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Original Article

Validity and reproducibility of an incremental sit-to-stand exercise test in healthy middle-aged individuals

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Abstract. [Purpose] We aimed to evaluate the validity and reproducibility of the incremental sit-to-stand exercise test for aerobic fitness evaluation in healthy middle-aged individuals. [Participants and Methods] Thirteen healthy middle-aged individuals randomly underwent the incremental sit-to-stand exercise and cycle ergometer tests, and the peak oxygen uptake was measured during both tests. Pearson's correlation coefficients were used to assess the strength of the association between the peak oxygen uptake measured during the aforementioned tests. Intraclass correlation coefficients with 95% confidence intervals for peak oxygen uptake obtained during the first, second, and third incremental sit-to-stand exercise tests were used to determine the reproducibility of this test. [Results] The peak oxygen uptake measured during the incremental sit-to-stand exercise test was strongly associated with that measured during the cycle ergometer test (r=0.86). The intraclass correlation coefficients (95% confidence intervals) used to verify the association of the peak oxygen uptake between the first and the second incremental sit-to-stand exercise tests and between the second and third incremental sit-to-stand exercise tests were 0.92 (0.66–0.99) and 0.96 (0.82–0.99), respectively. [Conclusion] The incremental sit-to-stand exercise test is a valid and reproducible tool to evaluate aerobic fitness in healthy middle-aged individuals.

Key words: Incremental sit-to-stand test, Assessment of exercise capacity, Rump exercise protocol

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INTRODUCTION

Exercise capacity evaluation is important in the clinical setting as it aims to determine exercise prescription, assess treatment effect, and estimate prognosis[1, 2)]. Exercise capacity can be assessed precisely by cardiopulmonary exercise (CPX) tests using either gas exchange analysis or blood lactate concentration. However, CPX tests are expensive and time consuming, requiring specific experiments and sophisticated equipment. On the other hand, sit-to-stand exercise (STS) is a simple exercise that can be performed by almost anybody. It consists of the repetitive motion of standing up and sitting down on a chair. STS, which requires only a chair and small space, can be performed by a large number of individuals, and the exercise load intensity can be easily adjusted by changing the standing frequency and chair height[3)]. Thus, we developed the incremental sit-to-stand exercise (ISTS) protocol based on the findings from a previous study[1, 3, 4)] for measuring aerobic fitness (Table 1). It is a potentially valid test for evaluating oxygen uptake volume (VO_2) and heart rate (HR) at the anaerobic threshold in healthy young adults[4)]. However, no reports are available on whether the ISTS test can determine aerobic exercise capacity in other age groups. If the validity of a simple test using STS to evaluate exercise capacity is established, then the aerobic fitness of a greater number of individuals could be evaluated in clinical practice. Thus, this study's aim was to determine the validity and reliability of the ISTS test in middle-aged individuals.

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Table 1. The ISTS protocol

Level	Time (seconds)	Standing up frequency (times/min)	Sum standing up (repetitions)
1	45	6	4
2	90	8	10
3	135	10	17
4	180	12	26
5	225	14	36
6	270	16	48
7	315	18	61
8	360	20	76
9	405	22	92
10	450	24	110
11	495	26	129
12	540	28	150
13	585	30	172
14	630	32	196
15	675	34	221
16	720	36	248

ISTS: incremental sit to stand exercise.
Standing up frequency during the ISTS was incremented 2 times/min every 45 seconds from 6 times/min in 12 min test session.
Sum standing up is number of cumulative stand-up repetitions completed during the ISTS.

PARTICIPANTS AND METHODS

The Shinshu University School of Medicine's Ethics Committee (approval number: 3174) and Matsumoto City Hospital's Ethics Committee approved this cross-sectional study conducted at Matsumoto City Hospiatal.

An appropriate sample size was estimated based on our hypothesis. Assuming a standardized effect size for Pearson's correlation analysis of 0.70 in order to achieve a statistical power of 80% with a 2-sided significance level of 0.05, we estimated that approximately 13 individuals were required[5)]. Thus, 13 healthy middle-aged individuals (6 males, 7 females) were recruited for the validity study (group A). Of those, 7 (4 males, 3 females) were recruited for the reproducibility study (group B). The selection criteria were as follows: (1) 45 to 65 years of age; (2) no history of bone, joint, or cardiorespiratory disease that could affect exercise capacity; and (3) voluntarily provided consent to participate in the research.

The ISTS started with 3 min of rest, followed by 3 min of warm-up and 12 min test session. The frequency during the ISTS test was 6 times/min during the warm-up period and 6 to 36 times/min during the exercise period (Table 1)[3)]. The frequency of standing up was controlled by audio signals provided by a metronome. The height of the chair was adjusted to the height of the upper end of the fibular head. The individuals were instructed to use both hands on the Nordic walking poles to push off during the STS exercise. We adjusted the poles' height so that the individuals' elbows were at a 30° angle in the upright position. Accordingly, individuals had to touch each target with their head in the standing and sitting positions, which defines the STS motion. Each target was set to touch the top of the head when in an upright sitting position or standing position. During the CE test, a ramp exercise protocol was used with a CE (Aerobike 75XLII; Combi, Tokyo, Japan). Following 3 min of seated rest, the individual commenced 3 min of warm-up at 10 watts. After the warm-up period, the power output was increased by 15 watts/min[1, 6)]. The individuals maintained a cadence of 60 pedal revolutions/min. The criteria for suspension of the test were as follows: (1) when it the indications for stopping an exercise tests[7)]; (2) when the timing given by the metronome was missed for three times in a row[3)]; and (3) when an individual became unable to maintain a cadence of 60 pedal revolutions/min.

The measurement items were peak VO_2 and peak hear rate (HR). During testing, VO_2 and HR were measured continuously. Respiratory gases were measured on a breath-by-breath basis. The breath-by-breath expired gas data were converted into time-series data and analyzed using AT1100 by ANIMA (Tokyo, Japan), in which the variable moving average was determined. The mean values of peak VO_2 and peak HR during the 30 s before the end of the ISTS and CE tests were used.

Statistical analysis was performed using SPSS version 18.0 J (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test was used to determine the normality of the values. Pearson's correlation coefficient was used to assess the bivariate relationships between peak VO_2 on the ISTS and CE tests, peak HR on the ISTS and CE tests, peak VO_2 and completion time on the ISTS test, and peak VO_2 on the CE test and completion time on the ISTS test. Prediction equations were calculated using linear regression analysis with completion time on the ISTS test as the independent variable and peak VO_2 on the CE test as the dependent variable. The paired t-test was used to determine differences in peak VO_2 and peak HR across the exercise conditions. Intraclass correlation coefficients (ICCs) (1,1) with 95% confidence intervals (CIs) for peak VO_2, peak HR, and completion time on the first (ISTS1), second (ISTS2), and third (ISTS3) ISTS tests were used to determine the reproducibility of the ISTS test.

Table 2. Physical characteristics of all participants included in the study

	Group A (n=13)			Group B (n=7)
	All (n=13)	Male (n=6)	Female (n=7)	All (n=7)
Age (years)	55.0 ± 4.0	54.3 ± 2.9	55.6 ± 4.9	53.4 ± 4.2
Height (cm)	161.5 ± 8.7	168.5 ± 4.5	155.4 ± 6.6	162.0 ± 8.3
Weight (kg)	61.7 ± 12.4	68.5 ± 12.1	55.9 ± 9.9	61.6 ± 14.0
Height of chair (cm)	42.1 ± 2.5	43.5 ± 1.6	40.9 ± 2.7	42.4 ± 1.7
BMI (kg/m^2)	23.5 ± 3.4	24.1 ± 4.2	23.0 ± 2.7	23.3 ± 4.3
Lower body strength (Nm/kg)	2.7 ± 0.5	3.1 ± 0.2	2.4 ± 0.5	3.0 ± 0.3

Values are presented as mean ± standard deviation.
BMI: body mass index.

Table 3. Peak VO_2 and peak HR were measured during the ISTS and CE tests

		ISTS	CE	p-value
Peak VO_2 (mL/min/kg)	All	23.4 ± 2.5	25.7 ± 3.4	0.001
	Male	25.4 ± 1.5	28.5 ± 2.4	0.008
	Female	21.6 ± 1.6	23.5 ± 2.2	0.03
Peak HR (bpm)	All	151.4 ± 8.1	159.2 ± 6.9	0.002
	Male	151.5 ± 7.1	164.3 ± 4.7	0.001
	Female	151.3 ± 9.4	156.0 ± 6.6	0.14

Values are presented as mean ± standard deviation
HR: heart rate; ISTS: incremental sit to stand exercise; CE: cycle ergometer.

RESULTS

There were 7 (54%) males and more than half of participants in this study (Table2). Except one participant, BMI in the participants was less than 25 kg/m^2. Three males completed the ISTS test, but all individuals did not complete the CE test. In the current study, peak VO_2 and peak HR were measured during the ISTS and CE tests (Table 3). The correlations between each variable were as follows: peak VO_2 on the ISTS and CE tests, r=0.86 ($p<0.05$); peak HR on the ISTS and CE tests, r=0.55 ($p<0.05$); completion time on the ISTS test and peak VO_2 on the CE test, r=0.87 ($p<0.05$); and completion time and peak VO_2 on the ISTS test, r=0.94 ($p<0.05$). However, when analyzing males and females separately, the correlation between completion time on the ISTS test and peak VO_2 on the CE test in males were r=0.52 ($p<0.05$) and in females were r=0.82. The regression equation for predicting peak VO_2 on the CE test was 0.04 × ISTS test completion time + 2.1. Peak VO_2 measured during the CE test was significantly higher than that during the ISTS test ($p<0.01$). Peak HR measured during the CE test was significantly higher than that during the ISTS test ($p<0.01$).

The ICCs (1,1) (95% CIs) used to verify the agreement of peak VO_2 between ISTS1 and ISTS2 and between ISTS2 and ISTS3 were 0.92 (0.66–0.99) and 0.96 (0.82–0.99), respectively. The ICCs for peak HR between ISTS1 and ISTS2 and between ISTS2 and ISTS3 were 0.88 (0.50–0.98) and 0.82 (0.32–0.97), respectively. The ICCs for completion time between ISTS1 and ISTS2 and between ISTS2 and ISTS3 were 0.98 (0.91–0.99) and 0.98 (0.94–0.99), respectively.

DISCUSSION

Peak VO_2 of all individuals was determined during the ISTS and CE tests. Itoh et al.[6] reported standard values of peak VO_2 in a normal Japanese population and showed that peak VO_2 during the CE test was 26.0 to 31.4 $mL \cdot min^{-1} \cdot kg^{-1}$ in middle-aged men and 23.5 to 27.5 $mL \cdot min^{-1} \cdot kg^{-1}$ in middle-aged women. Peak VO_2 values during the ISTS and CE tests in the present study are similar to the previous study by Itoh et al[6].

There were significant high correlations (r=0.86) for peak VO_2 between the ISTS and CE tests. Previous studies investigated the relationship between the incremental shuttle walking test (ISWT) and CPX test, and found a high correlation[8, 9]. Singh et al.[9] also reported a high correlation between performance on the ISWT and peak VO_2 on the treadmill test. The ISTS test is also controlled the incremental increasing exercise load and exercise speed by external signals similar to both the treadmill test and ISWT, and high correlations between peak VO_2 during the ISTS and treadmill tests and between performance on the ISTS test and peak VO_2 on the CE test have been demonstrated.

However, when analyzing males and females separately, the correlation between completion time on the ISTS test and peak VO_2 on the CE test was high in females (r=0.82) but only moderate in males (r=0.52). In this regard, we believe that there may be a ceiling effect for males only. In the present study, only 3 of 7 males completed the ISTS protocol. In order to be useful for trained men and other populations, chair height and frequency during the ISTS test may need to be modified in further studies. Furthermore, this study determined the regression equation for predicting peak VO_2 based on completion time on the ISTS test in middle-aged individuals. The results of the present study are consistent with those of a previous study in elderly patients with coronary artery disease[8].

In the present study, peak VO_2 measured during the ISTS test was approximately 19% lower than that during the CE test. In a previous study, peak VO_2 measured during cycling plus arm cranking was higher than that during cycling only[10], which may be due to the greater amount of muscle mass used in the combined exercise. In the present study, although definite reasons are unclear regarding the difference in peak VO_2 between the 2 exercises, because electromyography was not conducted during the exercises, the difference in the amount of muscle mass used in the exercise along with the difference in the frequency of the exercise or muscle activation pattern between the ISTS and CE tests are considered as a possibility. The frequency of STS movement was 6 to 36 times/min during the ISTS test, whereas the frequency during the CE test was 60 rpm. In addition, a ceiling effect in males may have contributed to the lower peak VO_2 values on the ISTS test.

Current data demonstrated high reliability of ISTS1-3 (ICCs, 0.80–0.98) among peak VO_2, peak HR, and completion time on the ISTS test. The reason for the high reliability is probably that the ISTS test was controlled exercise speed and exercise load by external signals as with CPX tests. Eng et al.[11] showed that the test-retest reliability coefficient for peak VO_2 measured during CE was 0.93. The high ICCs in the present study among peak VO_2, peak HR, and completion time on the ISTS are similar to those reported during CPX tests.

Our study has several limitations. First, the present study targeted middle-aged individuals. Therefore, future studies using elderly individuals are needed to develop the ISTS test as an aerobic fitness measure suitable for elderly and frail patients. Second, we need to modify the chair height when the ISTS test is performed by elderly individuals. Therefore, further studies investigating the effect of different chair heights on VO_2 values during the ISTS test are required.

In conclusion, the present study demonstrates that the relationships between peak VO_2 values during the ISTS and CE tests were significant and strong. In addition, our study determines regressions for predicting peak VO_2 based on complete time of ISTS. This result indicated that the ISTS is a potentially valid and reproducible test to estimate peak VO_2 in middle-aged individuals. These findings might be used to evaluate exercise capacity in middle-aged individuals as an alternative to conventional CPX using either cycle or treadmill ergometry in situations where these methods are difficult to implement.

Funding and Conflict of interest

There are none.

REFERENCES

1) Wasserman K, Hansen JE, Sue DY, et al.: Principles of exercise testing and interception. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2012, pp 129–153.
2) Itoh H, Taniguchi K, Koike A, et al.: Evaluation of severity of heart failure using ventilatory gas analysis. Circulation, 1990, 81: II31–II37. [Medline]
3) Nakamura K, Ohira M, Yokokawa Y: The effect of different standing up frequencies in sit-to-stand exercise on oxygen uptake. J Phys Ther Sci, 2014, 26: 1631–1633. [Medline] [CrossRef]
4) Nakamura K, Ohira M, Yokokawa Y, et al.: Validity and reproducibility of an incremental sit-to-stand exercise test for evaluating anaerobic threshold in young, healthy individuals. J Sports Sci Med, 2015, 14: 708–715. [Medline]
5) Hulley SB, Cummings SR, Browner WS, et al.: Designing clinical research. 4th edition. Philadelphia: Lippincott Williams & Wilkins, 2013.
6) Itoh H, Ajisaka R, Koike A, et al. Committee on Exercise Prescription for Patients (CEPP) Members: Heart rate and blood pressure response to ramp exercise and exercise capacity in relation to age, gender, and mode of exercise in a healthy population. J Cardiol, 2013, 61: 71–78. [Medline] [CrossRef]
7) American College of Sports Medicine: Interpretation of results. In: ACSM's guidelines for exercise testing and prescription. Philadelphia: Lippincott Williams & Wilkins, 2013, p 87.
8) Mandic S, Walker R, Stevens E, et al.: Estimating exercise capacity from walking tests in elderly individuals with stable coronary artery disease. Disabil Rehabil, 2013, 35: 1853–1858. [Medline] [CrossRef]
9) Singh SJ, Morgan MD, Hardman AE, et al.: Comparison of oxygen uptake during a conventional treadmill test and the shuttle walking test in chronic airflow limitation. Eur Respir J, 1994, 7: 2016–2020. [Medline]
10) Nagle FJ, Richie JP, Giese MD: VO_{2max} responses in separate and combined arm and leg air-braked ergometer exercise. Med Sci Sports Exerc, 1984, 16: 563–566. [Medline] [CrossRef]
11) Eng JJ, Dawson AS, Chu KS: Submaximal exercise in persons with stroke: test-retest reliability and concurrent validity with maximal oxygen consumption. Arch Phys Med Rehabil, 2004, 85: 113–118. [Medline] [CrossRef]