Significance of Health Fitness Appraisal in an Aging Society

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Abstract. There is no doubt that the older population in Japan is rapidly increasing. The over-65 age group is the fastest growing age group in Japanese society. The quality of life for this rapidly growing segment of the population can no longer be ignored without disastrous consequences. The advent of an increased life expectancy has focused attention on the issue of functionality versus disability. We are all faced with the inevitable consequences of aging, yet each of us has the capacity to modify the aging process physiologically through appropriate physical activity and other preventive health measures. Therefore, with the aid of a physically healthy lifestyle, an exercise participant can be physically capable, energetic, and live actively beyond the ages of 50, 60, or even 70 years. Consequently, a key issue for successful or healthy aging would appear to be the improvement in perception of physical ability through education, as well as improvement in health-related physical fitness through a change in lifestyle involving regular exercise. In addition, it is a major responsibility of the physical education profession and related health fields to clarify and publicize the benefits, risks, and specific parameters of physical activity, and to develop an effective prescription for physical activity in programs that are age adjusted. This review discusses from this perspective the significance of health fitness appraisal in the aged society. Much more research is needed to clarify these issues in Japanese society.

(*Appl Human Sci*, 16 (4): 123-131, 1997)

Keywords: aging society, physical activity, physical fitness, health, aging

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Introduction

In Japan, the percentage of elders over age 65 already reached 12.6% of the population by 1991. The Institute of Population Affairs of the Japanese Ministry of Welfare estimates that by the year 2025, the over 65 age phenomenon will peak with a twofold increase to approximately 26.6%. From this estimation it appears certain that during this period, Japan will be one of the

world's leaders in the acceleration in number of their aged society (Table 1). It is also estimated that there will be an increase in mean life expectancy of people who are 65 in 1992 by 16.3 years for males (81.3 years) and 20.2 years for females (87.2 years).

The average life span of Japanese people has set new records for the male, 76.3 years and female, 82.5 years. Due to the strong prediction that this extension of longevity will continue, in the year 2025 the average life span will reach 78.2 years for males and 85 years for females. Therefore, a question of major importance to both the individual and society is: "Is increasing the age at death adding high quality years to life or is it increasing the period of diseased or morbid state that precedes death?" Walford (1980) suggests that individuals should probably be contemplating the achievement of an average health expectancy rather than an average life expectancy.

As the older Japan population continues to increase, it is anticipated that while individuals may live longer, they may not necessarily enjoy active, happy, and independent lives. Thus, maintaining functional independence while aging has become a more important priority in Japan. Specifically, physical activity and physical fitness have been identified as priority objectives in general health promotion.

In some European countries and the United States, where the aged population ratio is equally high, development of a health policy for elders has been a priority since the 1960's. West Germany took the initial lead in designing community sports facilities under a Gold Plan in 1960. In 1972, Great Britain started the Sports Council for the health and welfare of elders, which became during a 10-year span, a world model under the rubric of Sports for All. In 1973, Sweden developed a program called KOM which aimed at reducing medical expense by 15% through improvement of dietary intake and the encouragement of sport. Also, the United States developed the program called Soft American under President Kennedy in 1960. In 1980, President Carter used a slogan "Healthy Country America" to propel a national policy called Fitness America for health improvement. Other countries such as Norway developed

Table 1 International comparison on acceleration of aging society

Country	Elders over 65		Years needed to increase from 10% to 20% (yr)
	Become 10% (yr)	Become 20% (yr)	
Japan	1985	2007	22
Hongkong	1996	2024	28
Canada	1983	2023	40
Finland	1973	2019	46
Netherlands	1969	2018	49
Switzerland	1959	2009	50
Sweden	1947	2012	65
United Kingdom	1946	2025	79

Source: Japan: Institute of Overpopulation Problems of Nihon University

Other countries: Estimation of World Population in Population Division of the United Nations.

Table 2 Elements of physical activity and exercise (Caspersen et al., 1985)

Physical Activity	Exercise
1. Bodily movement via skeletal muscles	1. Bodily movement via skeletal muscles
2. Results in energy expenditure	2. Results in energy expenditure
3. Energy expenditure (kilocalories) varies continuously from low to high	3. Energy expenditure (kilocalories) varies continuously from low to high
4. Positively correlated with physical fitness	4. Very positively correlated with physical fitness
	5. Planned, structured, and repetitive bodily movement
	6. An objective is to improve or maintain physical fitness component(s)

Trim and Canada a policy program called Sports Canada and later Fitness Canada. It is apparent that the development and encouragement of a health and sport policy was a common goal in the developed world during the past 30 years (Tanaka and Lee, 1995, 1996).

In 1972 Japan created an office of Health Promotion under the Japanese Ministry of Welfare, and in 1978 a policy termed The First National Health Promotion Plan was disseminated. Three years later in 1981, a policy for middle and old age workers called the Silver Health Plan was created. In 1988, the Japanese Ministry of Welfare created and implemented The Second National Health Promotion Plan named Active 80 Health Plan using the slogan "Health Administration To Health Making In Order To Live Until Their 80s." This policy was specifically aimed at *pursuing* a health promotion policy by establishing the exercise habit as a core improvement in the elderly lifestyle.

If we give consideration to Japan's realistic notion of a 21st century aged society, "bonus years at the end of a well-planned and healthful life would provide the individual with an enriched period of time in which to reflect on a mosaic of cherished memories as well as to synthesize and culminate projects so that life goals are fulfilled" (Spiriduso, 1989). Therefore, in the 21st century, the elderly should not just extend their lives

silently and sedentarily. What we strongly propose is an extensive public policy which enables as many elders as possible to participate in civic and social activity while they are living healthy productive lives.

From this perspective, we first need to understand the concepts and definitions of physical activity, physical fitness, and health. The purpose of this review is to define such key words as health, physical fitness, physical activity, and exercise and their relationships to successful aging. As an index of health status and aging, the concept and statistical approach for estimation of appropriate biological age ranges are also briefly reviewed. Finally, we propose a new concept of vital age and health-related physical fitness age for Japanese society.

Defining Key Constructs

I. Physical Activity, Exercise, Physical Fitness, and Health

Physical activity, exercise, and physical fitness are terms that describe different concepts. However, they are often confused with one another, and the terms are sometimes used interchangeably. Caspersen et al. (1985) proposed a framework for comparing studies that relate physical activity, exercise, and physical fitness to health (Table 2). Physical activity can be defined as "any body movement produced by the skeletal muscles that results

in substantial increase over the resting energy expenditure" (Bouchard et al., 1994). Hence, physical activity in daily life can be categorized into occupational, sports, conditioning, household, or other activities. Exercise, then, comprises a subset of physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective for improvement or maintenance of physical fitness. When prescribed by a physician or exercise specialist, the optimum regimen advised typically addresses the recommended mode, intensity, frequency, and duration of such activity (ACSM, 1992).

The World Health Organization (1968) defined physical fitness as "the ability to perform muscular work satisfactorily." Being physically fit has also been defined as "the ability to carry out daily tasks with vigor and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies." Health is a state of complete physical, mental and social well-being, and not merely the absence of disease and infirmity (World Health Organization, 1947).

As the above definitions of physical activity, physical fitness, and health are considered, there seems to be much overlapping with regard to the function of mind and body. The interrelationship among exercise, fitness, and health and their opposites can be represented by a series of ratios. In other words, if we increase the level of physical activity in daily life, the level of physical fitness will also increase. This may then contribute to the maintenance and improvement of health. As to the association between physical activity and physical fitness, the American Medical Association notes that "physical fitness depends on the individual's state of health, constitution, and present and previous physical activity." An increase of physical activity may be expected to increase various components of an individual's fitness, and any improvement in the aerobic component of fitness is in turn likely to improve a person's health.

II. Physical Fitness in Japan Versus United States

In general terms, physical fitness can be conceived as the matching of the individual to his or her physical and social environment. The meaning of each component of physical fitness can differ depending on generation, one's value system, and changes in the living environment. Up to the present, the significance of physical fitness has been advocated for such purposes as strengthening military personnel, labor power, and improvement of competitive sport performance. However, there is no universal agreement upon the precise definition of physical fitness and its dependent relationships.

In Western society, physical fitness is operationally allocated to promotion of two goals: performance and health. Performance-, motor-, or skill-related physical fitness refers to the component of physical fitness which

is necessary for optimal work or sport performance (Bouchard, 1994; Pate, 1983). Health-related physical fitness refers to the aspect of physiological and psychological functioning which is believed to offer an individual some protection against degenerative disease such as coronary heart disease (CHD), obesity, and various musculoskeletal disorders (Table 3). Adequate function in these components can have a positive effect on one's quality of life throughout the childhood and adult years. Surely, this type of physical fitness should be of primary concern to every individual within Japanese society, as in the United States. However, the components of speed, power, and agility have often been interpreted as skill-related physical fitness by many researchers. In our review, physical fitness is mainly considered from the health-related perspective. The importance of the four components that compose health-related physical fitness is discussed in detail in the next section.

III. The Four Basic Components of Health-related Physical Fitness

Cardiorespiratory endurance

Cardiorespiratory endurance (fitness) is the most important component of health-related fitness. It is defined as the heart's ability to pump blood and deliver oxygen throughout the body (ACSM, 1992). The basic criterion for cardiorespiratory fitness and physical working capacity is the relative level of function within the heart and circulatory system. Oxygen delivered to the active tissue is critical to the energy transformation that occurs within it, especially when activity is continuous for a significant length of time. Thus, heart and circulatory system functioning at a high level makes more oxygen available to the tissue. This increases the individual's ability to work and/or exercise at a greater intensity and/or a longer period of time. The fatigue prevention aspect of this action is very important.

Multiple methods for determining the level of an individual's cardiorespiratory fitness have been employed. Direct maximal oxygen consumption ($\dot{V}O_{2\max}$), or $\dot{V}O_{2\max}$ testing, is considered by most exercise scientists to be the prime standard for such assessment. $\dot{V}O_{2\max}$ is associated with several measures of health and disease risk status in adults. Studies have found that $\dot{V}O_{2\max}$, expressed as ml/kg/min or physical working capacity, is inversely associated with risk factors for CHD in men (Cooper et al., 1976) and women (Gibbons et al., 1983), myocardial infarction (Peters et al., 1983), and with all-cause mortality in women and men (Blair et al., 1989).

Body composition

Body composition refers to the chemical composition of the body. The model we use considers two simple components: fat mass and fat-free mass. Fat mass is

Table 3 Fitness zone interpretation for different parts of physical fitness (Whitehead, 1989)

Part of Physical Fitness	Fitness Zone		
	Too Low	Optimal for Health	High Performance / Too High
Cardiovascular Endurance	Increased risk of: • Coronary heart disease • Obesity • Adult onset diabetes • Low self-esteem	Sufficient for an active life style	Endurance athletes (e.g., long distance runners, swimmers, etc.)
Muscular Strength and Muscular Endurance	Increased risk of: • Low back pain or injury • Muscle and joint injuries • Osteoporosis • Low self-esteem	Can do day-to-day tasks and play vigorous sports relatively easily	Strength athletes (e.g., wrestlers, football players, field events athletes)
Flexibility	Increased risk of: • Low back pain or injury • Muscle and joint injuries	day-to-day tasks and most sports are not restricted	(e.g., gymnasts, swimmers) Too much flexibility may increase the risk of injury due to joint instability. (e.g., over-extendable)
Body Composition (Fatness)	Increased risk of: • Bone weakness (Osteoporosis) when older (mainly female) • Menstrual disorders • Stress fractures • Possible lowered resistance to disease	good appearance as well as health	Being obese increases the risk of: • Coronary heart disease • Cancer • Adult onset diabetes • Low self-esteem • Gallstones • Joint problems

often discussed in terms of relative body fat, which is the percentage of the total body mass. Fat-free mass simply implies tissue devoid of all extractable fat (Tanaka et al., 1992b).

Body composition is an important correlate to cardiorespiratory function with respect to health-related physical fitness. For example, for any given amount of work, the energy expenditure is increased in the obese. This greater demand for energy causes the circulatory system to work harder. Also, an obese person usually consumes a diet high in saturated fats and cholesterol. The resulting greater level of circulating blood lipid increases the probability of developing atherosclerosis—an important precursor to CHD.

Retention of body fat at any age is a health problem of considerable concern, but it is especially significant in children and adolescents because obese individuals in those age groups are much more likely to become fat adults than are their non-fat peers. In addition to an increased incidence of CHD among obese persons, certain other health problems are prevalent. Excess body fat is accompanied by an increased susceptibility to a variety of clinical disorders and a higher mortality rate (Andres, 1985; Osler, 1987; Simopoulos and Van Itallie, 1984).

Muscular strength and endurance

Muscular strength is usually defined as a muscle or muscle group's relative capacity for exerting force against some external resistance. The importance of strength to

general health is perhaps less readily apparent. However, stronger muscles better protect the joints which they cross. As a result, the individual is less susceptible to strains, sprains, and pulls that often occur when one participates in relatively vigorous physical activity. In addition, better tone in the muscles of the trunk aids in the prevention of the more common postural problems that plague society (e.g., sagging abnormal abdominal organs, round shoulders, and low back pain).

The strength of the abdominal musculature is of critical importance in the etiology of low back syndrome, one of the most prevalent chronic health problems. Physical fitness experts, physical therapists, and orthopedic surgeons link the high incidence of low back problems with a corresponding lack of exercise or sedentary lifestyle. The general logic is that muscles which are easily fatigued and/or strained can not support the spine in proper alignment. Weak abdominals and inflexible posterior thigh muscles, in particular, allow the pelvis to tilt forward, causing a concurrent abnormal arch in the low back. Thus, shortened, inflexible muscles result in decreased mobility and increased possibilities of strain, spasm, and pain. The clinical end result of these changes is "low back syndrome." In addition to protection from the problems described above, individuals possessing optimum levels of strength function are more likely to derive sustained satisfaction from participation in recreational sports.

Flexibility

The fourth important component of health-related physical fitness is flexibility. Flexibility refers to the degree to which a joint may move through its maximum possible normal range of motion. The determining factor in joint range of motion is the extensibility of the associated connective tissue (muscles, tendons and ligaments) in and around the joint.

From a health standpoint, loss of joint flexibility often contributes to postural problems. These usually result from the adaptive shortening of connective tissue on one side of a joint, concurrent with a loss of tone in the muscles on the opposite side of the joint. An example is the common adult problem of an inability to bend forward and touch the toes with the hands, while keeping the knees fully extended. A primary cause of the problem is adaptive shortening of the connective tissue in the lower back and posterior thigh areas. Thus, the implications for development and maintenance of adequate levels of flexibility and strength in the prevention of back problems are obvious.

Assessment of Aging and Health Status

Aging may be defined as the loss of an individual's ability to adapt to his/her environment (Comfort, 1979). Shock et al. (1984) considers it to be more the result of an interaction among many specific characteristics within an individual, rather than the results of a single process. While agreeing that aging processes are stable with respect to attainable life span, Fries and Crapo (1981) argue that many of the human determinants are plastic and modifiable. Therefore, a change in lifestyle and habit may help to postpone the onset of chronic diseases associated with human aging. Furthermore, it seems clear, that by maintaining a moderate to high level of physical conditioning, the aging individual can enjoy the functional capacity of a person who is 20 or more years younger (Tanaka et al., 1994).

Health is a human condition with physical, social, and psychological dimensions, each characterized positively and negatively (Bouchard et al., 1994). Positive health is associated with a capacity to enjoy life and to withstand challenges; it is not merely the absence of disease. Negative health is associated with morbidity and, in the extreme, with mortality. The discussion below is focused primarily on the physical health dimension. In addition to considering an index of positive health, the concept and method for estimation of biological age is discussed.

I. Chronological Age (CA) Versus Biological Age (BA)

CA is based on calendar time in years and is the only age that can be easily and accurately measured. However, there are many problems using only CA as a biological

Fig. 1 Theoretical patterns of biological age (BA)

In normal aging, the biological age (BA) increases by one year for each year of chronological age (CA). Accelerated aging may be caused by environmental insults such as poor diet, smoking, excess drinking, or inadequate exercise. Note that the BA is increasing more than one year for each year of CA. After initiating a successful age retarding program, the BA should increase less than one year for each year of CA (Dean, 1988).

index because of the differences in physical and mental function between people. For example, the rate of aging is not the same for all organs in any one organism, or for any one organ among different individuals. Thus, aging is a progressive and irreversible process that occurs in everyone, but at different rates. Consequently, it is not unusual to find individuals of the same CA who are remarkably different with respect to many of their functional abilities. The presence of such considerable functional heterogeneity has prompted gerontologists to develop indices of biological age (BA, sometimes referred to as physiological age, functional age, vital age, etc.) as an alternative index of senescence, which is more sensitive to the individual differences between people than CA alone.

Distinct from CA, BA has been defined as "the process of change in the organism, which lowers the probability of survival and reduces its physiological capacity for self regulation, repair, and adaptation to environmental demands" (Birren and Zarit, 1984). In general, BA is determined by reducing a relatively large number of sensory, motor, and cognitive measures to a single value, termed an age score. The assumption is that the average BA calculated for a group of people will be close to its average CA. In other words, theoretically, a "normal" person's BA — in terms of appearance, performance and functional capacity — should be the same as his/her CA (Fig. 1). One difference between the CA and BA may be attributed to a difference in the rate of aging. For example, an individual with a CA of 75 years

may be found to have a BA of 65 years. In this example, the individual's BA is ten years less than his/her CA, which is an indication that the person is aging less rapidly than most of his or her contemporaries.

In summary, the aging process is characterized as an inevitable, cumulative, and irreversible process. However, since the rate of aging varies widely among individuals and body systems, it is evident that CA is not the best predictor of physiological function. Certain aspects of the aging process may be modified to some extent by lifestyle habit such as regular physical activity. Assessing functional status seems a more rational basis for categorizing a person's age than is CA alone. Therefore, BA is an abstract concept that makes logical sense, even if it is not easily defined or measured.

II. Statistical Methods for Computing BA

Numerous approaches have been developed to assess BA and/or functional status of adult individuals. The main purpose of these approaches has been to develop theoretical models with which to understand the aging process better, as well as to determine whether these aging processes could be manipulated (Heikkinen et al., 1974). Comfort (1969) for example developed a test battery for aging assessment, and these physical measurements were used to compare the aging rates by geographical area (Wattana-Kaster and Spiers, 1973). However, a standardized system for measuring biological age has not yet been developed (Linn, 1975).

The three most common BA approaches are 1) age profile analysis (Borkan and Norris, 1980; Powell, 1987), 2) multiple regression analysis (Heikkinen et al., 1974; Furukawa et al., 1975; Webster and Logie, 1976; Dubina et al., 1984; Voitenko and Tokar, 1983) and 3) factor analysis/principal component analysis (Clark, 1960; Jalavisto et al., 1964; Brown and Forbes, 1976; Hofecker et al., 1980; Chodzko-Zajko and Ringel, 1987; Nakamura et al., 1988; Tanaka et al., 1990; Lee et al., 1993; Kim and Tanaka, 1995).

The most widely used approach for the assessment of BA has been to combine a large number of age-related physiological variables in a multiple regression equation taking CA as a dependent variable. The value predicted by the multiple regression equation is viewed as the BA of the individual (Hollingsworth et al., 1965; Damon, 1972; Heikkinen et al., 1974; Furukawa et al., 1975; Webster and Logie, 1976; Voitenko and Tokar, 1983; Dubina et al., 1984). This approach provides a fairly satisfactory result in estimating the combined effect of various age-related influences on aging, but it has been noted that the multiple regression equation derived for this purpose overestimates the individual BAs for the younger person and underestimates for the older person (Webster and Logie, 1976; Dubina et al., 1984; Nakamura, 1983).

In the third approach, information from a large

number of age-related variables is statistically reduced to a single score, usually expressed as an age score. Hofecker et al. (1980) also applied a factor analysis to data for 23 age parameters of the rat, and extracted 5 factors. The authors interpreted the 1st factor as representing primary aging, which appears to be very similar in most or all body systems, and interpreted factors 2 through 5 as secondary aging, which reflect the system-specific secondary processes of multicellular aging. In general, principal component analysis is a useful procedure whenever the task is to determine the minimum number of independent components needed to explain most of the variance of an original set of variables, assuming there is no dependent variable (Harman, 1967). Therefore, this statistical procedure can be used for analyzing the viability of a concept such as biological aging. In studies by Hofecker et al. (1980), Nakamura et al. (1988, 1989), Tanaka et al. (1990), Lee et al. (1993), and Kim and Tanaka (1995), the 1st component obtained from principal component analysis was used in an equation for assessing one's BA, variously called vital age, functional age, and physical fitness age, instead of using a multiple regression model. The validity of this statistical procedure for studying the rate of aging on biological vigour and physical fitness in cross-sectional research has been described very well by the above investigators.

Chodzko-Zajko and Ringel (1987) and Tanaka et al. (1995) have recently applied both factor analysis and multiple regression analysis to the derivation of functional status (FS). In these studies, multiple regression analysis was used with the factor analytically derived FS score as the dependent variable, and constituent measures as the independent variables. It should be noted that the index of FS score generated from the multiple regression equation is expressed in arbitrary units, since the FS score is obtained by summing a number of individually weighted factor scores.

The BA level estimated on the basis of the principal component (factor analysis) model of various physiological variables is theoretically more valid and practically more useful than a multiple regression model. The principal component model eliminates two major problems associated with the multiple regression model: (1) distortion of an individual's BA at the regression edges; and (2) a theoretical contradiction in that a perfect model (multiple correlation=1.0) will merely be predicting the subject's CA, not his or her BA. Thus, the factor analytical approach is better suited to assess the detail of BA components (Hofecker et al., 1980; Nakamura et al., 1988, 1989; Tanaka et al., 1990; Lee et al., 1993; Kim and Tanaka, 1995).

III. Approach of Estimation of Biological Age in Japan

This section of the review will address the concepts of vital age, physical fitness age, and health-related

physical fitness age which the authors have recently proposed (Lee et al., 1993, 1996).

Vital Age (VA)

Tanaka et al. (1990) developed a useful equation for estimating Japanese VA, as an objective measure for the assessment of physical health status and aging. The major differences between VA and the commonly used BA are that: (1) the former is predicted through the assessment of various factors measured not only under resting conditions but also during exercise, and (2) VA is derived from the status of coronary risk factors and physical fitness.

The rationale behind the concept of and computation of VA has been described in detail by Tanaka et al. (1990), and summarized for BA by others (Clark, 1960; Hofecker et al., 1980; Nakamura et al., 1988, 1989). The validity of VA in both cross-sectional and longitudinal studies has also been previously described (Tanaka et al., 1990, 1991, 1992a, 1994).

A total of 34 physiological and anthropometric variables were selected as a representative subset from a very large number of age related characteristic changes. The criterion for selection was that each variable had a positive or negative linear trend with CA in cross-sectional and longitudinal data (Borkan and Norris, 1980). The correlation matrix among the 11 selected variables was factored by principal component analysis (Tanaka et al., 1990). The first principal component was used as an overall index of the age-related change in various physiological variables, on the assumption that a healthy individual would be biologically more youthful than a diseased individual. The VA of each individual was estimated from the equation determining a vital score and correction factor (Z). The distortion of VA at the regression edges as a function of CA was corrected by calculating Z (Dubina et al., 1984).

Physical Fitness Age & Health-Related Physical Fitness Age

Physical function is widely recognized as a crucial component of the quality of life and perhaps the most universally accepted aspect of the definition of health. At the present time, there is an accumulated body of persuasive evidence that an exercise prescription of moderate volume can produce a higher level of physical fitness in the individual which appears to be protective against early mortality (Ekelund et al., 1988; Leon et al., 1987; Paffenbarger et al., 1993; Pekkanen et al., 1987). Blair et al. (1989) found, an inverse relationship between physical working capacity, maximal oxygen uptake, and heart rate during submaximal exercise and future risk of CHD, from a review of 10 longitudinal studies. Katz et al. (1983) found that elders with functional dependency were less likely to survive and more likely to decline than

those who functioned independently. These reports suggest that an active lifestyle contributes to improved survival. Survival effects may be translatable into gains in "active" life expectancy, notwithstanding the increased likelihood of morbidity with increased age. As a matter of fact, physically active elderly report an increase in life satisfaction, quality, and happiness (Heinzelman and Bagley 1970).

On the basis of the above studies, it has been hypothesized in the present review that a person's involvement in an active lifestyle and an accompanying high level of physical fitness diminishes his/her risk of loss of function; in the absence of pre-existing health problems, disease and impairment. Logically, physically active and fit men and women would be biologically more youthful and healthier than the inactive (Borkan and Norris, 1980).

It would be very useful for the elderly if considerable individual variability in physical function were to be expressed as a clearly understandable specific index. An equation for the estimation of a physical fitness age and health-related physical fitness has recently been developed (Lee et al., 1993). Physical fitness age is composed of eight age-related physical fitness variables. These include the oxygen uptake corresponding to lactate threshold (VO_{2LT}), maximal oxygen uptake (VO_{2max}), stepping side-to-side, grip strength, vertical jump, balancing on one leg with eyes closed, trunk extension from a lying position, and trunk flexion from a standing position. Health-related physical fitness age utilizes four common measures of health-related physical fitness (VO_{2max} , trunk flexion, body composition, grip strength). The health-related physical fitness age as well as vital age will become increasingly important in exercise and health science as a valid, normative measure of physical health status or senescence.

Acknowledgments. This study was supported partly by Tanaka project of TARA# University of Tsukuba. (#Tsukuba Advanced Research Alliance)

References

- American College of Sports Medicine (1992) ACSM fitness book. Champaign, IL. Leisure Press, 23
- Andres R (1985) Mortality and obesity: The rationale for age specific height-weight tables. In Andres R, Bierman EL, Hazzard WR eds. Principles of geriatric medicine. McGraw-Hill, New York, 311-318
- Birren JE, Zarit JM (1984) Concepts of health, behavior and aging. In Birren JE, Livingston J eds. Cognition, stress, and aging. Prentice Hall, Englewood Cliffs, NJ, 1-20
- Blair SN, Kohl HW III, Paffenbarger RS, Clark DG, Cooper KH, Gibbons LW (1989) Physical fitness and all-cause

- mortality: a prospective study of healthy men and women. *JAMA* 262: 2395-2401
- Borkan GA, Norris AH (1980) Biological age in adulthood: Comparison of active and inactive U.S. males. *Human Biol* 52: 787-802
- Bouchard C, Shephard RJ, Stephens T (1994) Physical activity, fitness, and health: Consensus statement. Human Kinetics, Champaign, IL
- Brown KS, Forbes WF (1976) Concerning the estimation of biological age. *Gerontology* 22: 428-437
- Caspersen CJ, Powell KE, Christenson GM (1985) Physical activity, exercise and physical fitness: Definitions and distinctions for health-related research. *Public Health Report* 100: 126-131
- Chodzko-Zajko WJ, Ringel RL (1987) Physiological fitness measures and sensory and motor performance in aging. *Exp Gerontol* 22: 317-328
- Chodzko-Zajko WJ, Schuler PB, Solomon JS, Heintz B, Ellis N (1992) The influence of age and physical fitness on automatic and effortful cognitive processing. *Int J Aging Human Dev* 35: 265-285
- Chodzko-Zajko WJ, Moore KA (1994) Physiological fitness and cognitive functioning in aging. *Exerc Sport Sci Rev* 22: 317-328
- Clark JW (1960) A factorial analysis of individual differences with age of psychological and physiological measurements. *J Gerontol* 15: 183-187
- Comfort A (1969) Test-battery to measure ageing-rate in man. *Lancet* 27: 1411-1415
- Comfort A (1979) *The Biology of senescence*. Elsevier, NY, 299-312
- Cooper KH, Pollock ML, Martin RP, White SR, Linnerud AC, Jackson A (1976) Physical fitness levels vs selected coronary risk factors. A cross-sectional study. *JAMA* 236: 166-169
- Corbin CB, Lindsey R (1985) Fitness for lifetime. *Br J Phys Educ* 16: 44-46
- Damon A (1972) Predicting age from body measurements and observations. *Aging Human Dev* 3: 169-173
- Dean W (1988) Biological aging measurement. Clinical applications. The Center for Bio-Gerontology, Los Angeles, California
- Dubina TL, Mints AY, Zhuk EV (1984) Biological age and its estimation. III. Introduction of a correction to the multiple regression model of biological age and assessment of biological age in cross-sectional and longitudinal studies. *Exp Gerontol* 19: 133-143
- Ekelund LD, Haskell WL, Whaley FS, Criqui MH, Sheps DS (1988) Physical fitness as a predictor of cardiovascular mortality in asymptomatic North American men: the lipid research clinics mortality follow-up study. *N Engl J Med* 319: 1379-1384
- Falls HB (1980) Modern concepts of physical fitness. *J Phys Educ Rec* 51: 25-27
- Fries JF, Crapo LM (1981) Vitality and aging. W.H. Freeman Co., San Francisco, CA, 123-127
- Furukawa T, Inoue M, Kajiya F, Inada H, Takasugi S, Fukui S, Takeda H, Abe H (1975) Assessment of biological age by multiple regression analysis. *J Gerontol* 30: 422-434
- Gibbons LW, Blair SN, Cooper KH, Smith M (1983) Association between coronary heart disease risk factor and physical fitness in healthy adult women. *Circulation* 67: 977-983
- Harman HH (1967) *Modern factor analysis*. 2nd ed. The University of Chicago Press, Chicago and London
- Heinzelman F, Bagley RW (1970) Response to physical activity programs and their effects on health behavior. *Public Health Report* 85: 905-911
- Heikkinen E, Kiiskinen A, Kayhty B, Rimpela M, Vuori I (1974) Assessment of biological age: Methodological study in two Finnish populations. *Gerontology*, 20: 33-43
- Hofecker G, Skalicky M, Kment A, Niedermuller H (1980) Models of the biological age of the rat. I. A factor model of age parameters. *Mech Ageing and Dev* 14: 345-359
- Hollingsworth JW, Hashizume A, Jablon S (1965) Correlations between tests of aging in Hiroshima subjects—An attempt to define “physiologic age”. *Yale J Biol Med* 38: 11-26
- Jalavisto E, Lindqvist C, Makkonen T (1964) Assessment of biological age. III. Mental and neural factors in longevity. *Ann Acad Sci Fenn* 106: 1-20
- Katz S, Branch LG, Branson MH (1983) Active life expectancy. *N Engl J Med* 309: 1218
- Kim HS, Tanaka K (1995) The assessment of functional age using “Activities of Daily Living” performance tests: A study of Korean women. *JAPA* 3: 39-53
- Kraus H, Hirshland RP (1954) Minimum muscular fitness tests in school children. *Res Quart* 25: 178-188
- Lee MS, Matsuura Y, Tanaka K (1993) Assessment of physical fitness age in middle-aged and elderly men. *Jpn J Phys Fitness Sports Med* 42: 59-68
- Lee MS, Tanaka K, Nakadomo F, Watanabe K, Takeshima N, Hiyama T (1996) Health-oriented physical fitness as an index of physical health. *J Exerc Sports Physiol* 3: 79-89
- Leon AS, Connett J, Jacobs DR, Rauramaa R (1987) Leisure-time physical activity levels and risk of coronary heart disease and death. *JAMA* 258: 2388-2395
- Linn BS (1975) Chronologic vs biologic age in geriatric patients. In Goldman R, Rockstein M eds. *The physiology and pathology of human aging*, Academic Press, New York, 9-18
- Nakamura E (1983) The physiological ages of middle and old aged people in relation to work capacity. *Kyouikuigaku* 28: 128-135
- Nakamura E, Miyao K, Oseki T (1988) Assessment of biological age by principal component analysis. *Mech*

- Ageing Dev 46: 1-18
- Nakamura E, Moritani T, Kanetaka A (1989) Biological age versus physical fitness age. *Eur J Appl Physiol* 58: 778-785
- Osler M (1987) Obesity and cancer. *Danish Medical Bulletin* 34: 267-274
- Paffenbarger RS Jr, Hyde RT, Wing AL, Lee IM, Jung DL, Kampert JB (1993) The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *N Engl J Med* 328: 538-545
- Pate RR (1983) A new definition of youth fitness. *Physician Sportsmed* 11: 77-83
- Peters RK, Cady LD Jr, Bischoff DP, Bernstein L, Pike MC (1983) Physical fitness and subsequent myocardial infarction in healthy workers. *JAMA* 249: 3052-3056
- Powell KE, Thompson PD, Caspersen CJ, Kendrick JC (1987) Physical activity and the incidence of coronary heart disease. *Ann Rev Public Health* 8: 253-287
- Shock NW, Greulich RC, Andres D, Costa PT, Lakatta EG, Tobin JD (1984) Normal human aging. The Baltimore longitudinal study of aging (NIH Publication No. 84-2450). U.S. Government Printing Office, Washington, DC
- Simopoulos AP, Van Itallie T (1984) Body weight, health and longevity. *Ann Intern Med* 100: 285-295
- Spirduso WW (1989) Physical activity and aging: Introduction In Spirduso WW and Eckert HM eds. *Physical activity and aging. Human Kinetics, Champaign, IL*, 1-5
- Tanaka K, Matsuura Y, Nakadomo F, Nakamura E (1990) Assessment of vital age of Japanese women by principal component analysis. *Jpn J Phys Educ* 35: 121-131
- Tanaka K, Yoshimura T, Maeda K, Nakadomo F, Takeshima N, Asano K, Takeda M, Kumazaki Y, Watanabe Y, Hiyama T (1991) Validity of CHD risk factor-dependent "vital age" as an index of health or aging status. *J Jpn Atheroscler Soc* 19: 303-310
- Tanaka K, Watanabe Y, Hiyama T, Takeda M, Yoshimura T (1992a) Validity of risk factor-dependent changes in vital age of CHD patients following a supervised aerobic conditioning program. *J Jpn Atheroscler Soc* 20: 239-244
- Tanaka K, Nakadomo F, Watanabe K, Inagaki A, Kim HK, Matsuura Y (1992b) Body composition prediction equations based on bioelectrical impedance and anthropometric variables for Japanese obese women. *Am J Human Biol* 4: 739-745
- Tanaka K, Takeda M, Hayakawa Y, Matsuura Y, Watanabe Y, Hiyama T (1994) Aerobic exercise lowers biological age of middle-aged and elderly patients with coronary heart disease or hypertension. In Harris S, Suominen H, Era P and Harris W eds. *Physical activity, aging and sports. Volume III: Towards healthy aging-- International perspectives-- Part 1. Physiological and biomedical aspects. Center for the Study of Aging, New York*, 235-245
- Tanaka K, Kim HS, Yang JH, Shimamoto H, Kokudo S, Nishijima T (1995) Index of assessing functional status in elderly Japanese men. *Appl Human Sci* 14: 65-71
- Tanaka K, Lee MS (1995) Significance of assessing health and physical fitness in aged society. *Bull Inst Health Sport Sci: Univ of Tsukuba* 18: 27-36
- Tanaka K, Lee MS (1996) Current theme in aged society-- Significance of physical activity for healthy aging. *Bull Inst Health Sport Sci: Univ of Tsukuba* 19: 9-18
- Voitenko VP, Tokar AV (1983) The assessment of biological age and sex differences of human aging. *Exp Aging Res* 9: 239-244
- Walford R (1980) The Kleemeir Award Presentation. Gerontological Society of America, San Diego.
- Wathana-Kaster S, Spiers PS (1973) Geographic mortality rates and rates of aging-- A possible relationship? *J Gerontol* 28: 374-379

Received: December 21, 1995

Accepted: April 30, 1997

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