The Relative Utility of Health-Related Fitness Tests and Skilled Motor Performance Tests as Measures of Biological Age in Japanese Men

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Abstract. In the present paper we report the results of a study in which we compared 2 different approaches to the computation of biological age (BA) in a sample of 322 Japanese men (age range 20 to 79 years). In the first approach, 4 commonly used measures of health-related fitness (VO2peak, trunk flexion from a standing position, body fat, and grip strength) were reduced to a single BA score (HRF Age) using principal component analysis. In contrast, in the second approach, 3 commonly used measures of skilled motor performance and agility (vertical jump, stepping side-to-side, and balancing on one leg with eyes closed) were reduced to a single BA score (SM Age) using similar multivariate procedures. The criterion-related validity of both of the BA measures was examined by assessing each measure's ability to discriminate between healthy and active groups of subjects. This was achieved by classifying the original subject pool into regularly active (ACT; n=108) and healthy (HLTH; n=169) subgroups on the basis of self-reported activity levels. Analyses revealed that HRF Age was a more powerful discriminator between the two activity groups than SMP Age. While HRF Age of HLTH subjects was very close to their chronological age (CA), in the ACT group, HRF Age was on average 15 years less than their CA (P<0.05).

In a separate analysis, we assessed the HRF Age of patients with ischemic heart disease, hypertension, obesity, or diabetes (PAT; n=45). The HRF Age of these subjects averaged 10 years above their CA. Our data suggest that commonly used measures of health-related fitness can be usefully employed as indices of BA which differentiate between individuals of similar ages but differing health and physical activity status. In contrast, measures of skilled motor performance were found to be less valuable measures of BA. The implication of our findings for future experimental design in exercise and aging research is discussed.


Keywords: biological age, health-related fitness, skilled motor performance, aging

Introduction

In 1994 the average span of life in Japanese people was 76.3 years for males and 82.5 years for females—the highest levels in the world. However, it is now realized that increases in life expectancy alone are probably insufficient unless also accompanied by corresponding improvements in the quality of life. Indeed, Walford (1980) suggests that individuals should probably be thinking about achieving an average health expectancy rather than an average life expectancy. Often, to lengthen the average health expectancy is linked to physical independence or high physical capacity.

Although decline in sensory, motor, and cognitive performance is an inevitable and inescapable consequence of senescence, there are often large differences between individuals with respect to the rate and extent to which functional performance declines with advancing age (Chodzko-Zajko et al., 1987, 1992, 1994; Comfort, 1969). Consequently, it is not unusual to find individuals of the same chronological age (CA) who are markedly different with respect to many of their functional abilities. For example, it is clear that by maintaining moderate to high levels of physical conditioning, the individual can have the functional capacity of the av-
erage person who is 20 or more years younger (Tanaka et al., 1990, 1991, 1992a). The presence of such considerable heterogeneity has prompted gerontologists to develop indices of biological age (BA), sometimes referred to as physiological age, functional age, vital age, physical fitness age, etc., as alternative indices of senescence which are more sensitive to individual differences between subjects than CA alone (Borkan et al., 1980; Brown and Forbes, 1976; Clark, 1960, Furukawa et al., 1975; Heikkinen et al., 1974; Hollingsworth et al., 1965; Kim and Tanaka, 1995; Lee et al., 1993; Nakamura et al., 1988, 1989; Tanaka et al., 1990; Webster and Logie, 1976). The main purpose of these attempts has been to develop theoretical models with which to better understand the aging process, as well as to determine whether these aging processes could be manipulated. However, there is no consensus with respect to which measures should be included in a BA inventory, or how best to reduce these measures to a single age score.

The purpose of the present study was to examine the extent to which commonly used measures of physical fitness can be used as measures of BA. In general, physical fitness tests designed for use with the general population have utilized one of two classes of items; Health-Related Fitness tasks (HRF) and Skilled Motor Performance (SMP) tasks for the assessment of physical fitness. HRF tasks generally refer to those aspects of physiological and psychological function which are thought to offer the individual protection against chronic degenerative diseases, such as, coronary heart disease, obesity, and various musculo-skeletal disorders (Caspersen et al. 1985; Falls, 1980; Gutin, 1980; Pate, 1983; Whitehead, 1989). In contrast, SMP tasks measure attributes such as agility and dexterity of the extremities. SMP is influenced not only by genetic endowment and training, but also by body size, motivation, practice, and immediate environmental conditions. Recently, the trend has been to include both HRF and SMP items in fitness test batteries designed for use with older adults (e.g. AAHPERD Functional Fitness Test). Unfortunately, little is known about the comparative utility of HRF and SMP tasks as predictors of BA. Specifically, it is unclear whether either or both HRF and SMP items can be used to discriminate between older adults who differ in functional ability while sharing the same CA.

Accordingly, the goal of the present study was to compare the value of the two different types of measures as indices of BA, i.e., HRF age and SMP age. The criterion-related validity of both of the BA measures was examined by assessing each measure's ability to discriminate between healthy and active groups of subjects. This was achieved by classifying the original subject pool into regularly active and healthy subgroups on the basis of self-reported activity levels. In essence our study is comprised of two quite different sections (1) the establishment of two measures of BA in 169 healthy Japanese males, and (2) the subsequent validation of these measures using two criterion references groups active and patient.

Methods

Subjects

The subjects were 322 men, 20 to 79 years of age, living in Tsukuba, Osaka, and Nagoya, Japan. All subjects were considered to be generally representative of the Japanese population living in urban areas. This study was achieved by classifying the original subject pool into three different experimental subgroups on the basis of self-reported activity levels; a healthy group (HLTH), a regularly active group (ACT), and a patient group (PAT). The HLTH subjects (n=169) were characterized as semi-sedentary, with no participation in regular strenuous physical activities. These men were healthy with respect to ECG tracings, and medical history, and did not exhibit any cardiac, respiratory, and metabolic disease. The ACT subjects (n=108) were apparently healthy recreational distance joggers who had been participated regularly in long distance running (3.5 ± 1.7 d/w, 80.2 ± 38.4 km/w). The PAT subjects (n=45) were patients with ischemic heart disease (IHD), hypertension, diabetes, and obesity. The 18 IHD patients had class I and II symptoms on the New York Heart Association. Seven men with systolic blood pressure over 160 mmHg or diastolic blood pressure over 95 mmHg were regarded as hypertensive, and 10 men whose fasting plasma glucose levels were over 100 mg/dl and whose plasma glucose in the glucose tolerance test were over 140 and 120 mg/dl at 1 h and 2 h, respectively, were diagnosed as diabetic. In addition, 10 non-active men with body mass index over 25 were regarded as obese. Most of the IHD, hypertension, and diabetes patients had been prescribed one or more medications for management of their cardiovascular and/or other medical conditions. The PAT subjects were referred by their physicians for participation in an exercise program. In every case informed consent was obtained from the individuals and both his spouse and physician.

Assessment of HRF and SMP tasks

In selecting several items for inclusion in the assessment of HRF and SMP, we referred to a number of previously published studies (ACSM, 1992; Caspersen et al., 1985; Falls, 1980; Gutin, 1980; Pate, 1983; Whitehead, 1989 and others). Each item had to demonstrate a significant correlation with CA in our preliminary analyses using about two hundred of men, ranging in age from 20 to 79 years. To ensure measurement consistency,
the same tester conducted the same measurement. The testing apparatuses were calibrated prior to all testing sessions. In the case of elderly (over the 65 years), two exercise assistants stood near the subject at all times to prevent falls after jumping and stepping. The tests for grip strength, trunk flexion from a standing position, vertical jump, balancing on one leg with eyes closed, and stepping side-to-side were conducted according to the procedures of the our previous studies (Lee et al., 1993; Tanaka et al., 1990). \( \text{VO}_2\text{peak} \) was used as a measure of maximal aerobic capacity and was measured during cycling on a mechanically braked cycle ergometer (Monark 818E, Sweden). The test continued with the increase of work load by 15 Watts every minute until symptoms limited further exercise or the authors terminated the exercise. All metabolic measurements of expiratory gases were determined using the standard techniques of open-circuit spirometry with Fukada Sangyo IS-6000 System. Exercising blood pressures, both systolic and diastolic, were also measured every 5 min by an automatic sphygmomanometer cuff technique using a Colin STBP 780 system. Electrocardiograms were recorded continuously for measurement of heart rates. Furthermore, ratings of perceived exertion (Borg, 1970) were checked. Body composition was assessed for Norm and ACT subjects by the underwater weighing, which estimates body density (\( \text{Bd} \)) using the Archimedian principle (Nakadomo et al., 1990; Tanaka et al., 1992b). \( \text{Bd} \) was also estimated from skinfold thicknesses determined at 2 sites (triceps (T) and subscapular (S)) using a skinfold caliper (Eiken MK-60) for PAT subjects. The following equation of Nagamine and Suzuki (1964) for men was used: \( \text{Bd}=1.0913 - 0.00116 \times \text{指数} \). The percent of body fat (\%fat) was estimated by the formula of Brozek et al. (1963): \%fat = \%fat as (4.570/\text{Bd}) - 4.142100.

Statistical Analysis

The results are expressed as mean values ± standard deviations. Principal component analysis is a useful tool in discerning the underlying structure of interrelationship among the test scores measured in a complex system or process, especially when not much is known about an area of investigation (Ingram, 1983). The first principal component was used as the single best descriptor of total HRF and SMP tasks (Harman, 1967). This approach has been frequently adopted in gerontological research (Chodzko-Zajko and Ringel, 1987; Kim and Tanaka, 1995; Lee et al., 1993; Nakamura et al., 1988, 1989; Tanaka et al., 1990). The main idea of this analysis is to reduce the dimensionality of a data set, which consists of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set (Harman, 1967). In order to reduce the 4 HRF and 3 SMP test items to a single score, the correlation matrix for the HRF and SMP tasks were subjected to principal component analysis. The principal components are described mathematically as linear combinations of the variables, with no question of statistical estimation. The factor score coefficients for the principal component in terms of the variables are obtained simply by dividing its “factor loadings” by its eigenvalue (Harman, 1967). Statistical comparisons of the individual subject data between HLTH and ACT, and between HLTH and PAT were performed using unpaired Student’s t test. Statistical significance between CA vs HRF Age and between CA vs SMP Age in each group was tested by the paired Student’s t test. Pearson's product-moment correlation coefficients were calculated to analyze the associations between CA and HRF Age. A probability level of \( P<0.05 \) was used as an indicator for statistically significant results in all the analyses.

Results

Initial HRF and SMP tests

Table 1 shows the mean and standard deviation of HRF and SMP tasks and Table 2 shows Pearson's product-moment correlation coefficients between those items and CA. All variables were significantly correlated with CA. The highest correlation with CA was found in vertical jump (\( -0.78 \)) and the second in stepping side-to-side (\( -0.73 \)).

| Table 1 Means and standard deviation of 7 fitness items and chronological age |
|-----------------|-----------------|---------------|---------------|-----------------|-----------------|
|                 | Total (n = 322) | HLTH (n = 169) | ACT (n = 108) | HLTH# (n = 122) | PAT (n = 45)    |
| Chronological Age (year) | 49.5 ±14.3 | 48.7 ±14.9 | 49.7 ±13.3 | 59.9 ±10.2 | 58.3 ±9.8 |
| Body Fat (%) | 16.0 ±4.9 | 17.0 ±4.3 | 14.5 ±5.5 | 17.4 ±4.4 | 19.2 ±5.4 |
| \( \text{VO}_2\text{peak} \) (\( \text{ml/kg/min} \)) | 40.8 ±12.0 | 35.9 ±8.5 | 51.1 ±8.9 | 32.6 ±6.8 | 24.2 ±6.2 |
| Grip Strength (kg) | 43.9 ±7.4 | 44.2 ±7.4 | 44.1 ±6.9 | 42.4 ±7.3 | 40.9 ±8.5 |
| Trunk Flexion from a Standing Position (cm) | 5.6 ±7.6 | 4.9 ±6.8 | 7.7 ±8.5 | 4.0 ±6.8 | -0.3 ±10.3 |
| Stepping Side-to-Side (num/20 s) | 37.3 ±7.8 | 37.7 ±7.3 | 38.3 ±7.2 | 35.1 ±6.6 | 26.3 ±8.4 |
| Vertical Jump (cm) | 41.9 ±10.6 | 42.7 ±10.8 | 42.4 ±9.6 | 38.4 ±8.6 | 33.5 ±9.2 |
| Balancing on One Leg with Eyes Closed (s) | 19.5 ±18.1 | 18.8 ±16.6 | 22.7 ±20.1 | 14.5 ±12.8 | 11.4 ±11.2 |

HLTH: healthy, ACT: active, PAT: patient. * Significantly different from HLTH (\( P<0.05 \)). # Data of 20s and 30s in HLTH group were deleted.
Table 2  Correlation coefficients between chronological age and each physical fitness item

<table>
<thead>
<tr>
<th>Item</th>
<th>Group</th>
<th>Total (n = 322)</th>
<th>HLTH (n = 169)</th>
<th>ACT (n = 108)</th>
<th>PAT (n = 45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Fat (%)</td>
<td>0.30*</td>
<td>0.22*</td>
<td>0.43*</td>
<td>0.28*</td>
<td></td>
</tr>
<tr>
<td>VO₂peak (ml/kg/min)</td>
<td>-0.57*</td>
<td>-0.80*</td>
<td>-0.77*</td>
<td>-0.28*</td>
<td></td>
</tr>
<tr>
<td>Grip Strength (kg)</td>
<td>-0.53*</td>
<td>-0.59*</td>
<td>-0.47*</td>
<td>-0.32*</td>
<td></td>
</tr>
<tr>
<td>Trunk Flexion from a Standing Position (cm)</td>
<td>-0.33*</td>
<td>-0.36*</td>
<td>-0.33*</td>
<td>-0.25*</td>
<td></td>
</tr>
<tr>
<td>Stepping Side-to-Side (num/20 s)</td>
<td>-0.73*</td>
<td>-0.79*</td>
<td>-0.67*</td>
<td>-0.68*</td>
<td></td>
</tr>
<tr>
<td>Vertical Jump (cm)</td>
<td>-0.78*</td>
<td>-0.82*</td>
<td>-0.75*</td>
<td>-0.56*</td>
<td></td>
</tr>
<tr>
<td>Balancing on One Leg with Eyes Closed (s)</td>
<td>-0.46*</td>
<td>-0.48*</td>
<td>-0.46*</td>
<td>-0.30*</td>
<td></td>
</tr>
</tbody>
</table>

HLTH: healthy, ACT: active, PAT: patient. * P<0.05.

Table 3  Results of principal component analysis

<table>
<thead>
<tr>
<th>Item</th>
<th>r</th>
<th>FSC</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂peak</td>
<td>0.84</td>
<td>-0.399</td>
<td>-0.579</td>
</tr>
<tr>
<td>Body Fat</td>
<td>-0.63</td>
<td>-0.299</td>
<td>0.433</td>
</tr>
<tr>
<td>Trunk Flexion from a Standing Position</td>
<td>0.69</td>
<td>-0.330</td>
<td>-0.479</td>
</tr>
<tr>
<td>Grip Strength</td>
<td>0.72</td>
<td>-0.343</td>
<td>-0.497</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>2.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent of Variance</td>
<td>52.50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stepping Side-to-Side                           | 0.91 | -0.403  | -0.607|
Vertical Jump                                   | 0.94 | -0.413  | -0.622|
Balancing on One Leg with Eyes Closed (s)       | 0.75 | -0.328  | -0.495|
| Eigenvalue                                    | 2.27 |         |       |
| Percent of Variance                           | 75.60|         |       |

r: correlation coefficient of the first principal component with each variable (i.e., factor loading), FSC: factor score coefficient, EV: eigenvector.

Estimation of HRF Age and SMP Age

The correlation matrix for the HRF (4 x 4) and SMP (3 x 3) items in HLTH group was subjected to a principal component analysis. The results of the principal component analysis are presented in Table 3. The first principal component (C1) accounted for the greatest proportion of the variance (eigenvalue = 2.1 and 2.3, respectively) among all components. That is, the C1 explained about 52.5 % of the total variance in the battery of the 4 HRF tasks, and 75.6 % of the total variance in the battery of the 3 SMP tasks. These results suggest that the C1 can be used as a relatively comprehensive index of HRF and SMP variables.

In order to derive health-related fitness score (HRF Score) and skilled motor performance score (SMP Score), we computed first principal component scores as Σ aᵢ xᵢ, where aᵢ is the factor score coefficient of the HRF and SMP test variables, and xᵢ is an individual's Z score (deviation vector from the mean) on the HRF and SMP variables. The aᵢ values for x₁ to x₅ were -0.399, -0.343, -0.330, -0.299, -0.408, -0.328, and -0.413, respectively. An individual's HRF Score and SMP Score as a function of the HRF or SMP variables were computed as follows:

HRF Score = 2.81 - 0.047x₁ - 0.047x₂ - 0.049x₃ + 0.069x₄
(1)

SMP Score = 4.09 - 0.055x₁ - 0.020x₅ - 0.038x₆
(2)

where x₁ = VO₂peak (ml/kg/min), x₂ = grip strength (kg), x₃ = trunk flexion from a standing position (cm), x₄ = body fat (%), x₅ = stepping side-to-side (num/20 s), x₆ = balancing on one leg with eyes closed (s), x₇ = vertical jump (cm). Note that -0.047x₁ can be obtained by dividing -0.039 by 8.5, which is the standard deviation (SD) for VO₂peak (x₁). The intercept 2.81 is obtained as Σ aᵢxᵢ/SD. The correlation between the HRF Score and CA was r = -0.70. Figure 1 shows the scatter plot between CA and HRF Score (Equation 1). As expected, advancing age was linearly associated with a decline in HRF tasks.

In order to transform the HRF Score and SMP Score into units of calendar age, the scores obtained from equations 1 and 2 were standardized using the mean (48.7) and standard deviation (14.9) of CA in the HLTH sample. The following equation expresses the transformation from HRF Score to HRF Age, and from SMP Score to SMP Age:
HRF Age = (14.9 HRF Score) + 48.7

SMP Age = (14.9 SMP Score) + 48.7

Although the estimated HRF Age should ideally be scattered symmetrically above and below the identity line CA = HRF Age, the slope of the regression differed considerably from 1.0. Before any statistically meaningful comparison could be made between HRF Age and CA, the distortions of HRF Age and CA at the regression edges had to be corrected (Dubina et al., 1984). The distortion of HRF Age at the regression edges as a function of CA was corrected by calculating Z according to the method proposed by Dubina et al. (1984). The correction term Z in Equation 5 is calculated from Z = (y_i - Y) (1 - b), where y_i is the CA of an individual, Y is the mean CA for the whole HLTH sample, and b is the coefficient of simple linear regression that expresses the relation between HRF Age and CA, and between SMP Age and CA. Finally, SMP Age and HRF Age of HLTH subjects were calculated by adding Z to the right side of Equations 3 and 4.

\[ Z = 0.18CA - 8.76 \]  

\[ HRF \text{ Age} = (14.9 \text{ HRF Score}) + 48.7 + Z \]  

\[ SMP \text{ Age} = (14.9 \text{ SMP Score}) + 48.7 + Z \]

Figure 2 describes the relationship between the individual's corrected HRF Age and CA in normative men (Equation 6). Individual's CA and HRF Age are scattered nearly symmetrically above and below the identity line CA = HRF Age. The correlations between HRF Age and CA (r = 0.81) and between SMP Age and CA (r = 0.87) were significant. These data suggest that CA, SMP Age, and HRF Age are highly interrelated but are not identical constructs.

To examine whether some pathological conditions and habitual exercise such as IHD, hypertension, diabetes, obesity and jogging may affect the degree of functional aging, the HRF Age and SMP Age of clinically diagnosed 45 patients and 108 joggers were calculated using the equation for HLTH subjects. Most HRF Age estimated on PAT group were scattered above the identity line CA = HRF Age and most of those estimated on ACT group far below the line (Fig. 3).

The differences between the mean HRF Age and
Table 4 Comparison of mean HRF Age vs. CA, and SMP Age vs. CA in three different groups

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>(a) CA</th>
<th>(b) HRF Age</th>
<th>(c) SMP Age</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTH</td>
<td>189</td>
<td>48.7 ±14.9</td>
<td>48.7 ±17.6</td>
<td>48.7 ±16.7</td>
<td>0.0 ± 9.9</td>
</tr>
<tr>
<td>ACT</td>
<td>108</td>
<td>49.7 ±13.3</td>
<td>36.1 ±15.1</td>
<td>47.6 ±16.2</td>
<td>−14.6 ±8.9*</td>
</tr>
<tr>
<td>PAT</td>
<td>45</td>
<td>58.3 ± 9.8</td>
<td>67.8 ±19.1</td>
<td>67.7 ±16.1</td>
<td>9.5 ±15.9*</td>
</tr>
</tbody>
</table>

HTH: healthy, ACT: active, and PAT: patient. *Significantly different from CA of the same group (P<0.05).

CA, and between the mean SMP Age and CA in each group were tested by a Student's paired t test (Table 4). The mean HRF Age and SMP Age of PAT group were estimated as 67.8 ± 19.1 years old, 67.7 ± 16.1 years old, respectively, and both were approximately 10 years higher than their mean CA (58.3 ± 9.8 years). Thus, the differences between the mean HRF Age and CA, and between the mean SMP Age and CA for PAT group were statistically significant (P<0.05). The mean HRF Age of ACT group, on the other hand, was estimated as 35.1 ± 15.1 years old, and was 14.6 years younger than their mean CA (49.7 ± 13.3 years), while the mean SMP Age was estimated as 47.6 ± 16.2 years old, and was only 2.1 years younger (P<0.05) than their mean CA.

Discussion

The advent of an increased life expectancy has focused attention on the issue of functionality versus disability. Aging was defined by Comfort (1979) as the loss of an individual's ability to adapt to his/her environment. Shock et al. (1984) defined aging as more the result of an interaction among many specific characteristics within an individual rather than the result of a single process. While agreeing that the processes are stable in terms of attainable life span, Fries and Crapo (1981) argue that many determinants of age in humans are plastic and modifiable, and that changes in lifestyle and health habits help to postpone the onset of the chronic disease associated with human aging. Therefore, CA is an insufficiently sensitive measure of senescence because it cannot distinguish between individuals who share the same CA but differ in physiological and/or functional status.

A common feature of all indices of BA requires to reduce a large number of age-related measures to a single score indicative of BA. The most common approach for the assessment of BA has been to combine a large number of age-related physiological and anthropometric variables in a multiple regression equation, taking the CA as a dependent variable (Dubina et al., 1984; Furukawa et al., 1975; Hollingsworth et al., 1965; Nakamura et al., 1988; Voitenko and Tokar, 1983). However, this method suffers from a theoretical contradiction, in that a perfect model (r = 1.0) would merely be predicting the subject's CA, not his BA. In an attempt to avoid this problem, several authors have adopted factor analytic approaches in order to define BA in the absence of an external criterion (Bell, 1972; Chodzik-Zajko and Ringel, 1987; Dirken, 1972; Nakamura et al., 1988; Tanaka et al., 1990, 1995). The major focus of these studies has been the identification of general factor of biological aging in which a number of biological or functional performance test items load together on a single independent factor.

In the present study, we attempted to evaluate the extent to which HRF and SMP tests can be used to assess the BA of adult Japanese men. In order to achieve this goal, we performed principal component analysis to reduce an initial battery of 4 HRF and 3 SMP tests to a BA single score (HRF Age and SMP Age). The first principal component (C1) obtained from principal component analysis is a combination that accounted for the largest amount of variance in the extracted components. And, this C1 has been suggested to be a useful statistical tool for the purpose of combining all of the explanatory variables into a single expression, in the event of there being no dependent variables (Harman, 1967).

C1 identified in our study explained about 53% (for HRF Score) and 76% (for SMP Score) of the total variance. This explanatory percentages is higher than those reported in previous studies (Hofecker et al., 1980; Kim and Tanaka, 1995; Nakamura et al., 1988; Tanaka et al., 1990). It is reasonable that the C1 was used as an overall index of age-related changes in various fitness variables on the assumption that healthy (active) individuals would be physically more youthful than diseased (inactive) individuals. In this study, it was hypothesized that a linear combination of many factors would be highly predictive of one's functional status. Thus, our results suggest that the above-mentioned fitness items can be combined into an index of functional status, which while highly correlated with CA, has the potential to discriminate among individuals of similar CA but differing functional abilities. Theoretically, a "normal" person's BA -- in terms of appearance, per-
formance and functional capacity — should be the same as his/her CA (Dean, 1988). A difference between the CA and BA may be attributed to a difference in the rate of aging.

With the above in mind, the effects of regular exercise and pathological conditions on HRF Age and SMP Age were investigated in the present study. It would be expected that the subject who had maintained his physical fitness through a program of regular physical activity would have a HRF Age and SMP Age lower than his CA. Kasch (1976) reported that active middle-aged men who followed a regular endurance exercise program over a 10-year-period were able to prevent the usual 9%-15% decline in physical working capacity and maximal aerobic power. In agreement with this result, while HLTH subjects' HRF Age did not differ from their CA, in the 108 ACT subjects, accustomed to regular physical activity, through a regular exercise program, HRF Age was on average 15 years less than their CA. Our data suggest that commonly used measures of HRF can be useful employed as measures of BA which differentiate between individuals of similar age but differing health and physical activity status. In contrast, measures of SMP were found to be less valuable measures of BA.

Since the life expectancy of hypertensive and diabetic persons is shorter than that of normotensives, on the other hand, the BAs of patients with IHD, hypertension, obesity, and diabetic men were compared with those of normotensives by using an aging measurement system devised in this study. The estimated HRF Age of most PAT subjects was higher by about 10 years than CA. The individual HRF Age estimated on the basis of the principal component model shows the equation's high sensitivity in detecting abnormalities or health status. This finding may indicate the adequacy of estimated HRF Age showing that various pathological conditions deteriorate physiological functions and then advance the HRF Age.

In summary, we report the results of a study in which we compared 2 different approaches to the computation of BA in a sample of Japanese men. Our data suggest that commonly used measures of health-related fitness can be usefully employed as indices of BA which differentiate between individuals of similar ages but differing in health and physical activity status. It is hoped that our concept and procedures for estimating HRF Age may provide an interesting tool to attack research problems related to aging. It seems clear that our index of HRF Age has the potential to serve as a useful additional measure of senescence that may help researchers and clinicians to discriminate between individuals who share the same CA but who differ in functional status.

References

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