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Original Article

The Effect of Different Standing up Frequencies in Sit-to-stand Exercise on Oxygen Uptake

Keisuke Nakamura, RPT, MS[1, 2)*], Masayoshi Ohira, RPT, MS[3)],
Yoshiharu Yokokawa, RPT, PhD[3)]

[1)] *Department of Rehabilitation, Matsumoto City Hospital: 4417-180 Hata, Matsumoto, Nagano 390-1401, Japan*
[2)] *Department of Health Sciences, Graduate School of Medicine, Shinshu University, Japan*
[3)] *Department of Physical Therapy, School of Health Sciences, Shinshu University, Japan*

Abstract. [Purpose] The aim of this study was to investigate the steady state of oxygen uptake (VO_2) at several standing up frequencies to clarify whether workload in the sit-to-stand exercise (STSE) is greater than the anaerobic threshold (AT). [Subjects] Ten healthy young subjects performed the STSE. [Methods] In the STSE, subjects stood up and sat down without using their arms to push-off from the chair at standing up frequencies of 6, 12, 18, 24, 30, and 36 times per minutes. Subjects exercised for 5 minutes at each frequency with 5 minutes of rest between each consecutive frequency trial. The steady state of VO_2 was evaluated by the difference in the VO_2 between the 3rd and 5th min at each frequency. The correlation between the VO_2 of the STSE and the standing up frequency was analyzed. [Results] At standing up frequencies greater than 24 times/min, the steady state of VO_2 could not be confirmed. The relationship between the standing up frequency (at less than 24 times/min) and VO_2 was strong (r=0.94). [Conclusion] The STSE may be a potentially useful test for determining AT and predicting the physical capacity of patients.

Key words: Sit-to-stand exercise (STSE), Oxygen uptake, Steady state

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INTRODUCTION

Physical capacity is evaluated to assess the prognosis of cardiac patients, and to help determine the exercise intensity for training in cardiac rehabilitation and for lifestyle related disease management[1, 2)]. Physical capacity, such as maximal oxygen uptake (VO_2max) and anaerobic threshold (AT), is measured by cardiopulmonary exercise testing (CPX) using a cycle ergometer, and treadmill, or field tests such as the incremental shuttle walking test (ISWT)[2–5)]. Laboratory assessment, such as CPX, is not widely available and is expensive. Furthermore, it may not be suitable for patients who cannot pedal or walk. Although the ISWT, which is a simple test and easily conducted, is often employed in clinical practice, it requires a large space and cannot be conducted with patients who cannot walk safely[4, 5)].

On the other hand, the sit-to-stand exercise (STSE) which is part of an individual's activity of daily living, and uses the repetitive motion of standing-up and siting down on a chair[6, 7)]. The STSE, which requires only a chair and small space, can be performed by a large number of patients, and the exercise load intensity can be easily adjusted by changing the standing up frequency[6, 7)]. Although the STSE has been recommended as an estimate of leg muscular power by many previous studies, there are few studies that have evaluated the subjects' physical capacity during the STSE[6–9)]. Kamimura[6)] examined the relationship between standing up frequency and physiological workload, and indicated that oxygen uptake (VO_2) and heart rate increase linearly as the standing up frequency increases. Moreover, Kamimura[6)] examined the relationship between VO_2 of STSE and the AT determined using a cycle ergometer, and estimated that the work rate at the standing up frequency of 30 times/minute was greater than the AT, and at 24 times/min less than the AT. However, there has been no study has investigated the relationship between the AT estimated by STSE and standing up frequency directly.

The purpose of this study was to confirm the steady state of VO_2 at several standing up frequencies to clarify whether the STSE workload is greater than the AT. Additionally, this study investigated the relationship between physiological workload and the standing up frequencies. It is necessary to clarify the STSE physiological workload in order to develop the STSE as a method of measurement of physical capacity.

SUBJECTS AND METHODS

An appropriate sample size was estimated based on the finding that the standing up speed is a predictor of the oxygen uptake[6, 7)]. Assuming a standardized effect size for

*Corresponding author. Keisuke Nakamura (E-mail: keipons55@yahoo.co.jp)

Pearson's correlation of 0.80, to achieve a statistical power of 80% at an α level of 0.05 (two-tailed), we estimated that about 9 subjects were needed[10]. Therefore, a total of ten subjects were recruited for this study. The selection criteria were as follows: 1) 20–29 years old, 2) no history of bone, joint disease or cardiorespiratory disease that have affected the exercise, and 3) voluntarily gave consent to take participation in the research. This research was conducted with the approval of the Shinshu University School of Medicine Ethics Committee and Matsumoto City Hospital Ethics Committee. All subjects gave their written consent to participation in this study.

The breath-by-breath gas analyzer used in this study was the AT1100 by ANIMA (Tokyo, Japan). The gas analyzer was carefully calibrated before the start of measurement.

The height of the chair used for the STSE was adjusted to the level of the upper end of the fibula head. Subjects were asked to cross their arms in front of their chest during exercise to prevent trick motion by the arm. The feet were placed in a comfortable position and set apart at shoulder breadth. Accordingly, subjects had to touch each target in the upright position and sitting position in order to define the STSE motion. The standing up frequencies of the STSE were set at 6, 12, 18, 24, 30, and 36 times per minute, and subjects exercised for 5 minutes at each frequency with 5 minutes of rest between each consecutive frequency trial. The frequency of standing up was controlled by audio signals given by a metronome. The criteria for the suspension of the test were as follows: 1) when it corresponded to general discontinuance criteria for exercise tests[11]; 2) when a heart rate reached 80% of the predicted maximum HR, or 3) if subjects missed the timing given by the audio signals for three times in a row[6]. When the steady state of VO_2 could not be confirmed after five minutes, the test was terminated. The steady state of VO_2 was evaluated by the difference in the VO_2 between the 3rd and 5th min (VO_2 5th − VO_2 3rd ≤ 0)[12].

The measurement items were VO_2, heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP), and the Borg scale of rate of perceived exertion (RPE) and fatigue of the leg. During testing, VO_2, and HR were continuously measured. Respiratory gases were measured on a breath-by-breath basis. The breath-by-breath expired gas data were converted into time series data. The data sets were calculated using the gas analysis software of the AT1100, in which the variable moving average was performed. The nine-point moving average of data was applied to the calculation for the respiratory gas parameters. The mean values of VO_2 and HR during the 30 seconds before the end of each standing up frequency were calculated. The rate of increase in HR at each standing up frequency to HR at rest (ΔHR) was calculated. After the exercise, BP and the Borg scale were measured. The temperature in the exercise room was maintained at between 21 °C and 24 °C.

Statistical analysis was performed with SPSS 11.0 J for Windows software (SPSS Inc., Chicago, IL, USA) .The correlation between the standing up frequency and VO_2 of the STSE was analyzed using Pearson's product-moment correlation coefficient. Simple linear regression analysis was used to determine the relationship of the standing up frequency to VO_2. Significance was accepted for values of $p<0.05$.

Table 1. Characteristics of all subjects (n=10)

	Mean±SD
Age (yr)	22.3±2.2
Height (cm)	169.6±9.8
Weight (kg)	58.1±8.1
Sitting height (cm)	89.5±3.1
Height of chair (cm)	43.5±1.8
BMI (kg/m^2)	22.5±4.1

RESULTS

Seven males and three females participated in this study. Their average age was 22.3±2.2 (yr), their average height was 169.6±9.8 (cm), their average weight was 58.1±8.1 (kg), and the average height of chair was 43.5±1.8 (cm) (Table 1). The reason for having to termination of the STSE was an inability to confirm the steady state of VO_2. There were no subjects who corresponded to the criteria for the premature suspension of the test at standing up frequencies up to 18 times/min. However, the steady state of VO_2 could not be confirmed for some subjects at 3 frequencies as follows: at 24 times/min (2 subjects out of 10), 30 times/min (6 subjects out of remaining 8), 36 times/min (2 subjects out of remaining 2). Therefore, the eight subjects who had completed at least 24 times/min were included in the analysis. The relationship between the standing up frequency and VO_2 was strong ($r=0.94$, $p<0.05$). It was represented by the regression equation (n=8): VO_2 (ml/min/kg) = 0.40 ×standing up frequency (times/min) + 5.23 ($R^2=0.88$). The data revealed that as the frequency of standing up increased, each subject demonstrated a gradual increase in VO_2, ΔHR, SBP, and Borg Scale (Table 2).

DISCUSSION

Because there weren't any subjects who corresponded to the discontinuance criteria of reaching 80% of predicted HR maximum, and Borg Scale of RPE and fatigue of the leg after exercise indicated moderate intensity, this protocol was considered to be of a safe physical workload.

We demonstrated that the STSE workload at standing up frequencies from 24 times/min to 36 times/min was above the AT. In general, a steady state of VO_2 cannot be reached at the workloads above the AT[11]. Therefore, in our study, the steady state of VO_2 could not be verified at the workloads during standing up frequencies from 24 times/min to 36 times/min. Kamimura[6] estimated that the standing up frequency of a work load, equal to the AT determined by cycle ergometer, was within the range from 24 times/min to 30 times/min, and the results of our study lend support to Kamimura's report[6]. This may be related to the resemblance of the exercise pattern, since both STSE and cycle ergometers used similar lower limb muscles and rhythmic

Table 2. Physiological work load of each standing up frequency (n=8)

Standing frequency (times/min)		Rest	6	12	18	24
Oxygen uptake volumes (ml/min/kg)[a]		-	7.8 ± 0.5	10.2 ± 1.1	12.7 ± 1.3	15.1 ± 1.3
ΔHR (%)[a]		-	14.2 ± 10.2	27.8 ± 13.9	43.7 ± 13.1	59.8 ± 14.7
SBP (mmHg)[a]		124.1 ± 10.6	123.1 ± 10.7	125.9 ± 6.5	129.0 ± 10.2	133.4 ± 9.9
DBP (mmHg)[a]		73.5 ± 5.0	74.6 ± 7.8	76.4 ± 6.3	78.5 ± 8.4	77.9 ± 8.5
Borg scale	RPE[b]	-	7 (7–8)	11 (10–11)	12.5 (11–13)	13.5 (13–14)
	Fatigue of the leg[b]	-	7.5 (7–8)	10.5 (9–11)	11 (10–13)	12 (12–15)

[a] Mean ± SD, [b] Median (interquartile range)

motion[13–15].

This study demonstrated the relationship between VO_2 and standing up frequency was strong, and VO_2 increased linearly with increase in standing up frequency. It is possible that the total muscle mass involved in the STSE increases as the speed of standing up also increases, and a response from the cardiovascular-respiratory system is elicited by the increase in the total muscle mass[13]. However, Shiomi[7] indicated VO_2 increases in a logarithmically function with increase in standing up frequency. The difference between the two study methods is the setting of the height of the chair. In Shiomi's report[7], the height of the chair was set at just 41 cm, which is lower than that used in our study. A lower height of chair requires greater muscle activities in the legs, and causes greater fatigue in the leg muscles[14]. This fatigue may cause an inability to elicit a greater response from the cardiovascular-respiratory system. Thus, the setting height of the chair is important for a linear increase in VO_2, and the setting in our study appears to be adequate.

The incremental increases in VO_2 and other physiological indexes confirm that the STSE test produces a gradual physiological response to exercise of increasing intensity, and these have been needed to determine the AT and estimate some sort of physical capacity[4, 5]. With regards to the ISWT, a strong relationship between walking distance (measured up to ability to maintain walking speed) and VO_2max has been reported, and therefore, VO_2max can be used to predict walking distance[4, 5]. In the STSE, elderly people may not be able to maintain the required speed when the activity at high frequencies is faster (e.g. greater than 24 times/min). Similar to the ISWT, the STSE may also be a potentially useful measurement for the prediction of physical capacity such as VO_2max from the standing up frequency.

The results of our present study suggest workload (VO_2, HR), adjusted by changing the standing up frequency, in the STSE can exceed the AT, but we did not determine whether the AT can be determined from the STSE directly, and this will need to be verified in future studies. Furthermore, the validity and reliability of the AT determined by the STSE will need to be investigated.

Also, because knee pain may be provoked when elderly people conduct the STSE, the height of the chair will need further consideration. Moreover, using the arms to push off when standing up may decrease the knee pain, and the relationship between the physiological workload and standing speed with arm push-off will have to be examined.

In conclusion, the STSE is a simple test which varies only the frequency of standing up. We propose that the STSE could be conducted with a relatively low risk for healthy young adults. The physiological workload when the standing up frequency is greater than 24 times/min is greater than the AT. Therefore, the STSE may be a potentially useful test for determining AT and predicting the physical capacity of patients who are unable to perform the tasks used in other methods of evaluation.

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