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Effect of Graded Unilateral Sanding Exercise on Metabolic and Cardiopulmonary Function in the Healthy and the Hemiparetic Elderly Subjects

Toshiaki Muraki

The purpose of this study was to investigate how 18 elderly subjects with cerebral vascular accident (CVA) (14 men and 4 women) and 19 healthy elderly subjects (6 men and 13 women) would respond to a five-step graded unilateral sanding activity. Three indicators of pulmonary function such as expiratory tidal volume, respiratory rate, and expiratory volume and four indicators of cardiometabolic function such as metabolic equivalents (METS), systolic blood pressure, heart rate, and pressure rate product were continuously recorded during the exercise. Moreover, plasma catecholamine was analyzed from every subject's venous blood three times. The exercise with the two independent variables: angle of the sanding board and sanding velocity, consisted of five grades: (1) Grade 1: sitting at rest; (2) Grade 2: 0° at 15 cycles per minute (cpm); (3) Grade 3: 0° at 30 cpm; (4) Grade 4: 15° at 15 cpm; and (5) Grade 5: 15° at 30 cpm. The characteristic findings indicated that an increase of the angle with the constant velocity did not always increase the mean values of the pulmonary and cardiometabolic measures. However, the increase of the velocity with the constant angle always increased that of the dependent variables. The another valuable finding indicated that METS reached at the greatest work load did not demonstrate greater than 2, corresponding to a light activity in daily life such as sewing at machine. Moreover, the data on plasma catecholamine represented that the exercise did not exert stressful influence on the patients with CVA. The present study suggested that a five-graded sanding exercise with the variable of angle and velocity was shown to provide valuable data on pulmonary and cardiometabolic functions and to be safely and effectively used in occupational therapy in elderly patients with CVA.

Key Words

Occupational therapy,
Sanding exercise,
Elderly,
Cerebral vascular accident,
Hemiparesis.

INTRODUCTION

Limited functions in elderly people are closely related to expensive health-related care costs and poor quality of life^{1,2)}. The role of chronic physical function in causing functional limitation is intuitively important, especially when the elderly becomes disabled due to cerebral vascular accident (CVA). Because one of the best predictors of the development of

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functional limitation was CVA³⁾, the effective evaluation and treatment of CVA may produce a modest reduction in the incidence of severe limited function.

Occupational therapists have made great efforts to get better clients' and patients' physical, mental, and social functions, and to restore them to a daily life as independently as possible, so that they can live at home and participate in a variety of community affairs.

Approaches to cardiovascular rehabilitation in occupational therapy have been recently laid greater weight on, which has led to various incremental programs requiring a work load of intensity, duration and frequency for the evaluation and treatment in clinical settings⁴⁾. One of them is a graded sanding exercise, used as a resistive exercise and prescribed frequently by occupational therapists on the ground of an easy-to-manage and goal-oriented exercise with the principles of graded, resistive repetition in a practical work load⁵⁾. There are found several studies on ventilatory and cardiometabolic responses to a unilateral sanding exercise including a small sample size and a few parameters⁶⁻¹¹⁾. However, no studies on unilateral sanding included comparative data on metabolic and cardiopulmonary measures of the activity with more parameters and the larger number of healthy and CVA elderly subjects.

The primary purpose of the present study was to investigate metabolic and cardiopulmonary responses to two factors: angle of the board and velocity during sanding, in five graded conditions in 19 healthy elder-

ly subjects and 18 elderly patients with CVA, and to offer occupational therapists some suggestions regarding data useful for the prediction of tolerance of the functions to a one hand sanding activity in a clinical setting and for applying the exercise to activities of daily living requiring similar METS values.

SUBJECTS AND METHODS

Subjects

Thirty-seven elderly volunteers with an age range of 55 to 89 years were selected for this study, one group (CVA) of which consisted of eighteen patients with cerebral vascular accidents (14 males and 4 females) at Hyogo Hospital, Kobe, Japan, and the other control group (Healthy) included nineteen healthy subjects living in a community (6 males and 13 females). Physical characteristics (mean value $\pm$ SD, range) for CVA (Healthy) were as follows: age, 67.3 ± 8.1 years, range = 55 to 86 years (68.9 ± 9.3 years, range = 56 to 85 years); height, 157.8 ± 7.7 cm, range = 142 to 174 cm (154.4 ± 8.8 cm, range = 141 to 171 cm; weight, 52.2 ± 6.1 kg, range = 42 to 62 kg (48.3 ± 7.1 kg, range = 37 to 62 kg). In the three parameters between the two groups no significant difference was found statistically by unpaired *t*-test. None of the participants had a history suggestive of muscle, upper limb, joint, or neurological disease in both sides of Healthy and in the nonaffected side of CVA. They were instructed to refrain from eating and drinking for 2 hours before data collection.

Instrumentation and physiological measurements

Sanding activity

As incremental work load a sanding set (SOT-1801, Sakai Iryo) and a unilateral sanding block (650 g) with no sandpaper on the bottom (SOT-1803, Sakai Iryo) were used.

The measurements of pulmonary functions

A medical gas analyzer (MG-360, Minato Medicals) was used to analyze the oxygen concentration of expired air, recorded on a recorder (R56, Rika Electronics). The volume of the expired air was recorded automatically from a generator attached to a respiromonitor (RM-200, Minato Medicals). The generator and respiromonitor were connected with a computer (PC8801, NEC) and a printer (VP1000, Epson) for data analysis, where the data on Metabolic Equivalents (METs), Expiratory Volume (VE: liters per min.), Respiratory Rate (RR: cycles per min.) and Expiratory Tidal Volume (TVE: ml) were printed out every 30 seconds. VE was calculated as multiplication of TVE by RR.

The measurements of cardiometabolic functions

An electric sphygmomanometer (STBP-680, Nippon Colin) was used to record automatically Arterial Systolic Blood Pressure (Sys.BP: mmHg) every minute. A telemeter (Fukuda Electronics) continuously measured

Heart Rate (HR: beats per min.) from the electrocardiogram waveform. Pressure Rate Product (PRP), calculated by multiplying Sys.BP by HR, was simultaneously recorded and printed out.

Venous blood was sampled during the sanding activity. Epinephrine and norepinephrine were analyzed with High Performance Liquid Chromatograph (LC-5A, Shimadzu).

Exercise procedure

The exercise was performed in an air-conditioned occupational therapy clinic, where temperature was maintained between 20 and 25°C and humidity was kept between 60 and 70%. All the individuals were explained in detail about the nature, purpose and risk of the study, and then the measurement instruments were shown to them so that every subject would be familiarized with the equipment. Moreover, the subjects were taught the way to give a team member the signal, if they wished to stop performing the sanding activity. The subjects gave their oral informed consent for their participation prior to the investigation.

The subjects were instructed to rest in the supine position on bed. First of all an indwelling cannula for blood sample was inserted in the affected-side (CVA) and the left (Healthy) antecubital vein 20 minutes before exercise started. Three-ml blood samples were obtained for measurement of epinephrine and norepinephrine at the last minute of Grades 1, 3 and 5. Ten minutes prior to the starting of the exercise, they sat up in bed and were then fitted with a rubber mouth-

piece, an electrical sphygmomanometer and an electrocardiograph transmitter. After the subject was instructed to sit at rest on a straight-backed chair before the sanding exercise table, resting records were observed to determine resting-state basal values. The experimental protocol was divided into five consecutive conditions (grades). Between each condition, a 3-min resting time was provided. During the sequence of the exercises a metronome was set up in front of the subjects to ensure correct exercise velocity and rhythm. The requirements for each grade were as follows.

Grade 1. The subject was instructed to sit relaxing and keep silent with his/her eyes closed and with both hands resting on the thighs for 3 minutes.

Grade 2 (0° angle, 15 cycles per min (cpm)). The subject held the upright handle of a sanding block and sanded on a white pine board, clamped to the table top. Sanding for all graded conditions was performed with the nonaffected (CVA) and the right dominant (Healthy) hand with the use of full range of motion of flexion and extension at the glenohumeral joint. The exercise was performed without any trunk motion.

Grades 3 to 5. Performance standards for these three grades were the same as for Grade 2. The different conditions were only pointed out in respect to the angle of the sanding board and the sanding velocity: Grade 3 (0°, 30 cpm); Grade 4 (15°, 15 cpm); and Grade 5 (15°, 30 cpm).

Date analysis

The results obtained were expressed

as mean value $\pm$ standard error of mean (SEM) for a 3-min sanding performance and the statistical analysis was carried out on StatView-J4.11 (Abacus Concept Inc., USA). Statistical analysis was given to the absolute values in all the parameters of pulmonary and cardiometabolic measures. First, comparisons among the three concentrations of epinephrine and norepinephrine as well as the five different grades in all the parameters but the two were drawn by means of a one-way analysis of variance (ANOVA) for repeated measures followed by Scheff's F as a post hoc test. Second, statistical differences at each grade of each parameter between CVA and Healthy were analyzed using student's unpaired *t*-test. Values of *P* equal to or smaller than 0.05 were considered to reflect statistical significance.

RESULTS

Pulmonary function

Mean value $\pm$ SEM for TVE, RR, and VE are presented in Table 1 and depicted as relative percentage change in Figures 1 to 3, respectively. The TVE value in CVA and Healthy ranged from a low of 555 ± 23 ml and 475 ± 22 ml at Grade 1 (basal sitting rest position), respectively, to a high of 737 ± 34 ml and 603 ± 41 ml at Grade 5 (15°, 30 cpm). This peak value of CVA (Healthy) corresponded to 38% (27%) greater than that at rest (Figure 1). The RR value in CVA (Healthy) increased from 17.1 ± 0.8 cpm (18.0 ± 0.9 cpm) at Grade 1 to 18.8 ± 1.0 cpm at Grade 5 (21.5 ± 1.3 cpm at Grade 3 (0°, 30 cpm)).

The mean value of CVA (Healthy) corresponded to a 10% (19%) increase over that of the basal sitting position (Figure 2). The VE value reached the peak at Grade 5 in CVA (13.6 ± 0.5 liter per min (lpm)) and at Grade 3 in Healthy (11.7 ± 0.6 lpm), exhibiting an increase of 51% and 41% over the mean value at Grade 1, respectively (Figure 3).

A one-way ANOVA for repeated measures indicated a significant difference among the TVE values in CVA ($p < 0.01$) and the VE in both groups ($p < 0.01$).

In respect to the TVE in CVA, Sheffe's F revealed a significant difference ($p < 0.05$) between the resting position and each grade of Grades 3 and 4, and a significant difference (p

< 0.01) was also found between Grades 1 and 5. About the VE in CVA, moreover, the post hoc test demonstrated a significant difference ($p < 0.05$) between the sitting position and Grade 4 (15° , 15 cpm), and between Grades 2 and 5. A significant difference ($p < 0.01$) was also shown between the basal position and each grade of Grades 3 and 5. In the VE in Healthy, the test demonstrated a significant difference between Grade 1 and each grade from Grades 3 to 5. The other measure indicated no significant difference.

Unpaired *t*-test at each grade between the two groups indicated that CVA's TVE values at all the grades and its VE at Grades 1, 4, and 5 differed significantly from Healthy's; $p <$

Table 1. The changes of pulmonary functions during sanding exercise in patients with cerebral vascular accident and health subjects.

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
TVE (ml) CVA	$555 \pm 23^*$	$657 \pm 26^{**}$	$711 \pm 34^{**}$	$691 \pm 28^{**}$	$737 \pm 34^*$
Healthy	475 ± 22	542 ± 33	566 ± 36	555 ± 33	603 ± 41
RR (cpm) CVA	17.1 ± 0.8	17.2 ± 0.7	18.5 ± 1.0	17.2 ± 0.6	18.8 ± 1.0
Healthy	18.0 ± 0.9	19.4 ± 1.0	21.5 ± 1.3	20.0 ± 1.2	20.5 ± 1.3
VE (lpm) CVA	$9.4 \pm 0.4^*$	11.2 ± 0.5	12.8 ± 0.5	$11.8 \pm 0.4^*$	$13.6 \pm 0.5^*$
Healthy	8.3 ± 0.3	10.1 ± 0.3	11.7 ± 0.6	10.6 ± 0.4	11.6 ± 0.5

CVA: patients with cerebral vascular accident (n=18)

Healthy: healthy subjects (n=19)

TVE: Expiratory Tidal Volume, RR: Respiratory rate, VE: Expiratory Volume

Note. cpm = cycles per min; lpm = liters per min. Grade 1 = sitting at rest; Grade 2 = 0° angle, 15 cpm; Grade 3 = 0° angle, 30 cpm; Grade 4 = 15° angle, 15 cpm; Grade 5 = 15° angle, 30 cpm.

The values are expressed as mean value $\pm$ SEM

* $p < 0.05$ ** $p < 0.01$

0.05 at Grades 1 and 5 (TVE) and Grades 1, 4, and 5 (VE), and $p < 0.01$ at each grade from Grades 2 to 4 (TVE). No significant difference was in the RR values and at any other grade than the above-mentioned in the two parameters.

Cardiometabolic function

Data for METS, Sys.BP, HR, PRP, epinephrine and norepinephrine are demonstrated in Table 2 and diagrammed in terms of relative percentage change in Figures 4 to 9, respectively. The METS value in CVA (Healthy)

increased from a of 1.02 ± 0.04 (0.97 ± 0.04) at sitting rest to a high of 1.71 ± 0.08 (1.54 ± 0.06) at Grade 5, in which the mean value demonstrated 71% (58%) higher than that at Grade 1 (Figure 4). Sys.BP in CVA (Healthy) ranged from 131 ± 4 mmHg (133 ± 3 mmHg) at rest to 147 ± 5 mmHg (150 ± 4 mmHg) at Grade 5, corresponding to an increase of 13% (13%) over the mean value at Grade 1 (Figure 5). The HR value in CVA (Healthy) ranged from 77 ± 3 beats per min (bpm) (77 ± 2 bpm) at Grade 1 to 89 ± 4 bpm (89 ± 3 bpm) at Grade 5, representing a 16% (15%) increase over the mean value when sitting at rest (Figure 6). The

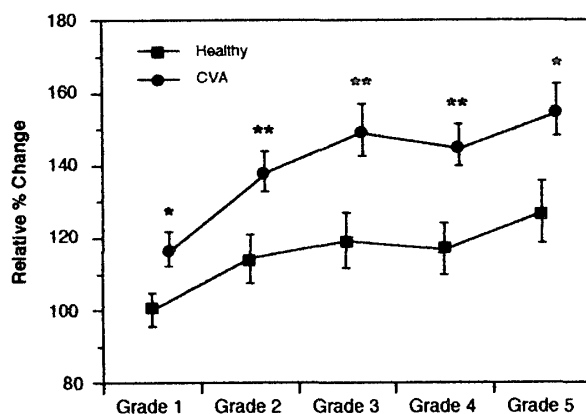


Figure 1. Time course of Expiratory Tidal Volume (TVE) during the five-step graded sanding exercise. The sitting at rest position at Grade 1 of Healthy was used as the reference state of 100 percent (474.72 ml). The greatest work load demonstrated 737.00 ± 34.21 ml ($155 \pm 7\%$) in CVA (Grade 5) and 603.22 ± 41.41 ml ($127 \pm 9\%$) in Healthy (Grade 5). * $p < 0.05$ and ** $p < 0.01$ vs. Healthy at each grade

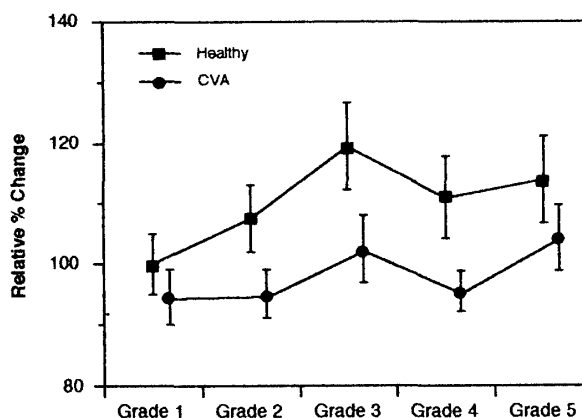


Figure 2. Time course of Respiratory Rate (RR) during the five-step graded sanding exercise. The mean value at the basal position of Healthy was calculated as 100% (18.0 cycles per minute). Grade 5 of CVA and Healthy represented the greatest mean value of 18.8 ± 1.0 cycles per minute ($104 \pm 5\%$) and 20.5 ± 1.3 cycles per minute ($114 \pm 7\%$), respectively.

PRP in CVA (Healthy) increased from a low of 10.1 ± 0.4 (10.1 ± 0.4) to a high of 13.2 ± 0.8 (13.1 ± 0.6) at Grade 5, exhibiting an increase of 31% (30%) over the mean value at Grade 1 (Figure 7). The epinephrine value in CVA (Healthy) ranged from 0.31 ± 0.16 ng per ml (0.27 ± 0.17 ng per ml) at rest to 0.39 ± 0.19 ng per ml (0.34 ± 0.17 ng per ml) at Grade 5 (Grade 3), with a 33% (27%) increase over the mean value at Grade 1 (Figure 8). The norepinephrine value in CVA (Healthy) reflected an increase from $0.30 \pm$

0.04 ng per ml (0.29 ± 0.03 ng per ml) at rest to 0.40 ± 0.06 ng per ml (0.47 ± 0.07 ng per ml) at Grade 5, a value corresponding to an increase of 32% (60%) over that at rest (Figure 9).

In respect to HR and Sys.BP in CVA, and epinephrine and norepinephrine in both groups, no significant difference was observed with ANOVA for repeated measures. However, PRP in CVA, and HR in Healthy differed significantly ($p < 0.05$). Moreover, a repeated-measures ANOVA showed a significant difference ($p < 0.01$) among the METS values (CVA and Healthy), and the

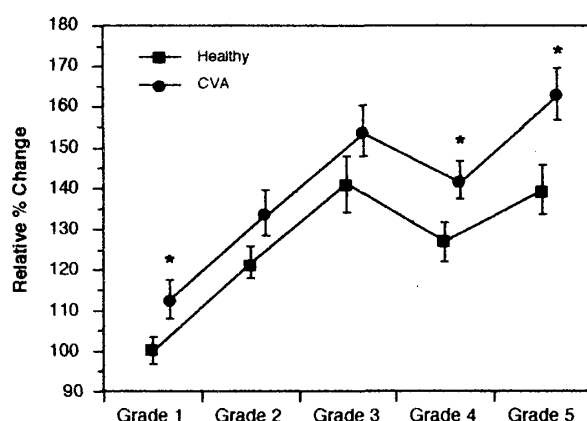


Figure 3. Time course of Expiratory Volume (VE) during the five-step graded sanding exercise. The standard value in Healthy as 100% (8.33 liters per minute) was based on the mean value at sitting rest. The maximal mean value in CVA and Healthy represented 13.59 ± 0.54 liters per minute ($163 \pm 7\%$) at Grade 5 and 11.74 ± 0.58 liters per minute ($147 \pm 7\%$) at Grade 3, respectively.

* $p < 0.05$ vs. Healthy at the corresponding grade

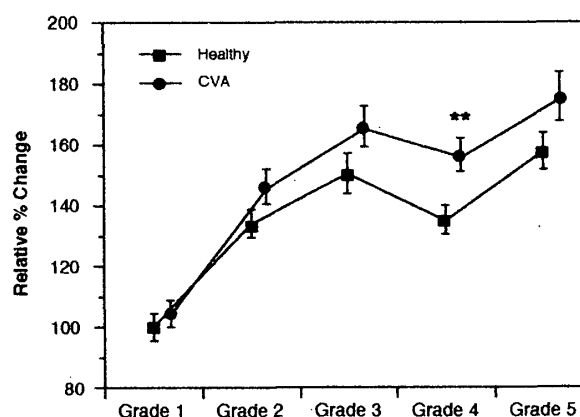


Figure 4. Time course of Metabolic Equivalents (METS) during the five-step graded sanding exercise. The basal sitting rest position at Grade 1 of Healthy indicated the reference state of 100 percent (0.97). The greatest work load demonstrated 1.71 ± 0.08 ($176 \pm 8\%$) in CVA (Grade 5) and 1.54 ± 0.06 ($158 \pm 6\%$) in Healthy (Grade 5). ** $p < 0.01$ vs. Healthy at the fourth grade

Sys.BP and the PRP values (Healthy).

In CVA, a significant difference was shown using Scheffe's F ($p < 0.05$ and $p < 0.01$) in the METS response between Grade 2 (0° , 15 cpm) and Grade 5, and between the basal rest position and each grade from Grades 2 to 5, respectively. In healthy's METS the same result was exhibited as in CVA. Concerning and Sys.BP

and HR in Healthy, a statistical difference between the basal rest position and Grade 5 was demonstrated ($p < 0.05$). In respect to the PRP response the post hoc test revealed a significant difference between Grades 1 and 5 at the $p < 0.05$ level (CVA) and between the rest position and each grade of Grades 3 and 5 at the $p < 0.01$ level (Healthy).

Table 2. The changes of cardiac functions and plasma catecholamines during sanding exercise in patients with cerebral vascular accident and healthy subjects.

		Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
METS	CVA	1.02 ± 0.04	1.43 ± 0.06	1.62 ± 0.07	$1.53 \pm 0.05^{**}$	1.71 ± 0.08
	Healthy	0.97 ± 0.04	1.31 ± 0.05	1.47 ± 0.07	1.32 ± 0.05	1.54 ± 0.06
Sys.BP (mmHg)	CVA	131 ± 4	140 ± 5	146 ± 4	144 ± 4	147 ± 5
	Healthy	133 ± 3	142 ± 4	149 ± 4	142 ± 4	150 ± 4
HR (bpm)	CVA	77 ± 3	85 ± 4	87 ± 4	87 ± 5	89 ± 4
	Healthy	77 ± 2	85 ± 3	87 ± 2	86 ± 3	89 ± 3
PRP ($\times 10^3$)	CVA	10.1 ± 0.4	11.8 ± 0.6	12.6 ± 0.6	12.5 ± 0.8	13.2 ± 0.8
	Healthy	10.1 ± 0.4	11.7 ± 0.5	12.8 ± 0.5	12.0 ± 0.4	13.1 ± 0.6
Epinephrine (ng/ml)	CVA	0.31 ± 0.16		0.37 ± 0.17		0.39 ± 0.19
	Healthy	0.27 ± 0.17		0.34 ± 0.17		0.27 ± 0.11
Norepinephrine (ng/ml)	CVA	0.30 ± 0.04		0.36 ± 0.02		0.40 ± 0.06
	Healthy	0.29 ± 0.03		0.39 ± 0.07		0.47 ± 0.07

CVA: patients with cerebral vascular accident (n=18)

Healthy: healthy subjects (n=19)

METS: Metabolic Equivalents, Sys.BP: Systolic Blood Pressure, HR: Heart Rate, PRP: Pressure Rate Product

Note. bpm = beats per min. Grade 1 = sitting at rest; Grade 2 = 0° angle, 15 cpm; Grade 3 = 0° angle, 30 cpm; Grade 4 = 15° angle, 15 cpm; Grade 5 = 15° angle, 30 cpm. The values are expressed as mean value $\pm$ SEM

$^{**}p < 0.01$

A significant difference between the two groups was found by unpaired *t*-test only at the fourth grade in METS ($p < 0.01$).

DISCUSSION

Arm activities for exercise, prescribed frequently by occupational therapists, may be used to advantage in different situations in clinical settings. Moreover, they provide an alternative diagnostic test for patients whom vascular, orthopedic or neurologic impairment could prevent from performing their routine lower-extremity exercises. Arm exercises

may play an important role, incorporated as an alternative to dynamic upper-extremity exercises for elderly in the process of restoration from diseases, as an integral part of whole body training in patients with cerebral vascular or cardiovascular diseases, and as evaluation and treatment with quantitative indexes applying to activities of daily living of elderly. Therefore, in occupational therapy treatment programs, it is of great importance to evaluate objectively to determine the characteristics of the exercise concerned.

The present study was designed not only to evaluate the effect of unilater-

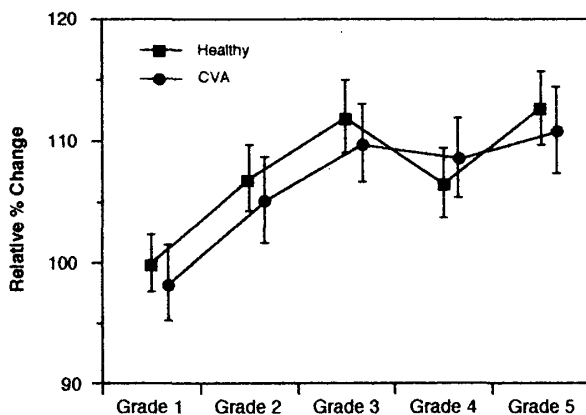


Figure 5. Time course of Systolic Blood Pressure (Sys.BP) during the five-step graded sanding exercise. The mean value at sitting rest position of Healthy was calculated as 100% (132.75 mmHg). The fifth grade of CVA and Healthy showed the greatest mean value of 147.31 ± 4.73 mmHg ($111 \pm 4\%$) and 149.75 ± 3.97 mmHg ($113 \pm 3\%$), respectively.

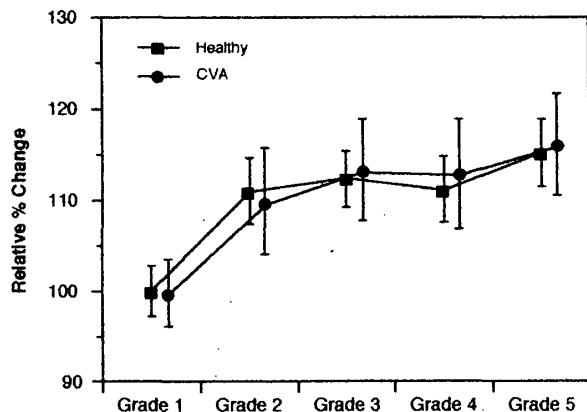


Figure 6. Time course of Heart Rate (HR) during the five-step graded sanding exercise. The standard value in Healthy as 100% (77 beats per minute) was based on the mean value at Grade 1. The maximal mean value in CVA and Healthy represented 89 ± 4 beats per minute ($116 \pm 6\%$) at Grade 5 and 89 ± 3 beats per minute ($115 \pm 4\%$) at Grade 5, respectively.

al graded sanding exercise in elderly with CVA, but also to provide some useful pieces of information about metabolic and cardiopulmonary functions at each of the five grades with two factors during the activity used in the rehabilitation of elderly patients with CVA in comparison with healthy elderly subjects. Therefore the comparative results obtained from here are applicable in the occupational therapy treatment setting.

Pulmonary function

In respect to the three parameters in both groups, each response always clearly increased in value with a greater velocity, and with a steeper

angle of board except the VE and the RR in Healthy. The CVA's changes from basal sitting rest position to Grade 5 appeared similar to the Healthy's. However, the mean values of the TVE and the VE responses at each grade showed greater in CVA than in Healthy, especially significantly in TVE at all grades and in VE at Grades 1, 4, and 5, whereas the RR inversely demonstrated the trend with no significant difference between the two groups. This finding suggests that the VE (its value: $TVE \times RR$) response in CVA will be influenced much more by TVE with a work load, with increases at a greater velocity with the same angle, and that in Healthy will be by RR, although the

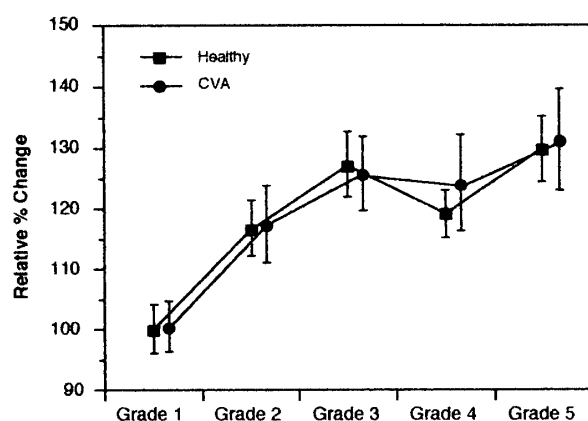


Figure 7. Time course of Pressure Rate Product (PRP) during the five-step graded sanding exercise. The basal sitting position of Healthy was used as the reference state of 100 percent (10.1×10^3). The maximal work load indicated (13.2 ± 0.8) $\times 10^3$ ($131 \pm 8\%$) in CVA (Grade 5) and (13.1 ± 0.6) $\times 10^3$ ($130 \pm 6\%$) in Healthy (Grade 5).

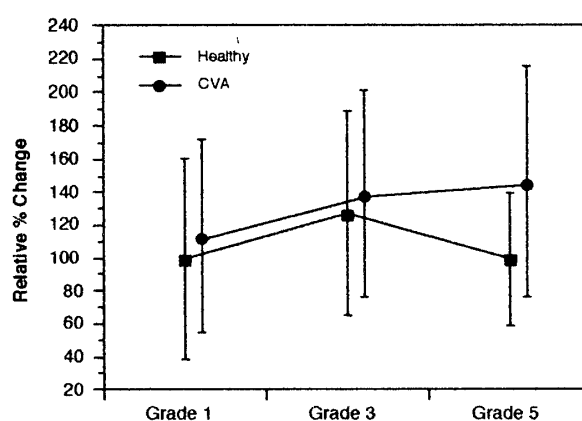


Figure 8. Time course of Epinephrine during the five-step graded sanding exercise. The mean value at the basal rest position of Healthy was calculated as 100% (0.27 ng per ml). Grade 5 of CVA and Grade 3 of Healthy represented the greatest mean value of 0.39 ± 0.19 ng per ml ($146 \pm 70\%$) and 0.34 ± 0.17 ng per ml ($127 \pm 62\%$), respectively.

maximum did not reach a 20% increase over the basal position. These findings indicated that therapists in treatment settings should pay greater attention to the TVE response in CVA and the RR in Healthy.

Cardiometabolic function

The mean value of the METS response, one of the metabolic indexes, clearly demonstrated in the two groups that the relationship between the board angle and the sanding velocity in the time course of the exercise is curvilinear, with increases at a steeper angle with the same velocity and at a greater velocity with the same angle. During a sequence of ex-

ercises the maximal METS value reached did not exceed 1.71 ± 0.08 in CVA and 1.54 ± 0.06 in Healthy, less than 2 METS, corresponding to a light activity such as sewing at machine, auto driving or typing^{5,12}). This finding is consistent with the VE response in relation to the independent variables, although the mean value of CVA showed a steeper curvilinearity immediately from the basal sitting rest position to the lightest work load (Grade 2) than that of Healthy. In general, however, the METS requirements reflected the low oxygen consumption requirements of this sanding load, which may be considered to be a safe, effective task with an increase of gradual work load in the two groups.

PRP ($\times 10^{-3}$), multiplying Sys.BP by HR: both easily measured hemodynamic variables, is a good predictor of myocardial oxygen consumption during exercise and is considered to be one of the most appropriate indexes of the grading of physical exertion level in daily living¹³). Although HR alone correlates well with METS¹⁴) and the rating of perceived exertion (a useful indicator of exercise intolerance)¹⁵), it is necessary for therapists to draw attention to Sys.BP in clinical situations where Sys.BP may not always rise *pari passu* with HR, for example, isometric exercise¹³).

Because of great differences among the subjects in the two groups indicated by standard deviations of the three parameters at all grades, none of the indexes yielded significant difference, even when the exercise's intensity of the exercise corresponded to low work load with less than 2 METS^{8,9,11}). It should be noted that in the case of CVA the mean values of

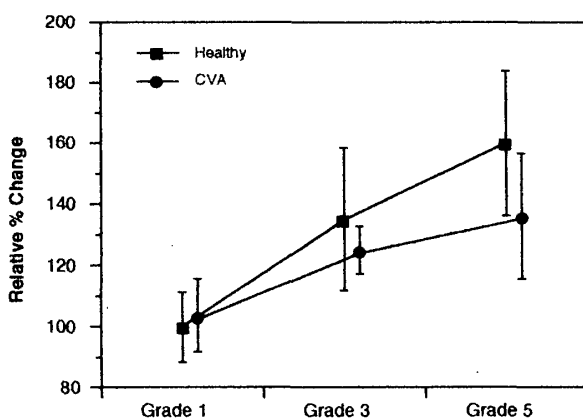


Figure 9. Time course of Nor-epinephrine during the five-step graded sanding exercise. The standard value in Healthy as 100% (0.29 ng per ml) was based on the mean value at Grade 1. The greatest mean value in CVA and Healthy showed 0.40 ± 0.06 ng per ml ($136 \pm 21\%$) at Grade 5 and 0.47 ± 0.07 ng per ml ($160 \pm 24\%$), respectively.

the three variables reflected the curvilinear locus similar to each other. Even the maximal exertion at Grade 5 did not reach a 20% and 30% increase over the basal position in Sys.BP and HR, and PRP, respectively. It is characteristic that PRP in CVA may be exerted greater influence on by HR, as shown by these curvilinearity at each grade. Therefore these findings obtained confirm that the exercise protocol for CVA is safe and effective to perform during a sequence of the activities with "Very light" in the scale for ratings of perceived exertion¹⁵⁾ as well as only about 64% of the greatest work load in the eighties¹⁶⁾.

From the viewpoint of sympathetic nervous system activity, the increment in plasma epinephrine and norepinephrine during work load at a given relative intensity have been shown both to be augmented^{17,18)} and to attenuated^{19,20)} in comparison between old and young. Possibly these inconsistent findings may be due to a lack of control over such factors. However, there is found no investigation of the basal and sanding-exercise-induced changes in the plasma epinephrine and norepinephrine concentration in comparisons of CVA and age-matched control.

This study has made it clear that a low-intensity upper extremity work load yielded no significant difference between the two age-matched groups and among the grades, possibly as a result of great different response to the same exercise stressor among the subjects. It is characteristic that a greater increase of plasma norepinephrine in both groups suggests that they have heightened the activity

of postganglionic sympathetic neurons during psychological stress anticipated and induced by exercise²¹⁾. It implies that unilateral sanding activity with a low-intensity work load may exert great influences on sympathetic nervous system. The reason why the grade of influence was greater in CVA than in Healthy might be attributed to its sedentary life style with handicap after onset³⁾. Although the positive correlations are observed between the groups with the exception of the epinephrine value at Grade 5 and between METS and the epinephrine/norepinephrine responses to sanding exercise, this endurance exercise might produce relative lower changes in plasma epinephrine and norepinephrine concentrations at a steeper angle with the same velocity, expressed as smaller stressors to CVA.

In conclusion, it can be pointed out as a valuable finding in occupational therapy treatment programs that the five-graded incremental one-handed sanding exercise may exert appropriate influences on the metabolic and cardiopulmonary responses. Moreover, it should be born in mind that the current study design at the specified angles of board and sanding activity velocities is considered to portray the parallel relationship among the nine variables of the two functions. However, the relationship suggests, even on modified condition of angle and velocity, that the absolute energy expenditures may not change too much. Further research is needed objectively to examine the influence of unilateral and bilateral sanding exercise on the functions studied. Studies are also needed to

evaluate the gradual increase of the intensity, duration, and frequency of the activity.

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T. Muraki

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