Age Scale for Assessing Activities of Daily Living

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Abstract: The purpose of this study was to develop an age scale for assessing activities of daily living (ADL) among community-dwelling adults aged 75 years or older. Participants were 1006 older Japanese: 312 men (79.6 ± 4.3 years) and 694 women, (79.9 ± 5.5 years). Participants completed a battery of 8 performance tests related to ADL and the Barthel index (BI) questionnaire. Spearman rank-order correlation analysis was applied to obtain the correlation of the 8 ADL performance tests with the total BI score. Three variables were high rank-order correlated with BI, secondly those items were subjected to the principal component analysis. The weighted combination of the principal component scores was summed. Resulting in an ADL score (ADLS), women = 0.075 X_1 – 0.082 X_2 – 0.063 X_3 + 0.124, men = 0.051 X_1 – 0.105 X_2 – 0.099 X_3 + 0.249, where X_1 = hand-grip strength, X_2 = timed up and go, X_3 = five-chair sit to stand. Individual ADLS was transformed to an ADL age scale (ADLA). The estimation was – 5.493 ADLS + 79.90 for women, and – 4.272 ADLS + 79.57 for men. Due to the distortion at the regression edges, the equation was corrected as suggested by Dubina *et al*. ADLA women after correction was = 0.447 (chronological age: CA) – 5.49ADLS + 44.17, men = 0.519CA – 4.27ADLS + 38.26. ADLA can be used to identify or monitor the characteristics of the ADL levels of physical abilities in older Japanese aged 75 years or older.

Keywords: Age assessment, principal component analysis, physical function, 75 years and older, older Japanese.

INTRODUCTION

Developed countries confront several problems related to rapidly elder population in recent years; thus, the increased rate of health care expenditure in these societies has become one of the major economic issues [1, 2]. Japan is considered as typical one of these societies. Presently, 25.0% of the all population in Japan is aged 65 years and more, half of this percentage (12.3%) is 75 years and older, the most vulnerable age in the country [3].

With the aging of population, the rising disability rates are becoming an increasingly important issue because of both their public health consequences in the form of adverse health outcomes and increasing health-care costs as well as the associated impairment in the quality of life older individuals [4, 5]. The frequency of physical disability becomes apparent as people age: 40% of people 65 years or older has a limited ability to carry out their activities of daily living (ADL), and over 22% of women and 15% of men depend on a caretaker to carry out their ADL [6]. Moreover, each year approximately 10% of non-disabled community-dwelling adults aged 75 years and older loses their ability to perform basic ADL independently [7].

The ability of older adults to perform everyday tasks is a crucial factor in determining the quality of life. In this context, finding ways to increase the health and independence of older adults is a national goal [8]. The primary health care goals should be the maintenance of functional fitness, as an indication of the degree of physical independence to perform various ADL [9]. Chronological age (CA) is not the best predictor of functional fitness for individuals, this is because aging is a highly personal process with individuals not only being different from one and other, but also having physiological system that deteriorates at different rates [10]. Until now, it has been assessed by using a wide variety of tests known collectively as ADL inventories [11-14]. However, most of them are a self-report in which actual performance is not measured [15, 16]. In 1990 Nakamura *et al*., considered that to assess the degree of individual aging, biological age is much better index than CA [17-19]. Only few biological age inventories have incorporated ADL items in their test battery, In 1995 Kim and Tanaka [8], developed a functional age using ADL items, but the range of age

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was wide and the subjects were only women. The aim of the current study pretends to develop an age scale for assessing ADL among community-dwelling adults aged 75 years or older. An additional goal of using ADL age is to provide a simple way for this population to become aware by them self of their current level of functional status, and motivate them to maintain a healthy lifestyle.

METHODS

Participants

Participants included in this investigation were 1202 Japanese community dwellers that are 75 years and older, who were recruited from 6 cities in 4 prefectures: Fukushima, Ibaraki, Chiba, which are located to the north east of Tokyo in the Kanto region and Kanagawa in the southwest. The participants were recruited through poster advertisement and flyers that were displayed in senior centers, leisure centers and residential retirement communities within Japanese community support projects. Inclusion criteria stated that the participants were: 1) community dwellers aged 75 years or older, 2) not care-dependent or support-dependent on a Japanese long-term care insurance system, 3) not restricted from exercising by a doctor. The exclusion criteria were as follows: (1) participants unable to perform the physical test (n = 187); and (2) unable to understand the instructions for the test and questionnaires (n = 9). The remaining 1006 participants (312 males aged 79.6 ±4.3 years and 694 women aged 79.9 ± 5.5 years) were included in the current study. The individuals who were recruited required nursing care, prevention programs or day-care service. Prior to the test, participants read and signed the informed consent form, which was approved by the institutional review board (IRB approval no.:696) this study was conducted in accordance with the guidelines proposed in the Declaration of Helsinki and the study protocol was reviewed and approved by the ethics committee, University of Tsukuba, Japan.

Demographic and Health-Related Information

Participants were interviewed to obtain demographic information, which included age, pain sites, comorbidities, alcohol drinking and smoking status, and health-related information. Body height and weight were measured with minimal clothing and no shoes. Participants were asked to rate their current health status as poor, fair, good, very good or excellent.

Assessment of ADL Ability Status

The ADL status was assessed through the Barthel Index (BI) which consists of 10 items that measure a person's daily functioning specifically the ADL and mobility. The scores for each of the items are summed to create a total score. Total possible scores range from 0– 100, with lower scores indicating increased disability [20].

Physical Performance Items

The following 8 physical performance items were selected according to further research that recognize them as a significantly related to ADL.

1. Hand-Grip Strength

Participants held the dynamometer in the hand in the standing position with their arms at right angles and the elbow by the side of their body. The handle of the dynamometer was adjusted if was required. Participants squeezed the dynamometer with maximum isometric effort, which was maintained for about 3 seconds. No other body movement was allowed [21]. The participant was strongly encouraged to give a maximum effort with good respiration to obtain a high record. The test was performed twice for each hand alternatively. The average of the sum of the scores of all trials, in kg, were used in the analysis. The hand-grip dynamometer was a GRIP-D, T.K.K 5401; Takei Scientific Instruments Co. Ltd., Tokyo Japan.

2. Alternate Step

Participants were asked to raise their legs alternately 8 times, which simulates walking stairs or walking in place. The highest recorded step was 19 cm [22]. The time until the last step taken was in seconds 0.01. Participants were allowed to do 2 trials. We used the average of both trials for the analysis.

3. One-Legged Stance with Eyes Open

With open eyes, gazing straight forward and with the hands on hips, participants were asked to stand on their preferred leg for a maximum of 60 seconds, raising gradually from the floor to a height of 10–20 cm, maintain balance as long as possible. The test was performed twice. The average of the sum of both scores, in seconds, were used in the analysis 23].

4. Functional Reach

Participants were asked to stand with their feet together, raise their arms, and hold the tips of their clasped hands at the 0-cm level of the scale while keeping their arms straight and horizontal. This test was assessed by the maximal distance that the participant could reach beyond arm's length. The average distance recorded that was nearest to 1 cm during two trials was used in the analysis [9].

5. Manipulating Pegs

The subjects were standing in front of a standard-height desk or table where a peg board was installed (Takei Scientific Instruments Co., Ltd.), this board had 96 holes divided in 2 sides, 48 at front and 48 at back side, there are only 48 pegs that were installed in the front side, the subjects were asked to move them from the front side to the back side using both hands (moving 2 pegs at a time) during 30 seconds. The number of pegs transferred during that time was used in the analysis [19].

6. Timed Up and Go (TUG)

Participants were asked sit down on a standard-height chair, after a signal they would stand up from that chair and walk forward as quickly as possible to a distance of 3 m, where a red cone was placed, turn 180 degrees at the cone, and walk back to the chair and sit down. Participants were allowed to use canes or walkers. The average time recorded was rounded to the nearest 0.01 s and times from the two trials were used in the analysis [24].

7. Usual Gait Time

Participants were instructed to stand with their feet behind them with their feet just touching a starting line marked with tape. After the examiner's command, they start to walk at their normal pace along a 7-m course [25]. Participants were allowed to used canes or walkers. The actual walking time was measured over 5-m starting with the first step past the 1-m line and ending with the first step after the 6-m line. The average of the two trials was used in the analysis. The time nearest to 0.01 s was recorded.

8. Five-Chair Sit to Stand (STS)

Participants were asked to stand up and sit down on a standard-height chair as quickly possible. Specifically, the start position was sitting with the knee joint angle at 90 degrees and the soles of their feet touching the floor completely. The time was measured

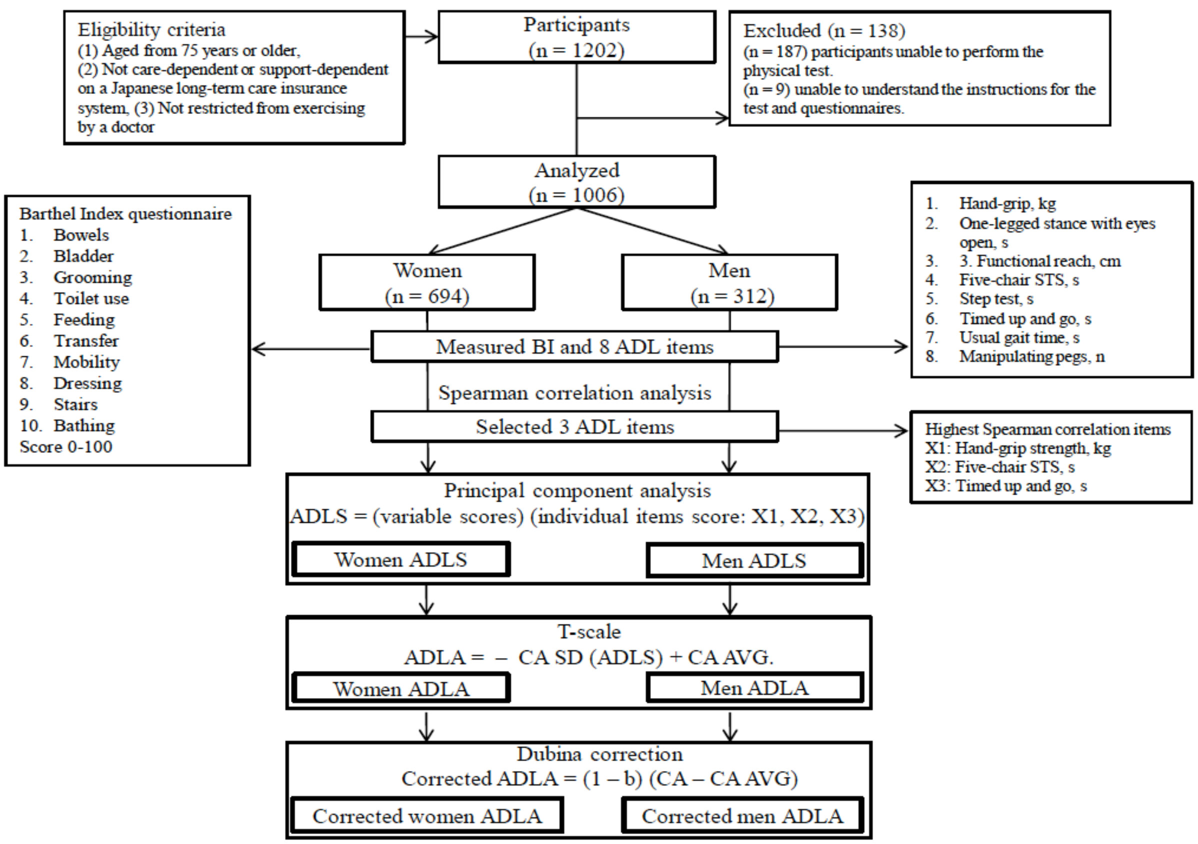


Figure 1: Flow chart of the study participants and development of the ADLA equations.

CA: Chronological age, SD: Standard deviation, ADLS: activities of daily living score, ADLA: activities of daily living age, AVG: average, b: coefficient of simple linear regression.

from the initial sitting position to the final fully erect position at the end of the fifth stand. The average time recorded nearest to 0.01 s during two trials was used in the analysis [26].

Statistical Analyses

Statistical analysis of the data began with calculation of the arithmetic means and standard deviations (SDs), and a correlation matrix among the 8 variables. The Spearman rank-order correlation coefficient was calculated to determine the association among BI score and each of the variables and submitted to principal component analysis [27], as shown in Figure **1**.

The first principal component, which accounts for the largest variance among the extracted components, is a useful statistical tool for the purpose of combining all the independents variables into a single expression. The first principal component was used as the best single descriptor of total ADL performance [28]. This approach has been frequently adopted in gerontology investigations [28-30].

In this study, the first principal component score was used as a unitary index ADL score (ADLS). To calculate individual ADLS, each score was first standardized, and the summed across tests in a weighted manner, using the coefficients of principal component scores obtained from the principal component analysis. To do so, the ADLS was converted into an age scale where the average and SD of CA was used. During this process, the fact that ADLs were distributed with a mean of 0 and a SD of 1.0 were taken into consideration. Finally, the equation was corrected as suggested by Dubina *et al*. (1984) due to the distortion of the individual ADLA at the regression edges. The data was analyzed using IBM SPSS Statistics software, version 21 (SPSS Inc., Chicago, IL, USA), with the level of statistical significance set at 5%.

RESULTS

Table **1** shows the characteristics of subjects. All subjects claimed no known neuromuscular, musculoskeletal or cardiovascular pathology that affected their ambulatory capacity to perform the items of the current study. Descriptive statistics for the BI and the 8 ADL performance test items and the Spearman rank-order correlations for the 8 performances items and the BI score are presented in Table **2**, where all of the 8 variables showed statistical significant correlations with BI in women and men. Statistical significance *P* values of all items were less than 0.01. r^a means the Spearman correlation among BI score and ADL tests. Although all items presented high correlation, we primarily decided for the highest Spearman rank-order correlation, according to this, the three items were selected. The order from the highest to the lowest for women were as follows: TUG, 5-m usual gait time, manipulating pegs, five-chair STS, alternate step, hand-grip strength, one-legged stance

Table 1: Characteristics of the Study Participants (n =1006)

Variables	Mean ± standard deviation or n (%)	
	Women (n = 694)	Men (n = 312)
Age, years	79.9 ± 5.5	79.6 ± 4.3
Geographic area, n (%)		
FUKUSHIMA	112 (16.1)	65 (20.8)
IBARAKI	391 (56.3)	149 (47.8)
CHIBA	168 (24.2)	82 (26.7)
KANAGAWA	23 (3.3)	16 (5.1)
Height, cm	144.9 ± 6.3	159.7 ± 6.8
Weight, kg	49.4 ± 8.3	60.9 ± 8.8
Body mass index, kg/m^2	23.5 ± 3.7	23.9 ± 3.1
Chronic disease, n (%)		
Hypertension	307 (44.2)	130 (41.7)
Stroke	21 (3.0)	21 (6.7)
Heart disease	83 (12.0)	50 (16.0)
Diabetes mellitus	76 (11.0)	50 (16.0)
Self-rated health, n (%)		
Excellent to good	669 (96.4)	302 (96.8)
Fair to poor	25 (3.6)	10 (3.2)
Alcohol drinking status, n (%)		
Current	338 (48.7)	220 (70.5)
No drink	356 (51.3)	92 (29.5)
Smoking status, n (%)		
Current	30 (4.3)	100 (32.1)
No smoke	664 (95.7)	212 (67.9)
Body pain, n(%)		
Waist	212 (30.5)	67 (21.5)
Shoulder joint	94 (13.5)	40 (12.8)
Elbow joint	10 (1.4)	4 (1.3)
Hip joint	28 (4.0)	13 (4.2)
Knee joint	230 (33.1)	59 (18.9)
Feet	48 (6.9)	6 (1.9)

Table 2: Descriptive Statistic for the 8 ADL Performances Test, Barthel Index and Spearman Correlation Coefficients

Variables	mean ± standard deviation or n (%)			
	Women (n = 694)	r[a]	Men (n = 312)	r[a]
Barthel Index (BI), score (0-100)	96.4 ± 9.2	1.0	97.6 ± 7.4	1.0
Physical performance measures				
hand-grip strength, kg	18.6 ± 4.6	0.325**	29.5 ± 7.0	0.365**
one-legged stance with eyes open, s	18.9 ± 20.0	0.314**	25.9 ± 22.9	0.208**
functional reach, cm	23.0 ± 6.8	0.245**	25.8 ± 6.7	0.161**
five-chair STS, s	10.4 ± 5.1	-0.397**	9.0 ± 3.9	-0.332**
step test, s	6.1 ± 2.9	-0.349**	5.4 ± 2.2	-0.392**
timed up and go, s	9.9 ± 6.3	-0.472**	8.2 ± 4.1	-0.377**
usual gait time, s	5.50 ± 3.80	-0.438**	4.70 ± 2.50	-0.349**
manipulating pegs, n	35.60 ± 6.90	0.422**	34.70 ± 7.00	0.351**

with eyes open and functional reach. For walking skills; the highest was TUG, and we cast the other 2 items aside (5-m usual gait time and alternate step). Lower extremity strength was five-chair STS that shown a higher correlation too and the last item for upper extremity strength was hand-grip strength.

In the case of men for walking skills TUG, represent the highest correlation with the total score of the BI, 5-m usual gait time and alternate step were eliminated from the list. For lower extremity strength, five-chair STS. For the upper extremity strength was hand-grip strength. After the selection of the 3 items, those were subjected to the principal component analysis.

The results of the principal component analysis are presented in Table **3**. Although one principal component was identified that met the minimum eigenvalue (< 1) criterion, the first principal component analysis accounted for a significantly greater proportion of the variance (eigenvalue = 2.15 for men and 2.12 for women) than any of the other components. The first component explained about the 71% and 70% for men and women respectively of the all variables. These results suggest that the first principal component can

Table 3: Factor Loadings by Principal Component Analysis

Variables	Women	Factor I
		Men
hand-grip strength, kg	-0.749	-0.766
five-chair STS, s	0.872	0.875
timed up and go, s	0.894	0.891
Eigen value	2.12	2.15
Percent variance	70.7	71.0

be used as a relatively comprehensive index of ADL functioning.

In order to compute ADLS for each subject, we calculated principal scores as Σ ai xi where ai is the factor loading of the 3 test items and the xi is an individual's standard score on the 3 test items.

The following equations were obtained for the ADLS:

Women ADLS = $0.075\ X_1 - 0.082\ X_2 - 0.063\ X_3 + 0.124$

Men ADLS = $0.051\ X_1 - 0.105\ X_2 - 0.099\ X_3 + 0.249$

Where X_1 = hand-grip strength, (kg), X_2= five-chair STS (s), X_3 = TUG (s).

The correlation between the first principal component score and CA was r = − 0.485 for men and r = − 0.474 for women.

To transform the individual ADLS to the age scale, using the T-scale idea and taking in consideration that they are distributed with a mean of 0 and a SD of 1.0. First the scores were standardized using the average and SD of CA.

The following equation for the ADLA was derived:

Women ADLA = − 5.493 ADLS + 79.90

Men ADLA = − 4.272 ADLS + 79.57

The above figures − 5.493 and 79.90 in women and − 4.272 and 79.57 are respectively the mean and SD of the CA of our sample of 1006 participants.

There were considerable differences between the slopes of the regression lines.

Figure **1** shows the relation between the estimated ADLA and the CA. Although the estimated ADLA scores should ideally be scattered symmetrically above and below the identity line CA = ADLA, the slope of the regression differed considerably from 1.0. Before any statistically meaningful comparison could be made between ADLA and CA, the distortion of ADLA at the regression edges as a function of CA and the disagreement between the slopes of both regression lines had to be corrected as suggested by Dubina *et al*. (1984). We calculated the following correction term according to the method of Dubina *et al*. (1984). The correction is calculated from $Z = (1 - b)(Y_i - Y)$, where "Y_i" is the CA of an individual, "Y" is the mean CA, and "b" is the coefficient of simple linear regression that expresses the relation between ADLA and CA. Finally, corrected ADLA was obtained summing the Z in the second equation.

The equations after correction were as follows:

$Z = (1 - 0.553)(CA - 79.90)$

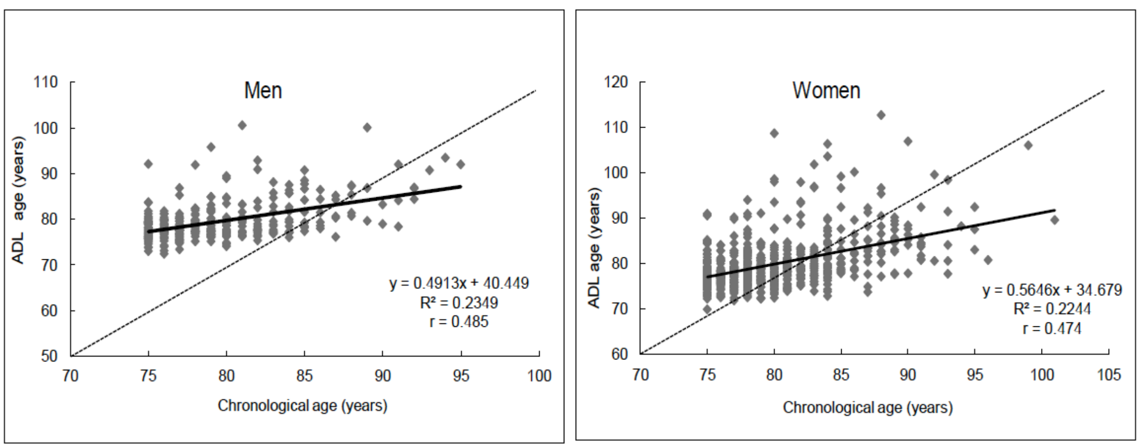
Women ADLA = 0.447CA − 5.49ADLS + 44.17

$Z = (1 - 0.480)(CA - 79.57)$

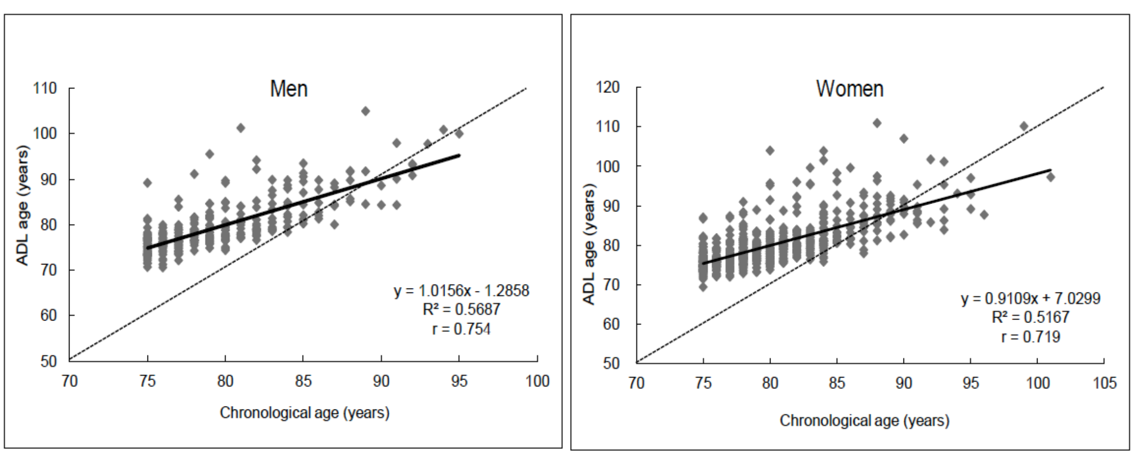
Men ADLA = 0.519CA − 4.27ADLS + 38.26

Figure **2a** shows the relationship between CA and the uncorrected ADLA. The correlation between ADLA and CA was (r = .485 in men and r = .474 in women).

The corrected ADLA scores were almost symmetrically scattered above and below the line of identity CA = ADLA. The correlation between ADLA and CA was significant (r = .754 for men and r = .719 for women) as shown in Figure **2b**. These data suggest that ADLA and CA are highly related but are not identical constructs.



a



b

Figure 2: a. Scatter diagram between chronological age and uncorrected activities of daily living age.
b. Scatter diagram between chronological age and after correction activities of daily living age.

DISCUSSION

In the current study, we developed an equation of ADLA with the aim to use it as a tool to assess the physical functionality among older Japanese community dwellers aged 75 years or older, in order to respond to the necessity of the ADL. The findings of the present study showed that 3 ADL performance test can be used together to identify or monitor the characteristics of ADL levels of physical abilities. When Spearman correlation analysis was applied, 3 ADL items of 8 were found to represent the major elements of physical functioning that are necessary for the successful completion of many ADL. Specifically, the 3 items assessed walking ability, upper and lower body extremity strength. As the statistical significance P values of all items were less than 0.01. According to the results of the principal component that equations have the potential to recognize the physical functionality in about 71% by the factor loadings as shown in Table **3**, representing the major elements necessary for the successful completion of ADL.

Our method for the process of computing the ADLA is generally consistent with several approaches previously reported in the experimental literature [29-32]. A common feature of all indices of biological age is the requirement to reduce a large number of variables to a single score. Specifically, the linear combination of measures that maximizes the prediction of CA is used to generate biological age, functional age or in this case ADLA [33-36]. As shown in Table **2**, we decided primarily for the highest Spearman rank-order correlation to 1. From the higher rank of correlation for women were as follows: 1) TUG, 2) 5-m usual gait time, 3) manipulating pegs, 4) five-chair STS, 5) alternate step, 6) hand-grip strength, 7) one-legged stance with eyes open and 8) functional reach. We chose the highest items by similar group of ability, the first 2 items refer to walking skills, for example for walking skill TUG was the higher compared with 5-m usual gait time and alternate step. We selected TUG cast the other 2 items aside. For the lower extremity strength five-chair STS showed a higher correlation too. The third item was selected for the upper extremity strength (i.e., hand-grip strength). In the case of upper extremity strength we decided to implement hand-grip strength for both sexes, to synchronize with the items used in men. The reason we decide hand-grip strength although this showed lower correlation than manipulating pegs in women was that according to some researches [37], hand-grip strength is not just a better descriptor of upper extremity strength, it also provides strong evidence that predicts functional limitations and disability while manipulating pegs involve finger-synchronization skills. A 25 years cohort study of Japanese-American subjects showed that people with lowest hand-grip strength tertile had the greatest risk and those in the middle tertile had intermediate risk compared with those in the highest tertile. Muscle strength is found to track over the lifespan: those who had higher hand-grip strength during midlife remained stronger than others in old age [38]. People with greater muscle strength during midlife are at lower risk of becoming disabled because of their greater reserve of strength regardless of chronic conditions that may develop. Also, hand-grip strength has been found to be correlated with strength of other muscle groups and is thus a good indicator of overall strength [39]. Consequently, hand-grip strength measurements could be used for early screening of populations to identify those at higher risk of physical disability related to low muscle strength. In these persons, exercise interventions aimed at improving strength in all muscle groups could potentially lower the risk of subsequent physical disability. There are also other potential explanations that hand-grip strength may be a marker of physical activity which itself preserves function and prevents disability [40]. Muscle strength can be increased substantially by physical exercise at all ages [41-43]. With this in mind, our aim is to focus more on those items which are closely related with the physical function and avoid motor disabilities, especially in the weak population that are people of 75 years or older. Finding in aforementioned references helped to choose hand-grip strength for women too.

For men, walking skills and lower extremity were the same items as women (TUG, five-chair STS and hand-grip strength), Although men's data were fewer than women's we conclude that this synchronization of items are credible by the reason that it has been proved that women have a notable lower death rate than men at all ages, women also seem to resist diseases better than men and seem to respond more readily to medical treatment at the same CA [44, 45].

After the first principal component analysis was applied to the three selected items, results showed that those items explained nearly the 71% of the total variance. This explanatory percentage is almost identical to that reported in previous studies [28, 30, 32].

Our data suggests that these 3 items (highly reliable ADL test and proved to assess functionality on elder population [32]) could be combined into an index of functional status (ADLA), which, found to be highly correlated with BI, has the potential to discriminate among individuals of similar CA but differing in the functional abilities.

The relevance of this study is that the ADLA equation it´s an easy and compact index that can be used with short ADL variables while avoiding the fatigue of the elderly with a long battery of test. In comparison to other studies this is the first time that an index for people over the age of 75 has been developed, previous studies typically have an elaborated index for healthier, and younger participants.

Hand-grip strength, five-chair STS and TUG can be used together to identify or monitor the characteristics of ADL levels of physical abilities on people over 75 years as an additional measure of senescence that may help researchers and clinicians to discriminate between individuals who are of the same CA but who differ in a physical function status.

This study has some limitations. First, our sample of the population could not be the representative of the all Japanese population, because we recruited our participants at community centers, limiting the participation in our study only to visitors of those centers. Second the subjects had a sufficiently mobile to commute to our study center, Thus, relatively healthier people tend to participate with a positive effect in the strata. Third the current ADLA has been established exclusively from cross-sectional data, and with nondisabled Japanese population over 75 years or older. Equations could not be functional in other countries or younger populations, because of complex factors related with lifestyle (environmental) and/or ethnicity. However, our findings might not be generalizable to older adults who are frailer. The equations are only appropriate for Japanese community-dwelling aged 75 years or older. It is necessary to assess the validity of it in longitudinal studies and or in short or long training studies as well (exercise interventions) in which there is an attempt to alter functional status through an intervention program.

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