

# The Relationship between Sit-to-stand Frequency and Anaerobic Threshold Determined by Cycle Ergometer

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**Abstract.** [Purpose] This study examined the adjustment of work load in the sit-to-stand exercise (STSE). [Subjects] The subjects were twenty-nine healthy young males, average age of nineteen. [Methods] Subjects did STSE and cycle ergometer exercise on the same day. The STSE protocol was standing-up frequencies set from 6 to 30 (times per minute), with an exercise time of three minutes at each frequency. The anaerobic threshold (AT) was determined on a cycle ergometer with a ramp protocol. The items measuring work load were oxygen uptake and heart rate. Cardiopulmonary function was measured from resting time to the end of the exercise. Oxygen uptake volume and heart rate relative to their AT values were calculated. [Results] Oxygen uptake volume and heart rate relative to their AT values frequencies from 6 to 30 times per minute ranged from 45.9 to 119.8 (%), and from 67.6 to 106.9 (%), respectively. [Conclusion] In case of STSE, the work load intensity of a subject cannot be quantitatively determined. Heart rate and oxygen uptake at standing exercise frequencies setting from 6 to 30 times/min relative to their anaerobic threshold values were 67.6–106.9 (%) and 45.9–119.8 (%), respectively. It was clarified that 30 times or less were anaerobic threshold that corresponded to work load. It is appropriate to adjust work load based on this standing up frequency only for young subjects.

**Key words:** Sit-to-stand exercise (STSE), Work load, Cycle ergometer

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## INTRODUCTION

The sit-to-stand exercise (STSE) uses the repeated motion of standing up from and sitting down on a chair. The subjects of STSE are mainly severe hemiplegic adults or older adults, and cardiopulmonary patients. STSE is an easy exercise which can be practiced at the bedside and in recreation rooms in health facilities for the elderly. In addition, STSE is used for cardiopulmonary assessment. However, there is a problem with STSE in that : its work load is difficult to predict. The problem is similar to that of other basic movement tests. Therefore, cardiopulmonary exercise tests use exercise devices, because work rate on a treadmill and cycle ergometer can be quantitatively determined. Accordingly, their work load can be predicted beforehand, but that of STSE is not. There are some reports about physiological work load of STSE<sup>1–3)</sup>. Iwasaki<sup>2)</sup> and Maruyama<sup>3)</sup> studied the relationship between chair height and STSE frequency and physiological work load. According to Maruyama, physiological work load increased with high STS frequency and low chair height, and approximate work load can be predicted, but the precise

adjustment of work load is difficult. For example, physiological work load changes when a chair of the same height and the same frequency of repeated standing is used by to different subjects. Kubota<sup>4,5)</sup> evaluated cardiopulmonary assessment using STSE performed by hemiplegic patients. The work load was adjusted by the height of the chair and the frequency of repeated standing exercise movement. Kubota listed and divided the results into 4 categories. The upper 2 categories were risk factors, which were dependent on STSE work load. That is, safety of the exercise could not be guaranteed only by the setting of the height of the chair and the standing up frequency. Examination of the influence of other factors is needed. Kogure studied STSE protocol to reach anaerobic threshold (AT)<sup>6)</sup>. Shiomi<sup>7)</sup> suggested a relationship between work rate of STSE and physiological work load, where STSE work rate is calculated according to the following equation:

STSE work rate(kg·m/min)=[Height–Height on the chair]×[Weight–Weight of lower limbs]×1.33 (Weight of lower limbs=Weight×0.35)

Shiomi made no mention of it, but from the above equation, it seems likely that physiological work load is affected by the physical characteristics, such as their height, weight, and muscle power. Miyashita<sup>8)</sup> reported that weight influences the change of heart rate in the step exercise test. The work rate should be set considering the physical characteristics of each subject. Therefore, assignment of STSE should be examined from many aspects including work load. Subjects have cardiopulmonary risk factors. But, few studies have investigated the relationships between subjects' physical characteristics and STSE work rate.

It is necessary to establish a standard of work load in order to use the STSE safely. A relationship between chair height or STSE frequency and physiological work load has been suggested; however, the physiological work load of STSE has not been examined in relation to physiological work load exercise device. Adjustment of STSE work load may elucidate a relationship between work rate and physiological reaction.

The aim of this study was to examine whether STSE work load could be defined by the STSE frequency of repeated standing exercise in relation to the anaerobic threshold (AT) determined by a cycling ergometer. A further aim was also to establish an upper limit for standing-up frequency to define the range of 'safe' frequencies.

## SUBJECTS AND METHODS

The subjects were twenty-nine healthy male students. Their average age was  $19.9 \pm 0.9$  (yr), their average height was  $1.72 \pm 5.8$  (m), and their average weight was  $64.1 \pm 7.9$  (kg). This study was approved by the Ethics Committee of the International University of Health and Welfare. All subjects gave their written consent to participation in the study.

Each subject was measured for height, weight, and lower limb muscle strength prior to testing. Subjects did ergometer exercise and STSE on the same day at random. Between the two exercises, each subject rested more than two hours. The measured items were respiratory gas, heart rate, blood pressure, and the Borg scale. Arrhythmia was monitored continuously by ECG.

Anaerobic threshold was determined using a cycle ergometer exercise. The cycle seat was adjusted so that each subject's knee joint was flexed at  $30^\circ$ . Subjects were instructed to set the cycling frequency to 50 rpm per minute. The work load protocol used a ramp protocol. Subjects rested for 3 minutes in the sitting position, then did cycling exercise, with increasing work load of 20 (W/min). Subjects were requested to suspend exercise when their heart rate reached 85% of estimated HR maximum of when subjects felt difficulty in continuing pedaling movement. AT determination was as follows:

At the point when  $\dot{V}E/\dot{V}CO_2$  did not increase but  $\dot{V}E/\dot{V}O_2$  increased.

At the point when  $PETCO_2$  did not change but  $PETO_2$  started increasing.

At that point  $\dot{V}CO_2$  when increase in volume was more than that of  $\dot{V}O_2$  volume.

**Table 1.** Characteristics of all subjects (n=29)

	Mean $\pm$ SD
Age (yr)	$19.9 \pm 0.9$
Height (cm)	$172.5 \pm 5.8$
Weight (kg)	$64.1 \pm 7.9$

**Table 2.** Physiological work load of each standing exercise frequency (n=29)

Standing frequency (times/min)	Oxygen uptake (ml/min/kg)	Heart rate (beats/min)
6	$10.3 \pm 1.1$	$83.1 \pm 11.6$
12	$14.6 \pm 1.5$	$96.1 \pm 12.2$
18	$18.7 \pm 1.9$	$106.3 \pm 12.6$
24	$22.9 \pm 2.5$	$119.0 \pm 14.9$
30	$26.8 \pm 2.5$	$130.9 \pm 15.1$

Mean  $\pm$  S.D.

AT exercise work load was confirmed to reach a middle level by heart rate and Borg scale.

The height of the chair used for STSE was adjusted to the height of each subject's tibia from the floor. Upper extremities positions were set to the front of chest during exercise, to prevent trunk motion by the arm. The feet were positioned apart at the breadth of shoulders. Accordingly, subjects took conformation foot position. The standing up frequency of the repeated standing exercise was set at 6, 12, 18, 24 and 30 times per minutes by metronome, and subjects exercised for 3 minutes at each frequency, performing exercise for a total of 15 minutes. Measurements were made before and after the exercise, at each repeated standing frequency. The measurement items and criteria of exercise suspension were the same as those of the ergometer exercise. The temperature in exercise room was maintained between 21 and 24 °C.

The mean values of  $\dot{V}O_2$  and HR during 30 seconds after each standing-up frequency were calculated and their ratios relative to their values at AT were calculated.

## RESULTS

The average values of oxygen uptake and heart rate at AT as determined by the ergometer were  $23.3 \pm 4.7$  (ml/min/kg), and  $123.4 \pm 13.5$  (beats/min) (n=29) (Table 1). The standing-up exercise frequency at all subjects were 30 (times/min). The average values of oxygen uptake and heart rate at each standing up frequency were shown in Table 2. The average oxygen uptake at the standing-up frequency of 6 (times/minute) was  $10.3 \pm 1.1$ , and afterwards it increased 3.9–4.3 (ml/min/kg) according with increasing standing up frequency. The average of heart rate at the standing-up frequency of 6 (time/minute) was  $83.1 \pm 11.6$ , and it increased 10 to 13 (beats/min) with increasing standing-up frequency. Oxygen uptake and heart rate relative to their AT values at the various standing-up frequencies ranged from 45.9 to 119.8 (%), and from 67.6 to 106.9 (%), respectively. (Table 3).

**Table 3.** Physiological work loads at each standing exercise frequency relative to their AT values

Standing frequency (times/min)	Oxygen uptake (%)	Heart rate (%)
6	45.9 ± 10.4	67.6 ± 7.8
12	65.0 ± 14.1	78.1 ± 7.8
18	83.1 ± 18.4	86.5 ± 8.9
24	101.9 ± 22.9	96.9 ± 10.8
30	119.8 ± 26.9	106.9 ± 12.9

Mean ± S.D.

## DISCUSSION

This study investigated the adjustment of work load by frequency of standing-up exercise in STSE. Setting of a safe work load was referenced to AT determined an ergometer. AT is very important for work load in therapeutic exercises<sup>9)</sup>. At work loads below AT enough oxygen is supplied to the muscles. Generally, work load setting based on AT does not cause distress and abnormal physiological responses. Therefore, a safe work load for patients and elderly persons should be based on AT<sup>10)</sup>. AT and cardiopulmonary assessments use a treadmill or an ergometer. The work rate of exercise devices are definite, but patients and elderly persons with physical impairment cannot use exercise devices effectively. As a result, a margin of error occurs in the result of the cardiopulmonary assessment. The STSE method does not use exercise devices. A merit of STSE method is that it can be adjusted according to the physical function of each subject, and STSE uses only basic movements, so it does not require special skills.

This study examined the safety of the work load and physiological responses at AT various standing frequencies, because the physiological response is closely related to work load. Both ergometer and STSE exercise use similar lower limb muscles<sup>11,12)</sup>. Oxygen uptake volume is influenced by the level of muscle activity. In this study the safety of the work load in STSE was examined with reference to AT. Oxygen uptake volume and heart rate relative to their AT values standing-up frequencies from 6 to 30 times per minute, ranged from 45.9 to 119.8 (%), and from 67.6 to 106.9 (%), at respectively. The work load at the

standing exercise frequency of 30 times/minute was more than AT and at 24 times/min less than at AT. At the standing frequency of 30 times/min, standing and sitting movement must be done in one second, respectively. This is very difficult to perform. Work load at standing exercise frequencies at more than 30 times/minute has not yet been measured. For healthy student subjects, the maximum standing exercise frequency for a safe workload around 24 times/minute. Safe standing-up frequencies for other ages will need to be established by examining the ratios of the physiological responses at various standing-up frequencies with reference to AT. In the future, the validity and reliability of the relationships between physiological work load at various standing frequencies in STSE and that AT determined by ergometer will have to be examined. Moreover, STSE work load will need to be adjusted for standing-up frequency and physical characteristics subjects. This study is a basic approach to quantify work load.

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