Ventilatory and Cardiometabolic Responses to Unilateral Sanding in Elderly Women With Ischemic Heart Disease: A Pilot Study

Toshiaki Muraki, Kenichi Kujime, Tasuku Kaneko, Michiyo Su, Yasuyuki Ueba

Key Words: occupational therapy (treatment) • rehabilitation, cardiac

This study was undertaken to investigate how 8 elderly women with ischemic heart disease would respond to a unilateral sanding activity. Three ventilatory measures—expiratory tidal volume, respiratory rate, and expiratory volume—and four cardiometabolic measures—metabolic equivalent, systolic blood pressure, heart rate, and pressure rate product—were continuously recorded during the sanding activity. The two independent variables were angle of the sanding board and sanding velocity. The activity was graded to yield five conditions: (a) sitting at rest; (b) 0° at 15 cycles per min (cpm); (c) 0° at 30 cpm; (d) 15° at 15 cpm; and (e) 15° at 30 cpm. The findings indicated that increasing the angle of the board while holding the velocity constant did not always increase the mean values of the ventilatory and cardiometabolic measures. However, increasing the velocity while holding the angle constant always increased the mean values of the dependent variables. The data also indicated that the metabolic equivalent reached during the sanding activity was no greater than 2, which corresponds to a light activity, such as playing a musical instrument. Replication of the study with a larger sample size may further elucidate the behavior of these two functions during a graded sanding activity. In the present study, a unilateral sanding activity by elderly patients with cardiac impairment was shown to provide valuable data on ventilatory and cardiometabolic functions. The study also demonstrated that a unilateral sanding activity can be safely used as a graded activity in occupational therapy for the cardiac rehabilitation of elderly women.

Occupational therapists make great efforts to increase patients' physical, mental, and social functions and to restore them to maximal self-sufficiency so that they are able to care for themselves, live at home, and take part in community affairs. In recent years, approaches to cardiovascular rehabilitation in occupational therapy have changed rapidly, given the findings that prolonged bed rest and convalescence with concomitant restriction of activities have led to marked cardiovascular deconditioning (Miller, Johnson, & Lamb, 1964). Various graded programs for the evaluation and restoration of a patient's ability, therefore, have been developed in adult cardiac rehabilitation, one of which is bilateral sanding. This activity is used as a resistive exercise and is prescribed frequently by occupational therapists in clinical settings (Trombly & Scott, 1977). However, we could find no studies on unilateral sanding that included data on ventilatory and cardiometabolic responses to this exercise in women with ischemic heart disease.

The primary purpose of the present study was to measure ventilatory and cardiometabolic responses in 8 elderly women with cardiac impairment. We used five conditions: (a) sitting at rest; (b) 0° at 15 cycles per min (cpm); (c) 0° at 30 cpm; (d) 15° at 15 cpm; and (e) 15° at 30 cpm. The findings indicated that increasing the angle of the board while holding the velocity constant did not always increase the mean values of the ventilatory and cardiometabolic measures. However, increasing the velocity while holding the angle constant always increased the mean values of the dependent variables. The data also indicated that the metabolic equivalent reached during the sanding activity was no greater than 2, which corresponds to a light activity, such as playing a musical instrument. Replication of the study with a larger sample size may further elucidate the behavior of these two functions during a graded sanding activity. In the present study, a unilateral sanding activity by elderly patients with cardiac impairment was shown to provide valuable data on ventilatory and cardiometabolic functions. The study also demonstrated that a unilateral sanding activity can be safely used as a graded activity in occupational therapy for the cardiac rehabilitation of elderly women.
graded conditions of a unilateral sanding activity with the use of the dominant right hand. We hoped to provide occupational therapists with data useful for the prediction of ventilatory and cardiovascular tolerance to a sanding activity in the clinical setting and to activities of daily living requiring similar metabolic equivalent values.

Literature Review

A graded sanding activity can be designed to be a simple, goal-oriented exercise that incorporates the principles of graded resistance and repetition in a practical task (Trombly & Scott, 1977). This activity has been applied as a technique for muscle strengthening (MacDonald, MacCaul, Mirrey, & Morrison, 1976) and for encouraging Brunnstrom's motor recovery patterns (Cynkin, 1979) and is frequently used as a treatment modality for patients after a spinal cord injury, brachial plexus lesion, or cerebrovascular accident (MacDonald et al., 1976). Graded sanding activities have also been used in electromyographic studies (Newall, Robinson, & Spaulding, 1981; Spaulding & Robinson, 1984) to analyze and understand the muscle patterns used during the activity.

Despite the flexible use of this technique in clinical practice, only one study has been conducted on cardiometabolic responses to bilateral sanding. The study involved 6 young nondysfunctional male subjects, aged 18 to 30 years, who sanded at a rate of 50 cycles per min (cpm) on a horizontal sanding board (Kotike, Kubicek, Olson, Hastings, & Quast, 1962) as one activity in a sequence of prevocational assessments. The researchers found that a bilateral sanding activity at this velocity on a horizontal plane doubled cardiac work and was comparable to many activities of self-care. The findings also indicated that certain normal daily activities, such as rapid walking, lifting, and stair climbing, exceeded this level of cardiac work.

Muraki, Kujime, Su, Kaneko, and Ueba (1987, 1988) examined the effect of unilateral sanding with the dominant hand on metabolic and cardiopulmonary functions in healthy young male and female subjects aged 18 to 32 years. The independent variables involved 10 graded conditions of unilateral sanding that incorporated combinations of sanding board angle and sanding velocity. The dependent variables were three ventilatory function measures—expiratory tidal volume, respiratory rate, and inspiratory volume—and four cardiometabolic measures—metabolic equivalents, systolic blood pressure, heart rate, and pressure rate product. The measures were evaluated as predictors of work potential in young adults. The data obtained indicated that respiratory rate exerted a greater influence on respiratory volume than did expiratory tidal volume. It was also found that the easily measured pressure rate product, which as a hemodynamic variable serves as an index of myocardial oxygen consumption (Gerola, Feinberg, & Katz, 1957; Gobel, Nordstrom, Nelson, Jorgensen, & Wang, 1978; Holmberg & Varnauskas, 1971; Holmberg, Wieslaw, & Varnauskas, 1971; Robinson, 1967), showed a better mutual relation to perceived exertion (Borg & Nobel, 1974; Gutmann, Squires, Pollock, Foster, & Anholm, 1981) than did heart rate alone. The mean metabolic equivalent level of the sanding activity, determined by oxygen consumption, reached no more than 2.5 during the heaviest work load. Because the data were derived from healthy young subjects, it seems unlikely that the mean value of metabolic equivalent will ever reach 3.

The effect of age on the findings of Muraki et al. (1987, 1988) was unknown, thus the study was replicated with 10 healthy elderly subjects aged 58 to 89 years (Muraki, Kujime, Kaneko, Su, & Ueba, 1990). Again, the effect of five graded unilateral sanding exercises on ventilatory and cardiometabolic functions was investigated. The findings revealed that only one index of pressure rate product was found to be statistically significant (p < .05) and that the effect of the sanding activity on the elderly subjects was a low-intensity response (about 2 metabolic equivalents) and varied among subjects. Because much of the data on the ventilatory and cardiometabolic responses to a sanding activity that have already been reported are derived from healthy young and elderly subjects, the data were not appropriate as a reference for elderly subjects with cardiac impairment. In the present study, we sought to extend the objective evaluation of two parameters of unilateral sanding—angle of the board and velocity during sanding—from healthy young and elderly subjects to the ventilatory and cardiometabolic functions of elderly women with ischemic heart disease.

Method

Subjects

Eight elderly women with ischemic heart disease at Hyogo Hospital in Kobe, Japan, volunteered to participate in this study and gave their informed consent. Each subject independently performed functional daily self-care routines in the hospital setting. The subjects' mean age was 81 years (SD = 6 years, range = 73 to 89 years); mean weight, 46 kg (SD = 10 kg, range = 33 to 62 kg); and mean height, 146 cm (SD = 7 cm, range = 138 to 159 cm). None of the subjects had a history suggestive of muscle, upper limb, joint, cerebrovascular, or neurological disease. At the time of the study, none of the subjects were engaged in daily occupational therapy or physical therapy. The subjects were instructed to refrain from eating and drinking for 2 hr before data collection.

Instrumentation

Sanding activity. A Sakai Iryo SOT-1801 sanding set and an SOT-1805 sanding block for one hand (650 g) were used.

1Mailing address: Hongo 3-15-9, Bunkyo-ku, Tokyo, 113 Japan.
Ventilatory measures. The oxygen concentration of expired air was analyzed with a Minato Medicals\(^2\) MG-360 gas analyzer and recorded on a Rika Electronics\(^3\) R56 recorder. The volume of expired air was recorded automatically from a generator attached to a Minato Medicals RM-200 respirator. The generator and respirator were connected with an NEC\(^4\) PC8801 computer for data analysis.

Cardiometabolic measures. The electrocardiograms (ECGs) were recorded and observed with a Fukuda Electronics\(^5\) telemeter, which continuously measured heart rate from the ECG waveform. Arterial blood pressure was automatically recorded every minute with a Nippon Colin\(^6\) STBP-680 electric sphygmomanometer.

Procedure

The study was performed in an air-conditioned occupational therapy clinic at a temperature between 20 and 25 °C and humidity between 60% and 70%. The sanding activity was explained in detail to every subject, and then the measurement instruments were shown so that the subjects would be familiar with the equipment. To allay the subjects’ concerns about the strenuousness of the activity, we shared with them the findings of the low-intensity work load of unilateral sanding from previous studies (Muraki et al., 1987, 1988). Each subject was taught how to signal a team member if she wished to stop performing the exercise.

The subjects were then fitted with the gas analyzer and sphygmomanometer and were instructed to watch a metronome during the sequence of the exercises to ensure correct sanding velocity and rhythm. All activities were performed under the supervision of a physician (the second author) and an occupational therapist (the first author). During the sanding activity, the physician monitored the subjects’ systolic blood pressure and heart rate using a headphone attached to the electric sphygmomanometer. Between each condition, or grade, a 3-min rest was provided. The requirements for each grade were as follows.

Grade 1. The subjects were seated at rest on a straight-backed chair in the position of exercise. They were instructed to relax with their eyes closed and with both hands resting on their thighs for 10 min. Recordings from the ECG, gas analyzer, and sphygmomanometer were taken to determine resting-state values. After the resting-state values were recorded, the occupational therapist signaled the subject to move on to Grade 2. Grade 2 (0° angle, 15 cpm). Using a sanding block, the subjects sanded on a white pine board, which was clamped to the tabletop in front of them. Sanding for all graded conditions was performed with the right dominant hand with the use of forward flexion and extension at the glenohumeral joint. During the experiment, trunk motion was not monitored.

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

Data Analysis

Expiratory volume, respiratory rate, and expiratory tidal volume were measured as indexes of ventilatory function. The parameters of cardiometabolic function, metabolic equivalent, heart rate, systolic blood pressure, and pressure rate product were used. The results obtained were presented as mean values for a 3-min period. A one-way analysis of variance (ANOVA) for repeated measures was used to examine differences among the five grades. Fisher’s least significant difference procedure was used between grades as a post hoc comparison.

Results

Ventilatory Function

Mean values and standard deviations for expiratory tidal volume, respiratory rate, and expiratory volume are diagrammed as relative percentage change in Figure 1. The expiratory tidal volume ranged from a low of 420 ± 109 ml at Grade 1 (sitting at rest) to a high of 493 ± 135 ml at Grade 4 (15°, 15 cm), where the mean value was 17% greater than that at rest. The respiratory rate increased from 22.1 ± 4.3 cpm at rest to 12.38 ± 1.79 cpm at Grade 5 (15°, 30 cpm), showing an increase of 39% over the mean value when sitting at rest.

A repeated-measures ANOVA indicated a significant difference among the expiratory volume values \((F = 7.0431, p < .01)\). Fisher’s least significant difference revealed a significant difference \((p < .05)\) in the expiratory volume response between the basal rest position and Grade 2 and between Grades 4 and 5. Significant differences \((p < .01)\) were also found between the resting position and each grade from Grades 3 to 5 and between Grades 2 and 5. The other measures demonstrated no significant differences.

Cardiometabolic Function

Data for metabolic equivalent, systolic blood pressure, heart rate, and pressure rate product are presented in...
Figure 1. Relative percentage change at each grade in ventilatory function for expiratory tidal volume (TVE) (left), respiratory rate (RR) (center), and expiratory volume (VE) (right). 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.

Figure 2. Relative percentage change in metabolic equivalents (METS) at each grade. Note. Grade 1 = sitting at rest; Grade 2 = 0° angle, 15 cycles per min (cpm); Grade 3 = 0° angle, 30 cpm; Grade 4 = 15° angle, 15 cpm; Grade 5 = 15° angle, 30 cpm.

Discussion
Activities that exercise the arms are often used in occupational therapy. Arm exercise provides an alternative diagnostic test for patients who cannot perform routine lower-extremity exercises because of vascular, orthopedic, or neurologic impairment. Arm exercise can also serve as an alternative to routine dynamic upper-extremity exercises in terms of relative percentage change in Figures 2 and 3.

The metabolic equivalent increased from 1.14 ± .32 at rest (Grade 1) to 1.69 ± .40 at Grade 5, in which the mean value presented 48% higher than that at rest (see Figure 2). Systolic blood pressure ranged from 145 ± 31 mm Hg at Grade 1 to 166 ± 29 mm Hg for the exercise at Grade 5, a value corresponding to a 114% increase over that at rest. The heart rate value increased from 85 ± 12 beats per min at rest to 96 ± 19 beats per min at Grade 5, showing an increase of 13% over the mean value at rest. The pressure rate product ranged from a low of 12.4 ± 2.8 to a high of 15.4 ± 4.0 for the exercise at Grade 5, with a 24% increase over the mean value at rest.

No significant F ratio was found with the repeated measures ANOVA for any of the indexes. However, Fisher's least significant difference demonstrated that metabolic equivalent values of the sitting at rest position differed significantly from those of Grades 3 and 5 at the p < .05 and the p < .01 levels, respectively.
that are restricted because of convalescent stage. Arm exercise can also be incorporated as an integral part of total body training, especially in patients with cardiovascular disease. In cardiac rehabilitation occupational therapy programs, activities must be evaluated objectively to determine whether they accomplish what they are designed to do.

The current study was conducted to provide useful information about ventilatory and cardiometabolic responses at each of the five grades of a unilateral sanding activity used in the cardiac rehabilitation of elderly women. The expiratory tidal volume response did not always increase in value with a steeper angle or with greater velocity. This finding was not surprising, given that each subject’s expiratory tidal volume value was great even at the basal sitting at rest position. Expiratory tidal volume is consistent with the respiratory rate response, although the value at Grade 5 was smaller than that of the others, except Grade 1. However, the expiratory volume values clearly demonstrated that the relationship between angle and velocity during a sequence of exercises is curvilinear, with increases at a steeper angle with the same velocity and at more cycles per minute with the same angle. The ventilatory findings indicated that the board angles of 0° and 15° and the sanding velocities of 15 cpm and 30 cpm could be appropriate gradations for a sanding activity, whereby subjects could carry out the activity without a great ventilatory work load.

In activities of daily living, the metabolic equivalent levels are the basis of most cardiac rehabilitation programs in use today. When therapists introduce and grade treatment activities, accurate administration of the energy costs of metabolic equivalent is essential for patients.

During the sanding activity, the maximal metabolic equivalent reached did not exceed 1.69 ± .40, equivalent to a light activity such as playing a musical instrument or fishing (American College of Sports Medicine, 1986). The metabolic equivalent requirements reflected the generally low minute oxygen consumption (V̇O₂) requirements of the unilateral sanding task. When there is no movement of the trunk, one-handed sanding can be considered to be an effective exercise that gradually increases the workload, especially between the resting position and Grade 3 or Grade 5.

The pressure rate product value [pressure rate product (×10⁻¹): systolic blood pressure × heart rate] is a valid predictor of myocardial oxygen consumption during exercise and is considered to be one of the main indexes of the daily physical work level (Gobel et al., 1978). The standard deviations of these three indexes at all grades indicated great differences among subjects and thus yielded no significant difference. Even at maximal exerci-
tion, the systolic blood pressure values increased only about 14% more than at rest. For heart rate values, the peak occurs at Grade 5 and still corresponds to only about 68% of the maximal heart rate of women in their 80s (Astrand & Rodahl, 1970). The fact that the five-step graded unilateral sanding activity did not exert great influence on the cardiometabolic response is a valuable finding.

One must remember that the curves portraying the relationship among indexes of the two functions appeared to be parallel at the specified board angles and sanding velocities. This relationship implies that, when comparing two velocities and two angles at a constant work rate, the absolute energy expenditures might differ, but the change in energy expended is similar.

Conclusion

Our findings suggested that the maximal mean value of cardiac equivalent expended by elderly women with ischemic cardiac disease during a graded unilateral sanding activity was no more than 1.69, which differs little from that of the young adults (Muraki et al., 1987, 1988) and the healthy elderly (Muraki et al., 1990). It was noteworthy that the increase in sanding speed produced more ventilatory and metabolic effect than did the increase in board angle. The results of this study indicate that the definite values of the indexes during graded one-handed sanding reflect a low-intensity exercise or activity that can be prescribed safely for elderly women with cardiac impairment. It further provides the data for a more scientific application of graded sanding activities in occupational therapy as well as a model for testing the ventilatory and cardiometabolic responses to other activities typically used by occupational therapists in cardiac rehabilitation.

Future studies designed to objectively evaluate the influences of unilateral and bilateral sanding on ventilatory and cardiometabolic function should include a larger sample size. Studies are also needed to examine the influence of sex on the functions studied, especially in the elderly. The ventilatory and cardiometabolic values obtained in this study demonstrated that to avoid complications when using a unilateral sanding activity with elderly impaired patients, one must increase the intensity, duration, and frequency of exercise and activity gradually and progressively over a period of months to attain the desired cardiac adaptations.

Acknowledgments

We thank Tohru Horimatsu, MD at Hyogo Hospital, Kobe, Japan, for his valuable advice on this experiment. This research was supported by a study grant from Kobe University, Kobe, Japan.

References


