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Proposal of VO2max estimation formula for elderly men and women using functional performance measurement

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Abstract

This study proposed a multiple regression equation for predicting VO2max of elderly men and women using functional performance variables required to conduct daily activities. The subjects of this study were 58 elderly men (72.4±5.9 yrs) and 117 elderly women (73.4±4.5 yrs) aged 65-90 who belong to the senior welfare center. The maximal graded exercise test using a cycle ergometer and functional performance representing muscle strength, endurance, static and dynamic flexibility, mobility, and agility were measured. For statistical processing, multiple regression analysis was performed, and the statistical significance level was $\alpha = .05$. As a result, the VO2max estimation formula for the elderly was 0.419 (standing up and sitting down a chair) + 0.199 (leg endurance against wall) + 5.383, and R2=0.406. In addition, the VO2max estimation formula for elderly women is - 0.737 (standing up from a supine position) - 0.144 (waking around two cones in a figure 8) - 0.135 (%body fat) + 0.042 (one leg balance with eyes open) + 29.395, R2=0.367 was calculated. The conclusion is that if the maximal graded exercise test is not available, it is considered that VO2max of the elderly can be predicted properly by using the estimation formula calculated based on the functional performance variable.

Keywords Elderly, VO2max, Functional Performance, Multiple Regression

Major classifications Health Science

1. Introduction

Recently, as life expectancy has significantly increased, various studies are being conducted on regular physical activity that can prevent health problems in the elderly (Ekblom-Bak et al., 2014). In general, cardiorespiratory fitness (CRF) is the capacity of the cardiovascular system to meet the oxygen demand of skeletal muscles during physical activity, and represents the maximum aerobic capacity (Kokkinos et al., 2017), which decreases with age (Betik & Hepple 2008). The rate of decline accelerated at the age of 45 and showed a more significant decrease from the age of 65 (Jackson et al., 2009).

CRF is independently associated with longevity in the elderly, and is also highly predictive of mortality from cerebrovascular diseases, hypertension, hyperlipidemia, and type 2 diabetes, and is inversely proportional to mortality as well as risk factors for cardiovascular disease (CVD). (Ross et al., 2016).

Since the inverse association between CRF and CVD is greater in the elderly than in other subjects (Kokkinos et al., 2017), evaluating CRF is more important in terms of health in the elderly. Through the functional performance evaluation necessary for the elderly's daily life activities, the need for regular exercise is required for individuals, and for this, accurate exercise prescriptions for individuals must be made first (ACSM, 2006). In particular, evaluation of CRF levels for exercise practice is not only an important factor in determining exercise intensity but also a useful indicator in evaluating an individual's health status, so it is important to receive exercise prescriptions based on exercise load tests from exercise leaders before starting an exercise program. In the early 1920s, motor physiologists discovered maximum oxygen uptake (VO2max), which turned the phenomenon to physiological limitations of the respiratory circulation system (Hill & Lupton, 1923).

VO2max is a widely accepted physiological index used for exercise prescription and evaluation (ACSM, 2014), and represents the highest oxygen carrying capacity and utilization rate. Since it includes an increase in cardiac output, an increase in blood volume, an increase in mitochondrial density in skeletal muscle, and a change in skeletal muscle fiber distribution (Lundby et al., 2017), it can be used by indicating the CRF level as a measure of VO2max and applying it to exercise prescription (Tharret et al., 2012). The CRF measured by VO2max is related to functional performance, and is one of the essential components for monitoring changes in functional performance, which is known to decrease with age and disease, as an objective method to evaluate motor performance, especially in the elderly. As one (Akalan et al., 2004), VO2max is known to be the best measure of CRF.

However, it has the disadvantage of being somewhat limited in terms of practicality and risk for the elderly because the VO2max measurement value must be obtained through an incremental exercise load test that leads to all-out using a treadmill or bicycle ergometer in the laboratory. Due to the burden of expensive measuring devices, professionals, and maximum exercise experienced by subjects, it is not easy to measure directly for the elderly or the sick, so the application of elderly welfare centers and nursing homes where daily exercise is carried out is limited. Therefore, in order to compensate for the shortcomings of exercise load testing in previous studies, various efforts have been made to indirectly estimate VO2max using variables that are easy to measure (Moon et al., 2011). In addition, most of the estimation formulas used to predict VO2max were developed based on general athletes and the general public. Therefore, there is a need for a valid estimation formula to evaluate the VO2max of the elderly in consideration of the safety and convenience that do not require the maximum effort for indirect measurement for the elderly, and the economic feasibility of not requiring expensive equipment. Considering that there is no easy method to measure considering the importance of VO2max prediction and functional performance, this study proposed a multiple regression equation to predict VO2max of elderly men and women using functional performance variables.

2. Research method

In this study, a formula for estimating cardiorespiratory endurance was developed using functional tablet performance measurement to select physical functions related to aging and diseases of the elderly and to use them to evaluate aging. Therefore, ‘longevityfitness’ was defined as the ability that the elderly need to safely perform housework, shopping, and social activities necessary in daily life. For self-reliance of physical activity, it is divided into primary life movements (housing, housework, basic physical movements, etc.) and secondary life movements (mobility ability, social activities, health promotion activities, etc.) (Tanaka et al., 1990; Guralnik et al., 1994).), validity (Bravo et al., 2010) and reliability (Shaulis et al., 1994) were selected for the following measurement items and methods.

For ethical consideration of the research, the research was conducted after receiving approval from the Clinical Ethics Review Committee of Inha University <INHA-IRB20211029012>.

2.1. Research subject

The subjects were 200 elderly people between the ages of 65 and 90 in K province, and were recruited to senior welfare centers through flyers and promotional materials. Of the total 200 volunteers, 7 persons under the age of 65, 6 persons who needed a cane or assistive device or had visual or auditory deficits, and 12 persons who did not meet the VO2max evaluation criteria were excluded. Finally, 58 elderly males and 117 elderly females, a total of 175 people, were selected for analysis. All subjects signed a consent form for voluntary participation after listening to oral explanations about the purpose of the study, the contents of functional performance measurement, and the right to refuse measurement, and the physical characteristics of the subjects are shown in Table 1.

Table 1: Subject's physical characteristics

variable	Male (n=58)		Female (n=117)	
	(M±SD)	range	(M±SD)	range
age (yrs)	72.4 ± 5.9	63.0 ~ 89.0	73.4 ± 4.5	62.0 ~ 89.0
height (cm)	164.4 ± 5.7	148.9 ~ 176.3	149.6 ± 12.1	135.0 ~ 163.1
weight (kg)	66.2 ± 9.0	45.9 ~ 87.1	54.8 ± 8.1	38.3 ~ 79.8
body mass index (㎏/㎡)	24.4 ± 2.4	16.3 ~ 30.7	24.1 ± 3.1	16.8 ~ 32.6
body fat mass(kg)	16.2 ± 3.9	04.5 ~ 28.9	18.2 ± 4.7	7.3 ~ 32.5
fat free mass(kg)	50.0 ± 6.6	36.0 ~ 71.0	36.5 ± 4.4	21.4 ~ 50.0
body fat percentage (%)	24.3 ± 4.1	09.9 ~ 33.3	32.6 ± 5.2	10.7 ~ 41.2

2.2. Metrics and Methods

2.2.1. body composition

Height was measured in units of 0.1 cm using an automatic height meter (DS-102 JENIX, Korea), and weight was measured in units of 0.1 kg using a weight scale (YG-200: Yagami, Nagoya, Japan). In addition, the body mass index (BMI) was calculated as weight/height2 (kg/m2) using the height value and the weight value. Body composition was measured using a multi-frequency impedance Inbody 770 (Inbody Co., Korea) to measure body fat mass (FM), fat free mass (FFM), and body fat percentage (%fat). Meals, beverages, alcohol, caffeine, etc. and vigorous physical activity were restricted 2 hours before the measurement.

2.2.2. exercise load test

Subjects were instructed to limit excessive physical activity the day before the measurement, and not to consume caffeine 2 hours before measurement and no food 90 minutes before measurement. Instructions on how to use the rating of perceived exertion (RPE) were also provided, starting with oral information about the test procedure by sitting for 10 minutes from 9:00 am on the day of measurement (Borg, 1973). A heart rate monitor (Polar RS 400 TM, Finland) with a transmitter belt attached to the chest was worn on the chest and HR and blood pressure were checked at rest, and then measurement was started. An automatic breathing gas analyzer (Ultima CPX, USA) and a bicycle ergometer (Monark 828E, Sweden) were used to instruct pedaling at a rotation rate of 60 rpm per minute, and neither spoke nor adjusted the chair height while pedaling.

The exercise load method was a multi-step incremental load method in which the load was increased by 0.5 kpm (15 watt) per minute after warm-up at 0 watt for 2 minutes (Nho et al., 1998). During the exercise load, the physiological and psychological state of the subject was continuously observed with RPE to ensure safety. Criteria for stopping exercise were: the subject's inability to pedal voluntarily, dyspnea, chest pain, facial pallor, ST decrease or elevation of more than 2 mm on electrocardiogram, and the appearance of ventricular extrasystole (Lown and Wolf, 1971), did not appear in this study. The criterion for VO2max was to satisfy two or more of VO2 did not increase any more (leveling off), respiratory exchange ratio was 1.10 or higher, and RPE was 17 or higher even when exercise load increased (Evans et al., 2013).

2.2.3. functional performance

(1) hand-grip (kg)
It is a method of measuring upper extremity muscle strength, such as moving an object without holding it or dropping it, and opening a can or bottle. Standing in a comfortable position, a digital dynamometer (GRIP-D, T.K.K. 5401: Takei Scientific Instruments, Tokyo, Japan) was held in hand, and both arms were naturally lowered so as not to attach to the body. The highest value on the left or right was used as the measurement value twice, respectively.

(2) one leg balance with eyes open (sec)
As a tool to measure static balance ability, in a posture with feet shoulder-width apart, raise one leg according to the examiner's instructions to balance it, and then lose balance and the raised leg touches the floor or the axis of the supporting leg shakes and moves In this case, the measurement was terminated. At 60 seconds, a perfect score was obtained, and two measurements were taken, and the highest value of the left or right foot was used as the measured value.

(3) standing up from a supine position (sec)
Waking up from lying down is a tool that measures the trunk ability to raise the upper body as a repetitive motion in daily life, and the strength of the lower extremities and upper extremities that support the body and stand up. The short time was used as the measured value by measuring a total of two times, starting from lying in an anatomical position on the mat and standing up as quickly as possible in free way.

(4) arm curl (num/30 sec)
It is a method of measuring the muscular endurance of the upper arm when pulling or lifting an object. Sitting in a stable chair, holding a dumbbell (male 3kg, female 2kg) in the lifting hand, with the arm lowered, flexed as quickly as possible for 30 seconds with the examiner's start.

(5) leg endurance against wall (sec)
As a method of measuring the muscular endurance of the lower extremities, in an upright position with the legs shoulder-width apart, with the back and buttocks in close contact with the wall, slowly bend the knees at 90° to maintain a sitting position, A maximum of 60 seconds was used as a perfect score.

(6) catching a dropped bar (cm)
As a method of measuring the agility of daily life, after sitting on a chair, use a paper cup to shape the hand. The examiner dropped the rod on which the unit was recorded while the subject was not conscious, and had him quickly grab the rod to measure the falling distance.

(7) waking around two cones in a figure 8 (sec)
In the case of movement and posture change, return points were installed on both sides of a 1.5 m×3.6 m line on the floor as a way to measure the ability to adjust multiple movements in combination, and then a chair was placed between them and the subject started sitting on the chair. Upon receiving the examiner's instructions, the subject returned to one of the turning points, sat down, got up again, returned to the other turning point, and sat down on the chair twice.

(8) standing up and sitting down a chair (num/30 s)
This is a method of measuring the muscular endurance of the lower extremities by motions when getting up from stairs, the floor, or a chair. Sit on a chair and sit for 30 seconds at the start and stand up as fast as possible. At this time, with both arms attached to the body, the standing motion was performed only with the legs, and the number of times was recorded.

(9) sit and reach (cm)
As a method of measuring the flexibility of daily life, the distance was measured by extending both hands forward while sitting with both knees extended on a mat and keeping the soles of the feet in close contact with the left flexor system.

(10) functional reach test (sec)
As a method of measuring posture and balance ability, stand with your feet shoulder-width apart and stand next to the wall, keep the bar held with both hands at shoulder height and level with the bar held with both hands, and place the tips of both

fingers at 0cm. At the beginning of the examiner, the distance reached to the maximum forward position without loss of balance by extending the arm to the maximum while maintaining the level with the bar held with both hands was measured. A practice opportunity was given, and the high value of the value measured twice was used as the measurement value.

2.2.4. data processing

For data processing, the mean and standard deviation (SD) of the measurement items were calculated using the SPSS Version 23.0 program. The correlation between each item was analyzed by Pearson's product correlation analysis to calculate the correlation coefficient r. Regression analysis was performed to calculate the estimation equation for VO2max prediction, and stepwise selection was performed to select independent variables with high partial correlation during regression analysis and remove non-significant variables. In the regression analysis, the fit of the estimation formula was calculated by calculating the multiple correlation coefficient (R) and the adjusted correlation coefficient square (adjusted R2) value. All statistical significance levels were α=.05.

3. Result

As a result of the exercise load test, VO2max was found to be 21.4±5.9 ml/kg/min for elderly men and 18.0±4.1 ml/kg/min for elderly women, and the functional performance is shown in Table 2.

Table 2: VO2max and functional performance in elderly men and women

(M±SD)

variable	elderly man (n=58)		elderly woman (n=117)	
	(M±SD)	range	(M±SD)	range
VO2max(ml/kg/min)	21.4±5.9	10.0~40.4	18.0±4.1	9.6~27.9
hand-grip (kg)	34.7±6.0	14.8~49.0	21.3±4.8	7.2~32.0
one leg balance with eyes open (sec)	18.4±18.7	1.6~60.0	17.6±17.7	1.3~60.0
standing up from a supine position (sec)	3.7±1.2	1.9~9.0	4.5±1.6	2.1~8.9
arm curl (num)	27.3±6.1	10.0~41.0	22.6±6.3	39.0~22.6
leg endurance against wall (sec)	45.5±14.7	10.0~60.0	37.8±19.1	7.0~60.0
catching a dropped bar (cm)	27.4±8.0	9.8~48.0	28.2±8.3	9.5~47.5
waking around two cones in a figure 8 (sec)	28.5±5.6	17.0~44.8	30.2±6.3	4.9~50.0
standing up and sitting down a chair (num)	16.6±4.8	7.0~34.0	14.6±3.8	7.0~2.0
sit and reach (cm)	2.8±8.4	-20.0~19.0	14.0±7.2	-6.0~28.0
functional reach test (cm)	34.2±7.4	17.5~56.0	29.0±7.7	10.0~45.0

Table 3 shows the correlation between the dependent variable VO2max and the independent variable physical characteristics and functional performance. Elderly males showed the highest correlation (r=.543) in leg endurance against wall, age (r=-507), waking around two cones in a figure 8 (r=-.419), and standing up and sitting down a chair (r=.414). one leg balance with eyes open (r=.359), hand-grip (r=.345), standing time r=-.330), and lifting dumbbells (r=.298) showed a correlation in the order (p<.01). In addition, in elderly women, height, body fat mass, standing time (r=-.520) catching a dropped bar, waking around two cones in a figure 8 (r=-.477), age (r=-.447), and standing up from a supine position (r= .426), one leg balance with eyes open (r=.390), lifting dumbbells (r=.354), and hand-grip (r=.328) showed a significant correlation in the order (p<.01).

Table 3: Correlation analysis of VO2max, physical characteristics and functional fitness of elderly men and women

(M±SD)

variable	VO2max	
	elderly man	elderly woman
age (yrs)	-.507**	-.447**
height (cm)	.096	.004
weight (kg)	-.037	-.096
body fat mass (kg)	-.188	-.194*
fat free mass (kg)	.055	.054
body fat percentage (%)	-.226	-.266**
body mass index (㎏/㎡)	-.087	-.188*
hand-grip (kg)	.345**	.328**
one leg balance with eyes open (sec)	.359**	.390**
standing up from a supine position (sec)	-.330*	-.520**
arm curl (num)	.298*	.354**
leg endurance against wall (sec)	.543**	270**
catching a dropped bar (cm)	-.146	-.093
waking around two cones in a figure 8 (sec)	-.419**	-.477**
standing up and sitting down a chair (num)	.414**	.426**
sit and reach (cm)	.075	.281**
functional reach test (sec)	.213	.299**

As a result of regression analysis of the independent variable for the VO2max equation, the result of regression analysis of the independent variable for the elderly male was 0.419 (standing up and sitting down a chair) + 0.199 (leg endurance against wall) + 5.383, multiple correlation coefficient R = 0.637, and the standard error of the estimate was 4.70 ml/ It was calculated as kg/min, and for elderly women -0.737 (standing up from a supine position) -0.144 (walking around two cones in a figure 8) -0.135 (% body fat percentage) + 0.042 (one leg balance with eyes open) +29.395, multiple correlation coefficient R=.606, standard of the estimate The error was 3.38 ml/kg/min Table 4.

Table 4: Estimation of VO2max using physical characteristics and functional performance

(M±SD)

%fat prediction model		R	R2	adjR2	SEE
elderly man	VO2max=0.419(standing up and sitting down a chair)+0.199(leg endurance against wall)+5.383	.637	.406	.384	4.691
elderly woman	VO2max=-0.737(standing up from a supine position)-0.144(waking around two cones in a figure 8)-0.135(body fat percentage)+0.042 (one leg balance with eyes open)+29.395	.606	.367	.344	3.382

Figure 1. shows the difference between the VO2max actual value and the VO2max predicted value of the elderly male with respect to the estimated value estimated by the multiple regression equation.

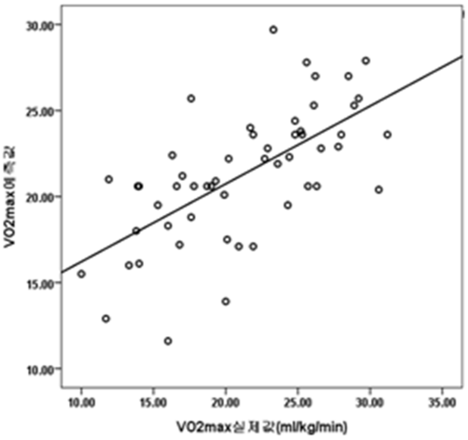

Figure 1: Correlation between actual VO2max and predicted VO2max in elderly men (y=0.419(standing up and sitting down a chair)+0.199(leg endurance against wall)+5.383, r=.637)

Figure 2. shows the difference between the VO2max actual value and the VO2max predicted value of the elderly woman with respect to the estimated value estimated by the multiple regression equation.

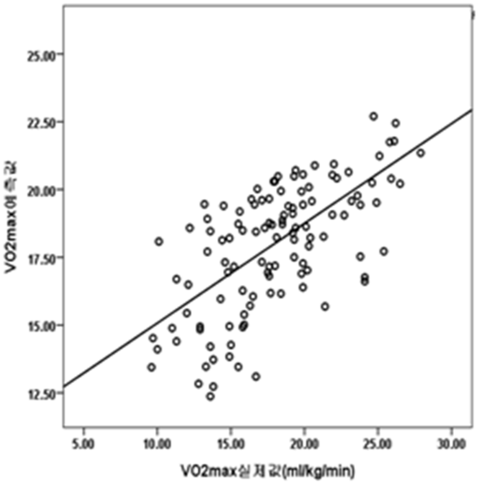

Figure 2: Correlation between actual VO2max and predicted VO2max in elderly women (y=-0.737(standing up from a supine position)-0.144(waking around two cones in a figure 8)-0.135(body fat percentage) +0.042(one leg balance with eyes open**)+29.395, r=.606)**

4. Discussion

It is difficult to conclude that the physical fitness for maintaining health of the elderly is healthy only by high VO2max, which represents aerobic capacity, as various health-related factors are recognized. It is thought that it would be reasonable to apply a simple VO2max estimation formula while paying attention not only to the interpretation that VO2max is good, but also to functional performance for daily living activities for self-reliance of the elderly. In this study, a multiple regression equation was proposed to predict VO2max in elderly men and women using easily measurable functional performance variables and body composition. Although VO2max is affected by heredity and aging, regular aerobic exercise can significantly improve it by about 15-20% or 0.5 l/min at any age (Bacon et al., 2013).

VO2max decreases from about 7% for women to 10% for men every 10 years from around the age of 25, but the exercise-related maximum metabolic demand in healthy elderly people occurs at the same rate or greater than the change with aging, so it does not support previous studies (Taylor & Johnson, 2010). As the age increases, the absolute decrease rate (ml/kg/min/yr) of VO2max becomes larger than that of sedentary people, and there is no difference in the relative decrease rate (%) (Trappe et al., 2013). In this study, VO2max by multi-step incremental loading was 21.4±5.9 ml/kg/min for elderly men and 18.0±4.1 ml/kg/min for elderly women. Because VO2max of 17.5 ml/kg/min (5 METs) is required for independent daily living and high survival rate (Myers et al., 1991), the subjects of this study were determined to be independent and physically active elderly people. 10 items with high reliability and validity were selected in consideration of ease and stability of measurement with reference to previous studies (Tanaka et al., 1990; Guralnik et al., 1994; Pedrero-Chamizo et al., 2012). In order to lead an independent life of the elderly, a correlation analysis was conducted between VO2max, physical characteristics, and functional performance as a functional performance item that can be easily and simply measured in daily life.

As a result, the elderly male leg endurance against wall (r=.543), age (r=-.507), waking around two cones in a figure 8 (r=-.419), and standing up and sitting down a chair (r=.414) in the following order. For elderly women, standing up from a supine position (r=-.520), waking around two cones in a figure 8 (r=-.477), age (r=-.447), standing up and sitting down a chair (r=.426), one leg balance with eyes open (r= .390) in the order of correlation (p<.01). The reason for the correlation between VO2max and functional performance may be related to the demands of daily living activities. In other words, since the daily performance of elderly men and women does not require the maximum aerobic capacity, it is considered that the oxygen intake below the maximum can better reflect the actual effort required for daily life. VO2max representing CRF is one of the important components and indicators of exercise effect. Given that direct or indirect measurements require sufficiently motivated measurement participants along with expensive equipment and specialized personnel, many researchers have sought simpler methods of predicting VO2max based on estimates derived in different ways. have been trying to find (Moon et al., 2011). Sanada et al. (2007) predicted VO2max without maximal exercise load using a regression equation based on independent variables evaluated by questionnaire (R2=0.83). However, it can be said that the test method used in this study lacks the accuracy of the test based on actual physical activity.

This study was composed of functional performance factors necessary to lead a more daily life using functional performance test, and it is considered that it can be widely applied to the elderly because the risk associated with maximal exercise is small. In addition, a study (Mahar et al., 2011) was conducted to develop an estimation formula for 20 m PSRT in 244 elderly men and women (60-70 years old) in the United States, similar to the number of subjects in this study. The SEE of the V̇ O2max estimation formula developed in this study was 6.29 ml/kg/min, and the correlation between the measured value and the predicted value was .74. In addition, comparing the validity coefficient (r = .73) obtained in this study with 9 previous studies related to the development of the estimation formula for the 20 m PSRT, the coefficient of Leger and Lambert (1982) and Boreham et al. (1990) (r = .73) .84, r=.90), similar to Leger et al. (1988), Mahar et al. (2011) (r=.71, r=.74), and van Mechelen et al. (1986), Liu et al. 1992), Stickland et al. (2003), and Aandstad et al. (2011) showed slightly higher coefficients (r=.69, r=.51, r=66, r=.69).

In this study, the formula for estimating VO2max for elderly men was calculated as 0.419 (getting up from a chair) + 0.199 (leg endurance against wall) + 5.383. The VO2max estimation formula was calculated as -0.737 (standing time) -0.144 (8-character walking) -0.135 (% body fat) + 0.042 (one leg balance with eyes open) + 29.395, including variables related to agility, static balance, and mobility. In the case of the lower extremities, women have less muscle mass than men, and the lower extremities appear faster than the muscle loss of the upper extremities, and the resulting functional decline is also large (Rikli & Jones, 1997). 2014; Seino et al., 2009; Guralnik et al., 1994). Therefore, it is considered that factors related to lower extremity strength were excluded from the estimation formula for elderly women in this study. This study contains far fewer risks than those associated with maximal exercise and does not reach the physical fatigue required in the maximal exercise load test, so it is considered that it can be widely applied to the elderly.

5. Conclusion

In this study, a multiple regression equation was proposed to predict the VO2max of elderly men and women using the functional performance variables required to engage in activities of daily living. As a result, it was possible to estimate VO2max in elderly men only by standing up and sitting down a chair and leg endurance against wall. The estimation formula was VO2max=0.419(standing up and sitting down a chair)+0.199(leg endurance against wall)+5.383, and R2 was 0.406. The estimation formula for elderly women was VO2max=-0.737(standing up from a supine position)-0.144(waking around two cones in a figure 8)-0.135(% body fat)+0.042(one leg balance with eyes open)+29.395, R2 was 0.367. From the above results, it is considered that the VO2max of the elderly can be predicted reasonably by using a regression equation that can be evaluated stably and easily based on functional performance variables in a situation where exercise load testing cannot be used.

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