear plots of age at sexual maturity versus average adult life span for different taxa.[41] Wild-derived mice lived a longer life due to delayed maturation than laboratory-adapted mice.[42] Moreover, age at the onset of senescence in birds and mammals was found to be predicted by early-life performance.[43] These phenomena suggested that the growth and aging may be supposed to be symmetrical with each other. The symmetrical hypothesis was supported by the removal of senescent cells. Baker *et al.* made use of a biomarker for senescence, p16(Ink4a), to design a novel transgene, INK-ATTAC, for inducible elimination of p16(Ink4a)-positive senescent cells upon administration of a drug, but they found that the removal of senescent cells cannot extend the lifespan of the INK-ATTAC mice.[44] If the symmetrical hypothesis may exactly hold, there should be the prime age **h** so that the most possible lifespan **y** should be 2 **h**+1.[5] Obviously, higher **Q**peak may mean longer **y**.

Chance has lived a longevity. A function in or far from its FSH is called a normal or dysfunctional function. There are two kinds of subfunctions maintaining a normal function, FSH-essential subfunctions and FSH-nonessential subfunctions.[5,20,21] All the FSH-essential subfunctions of a normal function are normal, but only some of FSH-nonessential subfunctions are normal. Work is a health-essential function.[24,30–33] High creativity[24] and not to retire[30–33] may mean high **Q**max. Science research is Chance's health-essential function in which prime time was in 1962 so that his prime age was 49 years old, but technology research, sailing and other physical activities are Chance's health-nonessential functions. Higher redundant levels may mean more

normal health-nonessential functions and then higher **Q**peak. In a summary, Chance has lived a longevity.

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