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Original Article

Age score for assessing motor function in Chinese older men

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Abstract

Background and objective: Motor performance plays an important role in daily activities for older adults. The purpose of the study was to construct a method for measuring physical fitness age that can be used to assess motor performance in elderly men and to verify its validity. **Methods:** Four items of physical fitness including grip strength, balancing on one leg with eyes open, 30 s chair stand test and 6 min walk test were selected and measured in a random order. Principal component analysis was employed to build physical fitness age based on motor performance variables from 94 elderly men with a mean age of 71.20 $\pm$ 5.05 years. Physical fitness age = 115.516-0.652 $\times$ grip strength - 0.142 $\times$ balancing on one leg with eyes open - 0.839 $\times$ 30 s chair stand - 0.061 $\times$ 6 min walk distance + 0.541 $\times$ chronological age. **Results:** Validation test from 13 men with exercise habit and 12 men without exercise habit showed that the physical fitness age in the exercised adults was significantly lower than its chronological age (63.91 $\pm$ 5.40 vs. 70.92 $\pm$ 4.17, $P < 0.001$), while no significant difference was observed between physical fitness age and chronological age in the elderly without exercise habits (71.23 $\pm$ 7.49 vs. 70.83 $\pm$ 5.19, $P = 0.646$). **Conclusion:** Physical fitness age is a valid indicator to evaluate and monitor motor performance. Participation in physical exercise may lower the physical fitness age by improving motor performance.

Keywords

Aging; Physical fitness; Motor function; Exercise

1. Introduction

Aging is a natural and inevitable process. For the past decades, human life expectancy has been adding gradually [1]. The proportion of people aged 60 and older is growing at a fast rate, which is not only restricted to developed countries but also occurs in developing countries such as P. R. China [2]. In P. R. China, it is estimated that the number of a net increase of people aged 60 or older has reached 110 million, and it will reach a peak of 487 million around 2050, accounting for 34.9 percent of the total population [3]. It is known that an age-related decline of physical function and motor performance is inevitable in elderly adults [4]. The elderly may have a poor quality of life and need long-term care if motor performance continues to decline. Maintaining or improving motor performance for such elderly adults by carrying out appropriate exercise or physical activity can enable them to stay active, maintain independence and keep their daily activities into later years of life.

Muscle strength is considered to be a basis of physical fitness and an engine of human movement [5]. It can be divided into muscle power and muscle endurance, which has been reported to be closely associated with sarcopenia in older adults [6–8]. Postural control is one of the most important capacity for the elderly. Multiple studies have found that postural control plays a crucial role in keeping balance and preventing falls [9–11]. Cardiopulmonary endurance is also regarded as one of the most important capacity for older individuals. It has been demonstrated to have a remarkable correlation with cardiovascular diseases and

TABLE 1. Characteristics of Chronological Age and Physical Fitness in Different Groups.

Variables	Constructing group of physical fitness age	Validating group of physical fitness age	
	Elderly men (n = 94)	Older men without exercise habits (n = 12)	Older men with exercise habits (n = 13)
Chronological age (yrs)	71.20 ± 5.05	70.83 ± 5.49	70.92 ± 4.17
Grip strength (kg)	35.37 ± 5.29	34.47 ± 4.85	36.43 ± 3.78
Balancing on one leg with eyes open (s)	43.09 ± 20.12	38.73 ± 20.11	53.63 ± 11.65
30 s chair stand test (repetitions/30 s)	20.91 ± 4.96	20.17 ± 3.74	24.38 ± 2.57
6 min walk test (m)	605.50 ± 62.45	622.17 ± 32.31	629.38 ± 58.81

other chronic diseases [12, 13] These components of physical fitness mentioned above are principal elements responsible for affecting motor performance and quality of life of older adults.

Conventional assessment methods such as short physical performance battery and functional fitness tests were broadly employed to evaluate motor performance in varied age stages [14–16]. These methods are fit for measuring individual motor performance, but they are not suitable for a comprehensive indicator of motor performance. This is because motor performance may be overestimated for young individuals and be underestimated for elderly adults by these assessment methods. Moreover, according to previous studies [17, 18], it is possible to convert the overall values of motor performance into age scores. With regard to elderly people, a feedback of motor performance as a comprehensive physical fitness age score rather than respective measurement values may be easier to understand and accept. Generally, physical fitness age may be a more meaningful definition of performance to older adults than values that come directly from physical performance measures.

Several physical fitness assessments have been built to evaluate fitness age for both middle-aged and elderly individuals using principal component analysis in the literature [17–20]. They are suitable to assess individual motor performance for different age groups. Latorre-Rojas *et al.* [21], demonstrated that the physical fitness age is a valid indicator of motor performance in adult and elderly individuals, as well as a useful motivational tool to undertake exercise programs. Though several equations of physical fitness age have been developed by researchers from different countries, due to the influence possibly caused by different races, test items and methods, whether these equations are applicable to the Chinese individuals is still unknown.

Motor performance plays an important role in daily activities for older adults. A standardized physical fitness age score for Chinese elderly men to assess motor performance has not yet been developed. Therefore, the purpose of this study was to obtain a method for measuring physical fitness age score by constructing an equation using the motor performance outcomes and its association with chronological age and to verify our results by comparing physical fitness age and chronological age in elderly men with and without exercise habit who came from another sample.

2. Methods

2.1 Participants

Men aged 60 and older were recruited through advertising in local newspapers and putting up posters. There were 2 samples in our study. One was used to construct physical fitness age and another was employed to verify the validation of the physical fitness age. The participants in the initial sample were 94 men with a mean age of 71.20 ± 5.05 years old, and they had no past and present motor function disorders and other cardiovascular diseases; the validation test sample comprised 13 men with exercise habit and 12 men without exercise habit (mean age of 70.92 ± 4.17 and 70.83 ± 5.49, respectively). The criterion of exercise habit was if light or moderate physical activities reached 150 minutes per week. Types of physical activity include various ball games, walking briskly, bicycling, dancing, Tai Chi and so on. A questionnaire was employed to investigate each participant's physical activities. The study's purpose and procedures were explained to every participant. Before the measurements, the participants were asked to read and sign a written informed consent form. The study was approved by the Human Ethics Board of our university (No: RAGH20180216).

2.2 Measurements

Physical fitness items including grip strength, balancing on one leg with eyes open, 30 s chair stand test and 6 min walk test were selected in this study. They could reflect muscle strength, postural control, muscle endurance and cardiopulmonary endurance. Selecting these 4 items to our study, we referred to a previous study by Rikli and Jones [15], Nofuji *et al.* [22], and ATS Committee [23]. Meanwhile, the items had been proved to have good reliability and validity in the previous study [15, 22–24]. In this study, grip strength, balancing on one leg with eyes open, 30 s chair stand test and 6 min walk test were measured in a random order.

Grip strength: The participant held the dynamometer (Grip-D5101, Takei, Japan) in the preferred hand with the arm down at bodyside, and then squeezed the handle to maximum force. There were 3 attempts for this test with 30 s rest between attempts. The best record to the nearest kilogram (kg) was adopted for further analysis.

Balancing on one leg with eyes open: Each participant was asked to keep balance using the preferred foot stood and the other foot left the floor, with eyes open and hands touching the waist. The record was the number of seconds between the time of the nonpreferred foot left the floor and the time of body balance lost. Three attempts were given, and the longest time (s) among attempts was recorded.

30 s chair stand test: Each participant was instructed to sit a 45 cm height chair with no armrests chair until feet were flat on the floor, then asked to stand up all the way until the knee and hip were fully extended and sit down, while the hands were folded across the chest. Then, the participant was instructed to perform this action as fast as possible for 30 seconds. Two trials were given, and the largest repetition (repetitions/30 s) among trials was recorded for further analysis.

6 min walk test: Before the test, each participant was asked to sit on a chair at the starting point to rest for at least 5 minutes. At the same time, participants were told to walk as soon as possible but not run. When testing, researchers encouraged participants to continue walking and informed them of the time consumed in every minute. After the test, meters (m) of walking distance for each participant were measured and recorded. There was only one attempt for this test.

2.3 Statistical analyses

Principal component analysis is a useful method in exploratory data analysis and for making predictive models, which has been frequently employed in several gerontological studies to develop age scoring models [17–20]. We constructed the assessment of physical fitness age by adopting the same principal component analysis procedures previously described by Kimura *et al.* [20]. First, correlation coefficients were tested between the measured 4 items and chronological age, and the correlation matrices among the 4 items of physical fitness were also built from 94 elderly men. Then, the 4 items that had been tested to highly correlate with chronological age were used to perform principal component analyses. The first extracted principal component was adopted to compute the physical fitness score. It was then converted into an age scale named physical fitness age. To verify the validity of the physical fitness age that we built, we compared it to the chronological age in the elderly with and without exercise habits using paired *t*-tests.

3. Results

Data from the initial sample (constructing group) that includes 94 elderly men were employed to build physical fitness age, while data from the validating group that consists of 12 older men without exercise habits and 13 older men with exercise habits were used to verify the validation. The characteristics of chronological age and motor performance in different samples were shown in Table 1.

Table 2 presented correlation coefficients between chronological age and the 4 motor performance items in 94 elderly men. All the 4 motor performance items were significantly associated with chronological age. The principal component analysis of the 4 items for physical fitness score was presented in Table 3. The eigen value of the first principal component was 2.0, and the percentage of variance was 50.0, which suggested that the principal component could be employed as a comprehensive indicator of physical fitness score variables. By calculating, the equation of physical fitness score was as follows:

TABLE 2. Correlation Coefficients between Chronological Age and the 4 Physical Fitness Items in 94 Elderly Men.

Variables	r	*P*
Grip strength (kg)	-0.385	< 0.001
Balancing on one leg with eyes open (s)	-0.273	0.008
30 s chair stand test (repetitions/30 s)	-0.233	0.024
6 min walk test (m)	-0.42	< 0.001

Physical fitness score = 0.129 × grip strength + 0.028 × balancing on one leg with eyes open - 0.166 × 30 s chair stand - 0.012 × 6 min walk distance - 16.390.

A scatter plot between uncorrected physical fitness age and chronological age was shown in Fig. 1. Since the physical fitness score constructed above was negatively related to chronological age (r = -0.459, $P < 0.001$), we must make it have a positive association with chronological age. Therefore, the mean value (71.20) and standard deviation (5.05) were used to standardize the equation of physical fitness score (-5.05 × physical fitness score -71.20). By computing, the equation of physical fitness age (uncorrected) was as follows:

Uncorrected physical fitness age = 154.035 - 0.652 × grip strength - 0.142 × balancing on one leg with eyes open - 0.839 × 30 s chair stand - 0.061 × 6 min walk distance.

A linear association was found between physical fitness age (uncorrected) and chronological age (r = 0.459, $P < 0.001$). Finally, we used a correction formula ($Z = (Y1 - Y) \times (1 - b)$) developed by Dubina *et al.* [25] to construct the equation of physical fitness age. Fig. 2 showed that a better relationship between physical fitness age (corrected) and chronological age (r = 0.634, $P < 0.001$). The equation of physical fitness age was as follows:

Physical fitness age = 115.516 - 0.652 × grip strength - 0.142 × balancing on one leg with eyes open - 0.839 × 30 s chair stand - 0.061 × 6 min walk distance + 0.541 × chronological age.

Twelve older men without exercise habits and 13 older men with exercise habits were recruited to verify the validation of the physical fitness age. In the older men without exercise habits, no significant difference was observed between the mean physical fitness age and chronological age (71.23 ± 7.49 vs. 70.83 ± 5.19, $P = 0.646$); while in older men with exercise habits, the mean physical fitness age was significantly lower than its chronological age (63.91 ± 5.40 vs. 70.92 ± 4.17, $P < 0.001$) as shown in Table 4.

4. Discussion

We used several items of physical fitness that were characterized by low technical difficulty and high test safety, including grip strength, balancing on one leg with eyes open, 30 s chair

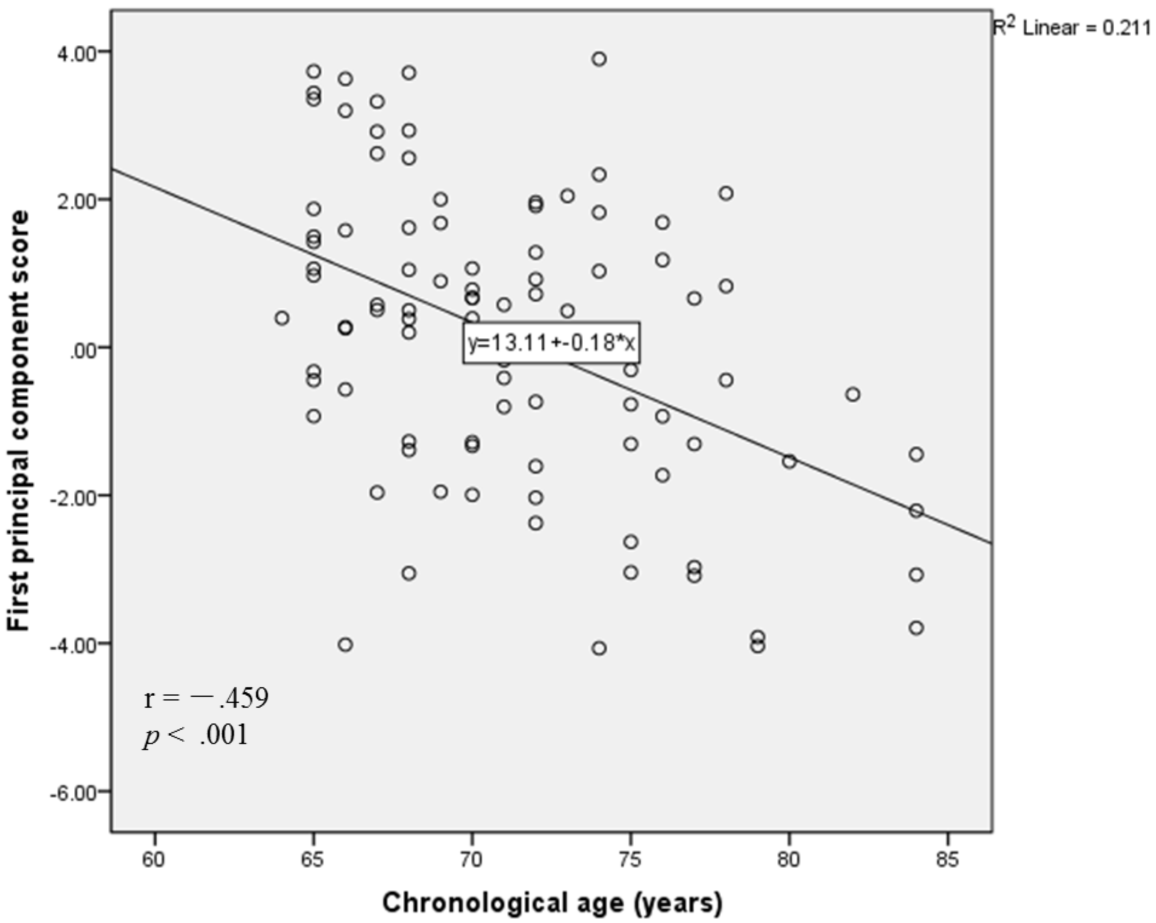

FIG. 1. Correlation between Chronological Age and First Principal Component Score.

TABLE 3. Principal Component Analysis of the 4 Items For Physical Fitness Age.

Variables	Factor loading	Factor score coefficient
Grip strength (kg)	2	0.682
Balancing on one leg with eyes open (s)	0.848	0.559
30 s chair stand test (repetitions/30 s)	0.677	0.824
6 min walk test (m)	0.475	0.738
Eigen value	2	
Percentage of variance	50	

TABLE 4. Comparisons between Chronological Age and Physical Fitness Age in Older Men with and without Exercise Habits.

	Older men without exercise habits (n = 12)	Older men with exercise habits (n = 13)
Chronological age (yrs)	70.83 ± 5.19	70.92 ± 4.17
Physical fitness age (yrs)	71.23 ± 7.49	63.91 ± 5.40**

**, $P < 0.001$ vs. chronological age.

stand test and 6 min walk test to construct physical fitness age. By comparing physical fitness age to chronological age, relevant information can be obtained for practitioners to formulate exercise programs [21, 26]. Our validation test showed that the mean physical fitness age in the exercised older adults was significantly lower than chronological age. It is indicated that physical fitness age is a valid assessment to evaluate motor performance in elderly men.

Several researchers have emphasized the importance of providing a comprehensive assessment to evaluate motor performance rather than individual series of test results [19, 21]. If a feedback of test result is only composed of respective measurement values, it is difficult to know the level of motor performance, particularly for the older individuals whose capacity of understanding may be lower than younger ones (cognitive function typically declines with aging). Therefore, a feedback of test results formed by a comprehensive assessment may be better to understand for elderly adults. In light of these, some researchers pointed out that series of test results of motor performance should be associated with age scales, where feedback was provided by changing the chronological age into a standard age such as physical fitness

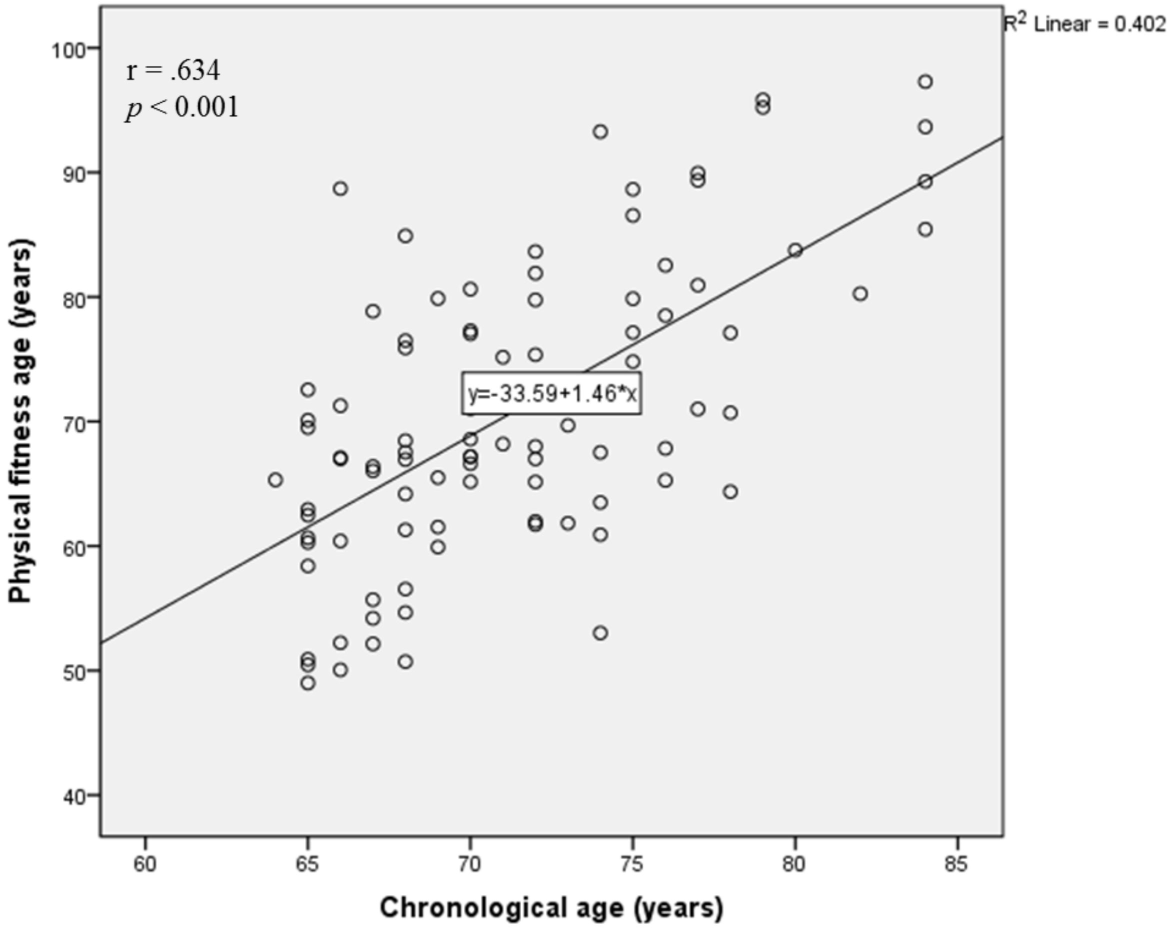

FIG. 2. Correlation between Chronological Age and Physical Fitness Age.

age [27, 28]. Based on the above viewpoints, we finally constructed a comprehensive assessment of physical fitness age to evaluate motor performance for elderly men. Additionally, age difference, obtained by comparing the physical fitness age to chronological age, may motivate individuals to keep or boost physical fitness by improving diet and participating in exercises and sports. It may also be helpful for nursing staff to assess the motor performance of the elderly.

The selection of motor performance items was crucially important for studies, and they may be influenced by races. For instance, Latorre-Rojas *et al.* [21] utilized chair stand, arm curl, 2-min step, chair sit-and-reach, back scratch and 8-foot up-and-go, while Nakagaichi *et al.* [27] employed grip strength, balancing on one leg with eyes open, 30 s chair stand and figure-of-8 walking test to develop physical fitness age for Spanish and Japanese respectively. The selecting principle of test items in our study was similar to previous studies [15, 22–24]. We selected 4 items including grip strength, balancing on one leg with eyes open, 30 s chair stand test and 6 min walk test. These items represented motor performance such as muscle strength, postural control, muscle endurance and cardiopulmonary endurance, which had been proved to highly correlate with chronological age in our study as shown in Table 2. Another reason for selecting these 4 items was that they were measurable in both healthy and exercise elderly individuals. On the other hand, there will be a periodic long-term follow-up test using the 4 fixed items in our research center in the future. A continuous monitor and feedback of motor performance will be carried out for the elderly individuals who took part in our study.

Åhlund *et al.* [29] selected hand-grip strength, the timed up and go test, 5-time sit-to-stand test, and 6-minute walk test to evaluate motor performance in hospitalized frail older adults in Sweden, finding that the lower limb motor performance of most hospitalized frail older adults was far lower than the previously described age-related reference value. These items mentioned above may be helpful in the assessment of motor performance in hospitalized frail older adults. They suggested that designing a realistic, individualized rehabilitation program may be beneficial to the hospitalized frail older individuals. In our study, unlike the timed up and go test, we used balancing on one leg with eyes open to assess postural control of elderly individuals. This was because postural control ability that is associated with falls is an important ability for elderly people. It already has been reported that there is a higher risk of fall and fall-related injuries in older adults than those younger individuals [30].

As to the statistical method, the principal component analysis used in this study has been considered a common method for constructing equations like physical fitness age [17–19]. Beyond the principal component analysis, multiple regression and principal component analysis combined multiple regression were also adopted frequently to build physical fitness age in previous studies [20, 21]. In the present study, we used principal component analysis to develop an equation of physical fitness age. After that, we also compared the physical fitness age to the chronological age of participants within the elderly with and without exercise habits. The results indicated that physical fitness age is a valid indicator to evaluate and monitor motor performance in Chinese elderly adults.

To verify the validity of the physical fitness age that we built, we compared it to the chronological age in older men with and without exercise habits. No significant difference was observed between the mean physical fitness age and chronological age in older men without exercise habits. While we found that the mean physical fitness age was significantly lower (by a mean of 5.91 years) than the chronological age in the exercised elderly men (Table 4). Similar results were also reported by Lee *et al.* [19]. They observed a 7 years' reduction of physical fitness age in subjects with coronary artery disease by providing a 4-month program of exercise combined with dietary improvement. These findings suggest that undertaking exercise may maintain and improve motor performance, thereby lowering physical fitness age.

In our study, physical fitness age was constructed by adopting the same procedures previously described by Kimura *et al.* [20] in Japan. There were similarities and differences between our study and the previous study. Besides the same statistical method, a major similarity was that the selected indicator could partly reflect physical fitness or physical function in both studies. However, the specific indicators that construct physical fitness age were different slightly. For instance, grip strength, balancing on one leg with eyes open, 30 s chair stand test and 6 min walk test were used in our study. While 10-m walk time, functional reach, one leg stand with eyes open, vertical jump and grip strength were selected in the previous study. Additionally, it is known that cardiopulmonary function plays an important role in the movement, but there was no such indicator in the previous study to construct physical fitness age.

There are several limitations to this study. To avoid the effect of sex differences, the participants for developing the equation of physical fitness age were restricted to Chinese older men aged 60 years and older. Thus, the equation may be unsuitable for other populations. Another limitation was the small sample size, which may lower the statistical power of the study. Furthermore, physical fitness age can be assessed by 4 fixed components, however, it is also necessary to measure each fitness component separately in order to tailor any exercise program based on the specific needs of an individual. Last, although it has been confirmed that exercise is a factor responsible for affecting physical fitness age, we had not distinguished what type of exercise and how many exercise time affect physical fitness age, which needs to be addressed in future studies.

5. Conclusions

An equation of physical fitness age was constructed based on motor performance of grip strength, balancing on one leg with eyes open, 30 s chair stand and 6 min walk test from elderly men. Physical fitness age = 115.516 - 0.652 $\times$ grip strength - 0.142 $\times$ balancing on one leg with eyes open - 0.839 $\times$ 30 s chair stand - 0.061 $\times$ 6 min walk distance + 0.541 $\times$ chronological age. The validation test showed that the mean physical fitness age in exercised adults was significantly lower than its chronological age. The findings suggest that physical fitness age is a valid indicator to evaluate motor performance in elderly men, and it may be helpful for practitioners including nursing staff to set exercise programs. Additionally, participation in physical exercise may lower the physical fitness age by improving motor performance.

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Conflict of interest

There is no conflict of interest.

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